

THE TIR CONSULTING GROUP LLC

The Third Industrial Revolution Roadmap Next Economy
for The Metropolitan Region of Rotterdam and The Hague



--- Final TIR Roadmap Next Economy ---



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The document contains the combined and integrated narrative and proposals from both the Metropolitan Region of Rotterdam and The Hague Working Groups and the TIR Consulting Group LLC to form a single collaborative report

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PREFACE

The Metropolitan Region of Rotterdam and The Hague (MRDH), which comprises 23 municipalities with a combined population of 2.3 million, has been working with TIR Consulting Group LLC over the past year in a joint project to craft an economic vision and development plan to transform this large swath of the Netherlands into a Third Industrial Revolution. This collaborative effort has resulted in a 152,000 word Roadmap Next Economy report to make this extended metropolitan region a pioneer in the build out of a smart Digital Europe.

The Netherlands has a long tradition of collaboration between government, businesses, the academic community, and nonprofit organizations in the pursuit of economic, social, and cultural goals. The Metropolitan Region of Rotterdam and The Hague has deepened and expanded on this tradition by bringing together more than 300 representatives from across various industries, professional associations, research institutes, civil society organizations, and other competencies in a multi-perspective endeavor in partnership with TIR Consulting Group LLC.

The joint initiative has transformed the governance model in the metropolitan region to reflect the nature of the new Third Industrial Revolution infrastructure being readied for deployment. The coming together of the Communication Internet, the Renewable Energy Internet, and the automated Mobility Internet, atop an Internet of Things platform, not only changes the way the MRDH manages, powers, and moves economic activity, but also the very nature of social engagement among the principal sectors of society. The near zero marginal cost of collaboration across vast digital networks is best advanced in a distributed, collaborative, open, and laterally-scaled fashion, changing the very nature of governance. Recognizing the new opportunities and challenges brought on by this new technological revolution, the 23 municipalities of the Metropolitan Region transformed their traditional role as a centralized overseer and planner to that of a lateral facilitator of a regional network of engaged stakeholders working together as equal partners to advance a new economic, social, and political vision that can take the region into the smart digital era.

The MRDH Roadmap Next Economy represents a real-world manifestation of one of the central tenants of the Maastricht Treaty – the subsidiarity principle. That principle requires that all political decision-making begins at the most local level and radiates out to broader domains stretching from localities to regions to nation-states, and finally to the continental European

Union and the global economy. The subsidiarity principle is quickly gaining prominence in cities and regions across every continent as the digital revolution crosses political boundaries, connecting communities in a smart planetary digital space. While the First and Second Industrial Revolution spawned a more top-down vertically integrated form of globalization, the Third Industrial Revolution takes the human family into a more laterally networked “glocalization” – with cities, regions, nation states, and continental unions collaborating side-by-side in vast global networks to create a more ecologically sustainable and equitable quality of life. The MRDH Roadmap Next Economy, with its emphasis on broad stakeholder participation in the deliberation and execution of a new technological infrastructure and accompanying economic narrative and game plan, exemplifies the deployment of the subsidiarity principle, and the shift from globalization to glocalization, providing a precedent for similar local and laterally designed governance models in urban metropolitan areas and regions across the 28 Member States of the EU and around the world.

Aware that digital interconnectivity breaks down traditional boundaries and borders and favors distributed and open flows in collaborative networks, MRDH and TIR Consulting Group LLC redefined the nature of participation in the establishment of the Working Groups responsible for preparing the Roadmap Next Economy, eliminating conventional sector divisions in favor of the pursuit of competencies. In the emerging Third Industrial Revolution era, industrial sectors become less important, while cross-discipline expertise becomes more relevant in defining relationships across the economic value chains. To this end, the Roadmap Next Economy is divided into five Transition Pathways, each reflecting a combination of competencies: Digital Gateway to Europe; Smart Energy Delta; Circular Economy; Entrepreneurial Region; and Next Society.

The Third Industrial Revolution Roadmap Next Economy breaks additional ground by applying this cross-disciplinary approach to the future development of the Metropolitan Region of Rotterdam and The Hague, combining social, cultural, and environmental narratives and economic theory and business practices, with the objective of reconceiving economic development within a larger frame of “quality of life.” While the advent of the digital Third Industrial Revolution in the United States focused largely on new technologies, products, and services – the Silicon Valley model –, MRDH has taken a more inclusive and globalizing approach by framing the relevance of the new products, technologies, and services to the emerging global interconnectivity and accompanying planetary stewardship of the Earth’s ecosystems – the Biosphere Valley model. In the Biosphere Era, MRDH and every other political

jurisdiction becomes responsible for its 19 kilometers of the biosphere stretching from the stratosphere to the sea, which makes up the life force of the planet and constitutes the indivisible community to which we are all beholden and whose well-being determines our own quality of life. Biosphere stewardship becomes the essential mission of each region and locality in reducing ecological footprint and addressing climate change in the coming era.

The Third Industrial Revolution narrative proposed in the Roadmap Next Economy introduces an innovative approach to biosphere stewardship based on ushering in digital ecosystems that mirror the dynamics of natural ecosystems, with the intention of pursuing a seamless symbiotic relationship between the circular flows of nature and the economic activities of Dutch society. With this in mind, the Roadmap Next Economy continually hones in on critical ecosystem features including self-organization, mutualism, co-evolution, diversity, emergence, resiliency, and adaptation in modelling the metropolitan region's new digital ecosystems and accompanying business practices and regulatory regime.

The Roadmap Next Economy gives the Metropolitan Region of Rotterdam and The Hague a blueprint for transitioning its 23 municipalities into a fully operational Third Industrial Revolution paradigm. The 40 year build out and scale up of the new digital infrastructure will transform the nature of business, require a range of new talents and skills, employ thousands of new workers, and give rise to a hybrid economic system comprised of the traditional capitalist market and the emerging Sharing Economy.

The Roadmap Next Economy positions the Metropolitan Region of Rotterdam and The Hague as an early adopter and role model for the thousands of other municipalities and metropolitan areas in the 28 Member States and adjoining partnership regions that are about to embark on a similar transition into smart regions in the Third Industrial Revolution era.

Jeremy Rifkin, President, TIR Consulting Group LLC

THE THIRD INDUSTRIAL REVOLUTION: THE DIGITAL INTERNET OF THINGS (IOT) PLATFORM AND THE PARADIGM SHIFT TO A SMART MRDH

The global economy is slowing, productivity is waning in every region of the world, and unemployment remains stubbornly high in every country. Economists are predicting 30 more years of low productivity and slow growth. And now, after two Industrial Revolutions in the 19th and 20th Centuries, we can begin to assess the impact of this economic period in human history. Arguably, 50% of the human race today is far better off than our ancestors were before the onset of the industrial era. It is also fair to say that 40% of the human race, that is still making two dollars per day or less, is not appreciably better off than its ancestors were before the Industrial Revolution. At the same time, economic inequality between the rich and the poor is at the highest point in human history. Today, the combined wealth of the 62 richest human beings in the world equals the accumulative wealth of half of the human beings currently living on Earth – 3.5 billion people.¹

This dire economic reality is now compounded by the rapid acceleration of climate change brought on by the increasing emissions of global warming gases during the First and Second Industrial Revolutions. James Hansen, former head of the NASA Goddard Institute for Space Studies and the chief climatologist for the U.S. government, forecasts a 6°C rise in the Earth's temperature between now and the turn of the century—and with it, the end of human civilization as we've come to know it. The only hope, according to Hansen, is to reduce the current concentration of carbon in the atmosphere from 385 ppm to 350 ppm or less—something no government is currently proposing.²

What makes these dramatic spikes in the Earth's temperature so terrifying is that the increase in heat radically shifts the planet's hydrological cycle. We are a watery planet. The Earth's diverse ecosystems have evolved over geological time in direct relationship to precipitation patterns. Each rise in temperature of 1°C results in a 7 percent increase in the moisture-holding capacity of the atmosphere. This causes a radical change in the way water is distributed, with more intense precipitation but a reduction in duration and frequency. The consequences are already being felt in eco-systems around the world. We are experiencing more bitter winter snows, more dramatic spring storms and floods, more prolonged summer droughts, more wildfires, more intense hurricanes (category 3, 4, and 5), a melting of the ice caps on the great mountain ranges, and a rise in sea levels.

¹ See: <http://www.oxfam.org.uk/media-centre/press-releases/2016/01/62-people-own-same-as-half-world-says-oxfam-inequality-report-davos-world-economic-forum>

² See: http://www.giss.nasa.gov/research/briefs/hansen_13/

The Earth's ecosystems cannot readjust to a disruptive change in the planet's water cycle in such a brief moment in time and are under increasing stress, with some on the verge of collapse. The destabilization of ecosystem dynamics around the world has now pushed the biosphere into the sixth extinction event of the past 450 million years of life on Earth. In each of the five previous extinctions, Earth's climate reached a critical tipping point, throwing the ecosystems into a positive feedback loop, leading to a quick wipe-out of the planet's biodiversity. On average, it took upward of 10 million years to recover the lost biodiversity. Biologists tell us that we could see the extinction of half the Earth's species by the end of the current century, resulting in a barren new era that could last for millions of years.

Now, however, a new economic paradigm is emerging that is going to radically change the way we organize economic life on the planet and dramatically reduce global warming emissions to address climate change. The European Union is embarking on a bold new course to create a high-tech 21st Century smart green digital economy, making Europe potentially the most productive commercial space in the world and the most ecologically sustainable society on Earth. The plan is called Digital Europe. The EU vision of a green digital economy is the cornerstone of the emerging Third Industrial Revolution.

To grasp the enormity of the economic change taking place, we need to understand the technological forces that have given rise to new economic systems throughout history. Every great economic paradigm requires three elements, each of which interacts with the other to enable the system to operate as a whole: new communication technologies to more efficiently manage economic activity; new sources of energy to more efficiently power economic activity; and new modes of transportation to more efficiently move economic activity.

In the 19th Century, steam-powered printing and the telegraph, abundant coal, and locomotives on national rail systems gave rise to the First Industrial Revolution. In the 20th Century, centralized electricity, the telephone, radio and television, cheap oil, and internal combustion vehicles on national road systems converged to create an infrastructure for the Second Industrial Revolution.

Today, the European Union is laying the groundwork for the Third Industrial Revolution. The plan calls for a digitally connected smart Europe. The Third Industrial Revolution involves much more than providing universal broadband, free Wi-Fi, and a flow of Big Data. The digital economy will revolutionize every commercial sector, disrupt the workings of virtually every industry, bring with it unprecedented new economic opportunities, put millions of people back to work, democratize economic life, and create a more sustainable low-carbon society to mitigate climate change. Equally important, the new economic narrative is being accompanied by a new biosphere consciousness, as the human race begins to perceive the Earth as its indivisible community. We are each beginning to take on our responsibilities as stewards of the planetary ecosystems which sustain all of life.

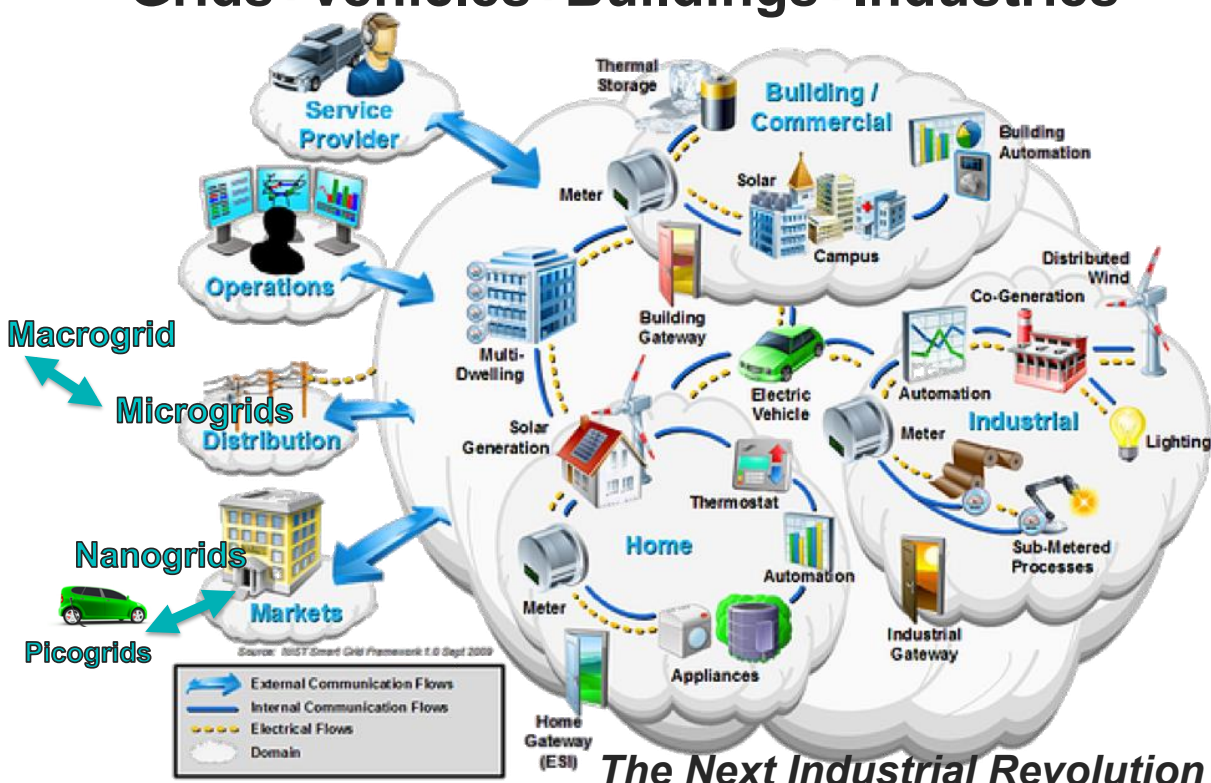
The digitalized Communication Internet is converging with a digitalized Renewable Energy Internet, and

a digitalized automated Transportation and Logistics Internet, to create a super-Internet to manage, power, and move economic activity. This super Internet rides atop an infrastructure called the Internet of Things (IoT). In the Internet of Things era, sensors and actuators will be embedded into every device and appliance, allowing them to communicate with each other and Internet users, providing up to the moment data on the managing, powering, and moving of economic activity in a smart Digital Europe. By 2030, it is estimated there will be more than 100 trillion sensors connecting the human and natural environment in a global distributed intelligent network. For the first time in history, the entire human race can collaborate directly with one another, democratizing economic life.

The digitalization of communication, energy, and transportation also raises risks and challenges, not the least of which are guaranteeing network neutrality, preventing the creation of new corporate monopolies, protecting personal privacy, ensuring data security, and thwarting cyber-crime and cyber-terrorism. The European Commission has already begun to address these issues by establishing the broad principle that “privacy, data protection, and information security are complimentary requirements for Internet of Things services.” These challenges will be addressed in the development and implementation of the TIR Roadmap Next Economy.

In this expanded digital economy, private enterprises connected to the Internet of Things will use Big Data and analytics to develop algorithms that speed aggregate efficiency, increase productivity, dramatically reduce ecological footprint, and lower the marginal cost of producing and distributing goods and services, making MRDH businesses more competitive in an emerging post-carbon global marketplace (marginal cost is the cost of producing an additional unit of a good or service, after fixed costs have been absorbed). The marginal cost of some goods and services in a Digital Europe will even approach zero, allowing millions of *prosumers*, connected to the Internet of Things, to produce and exchange things with one another, for nearly free, in the growing Sharing Economy.

Making Smarter & Integrated Sectors Grids+Vehicles+Buildings+Industries



AGGREGATE EFFICIENCIES AND PRODUCTIVITY

The transformation to an Internet of Things infrastructure and a Third Industrial Revolution paradigm is forcing a wholesale rethinking of economic theory and practice. The unleashing of extreme productivity wrought by the digitalization of communication, energy, and transportation is leading to a reassessment of the very nature of productivity and a new understanding of ecological sustainability. Conventional economists fail to recognize that the laws of thermodynamics govern all economic activity. The first and second laws of thermodynamics state that “the total energy content of the universe is constant and the total entropy is continually increasing.” The first law, the conservation law, posits that energy can

neither be created nor destroyed—that the amount of energy in the universe has remained the same since the beginning of time and will be until the end of time. While the energy remains fixed, it is continually changing form, but only in one direction, from available to unavailable. This is where the second law of thermodynamics comes into play. According to the second law, energy always flows from hot to cold, concentrated to dispersed, and ordered to disordered. For example, if a chunk of coal is burned, the sum total of the energy remains constant, but is dispersed into the atmosphere in the form of carbon dioxide, sulphur dioxide, and other gases. While no energy is lost, the dispersed energy is no longer capable of performing useful work. Physicists refer to the no-longer-useable energy as entropy.

All economic activity comes from harnessing available energy in nature—in material, liquid, or gaseous form—and converting it into goods and services. At every step in the extraction, production, storage, and distribution process, energy is used to transform nature’s resources into finished goods and services. Whatever energy is embedded in the product or service is at the expense of energy used and lost—the entropic bill—in moving the economic activity along the value chain. Eventually, the goods we produce are consumed, discarded, and recycled back into nature, again, with an increase in entropy. Engineers and chemists point out that in regard to economic activity there is never a net energy gain but always a loss in available energy in the process of converting nature’s resources into economic value. The only question is: when does the bill come due?

The entropic bill for the First and Second Industrial Revolutions has arrived. The accumulation in carbon dioxide emissions in the atmosphere from burning massive amounts of carbon energy has given rise to climate change, the wholesale destruction of the Earth’s biosphere, and the sixth extinction event in the history of our planet, throwing the existing economic model into question. The field of economics, by and large, has yet to confront the fact that economic activity is conditioned by the laws of thermodynamics.

Until very recently, economists were content to measure productivity by two factors: more capital invested in better performing machines and improved labor performance. But when Robert Solow—who won the Nobel Prize in economics in 1987 for his growth theory—tracked the Industrial Age, he found that machine capital and labor performance only accounted for approximately 12.5 percent of all of the economic growth, raising the question of what was responsible for the other 87.5 percent. This mystery led economist Moses Abramovitz, former president of the American Economic Association, to admit what other economists were afraid

to acknowledge—that the other 87.5 percent is a “measure of our ignorance.”³

Over the past 25 years, a number of analysts, including physicist Reiner Kümmel of the University of Würzburg, Germany, and economist Robert Ayres at INSEAD business school in Fontainebleau, France, have gone back and retraced the economic growth of the industrial period using a three-factor analysis of machine capital, labor performance, and thermodynamic efficiency of energy use. They found that it is “the increasing thermodynamic efficiency with which energy and raw materials are converted into useful work” that accounts for most of the rest of the gains in productivity and growth in industrial economies. In other words, “energy” is the missing factor.

A deeper look into the First and Second Industrial Revolutions reveals that the leaps in productivity and growth were made possible by the communication/energy/transportation matrix and accompanying infrastructure that comprised the general-purpose technology platform that firms connected to. For example, Henry Ford could not have enjoyed the dramatic advances in efficiency and productivity brought on by electrical power tools on the factory floor without an electricity grid. Nor could businesses reap the efficiencies and productivity gains of large, vertically integrated operations without the telegraph and, later, the telephone providing them with instant communication, both upstream to suppliers and downstream to distributors, as well as instant access to chains of command in their internal and external operations. Nor could businesses significantly reduce their logistics costs without a fully built-out road system across national markets. Likewise, the electricity grid, telecommunications networks, and cars and trucks running on a national road system were all powered by fossil fuel energy, which required a vertically integrated energy infrastructure to move the resource from the wellhead to the end users.

The general-purpose technology infrastructure of the Second Industrial Revolution provided the productive potential for a dramatic increase in growth in the 20th Century. Between 1900 and 1929, the United States built out an incipient Second Industrial Revolution infrastructure—the electricity grid, telecommunications network, road system, oil and gas pipelines, water and sewer systems, and public school systems. The Depression and World War II slowed the effort, but after the war the laying down of the interstate highway system and the completion of a nationwide electricity grid and telecommunications network provided a mature, fully integrated infrastructure. The Second Industrial Revolution infrastructure advanced productivity across

³ See: <http://www.nber.org/chapters/c5650.pdf>

every industry, from automobile production to suburban commercial and residential building developments along the interstate highway exits.

During the period from 1900 to 1980 in the United States, aggregate energy efficiency—the ratio of potential to useful physical work that can be extracted from materials—steadily rose along with the development of the nation’s infrastructure, from 2.48 percent to 12.3 percent. The aggregate energy efficiency leveled off in the 1990s at around 14 percent with the completion of the Second Industrial Revolution infrastructure.⁴ Despite a significant increase in efficiency, which gave the United States extraordinary productivity and growth, nearly 86 percent of the energy we used in the Second Industrial Revolution was wasted during transmission.

Even if we were to upgrade the Second Industrial Revolution infrastructure, there will be only a limited effect on aggregate efficiency, productivity, and growth. Fossil fuel energies have matured. And the technologies designed and engineered to run on these energies, like the internal-combustion engine and the centralized electricity grid, have exhausted their productivity, with little potential left to exploit.

Needless to say, 100 percent thermodynamic efficiency is impossible. New studies, however, including one conducted by our global consulting group, show that with the shift to a Third Industrial Revolution infrastructure, it is conceivable to increase aggregate energy efficiency to 60 percent or more over the next 40 years, amounting to a dramatic increase in productivity beyond what the economy experienced in the 20th Century.

A 2015 McKinsey report suggests that the build out and scale up of an Internet of Things infrastructure will have a 'value potential' of between \$3.9 trillion to \$11.1 trillion per year by 2025.⁵ A General Electric study published in November 2012 concludes that the efficiency gains and productivity advances induced by a smart industrial Internet could resound across virtually every economic sector by 2025, impacting “approximately one half of the global economy.”⁶ A 2016 AT Kearney study says that "over the next 10 years, the market for IoT solutions will be

⁴ John A. “Skip” Laitner, Steven Nadel, R. Neal Elliott, Harvey Sachs, and A Siddiq Khan, “The Long-Term Energy Efficiency Potential: What the Evidence Suggests,” American Council for an Energy-Efficient Economy, January 2012, http://www.garrisoninstitute.org/downloads/ecology/cmb/Laitner_Long-Term_E_E_Potential.pdf, 2

⁵ See: <http://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world>

⁶ See: https://www.ge.com/docs/chapters/Industrial_Internet.pdf

worth € 80 billion, and the potential value for the EU28 economy could reach € 1 trillion." The report goes on to say that the increase in productivity alone could exceed € 430 billion in the EU. However, AT Kearney is quick to add that the increased capabilities brought on by the digitalization of the infrastructure will "increase exponentially when connected objects are coordinated."⁷

The build out and scale up of the Third Industrial Revolution Internet of Things platform will enable businesses in MRDH to dramatically increase aggregate efficiencies across their value chains, increase productivity, and reduce marginal costs and ecological footprint, making the region a leader in the shift to the new economic paradigm and an ecological society.

The Internet of Things

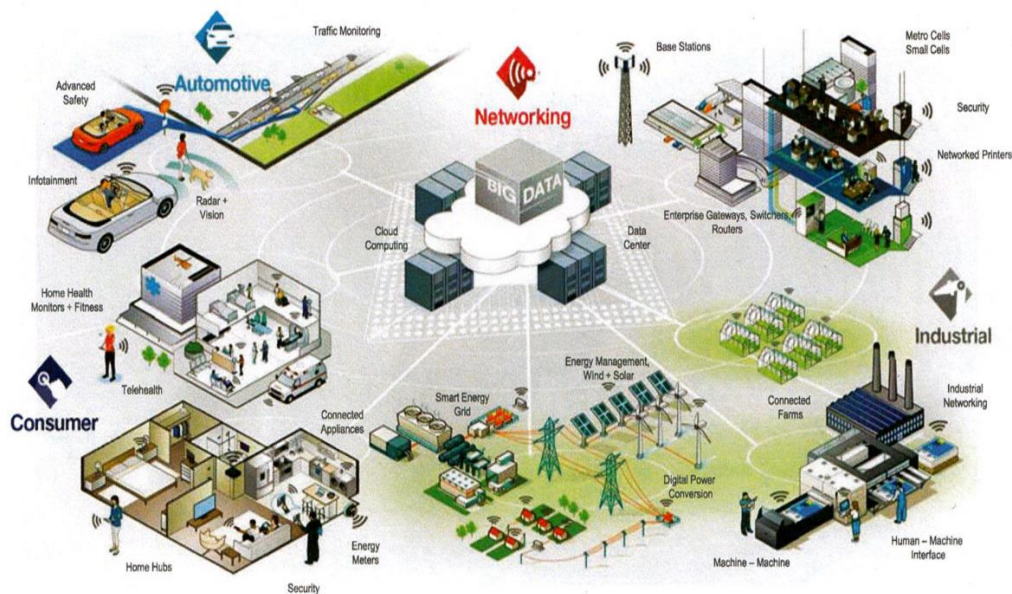


Image Source: http://www.mbuguanjihia.com/wp-content/uploads/2014/08/freescale_internet_of_things_overview_1.jpg

⁷ See: <https://www.atkearney.com/documents/10192/7125406/The+Internet+of+Things-A+New+Path+to+European+Prosperity.pdf/e5ad6a65-84e5-4c92-b468-200fa4e0b7bc>

DIGITAL GATEWAY TO EUROPE

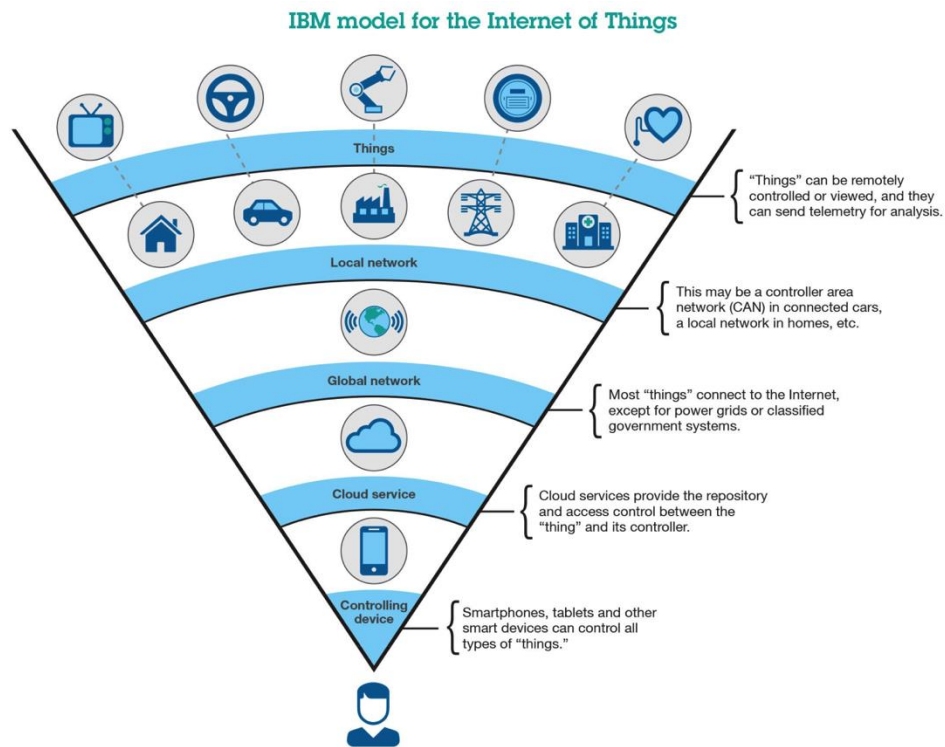
THE COMMUNICATIONS INTERNET

Three billion people, nearly half the human population on Earth, are currently connected to the Internet. Recently, China began manufacturing \$25 smart phones with more computing power than what was used to send astronauts to the moon, increasing the prospect that soon the entire human race will be connected and communicating with one another, sharing knowledge, work, and entertainment, making new friendships and finding mates in the largest extended fictional family in history. The Communication Internet is erasing border after border and connecting the human race in a single, global, virtual public square – and the marginal cost of participating is nearly zero and virtually free.

*Berry Vetjens and the Working Group
members from MRDH*

*Michael Waidner (Fraunhofer SIT), Philipp
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for TIR Consulting Group LLC*

New technologies for managing communications and Big Data over the radio frequencies have transformed the concept of the spectrum from a scarce to a reusable resource. That new reality is changing the very nature of wireless communications. Smart antennas, dynamic spectrum access, cognitive radio technologies, and mesh networks are among the new technologies that are expanding the spectrum to an abundant resource by using it more efficiently and with greater agility.



Graphic 1. IBM model for the Internet of Things

Source: IBM X-Force® Research and Development

The Netherlands leads the European Union in providing high-speed Internet access, with the most broadband subscriptions per 100 inhabitants. The Netherlands is also the heaviest user of the Internet, with 93.1% of the population actively online, compared to Germany with only 87.6% of the population online and Belgium with 85.1% of the population online.⁸ With proper investment in next-generation technologies, as outlined below, the Metropolitan Region of Rotterdam and The Hague has the opportunity of leaping forward and becoming the first region in the world to have 100% high-speed access to the Internet and universally available wireless communications, allowing all of its citizens quasi-free access to the airwaves 24/7.

Investment in future telecommunications infrastructure is needed since it is evident that the networks of today are not nearly sufficient to face the Internet traffic requirements of the Third Industrial Revolution. Indeed, Internet traffic is growing exponentially and it is already saturating the access networks as well as the optical core networks, a situation previously

⁸ See: <http://data.worldbank.org/indicator/IT.NET.USER.P2>

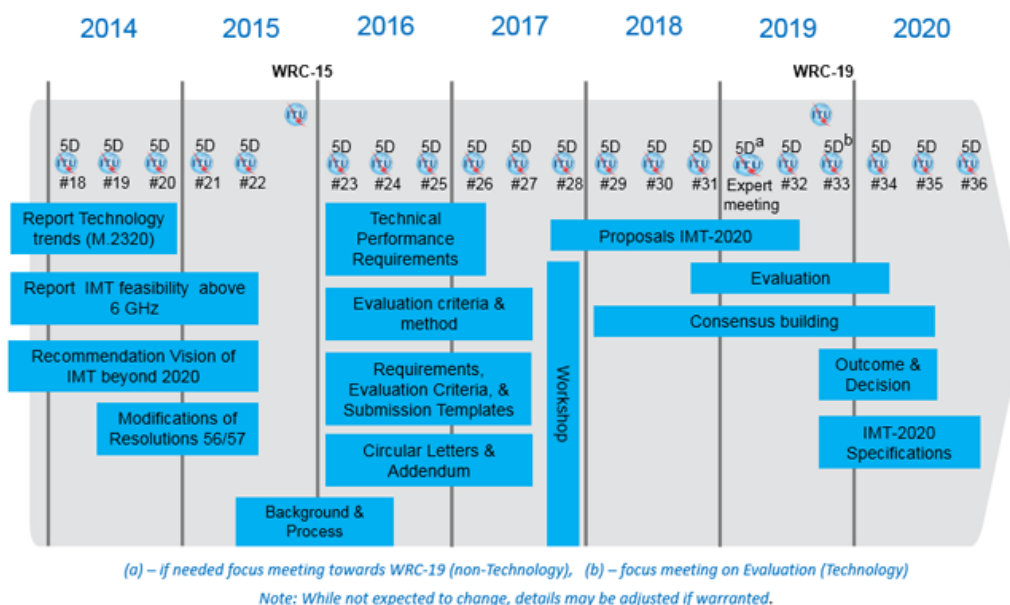
Third Industrial Revolution Consulting Group

unforeseeable.⁹ To carry the traffic of the Internet of Things requires not only huge investments in infrastructure, but also a fundamental re-design of the network to manage the new levels of complexity and assure comparable levels of flexibility. This is why the entire developed world is now engaged in the standardization of 5G networks, a completely new end-to-end system with unprecedented capabilities that will be needed to bring the Third Industrial Revolution into existence.

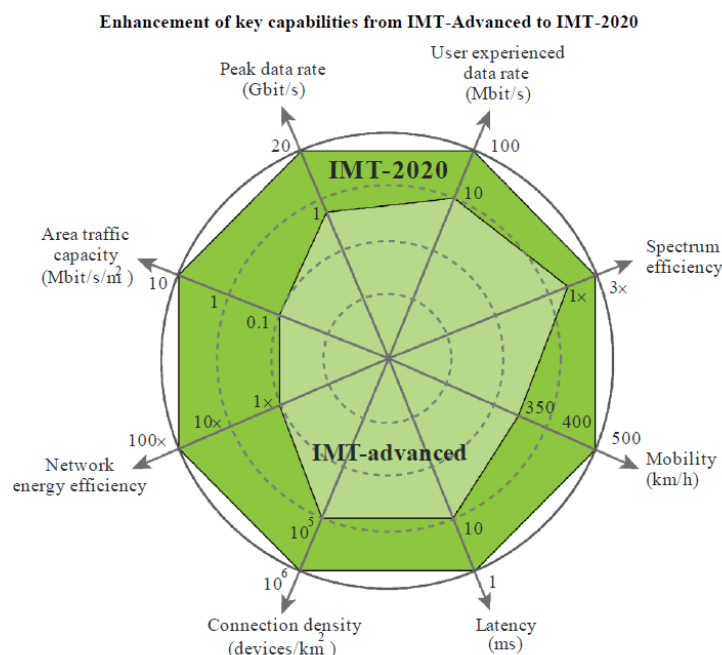
The International Telecommunications Union (ITU), the body in charge of 5G standardization, will integrate multiple technologies (i.e. mobile, fixed, satellite and optical), spectrum-regulatory frameworks (e.g. licensed and unlicensed) and enabling capabilities (e.g. the Internet of Things – IoT). Therefore, the corresponding standardization and regulatory bodies will need to work closely together, as well as align with the key vertical sectors of the Third Industrial Revolution.

The roadmap for 5G (IMT-2020) at ITU level is reported in the following figure:

Detailed Timeline & Process for IMT-2020 in ITU-R

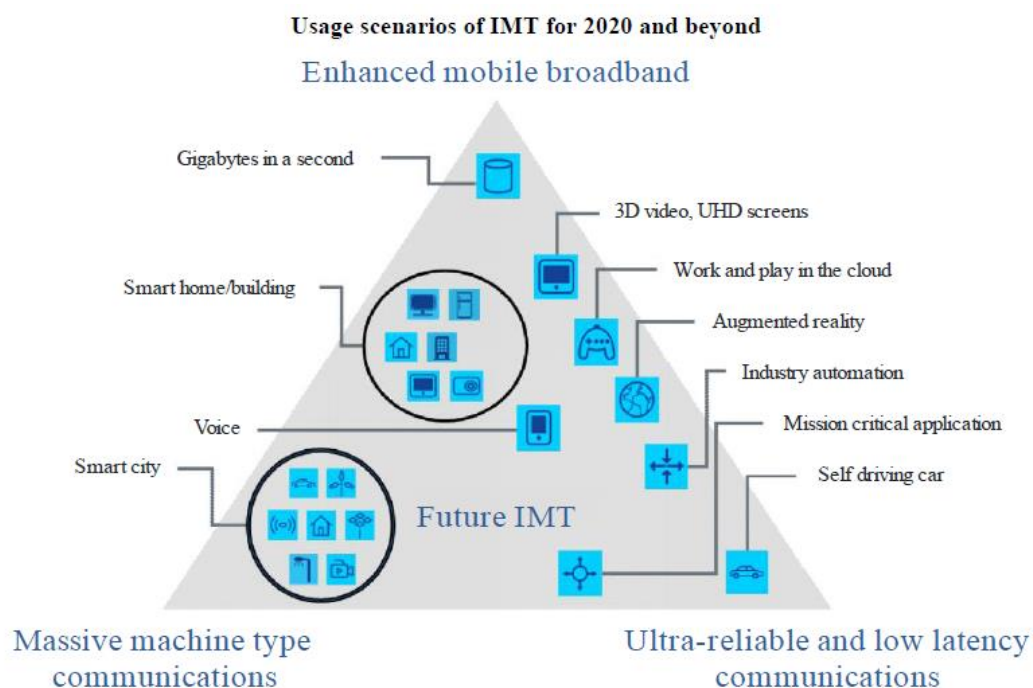


⁹ See: <http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html>



As can be extracted from the figure, 5G is expected to introduce a leap of several orders of magnitude in critical network features such as peak data rate, area traffic capacity, energy efficiency, spectrum efficiency, and reduced latency.

However, these general performance requirements are not needed for all services and in all user scenarios. Three main classes of usage have been envisioned: Enhanced Mobile Broadband, for faster interconnections of traffic hungry devices; Ultra Reliable and Low Latency Communications, for all mission critical applications such as autonomous driving, industry automation, or tactile Internet; Massive Machine Type Communications, which is the Internet of Things. These three macro segments are shown in the following ITU figure.



5G will offer ubiquitous access to a wide range of applications and services with increased resilience, continuity, and much higher resource efficiency than is possible today, while protecting security and privacy. In addition, 5G will provide enormous improvements in capacity and boost user data rates.¹⁰

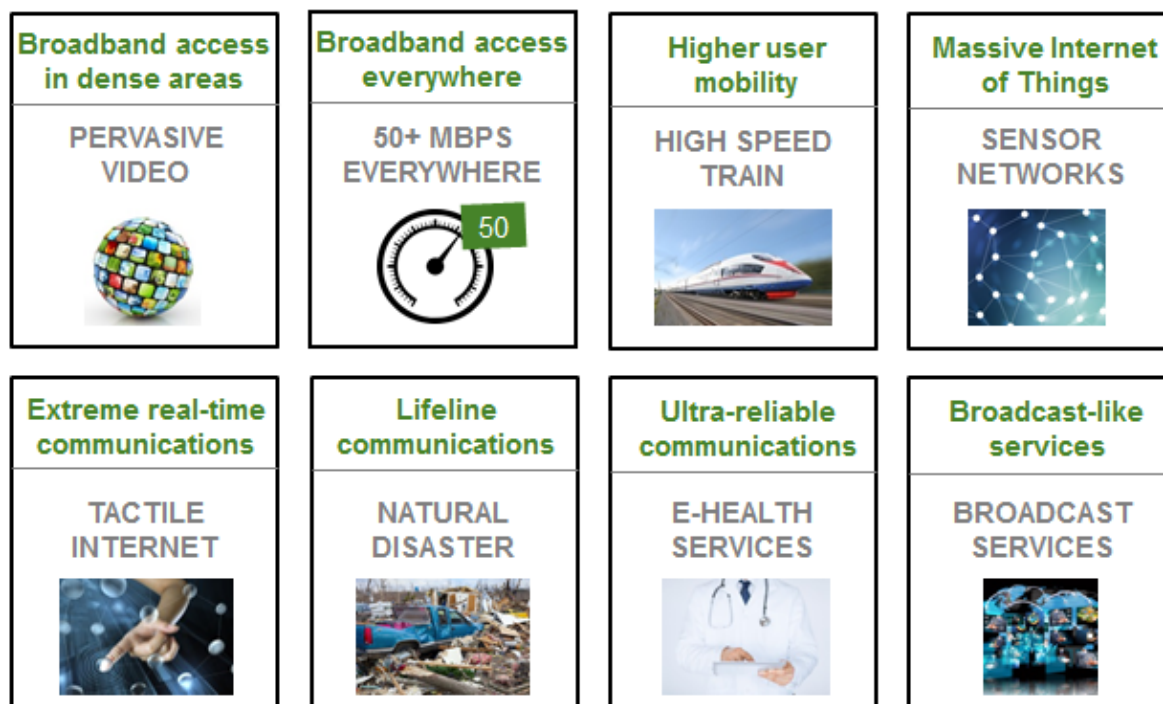
After several years of 5G development in academic and industrial laboratories, technologies for software-defined networks (SDNs) are just now being introduced into the market. SDNs are key to providing the required level of flexibility and reconfigurability, and also introduce the possibility to design “network slices,” i.e. virtual representations of the network that can be dedicated to specific purposes, such as those of a vertical market. In addition, network slicing can be used to generate new business models: different slices can be managed by different virtual operators in a multi-tenancy fashion. Therefore, a single infrastructure can enable a competitive market between local/regional entities.

The highly demanding capabilities of 5G require a high-level research and innovation effort.

¹⁰ See: <https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf>

MRDH should therefore actively participate in the R&D efforts that the European Commission is setting forth within the 5G-PPP initiative.¹¹ In particular, early demonstrations of technology could be foreseen.

Next Generation Mobile Networks (NGMN) describes 5G as: “an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models.”¹² NGMN identified eight use case families in early 2015, reported in the following figure:



5G will clearly impact all vertical industrial sectors and become one of the pillars upon which the Third Industrial Revolution can be developed and sustained. To illustrate this point with

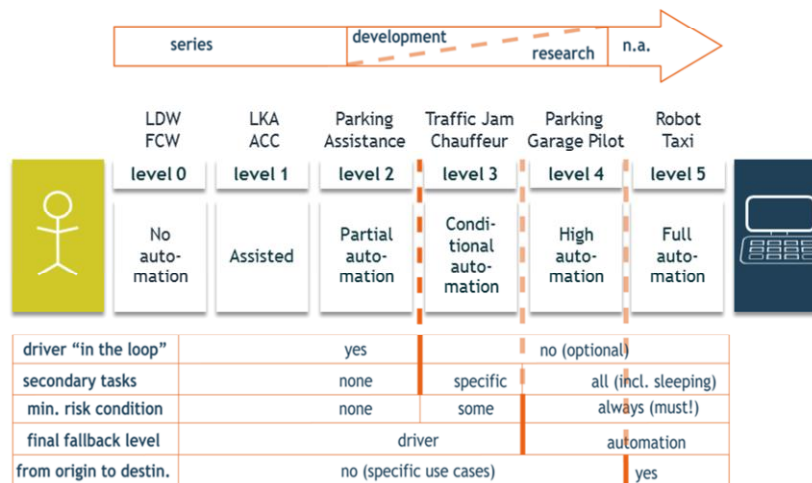
¹¹ See: <https://5g-ppp.eu/>

¹² See: https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf

further evidence, consider two of the most important industrial segments: transportation and energy, which are important parts of this Roadmap (see Sections on Mobility Internet and Renewable Energy Internet); here we consider specifically the support that the 5G Communications infrastructure will provide to these segments. In this analysis, we make reference to the work on vertical sectors performed at 5G-PPP level.¹³

In the automotive vertical sector, the introduction of advanced fully autonomous driving cars, and automated transportation systems promises not only fewer fatal accidents, less traffic congestion and lower pollution, but also a wide range of new business opportunities for a broad range of industries and benefits for the environment. On August 16, 2016, Ford announced publicly its plans to develop and mass-produce self-driving cars by 2021.¹⁴ A description of the levels of driving automation is shown in the following figure:

// Levels of driving automation acc. to SAE and VDA



Source: SAE document J3016, "Taxonomy and Definitions for Terms Related to On-Road Automated Motor Vehicles", Issued 2014-01-16, see also http://standards.sae.org/j3016_201401/

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iMobility Forum, Brussels

AdaptiVe

But to achieve the benefits which are promised by autonomous transportation systems, the artificial-intelligence-driven vehicles must be interconnected to the Internet with extremely low latency and high reliability, which are both critical for security and safety. These requirements

¹³ "5G Empowering Vertical Industries", https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

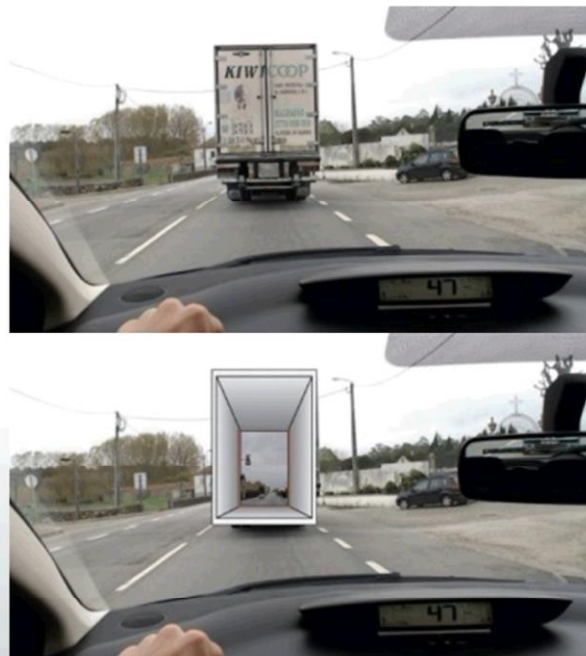
¹⁴ See: <http://www.ft.com/cms/s/0/d2cfc64e-63c0-11e6-a08a-c7ac04ef00aa.html#axzz4ILAvCXb7>

cannot be met by the networks of today. 5G will realise this vision by ensuring that critical sensor information will be exchanged in real time between thousands of cars connected in the same area.

Cooperative collision avoidance, for example, calls for ubiquitous reliability and unprecedented performance levels. This critical connectivity should be provided even in areas without network coverage, e.g., due to shadowing or other obstructions, by leveraging cooperation between vehicles, in a vehicle-to-vehicle communication paradigm. Cooperation can also be leveraged to create a collective perception of the environment, leading to enhanced visibility as shown in the figure below.

Collective Perception of Environment

Example See-Through Use Case



Source: University of Porto, Michel Ferreira

Most of the foreseen automotive applications will require a 5G communications infrastructure. Some of the performance requirements are highlighted in the figure below. With the introduction of 5G technologies, a myriad of new applications can be enabled. As an additional example, one could envision tele-operated driving - where a disabled individual could be driven with the help of a remote driver in areas where highly automatic driving is not possible. This would generate a new mobility dimension for the disabled and enhance safety for frail and elderly people during complex traffic situations.

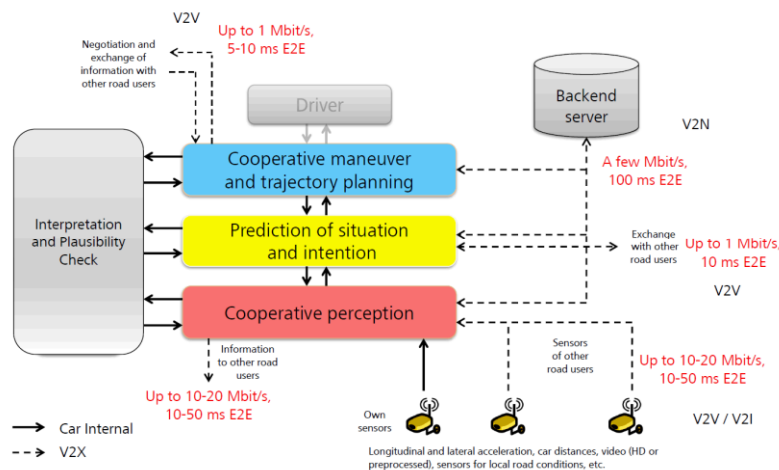
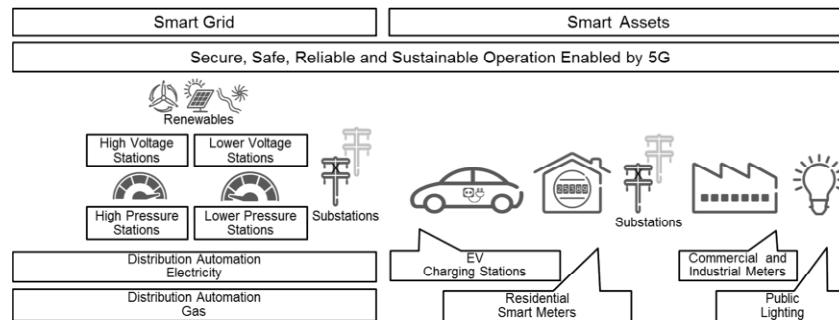


Figure 6. Connectivity demands of future connected vehicles
(adapted from (DFG-Schwerpunktprogramm SPP 1835, April 2014))

Major changes in the distribution network are also occurring in the electrical energy industry. Historically, predictable power consumption profiles used to allow precise scheduling of appropriate levels of production, meeting demand via large central thermal and hydro generation stations. But thanks to the introduction of distributed sources of renewable energy (solar, wind, etc.), we are now faced with unpredictable small generation stations and changing patterns of energy use by prosumers.

The physical energy infrastructure, identified as the Smart Grid or Energy Internet, will therefore need to support a bidirectional energy flow originating from and directed to the distributed energy sources and sinks, which in turn has new implications for communication technologies, intelligence, business models, and market structure. In order to manage these Smart Grids, 5G networks are being designed while keeping in mind the requirements of the energy industry.



Use cases for 5G in the Energy industry¹⁵

5G will enable a number of more sophisticated services, including: self-healing networks; ultra-fast fault location; reconfiguration of network topology; real-time monitoring of the energy level provided by distributed energy sources; management of micro-grids for the provision of energy in a local area (e.g., a household or a factory) through extensive signalling; real-time optimization of voltage profiles and power flows; and provision of forecasting tools to help large scale planning of energy generation and consumption.

Significant disruptions are also expected in the use of the spectrum: not only in terms of actual bands used (both below and above 6GHz) but also because for the first time 5G will encompass both licensed and unlicensed bands. It is likely, then, that 5G will start to compete with the incumbent Wi-Fi market, empowering self-installed access points at users' premises with the capacity of the new software-defined 5G core infrastructure. In wake of the 2013 FCC proposal for a US-wide free Wi-Fi network,¹⁶ consideration should be given to opening up a free 5G access network in the unlicensed bands to be used for offloading local Internet traffic, such as that for domestic broadband interconnection in households. This is an interesting idea which has not been discussed yet, but could start to materialize in the early 2020s.

As is the case with any technological revolution, the Internet has a dark side, too. Universal interconnectivity makes possible the democratization of communication and the flow of Big Data, but as already mentioned, it also poses serious challenges, not the least of which is guaranteeing network neutrality. Network neutrality is the principle that assures a

¹⁵ See: https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White_Paper-on-Energy-Vertical-Sector.pdf

¹⁶ See: <http://www.popsci.com/technology/article/2013-02/fcc-proposes-national-free-super-wifi-network>

nondiscriminatory and universal Communications Commons in which every participant enjoys equal access and inclusion.

It is important to note that on June 14, 2016, the US Court of Appeals for the District of Columbia Circuit ruled that high-speed Internet service should be considered a utility.¹⁷ Therefore, broadband access to the Internet must be considered as essential as the phone and electrical power, and should be available to all Americans, rather than a luxury that does not require close government supervision. In doing so, the Court backed the Open Internet Framework introduced by the FCC, essentially defining the meaning of net neutrality through the following three rules:¹⁸

- No Blocking: broadband providers may not block access to legal content, applications, services, or non-harmful devices.
- No Throttling: broadband providers may not impair or degrade lawful Internet traffic on the basis of content, applications, services, or non-harmful devices.
- No Paid Prioritization: broadband providers may not favor some lawful Internet traffic over other lawful traffic in exchange for consideration of any kind—in other words, no "fast lanes." This rule also bans ISPs from prioritizing content and services of their affiliates.

These rules are essential to avoid discrimination in the provision of broadband information/entertainment services over the Internet, which were practically the only use of the infrastructure in the Second Industrial Revolution. Yet, the range of services will change dramatically in the Third Industrial Revolution. As shown above in the discussion about 5G networks, the future communication infrastructure will not only be used to provide enhanced broadband services, but it will also be the backbone upon which mission critical services and the Internet of Things will run. These three segments of services have extremely different and sometimes opposite requirements. The paradigmatic example is that of the maximum acceptable network latency: it could be several minutes for an IoT sensor network, a few seconds for streaming content, and 1 ms to control a platoon of autonomous cars.

¹⁷ See: http://www.nytimes.com/2016/06/15/technology/net-neutrality-fcc-appeals-court-ruling.html?_r=0

¹⁸ See: <https://www.fcc.gov/general/open-internet>

In this new complex scenario, service differentiation cannot be considered an unlawful discrimination: it is simply a must. In fact, considering the wide range of mission critical services, such as those for self-driving cars and autonomous transportation, emergency communications and disaster recovery, personalized embodied medical care with remote control from doctors, and more, it is evident that their respective data should not be delivered with the same high-latency best-effort modality as is adequate, for example, for a YouTube video stream.

In the Third Industrial Revolution, the Communications Internet will be a critical infrastructure providing multiple utilities, some of which will determine human safety, as in the case of transportation. The introduction of 5G communication technology is already raising a plethora of thorny safety issues that go to the heart of network neutrality. For example, would anyone ethically accept that a car accident was caused by a delay in packet delivery caused by the absence of prioritization with respect to a video stream? It goes without saying that a new regulatory framework will be necessary in the EU and US as well as in the rest of the world. A very important and critical issue is how to provide the necessary differentiation while ensuring democratic access to the Internet. MRDH can participate proactively on this issue by interacting with the European Commission.

The concept of digital rights is being raised with increasing urgency with the growth of giant global Internet companies like Google, Facebook, Twitter, and Amazon. The dilemma is that, as enterprises like Google, Facebook, and Twitter continue to grow, the increasing number of users in their networks benefits everyone using the network. But because the networks are commercial enterprises, their interest is in maximizing profits by being able to sell information about their users to third parties, while their users' interest is optimizing their social connections. In other words, the problem is that companies are operating a social Commons as a commercial venture. Zeynep Tufekci, a sociology professor at the University of North Carolina, calls this practice "the corporatization of the social Commons."

Corporate giants like Google, Facebook, Twitter, eBay, and Amazon have each spent billions of dollars securing global markets whose user bases are many times larger than anything from the past we might want to measure them against. What does it mean when the collective knowledge of much of human history is controlled by the Google search engine? Or, when Facebook becomes the sole overseer of a virtual public square, connecting the social lives of 1.7 billion people? Or when Twitter becomes the exclusive gossip line for the human race? Or when

eBay becomes the only ring master for the global auction market? Or when Amazon becomes the go-to virtual marketplace for nearly everyone's purchases online? There is nothing comparable to these monopolies in the history of the brick and mortar world of commerce.

It's highly unlikely that the companies capturing these vast social spheres will escape some kind of regulatory restriction by way of either antitrust action or treating them as global social utilities with appropriate regulatory oversight. The nature and extent of the oversight is still very much an open question.

Connecting everyone and everything in a global digital network raises the critical issue of how to protect personal privacy. Today, the evolving Internet of Things is ripping away the layers of enclosure that made privacy sacrosanct and a right regarded as important as the right to life, liberty, and the pursuit of happiness. For a younger generation growing up in a globally connected world where every moment of their lives is eagerly posted and shared with the world via Facebook, Twitter, YouTube, Instagram, and countless other social media sites, privacy has lost much of its appeal. For them, freedom is not bound up in self-contained autonomy and exclusion, but rather, in enjoying access to others and inclusion in a global virtual public square. The moniker of the younger generation is transparency, its modus operandi is collaboration, and its self-expression is exercised by way of peer production in laterally scaled networks.

Still, privacy issues will continue to be a pivotal concern, determining, to a great extent, both the speed of the transition and the pathways taken into the next period of history. The central question is: When every human being and every thing is connected, what boundaries need to be established to ensure that an individual's right to privacy will be protected? The problem is that third parties with access to the flow of data across the IoT, and armed with sophisticated software skills, can penetrate every layer of the global nervous system in search of new ways to exploit the medium for their own ends. Cyber thieves can steal personal identities for commercial gain, social media sites can sell data to advertisers and marketers to enhance their profits, and political operatives can pass on vital information to foreign governments. How then do we ensure an open, transparent flow of data that can benefit everyone while guaranteeing that information concerning every aspect of one's life is not used without their permission and against their wishes in ways that compromise and harm their well-being?

The European Commission has begun to address these issues by establishing a broad principle to guide all future developments of the Internet of Things: "In general, we consider that privacy

and data protection and information security are complementary requirements for IoT services. In particular, information security is regarded as preserving the confidentiality, integrity and availability (CIA) of information. We also consider that information security is perceived as a basic requirement in the provision of IoT services for the industry, both with a view to ensure information security for the organization itself, but also for the benefit of citizens.”¹⁹

Governments and businesses around the world are also becoming increasingly alarmed over the escalation of cyberterrorist attacks aimed at infrastructure and are voicing growing concern over the possibility that they might cripple and even shut down many of the vital services necessary to operate society, leading to a high-tech Armageddon and the collapse of civilization. Governments are most worried about attacks aimed at the electrical power grid. If a cyberattack were to target key components of the power grid and disable them, the country could be without electrical power for several months, or a year or longer. Without electricity, virtually everything in modern society shuts down—the water system, gas pipelines, sewage, transport, heat, and light. Those that survive would have to flee to the countryside and attempt to eke out a subsistence survival, throwing humanity back into a preindustrial era. The mounting concern over cyberattacks has spawned a massive cyber-security industry. The global cyber-security market, already at \$61.1 billion in 2012, is expected to top \$100 billion by 2030, according to a study done by Morgan Stanley.

The Netherlands spends a greater proportion of its cybercrime funds on “prevention and protection” than neighboring countries – Germany, the UK, France, Finland, and Sweden. However, the Netherlands spends less of its cybercrime funds on “detect and respond” initiatives than some of its neighbors, undermining its ability to detect attacks and respond quickly to remediate the damage. Overall, Dutch expenditures in cybersecurity suggest that it perceives ‘detect and respond’ threats as a lesser priority than its Nordic neighbors. Local and global efforts that keep the Communication Internet up and running and Big Data flowing freely and not subject to massive disruption will define the political struggle in the coming decades – especially in highly developed regions like the Metropolitan Region of Rotterdam and The Hague that are far ahead in the build out and scale up of a ubiquitous communications network, and therefore more likely to be vulnerable to the forces of the Dark Net. In preparing for a Third Industrial Revolution future, the Metropolitan Region of Rotterdam and The Hague

¹⁹ See: http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=1753

will have to devote considerable human and financial resources to build resiliency into every part of the communication and Big Data network that is emerging.

From the above discussion, it should be clear that the telecommunications infrastructure will constitute a critical asset for communications, energy, and mobility, to carry the IoT traffic, but also for healthcare, entertainment, and factories of the future. This infrastructure, along with the smart grid for the distribution of electrical energy, must therefore be as resilient as possible since telecommunications and electricity networks are highly interdependent. Loss of power causes severe network and service outages in the communications sector.²⁰ Reliable telecommunications are critical to energy sector operations, especially in view of the smart grid of the future.²¹

Natural disasters, criminal attacks, and terrorism create the possibility of disruptions of service in areas of variable size, from local to regional. These conditions must be prevented, detected, mitigated, and resolved as quickly as possible, in order to minimize their impact on our society. For these purposes, it becomes crucial for the telecommunications network to be both self-healing and redundant.

As discussed above, 5G is designed to be a software-defined network, in which functions are virtualized over general purpose hardware. This is a key characteristic that allows the network to be reconfigured almost instantaneously, and services to be restored in minutes. Therefore, the intrinsic resilience of 5G networks is much higher than that of previous technologies, both cellular and Wi-Fi. However, this may not be sufficient in the presence of major black-outs. In these conditions, it becomes necessary to have alternative means of communications which do not rely on ground infrastructure. Satellite communications, including the use of high-altitude platforms (such as stratospheric balloons), become, therefore, the preferred back-up solution in these extreme conditions. Clearly, this requires that satellite links and gateways are included and their characteristics duly considered in the design of the 5G network standard. MRDH, also leveraging the presence of the European Space Agency ESA/ESTEC in Noordwijk, should consider how to contribute to the development and demonstration of highly resilient telecommunications networks.

²⁰ ENISA, 'Power Supply Dependencies in the Electronic Communications Sector', 2013.

²¹ Peter Campbell Johnston, *Climate Risk and Adaptation in the Electric Power Sector* (Mandaluyong City, Metro Manila, Philippines: Asian Development Bank, 2012).

MRDH has created a transition pathway for ushering in a seamless digital infrastructure and a Third Industrial Revolution economy. The Digital Gateway to Europe (DGtE) provides a framework for the MRDH Roadmap Next Economy. The DGtE transition encompasses the three key pillars that comprise the Third Industrial Revolution infrastructure: the Communication Internet, the Renewable Energy Internet, and the Mobility Internet, atop an Internet of Things platform.

The digital technologies introduced by DGtE function in a trans-sectoral and trans-governmental setting and respect the soft-values of Dutch citizens. DGtE technologies are based on a set of legal and political concepts allowing the Netherlands to function globally and digitally in commercial, legal and personal transactions. DGtE software systems support multiple legal domains and ownership concepts regarding data, goods and real estate, while defending the nation's basic data and ensuring cybersecurity. DGtE is tasked with helping to protect the MRDH citizenry in their interactions in both virtual and physical realms, including employment, mobility, finance, social and physical security, healthcare, well-being, and sustainability.

The DGtE strategy begins with “enabling” projects that set the stage for spawning a series of scalable “carrier” projects that can transform the sector into a fully operational Digital Gateway to Europe's economy. However, in developing a smart digital Third Industrial Revolution infrastructure, a number of obstacles will need to be overcome, including establishing secure extranets, ensuring secure digital marketplaces, providing appropriate legal channels for settling disputes over the use of digital data, and tracking digital transactions for purposes of taxation and compliance with laws and regulations.

IOT Landscape in 2015



Image source:ADITI, IoT Landscape in 2015

1.1.0 NEW BUSINESS MODELS AND VALUE CHAINS

1.1.0.1 Project Connect: Stimulate the emergence of ICT enabled trans-sectoral systems. This project is aimed at improving the existing MRDH network and IT infrastructure to support ubiquitous and secure IoT services. This infrastructure buildout is a capital-intensive undertaking and requires substantial financial support. Project Connect will result in a secure, open and future proof ICT environment. The scope of the project includes:

- Secure Extranets
- Secure extranet IEX as a service
- MRDH wide municipal fiber
- MRDH wide WiFi
- MRDH wide LoRa/LWPAN
- Dense 4G network for industrial and economic infrastructure (including offshore)
- 5G
- Roadside communication infrastructure for cooperative driving (WiFi-P)
- CEDD

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The objective of project Connect is to secure a chain of extranets coupled by a secure IEX, using existing and new telecom infrastructure and Internet connections that connect to mobile devices via all available wireless networks (4G, LoRa, etc.).

1.1.0.2 Launch public-funded contests for related entrepreneurial projects, especially for the younger generations.

1.1.0.3 Quick Wins – Within the Digital Gateway transition, several smaller enabling projects provide the opportunity for quick wins, leading to potential carrier scale up projects:

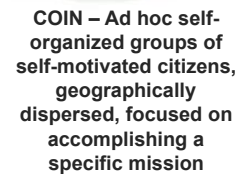
- Create an open smart lamppost infrastructure testbed that allows for multiple sensors to be attached. This builds on several initiatives already present in MRDH to test smart lighting.
- Provide free Municipal WiFi in several test locations.
- Establish MRDH-wide secure LoRa/LPWAN coverage.
- Launch Unmanned Valley, a large-scale testing facility to bundle drone initiatives.
- Introduce several Freezones within the MRDH with minimum regulatory and legislative restrictions to stimulate uptake of IoT services.
- Foster a FI-Ware Lab environment in MRDH.

1.1.1 TECHNICAL

1.1.1.1 Develop a smart strategy towards the 4G to 5G transition. This is critical as 5G will enable ultra-fast communications, the Internet of Things, as well as mission critical services. As discussed in the previous section, early demonstrations of technology can be pursued, in collaboration with large industries and operators of the telecommunications sectors. In particular, measures for increased network resilience in emergency conditions should be developed and tested. It is also very important to grow the skills in Data Science and to spin out a number of new companies developing applications in this field.

1.1.1.2 Establish a Collaborative Innovation/Collective Intelligence Network (COIN) open source, open access, open device Platform - Underpinning the exponential expansion of the Next Economy/Third Industrial Revolution is a myriad of COINs on IP platforms. COINs are proven means of pursuing missions and achieving goals by harnessing the collaboration and collective intelligence of self-motivated individuals self-organizing into ad hoc clusters focused on accomplishing a core mission(s) (e.g., Wikipedia, Linux). The open IP platform, accessible by

Catalyzing Collaborative Innovation Networks



1.1.1.4 Advance the security of supply chains – Foster integrated solutions and products that have been peer sourced in distributed networks. Suitable procedures and methods are

necessary in which all the segments of complex supply chains of ICT development will be considered. The responsibility to apply such procedures and methods typically lies with the supply chain's last link. But to develop more secure ICT, all suppliers should be included into the security processes from the outset. This is what we call Security by Design – to develop and optimize standardized engineering methods that can guarantee a defined level of IT security for MRDH. Together with partners in research and industry, MRDH could develop a Security by Design strategy to propose secure engineering approaches, formulate best practices, and optimize software development processes over the complete IoT life cycle. Elements of such a strategy should include: 1) Security design decisions/application-specific threat models; 2) Definition of protection goals; 3) Test methods for different software products; 4) Training programs for developers; and, 5) Evaluation and productive use of test tools.

1.1.1.5 Include Privacy by Design and Legal Protection by Design – Establish legal requirements for a level playing field that allows all stakeholders in an IoT platform to determine how their personal data – including creative content – is to be used and by whom and under what conditions.

1.1.1.6 To counter these security and privacy risks, a holistic cybersecurity concept for Industrial IoT systems is required that addresses the various security and privacy risks at all levels of engagement. This includes different aspects, such as platform security, secure engineering, security management, identity management, and industrial rights management. In particular, security and privacy aspects must be preserved during the lifetime of smart production and distribution systems; these are all Security at Large design issues.²²

1.1.1.7 MRDH should invest in implementing IoT Security at Large designs – Security at Large designs support resiliency. Guiding principles for such designs should be redundancy, distribution, isolation (avoiding single points of failure), minimal trust anchors, and scalable security protocols. Security at Large can be understood as an extension of “Security by Design” and focuses on the integration of IT components into large complex systems. Since MRDH constitutes such a large complex system (Living Lab), this is of special importance for the MRDH Roadmap Next Economy. Examples include Cyberphysical Systems, Cloud Computing and “Networked Industry.” This additional proposal is of special importance for the development and implementation of a **secure industrial / enterprise IoT** in MRDH.

²² M. Waidner, M. Kasper, T. Henkel, C. Rudolph, and O. Kuch. “Eberbacher Gespräch zu “Sicherheit in der Industrie 4.0”, 2013.

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1.1.1.8 Project DATA - This project provides access to currently available open data within MRDH, making the information accessible through dashboards (like the DATA USA initiative). Dashboards provide information, earmark opportunities, and identify bottlenecks for CI RNE. Based on current information and strategies, MRDH can establish effective policies to achieve CI RNE goals.

1.1.1.9 Project 3D - This project will create an MRDH-wide fully digital open platform on spatial data. A 3D MRDH ground truth database interfaces with building information management (BIM) systems, and environmental impact analyses, enabling a systemic digital approach to urban planning, from the design phase all the way to ultimate impact analysis.

1.1.1.10 Project Secure Digital Data Exchange - This project will create an MRDH-wide IT capacity for accessing IoT data across sectors. IoT Big Data flowing to the Communication Internet, Renewable Energy Internet, and Mobility Internet connects individuals, enterprises, and government agencies along a seamless smart infrastructure allowing all parties to engage directly with each other in a secure operating environment. Using open, interoperable elements (similar to FI-Ware), MRDH can:

- Create a cross-sector (“datarotonde”) IoT data enabling architecture
- Establish a storage facility for this type of data
- Support identification and localization
- Foster data discovery across chains
- Establish secure systems by design
- Ensure compliance with rights of privacy
- Create a business ecosystem that provides an ongoing flow of Big Data that can be mined with analytics to create algorithms and apps to increase aggregate efficiency and productivity
- Promote community building

1.1.1.11 Project Secure Digital Marketplace - This project creates an MRDH-wide IT capacity for developing services across sectors. A systems approach will allow enterprises to collaborate across sectors in the delivery of services in secure platforms. Using open, interoperable elements (similar to FI-Ware):

- Creating a cross sector IoT services/marketplace enabling architecture
- Supporting secure sensor based transactions, payments and accounting

- (blockchain supported)
- Supporting taxation and compliance with other government regulations
- Creating a business ecosystem that provides data and process analysis services within the IoT services/marketplace

1.1.2 REGULATORY

1.1.2.1 Establish a new Commissioner on Security and Resilience – While Rotterdam already has a Chief Resilience Officer, it will be important to expand the Resilience mandate with the appointment of a Commissioner on Security and Resilience. The multitude of inter-related issues, challenges, and opportunities emerging from the expansion of pervasive IPv6 addressability throughout the economy necessitates ongoing reviews of regulatory and policy measures to sustain security and resilience of the Internet of networks. Information security threats have evolved from the familiar low-risk automated attacks of worms and viruses to more insidious high-risk threats coming from both outsider and insider perpetrators, requiring ever more sophisticated regulatory oversight and response mechanisms, and more resilience built into the fabrics of the networks.

1.1.2.2 Implement protocols for safe-operating conditions of autonomous systems - Robots, driverless vehicles, drones, and other autonomous systems will need to be regulated for safety and be certified to operate in controlled environments. Relevant field-labs should be established as part of crossover knowledge centers with other sectors to advance the various issues relevant to securing safe operating protocols for autonomous systems.

1.1.2.3 Create legislative Cybersecurity working group for MRDH - MRDH should establish itself as an innovator in recommending appropriate legislative proposals on Cybersecurity at the Dutch and EU levels.

1.1.2.4 Promulgate regulations to ensure network neutrality, privacy, and data security - The trade-offs between security, privacy and value creation warrant a thorough analysis. The success of IoT depends on the sharing of data and large-scale participation by prosumers. Data sharing, to accommodate all legitimate interests and objectives, requires trust amongst all stakeholders. This, in turn, requires a coherent and transparent approach to privacy and security. End-user acceptance also requires that the value created in the IoT is allocated to stakeholders in a fair, transparent and unambiguous way. At the same time, regulation must

preserve the possibility of delivering high-quality and low-latency mission critical services, such as those for self-driving cars and autonomous transportation, emergency communications and disaster recovery, and personalized health care. In all these cases, poor network performance would cause loss of lives.

1.1.2.5 Develop The Hague Security Delta (HSD) campus – Designate the HSD as the leading innovation center on security in the areas of Cyber Security, Critical Infrastructure, Forensics, Urban Security, and National Security. Develop HSD as a significant part of a European Knowledge and Innovation Community (KIC).

1.1.2.6 Reform regulatory policies at the Netherlands and at the European Union levels to encourage an integrated communication network across the EU.

1.1.2.7 Project Digital Dispute Resolution – This project will democratize justice services through the creation of an online platform for resolving cyber and digital issues. The Digital Dispute Resolution Project allows litigants, attorneys, and judges to work together towards fair and effective resolutions. The approach is internationally scalable and can be implemented for different types of conflict. The platform will be supported by data analytics and machine learning modules (for instance anomaly detection).

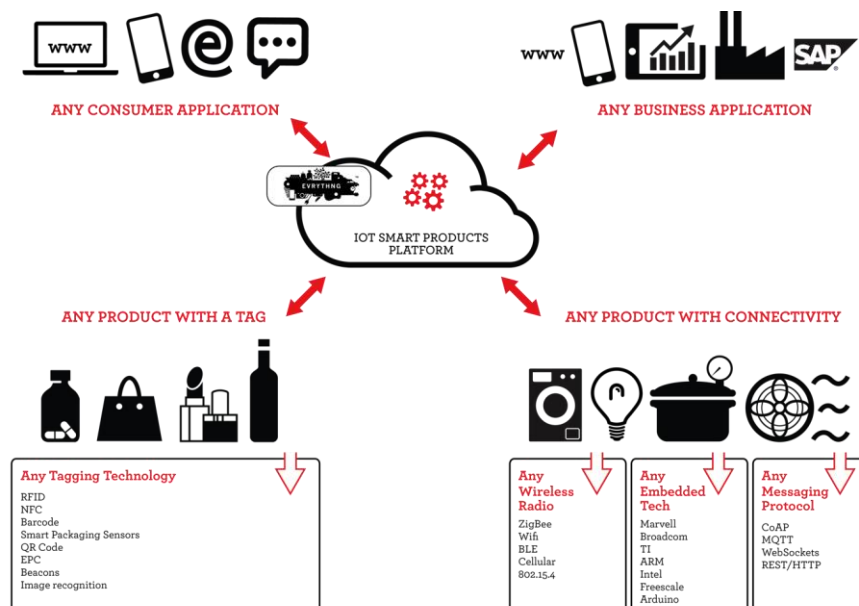


Image source: SAP.

1.1.3 POLICY

1.1.3.1 Address the resiliency of cities and the antifragile interdependency of critical infrastructures - Measures to increase resilience should be discussed and shared amongst different stakeholders, as measures taken by one stakeholder can impact the effectiveness and, therefore, also the financial benefits of measures taken by other stakeholders. Approaches to increase resiliency should not be limited to a technical assessment and technical solutions, but also include governance aspects and institutional innovation. Antifragile options should also be examined, since antifragility goes beyond resilience or robustness. The resilient absorbs shocks and stays the same; the antifragile is proactive and anticipates threats that may occur in the future.

1.1.3.2 Develop well-focused incentives – Start-ups and IoT communication initiatives require a different set of investment funds and subsidies and need to be examined in greater detail.

1.1.3.3 Remove silo bottlenecks – MRDH should encourage an integrated and systemic approach to ushering in a smart IoT Third Industrial Revolution infrastructure. To date, the vast majority of efforts to advance the transition to a smart economic paradigm has been incremental and isolated, and has contributed little to the build-out and scale-up of an integrated and interconnected Third Industrial Revolution platform. A systems approach to governance is essential to assure a coherent transition into the next economy infrastructure. The transition requires collaboration at every level, as well as joint investments in the TIR infrastructure build-out in MRDH.

1.1.3.4 Review laws and policies essential and helpful in promoting Digitalization and Internetization – Many of the policies, laws, regulations, and incentives that have come into force during the Second Industrial Revolution need reassessment in light of the unique features of the Communication Internet. New issues are also arising around connectivity, security, privacy, transparency, interoperability, financial transactions, customs, taxing, and virtual market places. A comprehensive policy overhaul will be required for improving digital trust, settling disputes, controlling Big Data, and other emerging issues. A delicate balance must be struck between over and under prescribing or proscribing policy initiatives in the transition from a Second to a Third Industrial Revolution system of governance.

1.1.4 EDUCATION

1.1.4.1 Incorporate the range of cybersecurity issues that pose security challenges to organizations' data, information, and operations into the educational curriculum. The incorporation should be implemented through the Co-op route, and vocational education on cybersecurity, notably the ROC Mondriaan College of Order & Safety (ROC Mondriaan School voor Orde & Veiligheid) and Hague University of Applied Sciences (de Haagse Hogeschool, HHS) & Hague Security Delta (HSD); as well as the Cyber security bachelor of education, and the Lectoraat/Professorship of Cyber security and safety, HHS.

1.1.4.2 Develop a Safety & Security campus in The Hague. This involves developing a center of Expertise in Cyber Security & Safety (jointly with Deltalinqs), where students of various competences and backgrounds work and learn in innovation teams on the socio-technical complex “wicked problems” confronting companies and government. The focus should be on the interlinkages between business, techniques, norms, standards, and cross-sectoral solutions. An innovative organizational structure and function should enhance the ability to swiftly adapt to new and unexpected opportunities and threats.

1.1.4.3 Develop cybersecurity livinglabs/fieldlabs. Given the pervasive challenges that cybersecurity poses to many socio-economic domains (e.g., energy grids, banking, medical data, security systems), the range of cybersecurity issues should be integrated into all education and training programs in the existing and emerging innovation and field labs. These labs include: the VitalITy lab in Zoetermeer, which is a partnership between students, companies, and governments, focusing on innovative technological applications promoting positive health; the Netherland Forensics Lab, NFI, within the Ministry of Security and Justice, which provides courses, workshops, and training programs; and the Start-up Ecosystem, which connects the ten innovative Dutch hubs into a unified Hub. The Startup Delta comprises Europe's largest and best-linked startup ecosystem. The Secure Critical infrastructure lab, located within The Hague Security Delta, is developing a holistic approach to securing Critical Infrastructures in the Netherlands through the use of a multi-sector testbed; and ENCS, the European Network for CyberSecurity, located in The Hague, which brings together critical infrastructure stakeholders and security experts to deploy secure European critical energy grids and infrastructures.

1.1.4.4 Develop educational resources online, in classrooms, and on the field, for cultivating next generation skills – A strong grounding in skills and competences is needed in ICT (Big Data applications, IoT, smart sensors), automated planning and control, additive manufacturing,

(green) engineering and maintenance, etc. The workforce is lacking a number of crucial skill sets at the moment, including qualified software engineers and IT professionals. This is a potential problem for the development of the MRDH Next Economy. 'Learning capacity' should be improved. New tools and technologies including serious gaming and smart-IT platforms for collaboration and the exchange of ideas are available and should be introduced in schools across MRDH. Business Universities should be actively engaged in transforming curricula to accommodate the new business models and business practices that accompany the transformation to a Third Industrial Revolution.

1.1.4.5 Reverse Mentoring – Students are often more competent in the diversity of digital technologies, apps, and social media than teachers and administrators. Reverse mentoring should be employed, leveraging student knowledge, experience, and enthusiasm for accelerating learning processes. Reverse mentoring has become a widespread practice in business, whereby older executives are paired with and mentored by younger employees on digital and Internet topics such as technologies, apps, social media and trending developments.

1.1.4.6 Creativity and Innovation – It is evident that the Third Industrial Revolution will deeply transform our professional lives and the job market. The rise of artificial intelligence will resolve many routine tasks, while also providing ultra-fast support for decision-making through Big Data analytics. It is, therefore, of utmost importance to transform the educational system by introducing mandatory courses on the most unique and peculiar human skill, i.e. the ability to generate new ideas that are both original and effective. Creativity can no longer be left as a natural talent of the elite, but must be transformed into a scientific discipline accessed by everyone in a democratic way. Courses and degrees in creativity and innovation are emerging around the world, and MRDH should be upfront in this crucial field.

1.1.5 FINANCIAL

1.1.5.1 MRDH should seek to capture the major benefits of early on investments in 5G communication. 5G will address three markets, all fundamental for the realization of the TIR: 1) ultra-wide band wireless communications, with peak data rates per device which are orders of magnitude larger than those achievable today (up to 1 Gigabit/second) thanks to the exploitation of millimeter-wave bands; 2) the exponential leap into IoT services brought on by the interconnection of trillions of devices; 3) mission critical services that address issues of

network latency, availability and reliability, and foster real-time operations in demanding environments, such as automotive, industrial production, remote operational healthcare, emergencies and disaster relief.

1.1.5.2 Use a Weighted-Average-Cost-of-Capital (WACC) in determining investments in the IoT of Communications, Energy, and Transportation and Logistics. This financial metric provides insight on the discount rate to use in determining the risk of an investment. At the same time, mounting evidence shows businesses and agencies fail to fully account for risk when performing investment project valuations. This leads to decisions resulting in value-collapsing outcomes. The crux of the problem is over-dependency on just one discount rate to evaluate the risk of all investment projects. This truncated measurement and distortion of risk is a practice known as the WACC fallacy. The WACC fallacy causes firms to over-value riskier investment options, while under-valuing safer projects.

1.1.5.3 Employ Econometrics for the digital economy (i.e. input, output data) – Econometric analyses will become increasingly important when the MRDH leadership has to address policy challenges. How big is the digital economy in the region? Who are the actors? What are their inputs and outputs? Where exactly are digital firms located? What impact will particular policy initiatives have on multiple sectors? MRDH should establish an annual “Digital Economy Report” using the latest econometric models to provide policy makers with quantitative and qualitative data on the MRDH Digital Economy.

1.1.5.4 Implement Big Data analytics, data mining, and other advanced digital economy data gathering tools that go beyond the traditional International Standard Industrial Classifications (ISIC) and the General Industrial Classification of Economic Activities within the European Communities (NACE) standards and facilitate so-called evidence-based policy making. The increasing ability to mine Big Data has transformed the field of economics. Big Data sets from both public and private sectors can be employed for significantly advancing the methods by which economic activities are monitored, measured, and analyzed. Such procedures give rise to innovative design methods that enable the evaluation of the impacts and outcomes of various public policies. A notable example is the UK government’s Big Data initiative that is designed to advance national statistics by opening economic statistics to users and outside experts.

1.1.6 R&D

1.1.6.1 Increase government ICT R&D funding levels. According to the most recent figures, 1.98 percent of Dutch GDP was allocated for R&D, modestly higher than the EU-28 average of 1.92 percent. The government's goal is to increase spending on R&D by 2020 to 2.5 percent of GDP, less than the Europe 2020 Strategy target of 3 percent of the EU's total GDP allocated to R&D by 2020.

1.1.6.2 Facilitate crossover R&D between the ICT sector and other sectors. According to Statistics Netherlands's *ICT, Knowledge and the Economy 2015* report, ICT businesses comprise one out of six Dutch companies involved in R&D, representing 15% of overall R&D expenditures. Moreover, 20% of R&D researchers come from the ICT sector. Given the interconnection of the Internets of Communication, Energy, Mobility & Logistics, and Buildings as Nodes, it is critical to catalyze crossover R&D between these sectors, especially regarding issues of technology protocols, standards, and harmonization.

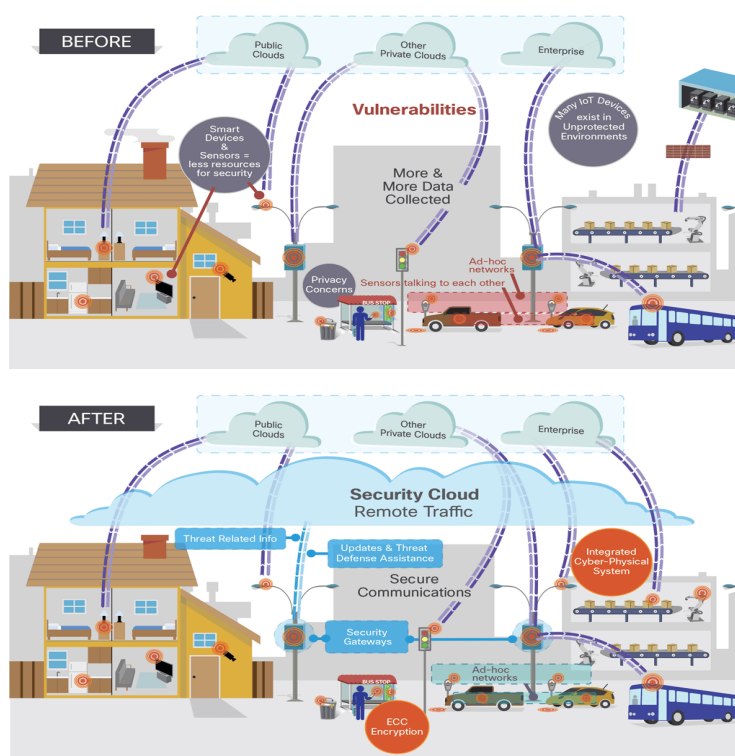


Image source: Cisco

THE MOBILITY & LOGISTICS INTERNET

The Netherlands is one of the most densely populated countries in the European Union and enjoys a well-developed transportation system of road, rail, water, and air mobility. Approximately 50% of all trips in the Netherlands are made by automobile, 25% by bicycle, 20% by walking, and 5% by public transport.²³ The airports of the Netherlands accommodate 58 million passengers per year. The emerging digital revolution is forcing the Netherlands to rethink its Second Industrial Revolution transportation and logistics platform.

Michiel Jak and the Working Group members from MRDH

Elisabetta Cherchi (Technical University of Denmark), Francesco Sechi (MLab srl), Luca Guala (MLab srl), and Jeremy Rifkin for TIR Consulting Group LLC

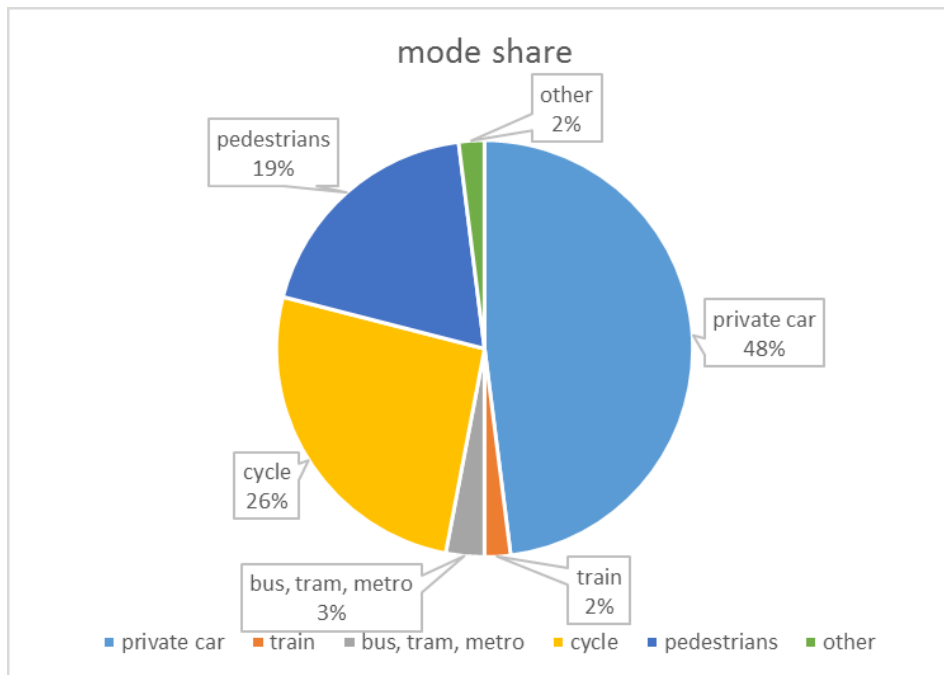


Figure 1 - Modal share in the Netherlands

²³ From: Mobiliteitsonderzoek Nederland
<http://beheer.nisb.nl/cogito/modules/uploads/docs/18351343986023.pdf>

The meshing of the Communication Internet and the Energy Internet makes possible the build-out and scale-up of the automated Transportation and Logistics Internet. The convergence of these three Internets comprise the kernel of the Internet of Things platform for managing, powering, and transporting goods in a Third Industrial Revolution economy. The automated Transportation and Logistics Internet is made up of four foundational pillars, which, like the Energy Internet, have to be phased-in simultaneously in the Metropolitan Region of Rotterdam and The Hague for the system to operate efficiently.

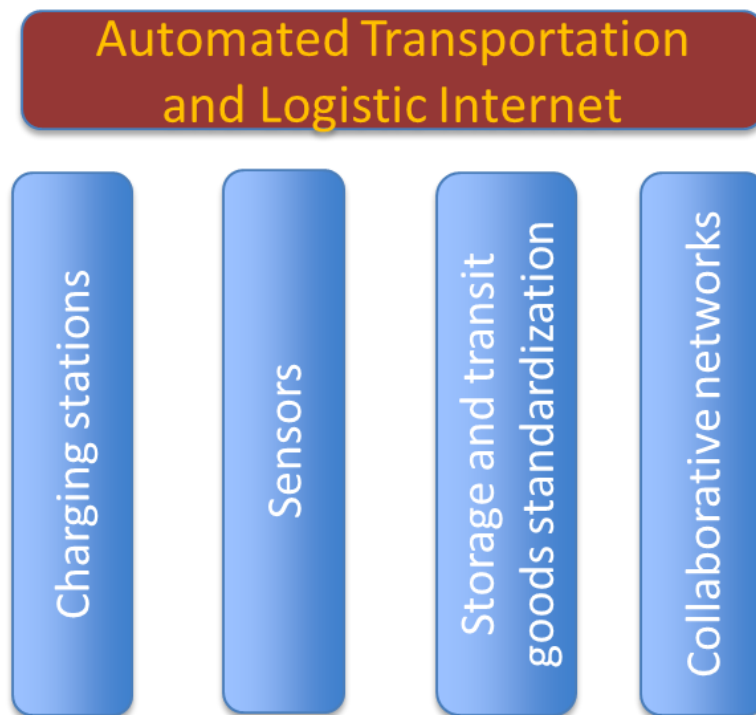


Figure 2 - The four pillars of the Automated Transportation and Logistics Internet

First, charging stations will need to be installed ubiquitously across land masses, allowing cars, buses, and trucks to power up or send back electricity to the grid. *Second*, sensors need to be embedded in devices across road networks to manage traffic flows, identify the best itineraries for automated vehicles, and provide information to the users (i.e. collective public transport information, car-sharing and car-pooling, etc.), and across logistics networks to allow factories, warehouses, wholesalers, retailers, and end users to have up-to-the-moment data on logistical flows that affect their value chain. *Third*, the storage and transit of all physical goods will need

to be standardized so that they can be efficiently passed off to any node and sent along any passageway, operating across the logistics system in the same way that information flows effortlessly and efficiently across the World Wide Web. *Fourth*, all of the operators in public transport systems and logistic corridors need to operate in synergy and seamlessly. Public transport operators must provide a fully seamless public transport system based on the coordination and interchange between different transport modes, with a single tariff system and travel document. The operators along the logistics corridors need to aggregate into collaborative networks to bring all of their assets into a shared logistical space to optimize the shipment of goods, taking advantage of lateral economies of scale. For example, thousands of warehouses and distribution centers might establish cooperatives to share unused spaces, allowing carriers to drop off and pick up shipments using the most efficient path en route to their destination. The Internet of Things platform will provide real-time logistical data on pick-up and delivery schedules, weather conditions, traffic flows, and up-to-the-moment information on warehouse storage capacities in the Metropolitan Region of Rotterdam and The Hague. Automated dispatching will use Big Data and analytics to create algorithms and applications to ensure the optimization of aggregate efficiencies along the logistical routes and, by so doing, dramatically increase productivity while reducing the ecological footprint and marginal cost of every shipment.

By 2025, at least some of the shipments on roads, railways, water, and air corridors will likely be carried out by driverless electric and fuel cell transport, powered by near zero marginal cost renewable energies, and operated by increasingly sophisticated analytics and algorithms. Driverless transport will accelerate productivity and reduce the marginal labor cost of shipping goods and moving people toward near zero on a smart automated Transportation and Logistics Internet. The Netherlands is already committing funds to the build out of a smart transportation Internet. In 2015, the government announced a € 70 million investment in smart transport. While this first round of investments is primarily targeted to assisting commuters with Big Data and apps to help them better manage daily traffic conditions en route to and from work, more far-reaching changes in transportation modes are afoot. In 2005, after 6 years of testing, the Netherlands became the first country to provide a driverless shuttle bus service. While the pilot project is limited in nature and designed to provide Big Data feedback for a vast expansion in driverless public transport, the country also expects to hold similar trial runs of driverless semi-trucks at the Port of Rotterdam in 2016, with the goal of shipping goods by autonomous road trains throughout the continent by 2019.

The erection of the automated Transportation and Logistics Internet will transform the very way the Metropolitan Region of Rotterdam and The Hague inhabitants view mobility. Today's youth are using mobile communication technology and GPS guidance on an incipient automated Transportation and Logistics Internet to connect with willing drivers in car sharing services. Young people prefer "access to mobility" over ownership of vehicles. Future generations will likely own far fewer vehicles in a smart automated mobility era.

For every vehicle shared, however, 15 vehicles are eliminated from production. Larry Burns, a former Vice President of General Motors, and now a professor at the University of Michigan, did a study of mobility patterns in Ann Arbor,²⁴ a mid-sized American city, and found that car-sharing services can eliminate 80% of the vehicles currently on the road and provide the same, or better, mobility at a lesser cost.

²⁴ See: <http://sustainablemobility.ei.columbia.edu/files/2012/12/Transforming-Personal-Mobility-Jan-27-20132.pdf>

Figure 8. Potential value shifts



^aDeloitte analysis; annual percentage decrease is calculated prior to any changes in fuel mix and is equivalent to a decrease of 10% to 25% of overall US emissions.

^b2013 figure for US only; global figure is 1.24 million annually (WHO)

^cDeloitte analysis based on miles driven in the US in 2014 (DOT) and average travel speed in miles per hour (Columbia University)

Source: Deloitte analysis

Graphic: Deloitte University Press | DUPress.com

There are currently a 1.2 billion cars, buses, and trucks crawling along in traffic in dense urban areas around the world.²⁵ Gasoline-powered internal combustion vehicles were the centerpiece of the Second Industrial Revolution. The mass production of these vehicles devoured vast amounts of the Earth's natural resources. Cars, buses, and trucks also burn massive amounts of

²⁵ See: <http://www.navigantresearch.com/research/transportation-forecast-light-duty-vehicles>

oil and are the third major contributor to global warming gas emissions, after buildings and beef production and related agricultural production practices.

Burns' study suggests that 80% of the vehicles currently on the road are likely to be eliminated with widespread adoption of car sharing services over the course of the next generation. The remaining 240 million vehicles will be electric and fuel cell transport, powered by near zero marginal cost renewable energy. Those shared vehicles, in turn, will be driverless and running on automated smart road systems.

The long-term transition from ownership of vehicles to access to mobility in driverless vehicles on smart road systems will fundamentally alter the business model for the transportation industry. While the big auto manufacturers around the world will produce fewer vehicles over the course of the next 30 years, they will likely increasingly reposition themselves as aggregators of the global automated Transportation and Logistics Internet, managing mobility services and logistics.

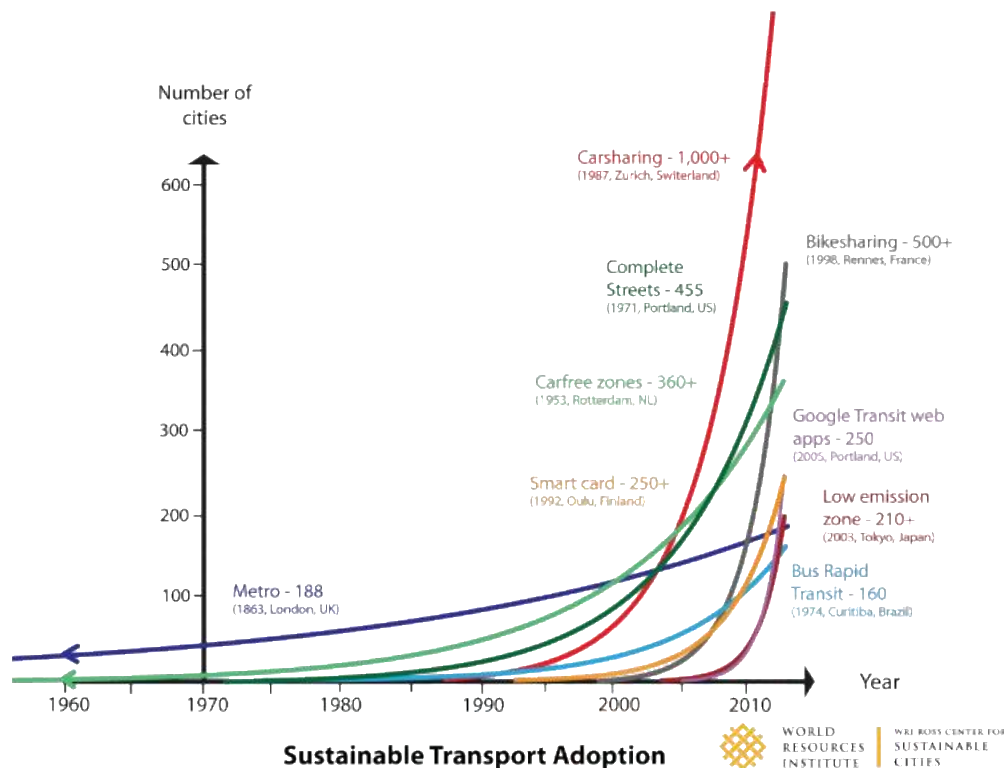


Figure 4 - Sustainable transport adoption

Daimler Trucks leads the field in connectivity for commercial vehicles. The leader in advanced global truck manufacturing has been pushing connectivity in recent years as a fundamental component of its technology innovation vision. Since 2013 Daimler has implemented connectivity in 365,000 vehicles worldwide.²⁶ These driverless trucks are effectively mobile big data centers equipped with sensors that are gathering real time information on weather, traffic conditions, warehouse accessibility, and various other logistics data. Daimler mines this information with Big Data analytics in real time, enabling it to generate algorithms and apps for businesses to use to improve their productivity and aggregate efficiencies throughout the entire logistical supply chain. Daimler is operating in hybrid mode, continuing to market their trucks in a Second Industrial Revolution system, while also emerging as a leading player in constructing, innovating, and automating a Logistics Internet in a Third Industrial Revolution economy.

Through V2V and V2I communication – Vehicle to Vehicle and Vehicle to Infrastructure –, connectivity can prevent gridlocks, markedly reduce fuel consumption and emissions, and lower the number of traffic accidents. Society benefits from enhanced safety and a reduced strain on resources and the environment. Companies benefit from optimized logistic processes, saving time and cutting costs, and the strain on truck drivers is significantly reduced. The intelligent, fully connected truck is the success formula for companies, drivers, and society alike. Daimler Trucks is systematically developing and expanding its corresponding services and technologies, becoming an early leader in the erection and management of an automated GPS and driverless Transportation and Logistics Internet.

Introduction

The Netherlands is a pioneer of a mobility revolution, motivated by environmental concerns, congestion/space occupancy issues, and boosted by technological innovations and behavioral changes in the population. This revolution is currently transforming the transport system from one based on ownership of gasoline powered cars to a system based on sharing, electric and hydrogen powered vehicles, accompanied by bicycle lanes, walking paths, and green areas. In fact:

²⁶ See: <https://www.daimler.com/innovation/connectivity/connected-trucks.html>

- In 2015, the Dutch market share for plug-in passenger cars rose to 9.74%, the second highest after Norway (22.4%).
- In 2014, Rotterdam Taxi Centre put into service two electric taxis and, after around one year's trial time with much positive feedback, it planned to extend it to 25 vehicles.
- In 2013, Rotterdam city made plans to install 500 charging points.
- In 2016 (April) the Dutch railway agreed to construct fast-charging stations for EV on vacant lots in Amsterdam, Rotterdam, and The Hague.
- The Netherlands is also the first European country to adopt stations for "level 3" fast-charging.
- In 1999, the ParkShuttle, an automated PT, was realized; in 2005 it started public service.

MRDH also has specific strengths that greatly impact mobility and logistics (M&L). The most relevant are:

- A high-level knowledge, education, and innovation ecosystem, with universities in Leiden, Delft, and Rotterdam that are ranked in the world top 100.²⁷
- A world-class port with an enormous industrial cluster and a "gateway to Europe" transport infrastructure.
- A world-class greenery cluster including greenhouses, wholesalers, conditioned storage, and export facilities.
- A centrally positioned international airport.
- The logistical sector in relation to the maritime clusters. The Port of Rotterdam is well connected through rail (BetuweRoute) and inland waterways (Rhein, Antwerpen connection, inland).
- A large number of distribution centers and world class logistics operations.
- A large number of multi-modal logistical movements (related to the previous two points).
- Advanced automated container processes in the port, especially at Maasvlakte 2.
- The most extended hydrogen grid and production facilities in the world.

²⁷ Times higher education World University ranking (www.timeshighereducation.com)

- The first driverless public transport system in operation (Parkshuttle/Capelle aan den IJssel).
- A polycentric settlement structure and high density of inhabitants (the densest region in the Netherlands).
- An existing collaboration between 23 municipalities in MRDH and the province of South-Holland, which led to the Innovation-agenda on Mobility, aims at better mobility solutions and more opportunities for business and knowledge institutes.

Despite all of its strengths, the region will face serious challenges in the field of mobility and logistics over the next several decades. The growth in the number of users will put even more pressure on the transport infrastructures, requiring vast improvements in the quality of the transport system.

Current Criticalities and Trends

The following criticalities, due to the effects of the Second Industrial Revolution, and trend scenarios will affect the quality of mobility:

- An estimated population growth of about 900,000 inhabitants over the next two decades (whole Randstad area).
- An aging population.
- Lower benefits from potential agglomeration in comparison to other regions (OESO rapport).
- Proximity of The Hague and Rotterdam, but weak public transportation connections (travel time is relatively long and often transfers are required).
- Poor or undeveloped last mile transport at several sites.
- The Hague and Rotterdam have the highest percentage (80%) of intercity daily car traffic among comparable regions.
- Increased vehicle congestion in municipalities like Zoetermeer, Pijnacker-Nootdorp, Lansingerland and Barendrecht, due to population growth.
- Increasing travel between the bigger cities within the Randstad region (Amsterdam/Schiphol, Utrecht, Leiden etc.) triggered by jobs requiring higher levels of education.
- A significantly lower percentage of bicycle use (20-25% of all movements) compared to other Dutch cities like Amsterdam or Utrecht despite the fact that in the city centers of Rotterdam and The Hague, there is currently an increase in the use of bicycles and a

decrease in the use of cars. Twenty percent of bicycles sold are E-bikes which increase the acceptable cycling range from about 5 up to 15 kilometers.

- Presence of several bottlenecks that limit the improvement of the transport infrastructures.

A significant reduction in emissions (CO₂, NO_x and PM) and a rethinking of the transportation and logistics platform model based on the Second Industrial Revolution is needed.

Impact of Different Transportation Systems

Transportation studies show that Dutch citizens prefer to travel by car. Car trips make up 48% of all trips. Not surprisingly, the bicycle is the next most favored choice of travel mode of the Dutch with 26% of the share, followed by trips on foot (19%), and public transport (5%).²⁸

Since trips by car and public transport are typically longer than trips by bike and on foot, a more interesting data-set is the passenger per kilometers, which accounts for the length of the trips. Considering this parameter, the trips made by car expand to 76% of the total and public transport trips to nearly 12%, while bicycle trips shrink to 7% and pedestrian trips to only 2.3%.

Energy consumption, pollution and GHG emissions are strictly related to the length of the trip performed with each mode. Assuming the average occupancy rates for the Netherlands and average consumption rates for each type of vehicle²⁹, one car passenger requires three times as much fuel as a bus passenger. This also means about three times more pollution and GHG emissions generated by fossil fuel consumption. In terms of occupying space, the difference is even greater, since a car passenger occupies about eight times the space taken up by a bus passenger³⁰.

²⁸ These numbers refer to the entire nation of the Netherlands. When referred to the Region of South Holland, the numbers do not vary much.

²⁹ Occupancy: 1.6 passengers per car, 25 passengers per bus (Eurostat 2002); fuel consumption: cars 7.5 l/100 km; buses 42 l/100 km

³⁰ Assuming average values for the space occupied by vehicles in motion and by parked vehicles, considering that buses do not stay parked most of the time

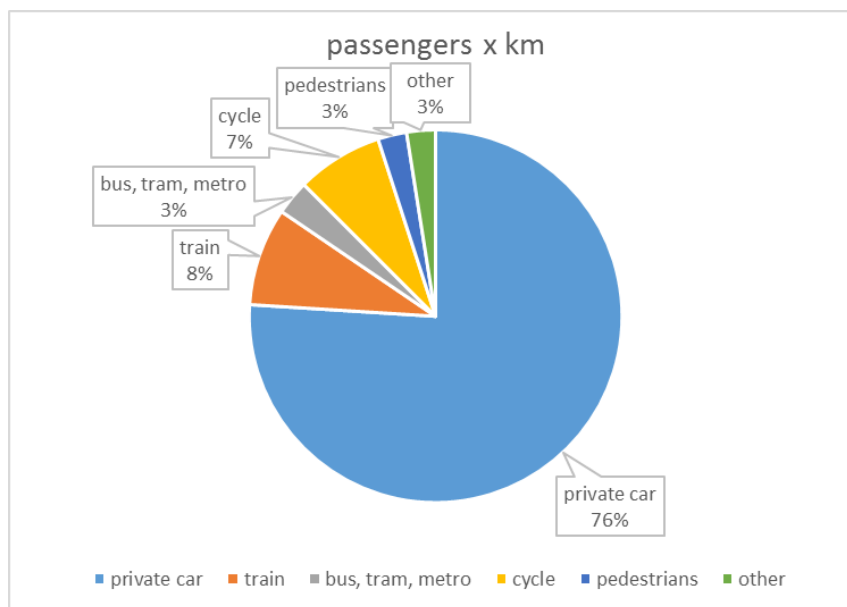


Figure 5- Passenger per kilometers in the Netherlands (Mobiliteitsonderzoek Nederland)

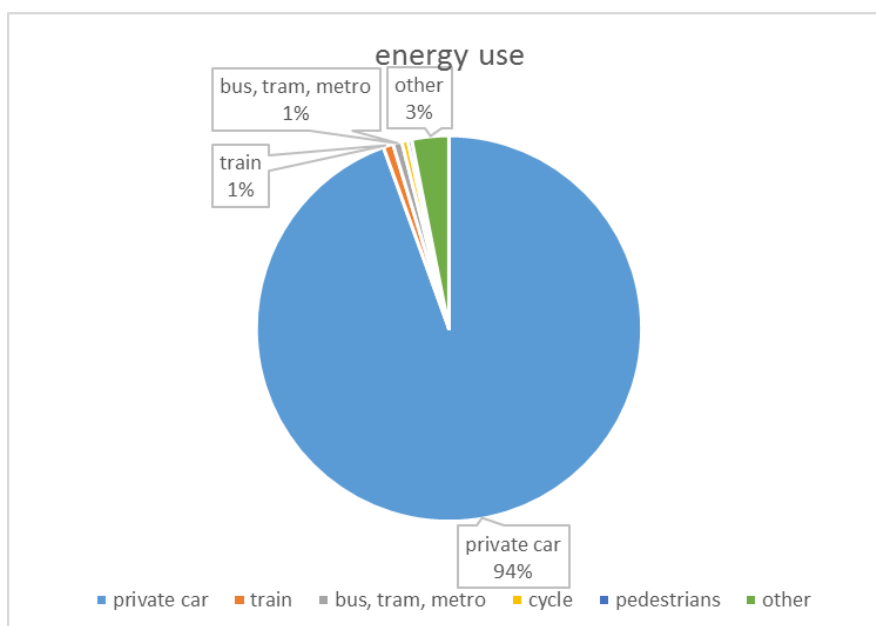


Figure 6 - Energy use by means of transport

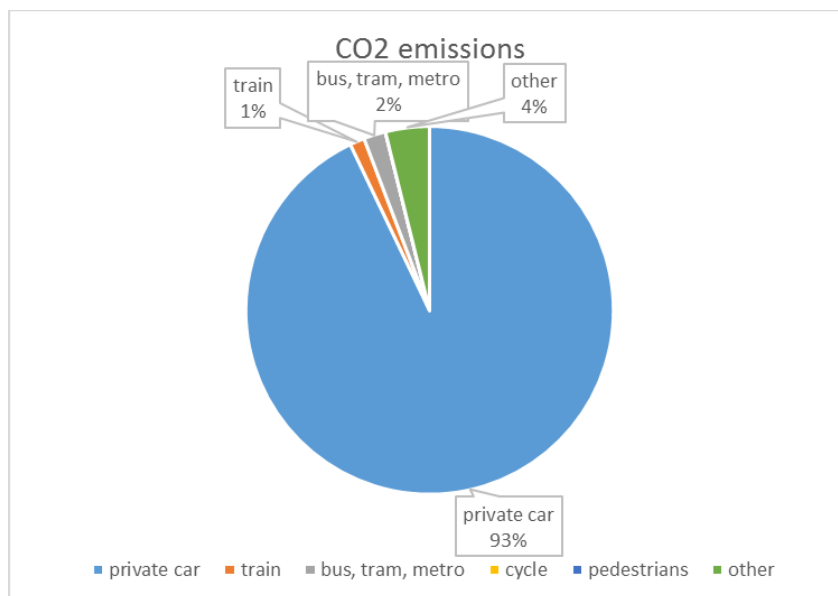


Figure - 7 CO₂ emissions by means of transport

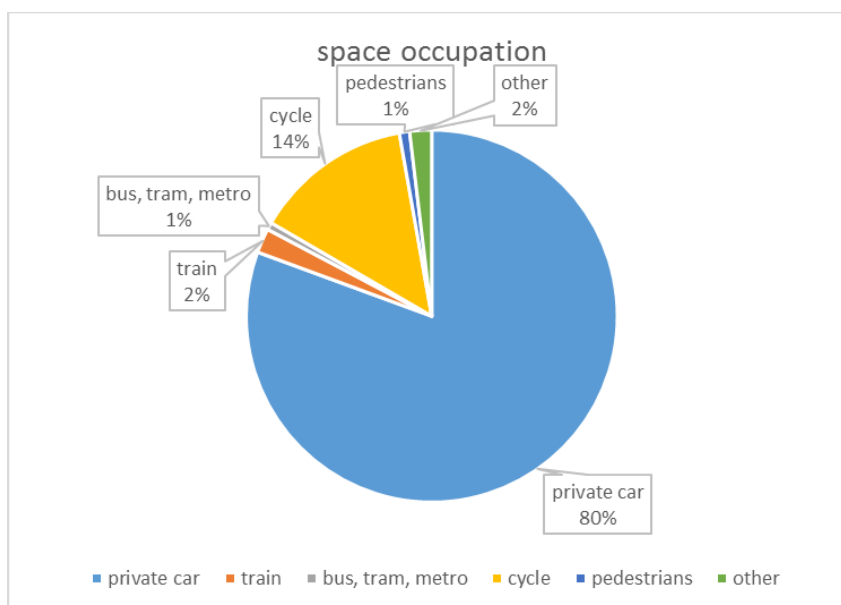


Figure 8 - Space occupation by means of transport

Despite car travelers accounting for only roughly half of those who travel, the graphs above show that people who travel by car use between 80% and 94% of the budget for energy, GHG emissions, and space occupation allocated to mobility.

The fossil fuel powered car is an incredibly inefficient way to manage mobility, by all parameters considered, with the sole exception of personal convenience. It is clear that any reduction in the use of the personal car will correspond to a significant reduction in the amount of resources assigned to mobility. These resources: energy, space, and even GHG emissions, can be assigned to other uses (in the case of GHG emissions in the form of GHG credits) or simply spared.

By transferring trips from the private car to public transport, those who change mode will significantly reduce their impact on the built environment, even if nothing else is changed. A policy to limit the use of cars and further improve mass public transport, especially over long distances, is therefore a winning policy toward realizing the objectives of a Third Industrial Revolution.

When compared to a shift from fossil-fuel powered cars to electric cars, the result is that transferring trips from cars to buses yields similar or better results than transferring trips to electric cars. In fact, the energy efficiency of electric-powered trains is about three times that of fossil-fuel motors, which results in three times less energy consumption. This is the same advantage resulting from travelling by bus, rather than by car. In addition to this, no advantage in terms of space occupation results when a fossil-fuel car is replaced with an electric car of similar size and performance.³¹

³¹ A considerable reduction of space occupation can be obtained by adopting shared vehicles and implementing a high level of automation, but it does not reach the levels obtained by an efficient public transport system.

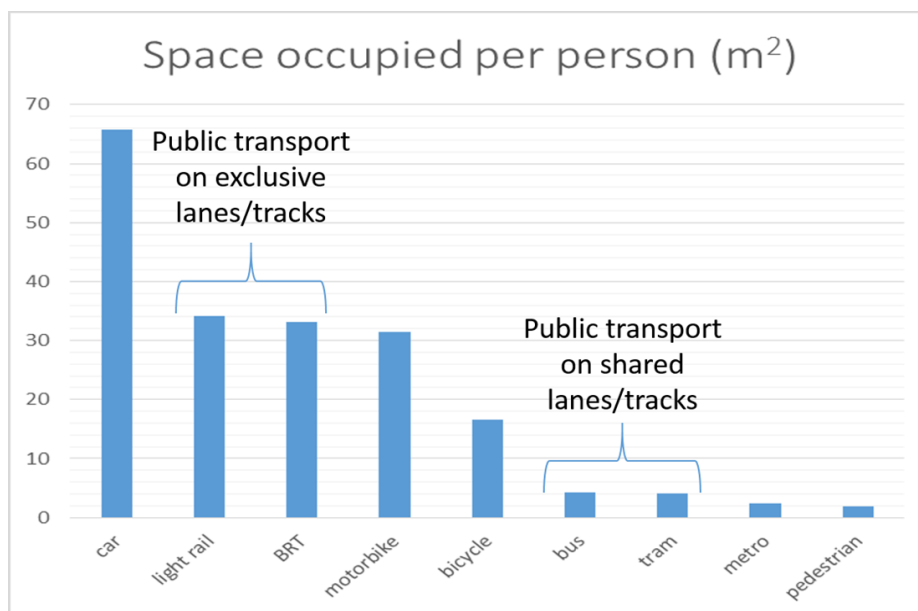


Figure 9 - Space occupation per passenger by means of transport

The Mobility Program for MRDH – Key Topics

The general objective pursued in the mobility program is to create a virtuous circle involving innovation, production, new jobs, and education/training. MRDH should start with pioneer programs, based on the Internet of Things and able to generate a critical mass, thereby making the region attractive for global investors. The goal of the programs is a wider-scale deployment of smart technologies, rather than small-scale technology demonstrations.

The challenge for transport is to accommodate the increasing needs using existing transport infrastructures in the smartest way within the scenario of the Mobility Internet, characterized by “being informed, being connected and being empowered.” High population density and activity, rather than urban sprawl, will help to develop an efficient transport system in MRDH. This transport paradigm will be based on well-infrastructured and thoroughly connected multi-modal hubs and corridors. However, while the increase in demand and the urgent need to match it with an adequate supply of transport options makes the need of smart solutions impellent, the realization of a technological platform such as the IoT goes far beyond these specific challenges. It will solve, in a smart way, the contingent problem but it will also produce

a leap in productivity in several fields, positioning the region at the international forefront, attracting talent, companies, investors, and creating new jobs.

Four fundamental innovations are occurring in transportation, which can radically transform the way mobility is managed: electrification, automation, communication, and sharing. These innovations will prove fundamental in revolutionizing transport; they will reinforce one another through synergic action and allow MRDH to reach a much more efficient and sustainable mobility system than the one which is in operation today.

Another innovative change is taking place which will influence mobility indirectly but strongly: the possibility of gaining access to opportunities without the need to travel. This is obtained by widespread access to the Internet, which brings work, shopping and services directly to one's home, and by a radical rethinking of urban planning, allowing many opportunities to be accessible within a short distance that can be covered on foot instead of using a motor vehicle. This is the "main beam" over which a modern sustainable mobility strategy lies. These four innovations are of great relevance for a Third Industrial Revolution scenario.

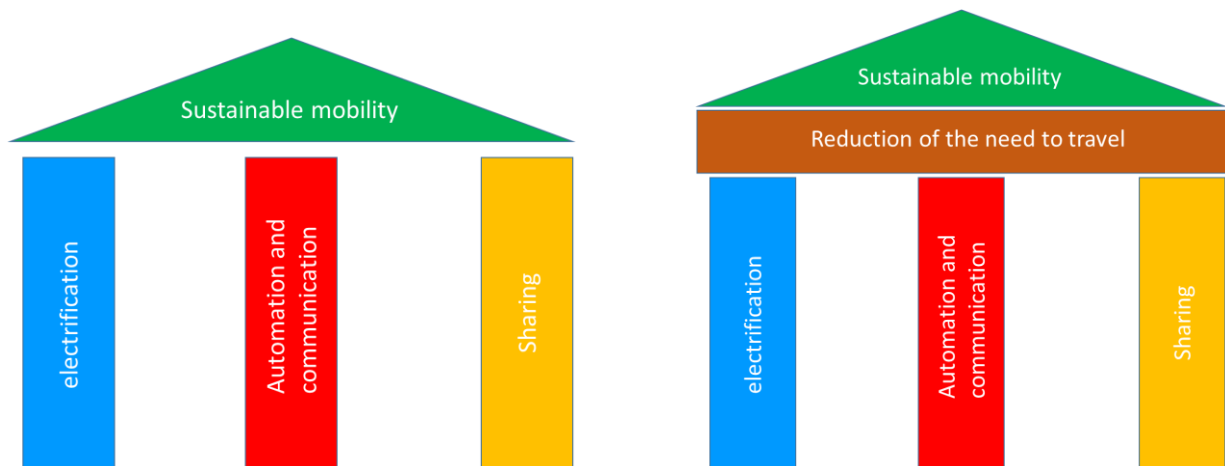


Figure 10 – Sustainable mobility is supported by the three “pillars” of electrification, automation and sharing, but it won’t stay up without the main beam of a new urban shape

To effectively achieve the objectives of a Third Industrial Revolution in MRDH, it is essential that all interventions be included in a broader systemic frame. With this in mind, MRDH will need to act on six fundamental fields of action:

- **Infrastructure:** reduce heavy investments aimed at solving the problems created by the current status of things, and invest in infrastructure – and organization - that will radically change the way people move.
- **Technology:** simultaneously implementing various technologies that will best increase the efficiency of mobility, in terms of energy use, space occupation, safety, pollution and GHG emissions.
- **Cultural shift:** actively promote the onset of a new cultural mindset that includes new mobility paradigms and new logistics expectations, such as shifting from owning a car to sharing mobility in car sharing networks.
- **Pull + Push policy:** fiscal policy subsidies and legislation are among the tools with which the authorities can rapidly leverage the behavior of persons towards sustainable mobility. Administrative and supply policies are particularly effective in the long run.
- **Urban planning:** urban planning and transport planning are so thoroughly entwined that they should be considered two faces of the same issue. The planning of public spaces must always account for mobility, with pedestrians and soft mobility put at the top of the organizational pyramid.
- **Global policy:** MRDH must coordinate its actions with those across the Netherlands and other EU Member States and, at the same time, require that its plans and actions be acknowledged at the national and international levels.

Resilience and the Transportation System for MRDH

The transportation system is an essential asset of every community. Its failing may cause serious consequences across the entire economic system. The interventions identified in the TIR transport scenario based on electricity from renewable sources, the Sharing Economy, and automation will play an active role in mitigating climate change, providing a more efficient and sustainable society, and guaranteeing a high level of efficient mobility. At the same time, the transport system must be highly resilient to extraordinary events (extreme weather, terrorism, economic crisis, cyber-attacks, and failure of energy provision...) that can cause disruption of services or strong deterioration of the level of service, safety, and security.

As the electricity and communication grids become smarter and controlled and accessible via the Internet, as well as the V2V and V2i communication systems, each connected component will potentially be exposed to increasing cyber-attacks and more extreme weather events (storms, floods, droughts, high temperatures, etc.).

The transport system in MRDH must, therefore, have a high level of built-in resilience: in the case of extraordinary events, the transport system must be able to change, adapt, and transform itself in response to stresses and strains and, if possible, be capable of returning to the previous existing equilibrium.

Resilience for the individual means that each person must have alternative transport options available, so that personal mobility will be guaranteed even under unexpected or catastrophic conditions.

Resilience for the society means that the transport system will guarantee the mobility of persons and goods even under unexpected conditions that temporarily cripple single infrastructures or complementary transport systems (the unavailability of electric power or cyber-attack on the network, or part of it).

The proposed TIR transport system will rely, in great part, on the same physical infrastructure of the existing transport system and will inherit its positive features that guarantee its resilience: ability to accommodate many different types of vehicles (diversity); offering multiple alternative modes and routes (redundancy); capacity to function even if partly damaged (robustness).

The risks for the transport system in the TIR scenario are mainly twofold:

- the interruption of the supply of electricity to power vehicles and communication systems;
- the collapse of infrastructure components exposed to extreme weather events, terrorism, and cyber-attacks.

The TIR strategy for transport and mobility proposes a number of changes in the transport system to build resiliency across the mobility sector:

- **Total shift towards local renewable resources:** Renewable energy is produced locally and mainly at small, independent generation plants distributed throughout the region. This greatly increases the mobility sector's resilience since it is protected against geo-

political events that may threaten the supply of fossil fuels. Distributed generation of renewable energy also makes it less likely that multiple failures of small generation plants will happen, causing a catastrophic failure of the entire system. The electricity distribution system for transport can be made more resilient by making it redundant and self-fixing (robust).

- **Mixed strategy for the powertrain of the vehicles:** The electrification of all vehicles may increase the robustness of the distribution system, which does not rely on road-going tankers and shipments of fuels. Electric vehicles, having a much higher efficiency than fossil-fuel vehicles, are also more resilient against economic collapse. Electrification may also make the system less robust, since it cannot count on reservoirs. Liquid and gas fossil fuels can be stored in large quantities, while electric energy is extremely difficult to store. The system can be made more resilient by adopting a mixed strategy of power supply, comprising external supply and on-board batteries and hydrogen fuel cells (diversity and redundancy). Hydrogen can be stored (although not as easily as fossil fuels) and it can also be produced locally, at the point of distribution.
- **Diversity of means for an interconnected collective transportation:** Today, in the Netherlands about 50% of trips are accomplished by private individual transportation, while public transport accounts for only 5%. Public transport can operate as a backup system if it is designed to carry out a high percentage of trips and if it is well-diversified. The TIR transport strategy is strongly centered on public transport, which comprises buses (battery electric or hydrogen-fuel cells), trolley buses, trams, trains, automated shuttles and micro-mobility vehicles. This diversity of means is one of the keys to increased resilience. The system can be made more resilient by improving the security at stations and on board the vehicles (robustness), by implementing various different types of interconnected modes (train, tram, bus, and shuttle, all providing options) and connecting the major origin-destination pairs by different parallel modes (redundancy provided, for example by parallel bus and train lines).
- **Promotion of “soft modes”:** Active modes are the most resilient modes of transportation thanks to their independence from energy, technology, and infrastructure. Walking and cycling do not require energy supply, connection to a grid, or an informative system. Walking hardly needs any specific infrastructure. A policy to promote walking and cycling and provide a dense network of dedicated infrastructures,

will greatly improve the resilience of the system of mobility, and act as a complement to other means of transport, overcoming the limits of distance that are inherent with active transportation.

- **Increase in the use of shared vehicles:** This strategy can have positive but also negative effects on resilience. It allows anyone to have access to any vehicle of the sharing service, thus greatly increasing the resilience of the system by exploiting its diversity and redundancy. However, sharing also relies on an information and communication system which may be prone to failure in cases of extreme conditions, making all the vehicles of the service unavailable. The mobility system can be made more robust by increasing the redundancy and security of the communication and information system against cyber-attacks. Diversity and redundancy can also be amplified by assigning the shared vehicle service to several independent operators, so that economic failure or cyber-attacks on one operator will not cause the complete failure of the system.
- **Increase in the use of automated, highly connected vehicles:** The increase in the share of highly automated and driverless vehicles will require the connection of cars and buses through V2V and V2I communication networks. These networks are vulnerable and at risk of being targeted by a cyber-attack, but they are not essential in today's transport system. A failure in the communication system may damage both the collective transport system and the individual transport modes. Automated vehicle systems also require the availability of a large number of highly skilled personnel. Automation and communication is one area where a strategy to increase redundancy, robustness, and diversity is essential. The system can be made more robust by allowing a human driver to take control of an automated vehicle in case of failure, and also for the vehicle to function in "emergency mode" in the absence of communication. Redundancy and diversity can be increased by allowing different communication protocols to act together (redundancy). Training the personnel locally is essential to make the system robust against lack of the adequate skills. The security of the communication networks is also of the utmost importance (robustness).
- **Change of the urban landscape to a compact and dense model, with mixed-use neighborhoods:** The change of the urban shape is a long term proposition as the development of a city takes place along very long time frames. Nonetheless, a compact city, with mixed use neighborhoods, is the preferred solution for increasing the

resilience of the transport system by reducing the need to travel and increasing the utility and effectiveness of active modes of travel. For these reasons, a compact and mixed urban landscape allows for the most resilient transportation system. A resilient city will provide various alternative destinations (redundancy); different places to carry out the daily activities (diversity) and the possibility to reach them even in the case of a near-total failure of the transport system (robustness).

A number of actions and programs are necessary to evaluate and monitor the resilience of the transport system:

- **Monitoring program:** all the effects brought on by the new transport strategies must be frequently monitored in order to understand to what extent the goals established during the transport planning phase are reachable. To achieve this, a robust monitoring program able to oversee traffic conditions, passengers, the flow of goods, the capacity of the infrastructure, and the energy demand (also in relationship with other energy demands) must be defined and carried out.
- **Vulnerability assessment:** identifying the weaknesses of the various elements of the transport system is a fundamental requirement in developing a resilient transport network. A vulnerability assessment that uses transport simulations is able to better predict the effects of the failure of the system's components (infrastructures, energy supply, communications), and identify the interdependencies between the various critical infrastructures and components in relation to the other systems.
- **Update transport plans:** the transport plans need to be continuously updated. Updated transport plans improve the "resilience" strategies and accompanying measures that increase the capacity of the system to adapt to new conditions.
- **Cooperation with stakeholders:** strategies and measures must be identified, monitored and updated in strict cooperation with key stakeholders. They must take into account not only the technical aspects but also the social and governance aspects.
- **Microgrids:** in order to make the Smart Grid robust and resilient, the grid infrastructures must be designed and implemented with modular elements based on complementary and independent microgrids provided by local operators, generators and storage systems.

- **Climate design values:** the design of the infrastructure must take into account not only the historical climate design values, but also the estimated climate trends in the region, and the probability of a rise in the frequency and magnitude of extreme weather events.
- **Mobility and logistic platform:** create a common mobility and logistic platform for the Port and the cities.
- **Emergency transport system:** provide power backup systems (also using H2 storage and fuel cells) with charging stations dedicated to emergency vehicles and the public transport system.
- **National Cybersecurity Oversight:** establish a “National Cybersecurity Oversight Network” able to define and measure the effectiveness of cybersecurity strategies and tactics and make benchmarks for regulators and utility executives.
- **Awareness campaign:** improve the awareness and importance of enhancing the resilience of the transport system in order to address extraordinary and unforeseen conditions associated with weather, economic events, and cyber-attacks.

Proposals

Automation, Electrification, Hydrogen and Sharing, based on the IoT for Mobility and Logistics, have already obtained a degree of collective support and will induce the step-change. These three topics:

- are relevant to guide mobility and logistics in MRDH towards the Next Economy
- are based on existing knowledge and experience in the region
- are relevant for the transportation of people as well as goods
- will strengthen the knowledge economy in MRDH, leading to new opportunities for businesses and knowledge institutes.

Important developments and solutions such as mobility management, biking and other investments in, for instance, public transport infrastructure, contribute significantly to the challenges at hand. In particular, for the success of any policy aimed at reducing energy consumption,³² CO₂ emissions, and urban space occupation, it is crucial that a policy of

³² The reduction of energy consumption in a near-zero marginal cost economy may seem superfluous, but it is an important goal in order to best exploit the technologies available to produce, distribute and transport energy.

electrification of vehicles be complemented by a policy that promotes the use of public transport and limits the use of the car.

Reducing energy use, CO₂ emissions, and urban space occupation will require policy initiatives and significant infrastructure investments. Over the last Century, extensive (and expensive) infrastructure was built to accommodate cars, which constituted the backbone of mobility for the Second Industrial Revolution.

The magnitude of the effect of each measure will strictly depend on how thoroughly and intensely each measure is pursued, as well as the synergy effects. Many measures, in fact, will reinforce one another: for example, the improvement of public transport will be reinforced by the implementation of last-mile solutions and by the improvement of mobility and convenience.

Adopt the measure:	To reach the goal of reducing:
Build a dense network of fast recharging stations; experiment with hydrogen, especially on larger vehicles	energy consumption, local pollution and GHG emissions
Strongly limit the use of fossil-fuel cars by means of: parking pricing, access pricing, and access limitations	
Electrify public transport and service vehicles (hybrid powertrains as interim solution)	
Improve all public transport in terms of comfort, frequency, availability, span of service, area coverage, connectivity, accessibility, integration	energy consumption, local pollution and GHG emissions space occupation, especially in cities
Simplify access to public transport by means of information, integrated ticketing, wayfinding	
Implement last-mile personal and group transport solutions	
Improve pedestrian mobility, wayfinding and convenience	
Incentivate vehicle sharing	occupation of space, especially in cities
Strongly limit the use of all personal cars by means of: parking pricing, access pricing, access limitations	
Hasten the onset of vehicle automation	
Promote cycling	

Table 1 – Effects of the measures

Low energy consumption means less space occupied by generation plants, less network losses, shorter recharging times and longer vehicle range and less GHG emissions.

1.2.0 NEW BUSINESS MODELS AND VALUE CHAINS

1.2.0.1 Quadruple helix innovation model - To leverage the opportunities brought on by the Internet of Things in the Third Industrial Revolution scenario, a collaborative model in an innovation environment must be carried out. This model must include the main players in the Region belonging to four different entities:

- Government
- Industry
- University
- Civil Society

These four sectors will need to work together to establish regulatory norms and standards and foster new innovations in education, pursue collaborative financial policies, and engage in collective research and development projects.

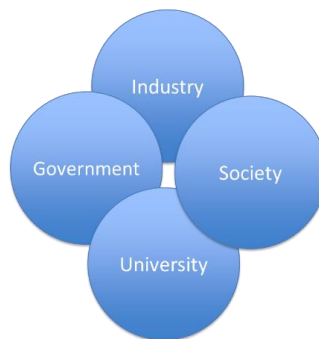


Figure 11 - Quadruple helix

Currently, a soft collaboration between the main players in a triple helix organization (Government, University and Industry) exists but, according to the OECD (2016), less than 50% of the economic potency of the region is utilized: that means having the knowledge but not commercializing it in an adequate manner. Common ideas and a shared focus need to be adopted by all parties, including local authorities. This bolsters the roadmap because it focuses on the end goals and it can support the needed short and mid-term projects.

There is currently a favorable situation in the Brainport/Brabant region on some key topics. There is also collaboration among the 23 Municipalities in MRDH and the province of South-

Holland with the release of the “Innovation-agenda on Mobility”, aimed at better mobility solutions and more opportunities for businesses and knowledge institutes.

The advantage lies in having the main port and its related skills, The Hague Security Delta, the Delft and Erasmus universities, and the higher vocational education structure included as part of an extended innovation eco-system operating in the short to middle term. However, there is a major challenge in the mid-to-long term in amassing the kind of skills and craftsmanship needed for mobility and logistics in the Next Economy.

Furthermore, a more intensive collaboration must be carried out between traditional big companies and emerging start-ups and with foreign institutes and companies specializing in innovative transport solutions.

1.2.0.2 Automated/connected Mobility – Automated mobility can yield several advantages that advance the success of the Third Industrial Revolution:

- It increases safety on the road, especially for vulnerable users, reduces the occurrence of congestion, and reduces the overall space occupied by cars, both parked and in motion.
- It offers greater mobility and access opportunities for the elderly and the disabled – very important considering the increase of the aging population.
- It makes public transport cheaper and more available at low demand times, such as night time, and in low demand areas, where traditional public transport with a driver is not convenient.
- It opens new job opportunities in the automotive, technology, telecommunication and freight industry, generating economic development.
- It opens new scenarios for shared vehicles, in which the electric, driverless vehicles can move to a different location, pick up passengers, and autonomously reach a recharging station. This will make the shared vehicle service work as a taxi service, but without taxi drivers.

An important automated transport program is operationalizing in the short to medium term in MRDH, moving from an advanced driver assistance support system in 2020 towards fully autonomous vehicles by 2030:

- Short-term (2020-2025): Automated transport (both truck platooning and automated cooperative mobility) is happening on open or semi- dedicated infrastructure, based on

large-scale piloting. Technology is limited to SAE Level 2 for general heavy-duty vehicles, whereas the first SAE Level 3 pilots are being deployed for personal and collective mobility with conditional automation. C-ITS infrastructure is deployed intra-port.³³

- Intra-port autonomous-ready vehicles and truck platooning
- Beyond the port truck platooning
- Automated vehicle and platoon matching
- C-ITS infrastructure deployed in the Port of Rotterdam
- Cooperative automated driving across Urban Axis
- C-ITS infrastructure across Urban Axis motorways
- Mid-term (2025-2040): Automated transport matures with highly automated systems (SAE Level 4) deployed commercially in society with C-ITS infrastructure broadly deployed to aid automated transport
 - Scaling up truck platooning to 50% adoption
 - Cooperative automated driving across Stedelijke As
- Long-term (>2040): Full automation SAE Level 5 becomes generally available. Vehicles can be fully autonomous – platoons can still be formed. C-ITS infrastructure aids automated transport.
 - Truck platooning and autonomous transport merge together
- Public transport and city distribution automation: a more reliable and efficient public transport system by automation
 - Short term (2020-2025): last mile automation on 6 locations in MRDH as add on to existing public transport system.
 - Scale-up of small-scale demand-driven transport Split/Uber-like
 - Medium term (2025-2030): implementation of automation in PT including automated metro/light-rail, bus services

³³ See page 71 for an overview of the SAE classification scale for automated driving systems.

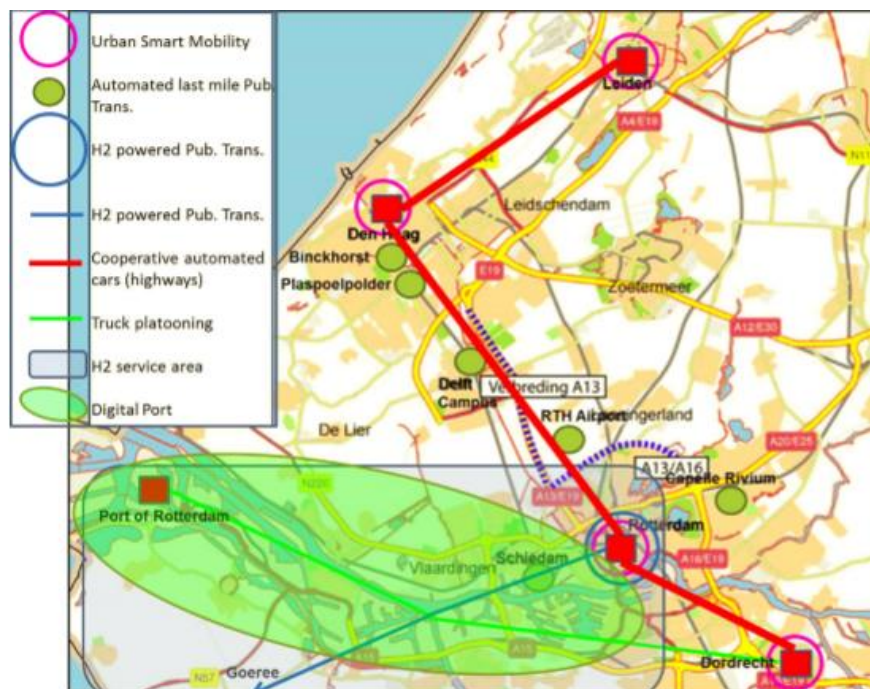


Figure 12 – Relevant test-bed projects programmed in the MRDH

Rotterdam already has an example of a small size autonomous public transport shuttle that has been operating successfully since 2005³⁴. The Rivium Park shuttle has no human driver but travels on a segregated route and obeys railway type regulations. The first large-sized driverless public transport vehicles allowed to share the environment with other non-autonomous vehicles will behave in a similar way to this shuttle, but will have more sophisticated object detection features, and will be able to deal with various types of environmental conditions.

³⁴ Rivium park shuttle driverless bus service, connecting Kralingse Zoom with Capelle aan den IJssel - first started as a test in 1999 and became fully operational in 2005 <http://www.2getthere.eu/projects/rivium-grt/>



Figure 13 -The driverless Rivium Park shuttle

Other more recent experiments are being carried out in a mixed environment.³⁵ All these tests require that a “supervisor” be on board and be responsible for the vehicle, since current regulations do not allow unmanned vehicles to travel on routes accessible to the public. A strong effort is needed to draw a proper set of rules that will allow driverless vehicles to be tested on public roads, under certain conditions.

Classifying automation - The Society of American Engineers (SAE) proposed a scale to classify vehicle automation in six levels. In the first three levels (zero to two), the human driver monitors the environment, while in the following three levels it is the automated driving system which monitors the environment. Level zero corresponds to “no automation” and full automation, not requiring the presence of a human driver on board regardless of infrastructure, traffic, and weather conditions, corresponds to the highest “level 5”.

³⁵ For example the CityMobil2 EC FP7 project www.citymobil2.eu the WEpods in the Netherlands www.wepods.com and the city centre shuttle bus in Sion, Switzerland <http://navya.tech/2016/06/lancement-de-lexperimentation-sur-voie-publique-en-suisse-2/?lang=en>

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/Deceleration	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
Human driver monitors the driving environment						
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the <i>driving mode</i> -specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i>	System	Human driver	Human driver	Some driving modes
Automated driving system ("system") monitors the driving environment						
3	Conditional Automation	the <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	System	Human driver	Some driving modes
4	High Automation	the <i>driving mode</i> -specific performance by an automated driving system of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	System	Some driving modes
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes

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Table 2 - Levels of automation as defined by SAE

Public transport on dedicated routes will be able take advantage of the features of the infrastructure by means of advanced V2I communication, the control of access, and the scheduling of the vehicles, as well as V2V communication among the vehicles of the fleet, to enhance the performance of its automated driving system and jump directly to levels 3 and 4 of automation. Level 4 automation is forecast to appear in the mid-term, possibly as soon as 2025. In a partially controlled environment, where all the conditions that require human intervention in an emergency are removed, a "level-4" automated vehicle can operate as a "conditioned level-5" vehicle, not requiring a driver on board.

On free-ranging vehicles, automation is already appearing in the form of "driving aids" in which the vehicle is still controlled by a human driver (levels 1 and 2), but will be able to follow a

specified route under the guidance of the automation system, as well as take autonomous decisions such as changing lanes when overtaking another vehicle, or braking in an emergency.

It can be forecast that “level 3” and “level 4” automation will likely appear on free-ranging vehicles as soon as 2025 in controlled environments such as parking structures and specifically equipped commuter routes. The advent of level-5 fully autonomous vehicles will still require a considerable amount of testing and development, as well as a new set of rules to allow driverless vehicles to share the road with human-driven vehicles, pedestrians, and cyclists. A scenario where the vehicles on the roads will be fully autonomous under any condition could occur after 2040.³⁶

Boosting automated public transport - In the Third Industrial Revolution scenario, great expectation is put on the automation of public transport systems to reach “conditioned level-5” automation as soon as possible. Not needing drivers will reduce the operational cost, making an increase in scheduled services possible, especially in the low demand areas and time bands, while also realizing efficient and effective on-demand public transport services.

The scenario for the implementation of the first fully-automated group transit system is not far off since the main barriers at this moment are not technological but regulatory. As the experience of the Rivium Park shuttle shows, specific corridors can be equipped with sensors and access can be controlled to realize safe automated transport systems in urban and suburban areas. Personal automated transit systems could prove extremely efficient as last mile solutions, but since they will not be able to rely on dedicated infrastructures, they will likely come online after automated public transport.

³⁶ Dr. Steven Shladover, of UC Berkeley, is even more pessimistic: <http://www.scientificamerican.com/article/the-road-to-self-driving-cars/>



Figure 14 - Testing of fully autonomous, driverless shuttle buses in Bordeaux, 2015

Several academic institutions and research bodies in Europe and worldwide are currently experimenting with automated public transport and shared vehicles. These applications are very promising for ushering in an era of sustainable mobility. On the other hand, the automotive industries are focusing most of their efforts on autonomous cars, which are the most complex and long-term propositions in the field, but which are already appearing in “partially automated” form (level 3) on the roads.

Boosting automated freight transport - Like public transport, freight transport can also benefit from automation, and this will likely happen earlier than for personal cars. Freight vehicles, excluding the final delivery vehicles, can travel on specialized corridors. These vehicles will travel in platoons and take advantage of a high level of automation, enhanced by efficient V2V and V2I communication. Within the loading-unloading areas, the freight vehicles can shift from partial to total automation and maneuver on their own, achieving level-5 performance. This technological change will likely occur early, possibly within the next five years.

1.2.0.3 Port as a Service - Develop a remotely managed robotized Port of Rotterdam, including automated vessels, smart maintenance of port infrastructure, automated supply, port monitoring systems, and logistics platforms. Major developments: crew-less shipping and trucking/smart mobility, port monitoring (sensing) and scaling up of the Maritime Field Lab to a digital manufacturing port infrastructure.

1.2.0.4 Transform the business model for the transportation industry - From vehicle sales to managing automated GPS-guided and driverless mobility networks. The erection and management of the Mobility Internet will require collaboration across sectors and multiple competences. Companies will have to share their knowledge and expertise in dedicated blockchains and determine their value-added contributions to the joint efforts of the network in sharing both the cost of operations and returns on investment.

1.2.0.5 Shift towards emission-free vehicles - Low or zero-CO₂ alternatives to oil are indispensable for a gradual decarbonization of transport and to reach the ambitious objective of reducing the emissions of CO₂ from transport by 60% by 2050 and achieving a CO₂-free logistics in major urban centers by 2030.³⁷

There is a common trend throughout the European Union to exploit the potential of alternative fuels in the transport field, and the Netherlands is one of the Member States that is adopting the most ambitious targets and initiatives in order to favor the roll out of the use of alternative fuels.

Electric mobility – either battery or hydrogen fueled – is the key to move mobility to near zero marginal cost. EVs are particularly suited for urban areas because they emit no local pollutants and minimal noise. The latter is especially important during night hours when several transport and maintenance services, not feasible during the daylight hours, can be carried out. E-mobility includes electric passenger cars (both shared and owned), E-bikes, and public transport.

³⁷ COM (2011) 144 - White Paper “Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system”



2015 Renault's ZOE EV, all-carbon body, 800 lbs lighter than Tesla.



Europeans bought 100,000 EVs in 2015, 47% more than in 2014. Renault's ZOE (above) was the top seller.



Renault Twizy EV urban runabout: legal for teenagers to drive in France.



Malaysia Launches First EV Carshare Program

Figure 15-Types of Electric Vehicles

1.2.0.6 Electrification and change of mode share - The complete electrification of public transport will lead to a Third Industrial Revolution mobility scenario. While trains, trams, and the metro are already electric, buses are still primarily powered by diesel. Any effort towards improving public transport cannot neglect the electrification of the entire fleet of buses, which will be powered with electricity coming from sustainable sources.

VEHICLE	ENERGY CONSUMPTION	CO2 EMISSIONS	SPACE OCCUPATION
Fuel car with 1.6 passengers	100%	100%	100%
Electric car with 1.6 passengers	25-30%	0%	100%
Diesel bus with 25 passengers	30-35%	30-35%	12-14%
Electric bus with 25 passengers	10-12%	0%	12-14%

Table 3- Values per passenger relative to a fossil-fuel powered car. Electric energy is assumed derived from renewable sources

Because of their high energy consumption, buses cannot take full advantage of batteries as a source of electric energy. This means that more articulated solutions must be found, including: replacing diesel buses with trolleybuses or trams on some lines; hybrid solutions combining batteries and overhead wires; and using hydrogen and fuel cells as a source of energy. While these complex technologies are being developed and made competitive, an interim solution can be found in hybrid buses, which pair electric motors and batteries with a fossil-fuel generator of electric energy. This generator can be an internal combustion motor or a turbine, powered by natural gas to minimize GHG emissions and pollution.³⁸

Three development scenarios will be contemplated here: the first is the “Stroomstoot” scenario that plans to introduce 200,000 full-electric vehicles in MRDH by 2025. There are currently about one million cars in MRDH. This means that 20% of them will have to be fully electric nine years from now. What will the impacts be? Is a policy of vehicle electrification sufficient on its own or even the best policy? This is not an easy question to answer as it requires complex mathematical modeling to make reliable predictions. However, some simple calculations can give at least a preliminary idea, as illustrated in the table below.

³⁸ Burning natural gas produces no NOx (Nitrogen oxides) or PM (fine particulate matter) and emits about 73% the amount of CO₂ per energy unit compared with diesel fuel. This can be further reduced thanks to the better efficiency of a motor operated at fixed RPM and power output level to generate electricity.

Based on the above considerations, an alternative scenario is plausible – a 20% modal shift to PT by 2025. The assumptions are that all electric cars will be powered by fully renewable, zero CO₂ energy while the mix of electric and fuel PT vehicles remains as is today. In addition to this, a third “combined” scenario will be considered that will assume that by 2025:

- 20% of cars will become electric
- 20% of passenger km will shift to PT
- Full electrification of PT will be implemented

POLICY 2025	ENERGY SAVING	CO ₂ REDUCTION	SPACE SAVING
20% of electric cars	13%	18%	0%
20% of modal shift from cars to PT	15%	16%	13%
Both the above + 100% electrification of PT	30%	38%	13%

Table 4 –Mid-term policies and reduction of energy consumption, CO₂ emissions and space occupation, compared with today’s mix

A shift of 20% of trips from cars to public transport has similar effects to the replacement of 20% of fossil-fuel cars with fully-electric cars. The numbers presented assume that no changes take place to other parameters of mobility³⁹ and that public transport will also be able to replace the longest trips made by car.

A very efficient strategy is to act in order to replace a quota of trips by car with public transport and, at the same time, a quota of fossil-fuel cars with electric cars. Together with the complete electrification of public transport, this combined strategy will yield the best results in terms of energy saving, GHG emissions, pollution reduction, and space saving, while limiting the impact on the mobility of goods and persons.

1.2.0.7 Adopt electric service vehicles - Thousands of service vehicles travel the streets of cities and peripheral areas: waste collection, road cleaning, road repairs, sewage cleaning, maintenance of technical appliances, control and monitoring of the infrastructures, emergency, delivery and pick up, etc. Generally these vehicles travel at low speed and stop and start

³⁹ For example, public transport and cycling are in strong competition: an improvement in the efficiency of one mode, will reduce the share of the other.

frequently: these are conditions that generate significant pollution and energy expenditure. The gradual electrification of the fleet of delivery vehicles can be an important step towards a more sustainable system of mobility, not only for its direct effects (reduction of pollution and energy use) but also for the promotion of a “clean region strategy” that is derived from thousands of quiet, non-polluting electric vehicles taking care of the basic needs of the city. On a second-tier measure, these vehicles can be partially or totally automated.

1.2.0.8 Promoting car sharing - Car sharing reduces the number of cars needed to provide a certain level of mobility, and reduces congestion. Ownership of a car implies a high upfront cost (the purchase) followed by modest running costs. This upfront cost needs to be amortized over time (the more the car is used the more the cost is amortized, which increases usage). This affects the modal choice: if the car is already paid for, it will more often be chosen over other means of transport: “I have a car, so why not use it?” Using a shared car, instead, implies no upfront cost but an immediate, out-of-pocket cost, which places the shared car on the same level as public transport. Car-sharing has enjoyed fast growth and it can be implemented immediately (first in major city centers and later in the whole Metropolitan Region).⁴⁰

1.2.0.9 Integrate Electric mobility with car sharing – Car sharing helps reduce congestion, but if based on conventional cars, it will have minimal effect on pollution. It would be far better to promote the sharing of electric vehicles. The public will benefit first-hand from the development of e-carsharing, since it will allow the population to acquire knowledge about e-mobility at “zero searching/learning cost.”⁴¹

⁴⁰ Car sharing grew worldwide from 350,000 members in 2006 to 5 million in 2014, the forecast that it will grow worldwide up to 26 million people in 2020 is then then realistic). On the other hand all forecasts of EV markets have been wrong.

⁴¹ For the role of knowledge and experience in the uptake of EV, see Jensen, A., Cherchi, E. and Mabit, S. (2013) On the stability of preferences and attitudes before and after experiencing an electric vehicle. Transportation Research D 25, 24-32.



Figure 16 – Walking, multimodality, automated last mile solutions and bike sharing- public transport is central to all

1.2.0.10 Faster & Further: Hydrogen for Zero-Emission Public Transport – MRDH has established a goal of introducing 50-100 hydrogen buses, 5-10 hydrogen fuelling stations, and 50 hydrogen cars by 2020. The introduction of hydrogen-powered buses takes MRDH on the path toward a zero-emission public transport fleet. The buses can be either electric or hydrogen-electric. A Rotterdam-based pilot is already underway with two hydrogen buses scheduled to be on the road by 2017. The province of South Holland is also developing a pilot on Goeree Overflakkee. The goal is to have 10 hydrogen buses and 1 hydrogen fuelling station operational within 2 years and 50-100 busses and 5-10 fuelling stations operational in 5 years [See also proposal 2.1.1.4].

The goal is to make hydrogen buses and fuelling stations available region-wide. The hydrogen fuelling station infrastructure will also enable hydrogen-powered automobiles to power up, facilitating the wide-spread introduction of hydrogen transport. An innovation and education/training center will be developed to train the workforce with the new skills that accompany the introduction of the zero emission Transportation and Logistics Internet.

To further scale-up deployment beyond demonstration projects, it is recommended that government employees and public transport embrace the use of hydrogen-fuelled vehicles. MRDH should also work in partnership with incubators like Start-Up Nation to define new business models for hydrogen-fuelled mobility. Further, the Dutch government is

contemplating a ban on non-electric vehicles with the exception of hydrogen fuel cars by 2025. This ban would encourage an aggressive uptake of EV and hydrogen-fuelled vehicles.

1.2.0.11 Rooftop PV for Public Transport Locations – Plans are afoot to install PV panels on four metro station rooftops. The renewable power generated on-site will provide the power for the facility. The fixed cost of establishing solar power on-site will be incentivized with the establishment of a state tariff subsidy. MRDH calculates that the return on investment will be approximately 10 years, after which the marginal cost of generating the electricity will be nearly zero. MRDH has more than 50 metro stations and 30 light rail stations with rooftop volume suitable for solar panels, enabling the region's transport hubs to also serve as micro power generating plants.

1.2.0.12 Smarter & Further: Urban – Industrial Balancing Act - A hybrid energy system for Rotterdam City that utilizes the Rotterdam Harbor Industrial Complex for power balancing needs, guaranteeing enough flexible capacity (MWh per year) for Rotterdam's future "Full Electric Vehicles (FEVs)" growth goals. Rotterdam's ambition is to be a frontrunner in the deployment of zero emission electric mobility for cleaner air, less traffic noise and less fuel dependency. In addition, electric mobility delivers a significant contribution to the goal of reducing road traffic CO₂ emissions by 50% by 2025 (ref. 1990), both because it is more efficient than combustion engines and it shifts transport to clean, renewable power sources.

Rotterdam's "Stroomstoot" (Power Surge) program was launched to help scale-up FEVs to 200,000 by 2025. Four pillars drive the Stroomstoot program: 1) Market development; 2) Infrastructure; 3) District approach; and 4) Research activities. In 2025, approximately 15% of all FEVs in the Netherlands will be in MRDH. The energy demand profiles of the Harbor Industry Complex (HIC) versus the Residential Built Environment differ quite substantially. The energy demand curve for the industry is flat, while the residential area fluctuates diurnally and seasonally. The base load of the Rotterdam HIC (including logistics) is about twice as much as the energy demand of the city of Rotterdam. In total, the HIC electricity consumption on a yearly basis is about 6 times the electricity consumption of Rotterdam's built environment. Realizing the "stroomstoot" ambitions by 2025 of charging 200,000 FEVs in the Rotterdam Area will require more electrical power than the City and Harbor currently generate. The required power can be delivered through a diversity of options: increasing end-use efficiency improvements; load management, including valley-filling and peak-saving measures; real-time demand response load-reduction; additional deployment of the production assets, e.g.,

increasing combined heat and power (CHP) opportunities; the addition of new offshore wind and solar PV systems on roofs and ground spots; and augmented through smart grid flexibility measures. Assessing the levelized cost of electricity (LCOE) of each option for satisfying delivered electricity services will enable a priority ranking of least cost options.

From now on every new charging pole in the MRDH should be bi-directional providing a no-regret basis for the near future Vehicle-to-Grid extension of the Energy Internet.

1.2.0.13 Assemble a “Coalition of the Willing” - Given the complexity of issues and multiple knowledge domains required, a coalition of the willing will need to be comprised of players in the field of ICT and consumer electronics, Big Data generation and management, public transport, IoT hardware, logistics (especially shippers and the Port of Rotterdam), and mobility service providers.

1.2.1 TECHNICAL

1.2.1.1 Internet Of Things for Mobility and Logistics (IoT4M&L): Being informed, connected, and empowered - IoT4M&L is about the use of situational awareness, sensors, and algorithms in order to optimize the mobility and logistics processes both in the urban environment (Rotterdam and The Hague) and in the Port area.

Short and mid-term goals are covered by two programs:

- Development of the mobility platform for Rotterdam and The Hague
- The Transport and logistics platform for the Port area and the cities of Rotterdam and The Hague

The long term goals include the roll-out to all cities and hot spots in MRDH and setting the standard for the related cities and hubs in the Netherlands and beyond. Similar to ESCOs (energy service companies), the introduction of a TranSCO (transport service companies) or MSCo (mobility service companies) is the ultimate goal, as long as the platform is accessible for all users. Concepts such as “car-as-a-sensor” for distributed monitoring of infrastructure and conditions can be implemented in the TranSCO. Existing programs and roadmaps (e.g. Beter Benutten, Connecting Mobility, Topsector Logistics, Uitvoeringsagenda VA-MRDH en Mobiliteitsagenda PZH-MRDH) will be followed.

1.2.1.2 Development of the mobility platform for Rotterdam and The Hague - The objective is to have a single standardized platform and dashboard for at least the whole region, using standardized data collection, handling, and information generation. This data platform will have to be used for smart traffic management for all the transport modes, including smart parking, smart traffic lights, event management and predictive traffic intensity and accessibility. Developing all kinds of (mobility) services is part of the Smart City Operational System and contains reliable and high-quality data and algorithms.

The Praktijkproef Amsterdam for both “regular traffic” as well as for “events” is an example of this. Possible application cases are:

- Dynamic traffic management including target group users (e.g. public transport, road side application - traffic control center/traffic lights)
- Smart parking (in-car and road side application)
- Event management (in-car and road side application)
- Predictive traffic intensity and accessibility (Smart routing, in-car application and road side)

The specific goal for 2020 is to involve 10,000 active users per city.

1.2.1.3 Transport and logistics platform for the Port area (Digital Port) and the cities of Rotterdam and The Hague – Rotterdam has to be at the forefront of the adoption of IoT technologies for supply chain management and logistics. Digital tracking, optimized dispatching and scheduling, integrated resource management, and advanced information services are all part of this picture, as are the enabling capabilities of enhanced cyber security and data brokerage.

Important actions need to be addressed in the construction of a collaborative network that brings together the key players that operate in the logistic field (transport companies and producers of goods) in the Region, in the Netherlands, and in neighboring countries, in order to create a common shared logistics space (fourth pillar of the Mobility Internet).

Cooperation can be implemented at two levels: short-distance logistics collaboration (for city center delivery grouping), and long-distance logistics collaboration for international transport. The first, in particular, requires the implementation of a city-wide logistics process to optimize the logistics and transport activities in urban areas in order to reduce the number of freight vehicles on the streets; using appropriate vehicles in terms of size and sustainable

motorization; optimizing the load factor and defining appropriate time bands available for the drop off and pick up operations outside the peak commute hours.



Figure 17 – Port of Rotterdam integration

Specific programs have been defined for the logistics platform in MRDH:

- Integration of logistics data platforms (Smart Data Factory as a federative system) including: Portbase, Rotterdam Logistics Lab, Neutral Logistics Information Platform, and Next Logic.
- Use of situational awareness and logistics information for optimal multi-modal planning.
- Optimized waste collection based on predicted traffic and smart waste containers (in-car application).
- Smart city logistics including predictive parking for delivery.
- Optimized e-commerce service based on predicted traffic and availability/urgency at receiver and city distribution centers (in-car application).

The specific goal for 2020 is to create 50 new application development ventures and 250 new jobs related to hardware and software development. Furthermore (see Automation as well), a full coverage of WiFi/5G in the relevant areas, accessible for all users, needs to be realized.

1.2.1.4 Technical aspect of E-mobility and H2-mobility - In terms of electric vehicles, it is crucial to establish a clear distinction between individual cars, public transport, and freight transport (last-mile, long and very long distance). Each of these categories represents a different challenge. Deploying electric cars is probably the most challenging intervention because of the number of vehicles and the infrastructure required. Trucks and public transport pose another challenge due to the size and weight of the energy storage (batteries or hydrogen).

Battery vs. Hydrogen electric power supply - Two mainstream technologies are available today to store the energy required for electric traction on-board the vehicles: batteries and hydrogen gas coupled with fuel cells (HFC).

Batteries - Lithium Ion batteries are technically consolidated, relatively cheap, widely available, efficient, safe, and reliable to use. The existing domestic and industrial electricity distribution network can double as a “fuel distribution network,” eliminating the need to erect a new network and remove fuel tanker trucks from the streets. Batteries could replace fossil fuels as a source of energy, allowing vehicles to store solar and wind energy in a portable form and retrieve it with a high efficiency.

The main limitation of batteries is their low energy density compared to fossil fuels: it takes 40-90 kg of Li-ion batteries to store the energy equivalent of one liter of diesel fuel. Even accounting for the higher efficiency of electric motors, in order to obtain a range of 800 km, a car would need to carry almost a ton of batteries and a bus would require nearly five tons. Although constant progress is being made in this area, this limitation still prevents the use of batteries on the larger vehicles.

Batteries also need a much longer recharging time than the typical refueling time required by fossil fuel vehicles. This will require a radical change of habit by users (no more casual refueling, but planned ones) as well as the need for more recharging points given that only 1-2 vehicles can be served in an hour by each charging point. The location of charging points will have to be disbursed to allow for the longer duration of the recharge stop: not so much along the routes, but at home, hotels, parking lots and at exchange stations for shared vehicles.

Hydrogen - Hydrogen (H₂) is a “universal energy carrier” that can be produced by exploiting any energy source. It is a less widespread technology for automotive use than batteries are, and it still has some “dentition problems.” But H₂ has a very high energy density and on-board H₂ tanks are only marginally heavier than fossil fuels tanks. Replacing fossil fuels with H₂ will require only a minor change of habits by users, because refueling is almost as quick as for fossil fuels. Thanks to its high energy density, H₂ is also perfectly suitable as a zero-emissions fuel for long distance trucks and buses.

The major drawbacks to the adoption of H₂ as a sustainable fuel, are the significant cost of H₂ refueling stations (up to 20 times that of a battery fast-recharging point) and the lower efficiency of the conversion of solar and wind energy in the hydrogen-fuel cell system (which is, however, much higher than that of fossil-fuel engines).

Given the short amount of time required for refueling, hydrogen stations can gradually replace the existing fossil-fuel stations, with no need to increase their number or change their location. On the other hand, the lack of a specific distribution network will require high investments to supply a network of hydrogen refueling points.

An alternative strategy to the construction of a distribution network is the production of hydrogen on the spot. This may be applied initially to small, low-consumption applications such as micromobility or e-bikes.

External electric power supply - Electric energy can also be supplied to vehicles on the run, replacing the on-board power supply or reducing its size. This requires a distribution network that reaches moving vehicles, rather than recharging or refueling points. The external distribution network can obviously only be extended to some designated routes, and it cannot power free-ranging vehicles. It is already used to power electric public transport (trains, trams and trolleybuses all rely on an external energy supply system), and freight vehicles along some dedicated corridors, for example connecting large warehouses and ports. External power supply can be coupled with batteries or an HFC (Hybrid fiber-coaxial) power source to extend the range of the vehicles. Once the network is connected to wind and solar power sources, the vehicles immediately become zero-emissions and zero GHG modes of mobility. Hybrid trolley trucks are currently being tested by several producers in the USA, Sweden, and Germany.



Figure 18 - A trolley truck being tested in USA by Siemens (image from www.welt.de)

Each of the technologies to power electric vehicles described above can be applied to different types of vehicles:

- Battery electric power for personal cars, micromobility vehicles, small city buses, short distance service and delivery trucks, e-bikes and e-scooters;
- Hydrogen coupled with fuel cells for long distance freight vehicles and buses, heavyweight service trucks, with possible experiments of on-site production of small quantities of hydrogen to power e-bikes;
- External power source (overhead wires) for public transport (trains, trams and trolley buses) as well as hybrid trucks on designated corridors, independently or as a complement to an on-board power source.

Considering the specificity of MRDH as a region, and given its relatively small size and diffuse urbanization, it can be forecast that battery electric personal vehicles will be a feasible choice for most residents in the medium term, without incurring the problem of insufficient range. The recharging stations for car sharing can also be made available for private vehicles. Many

suburban commuters will also have access to recharging facilities in their homes, allowing for overnight recharging.



Figure 19 - Electric cars recharging at Kralingse Zoom interchange node in Rotterdam

Implement Intermodal collective transport – The paradigm of accomplishing a whole trip with one single means of transport doesn't fit the way collective transport works. Any attempt to force mass transit to adapt to this paradigm results in reduced efficiency of the system.⁴² For the success of a sustainable transport strategy, it is necessary that any trip be accomplished by a combination of means, both private and collective. The interchange between modes must be made as quick and as convenient as possible.

Park and ride locations allowing the interchange between private cars and mass transit are already present at various locations in MRDH, especially where highways meet train stations, as well as interchanges between inter-city and local public transport. A diffuse P+R system in the entire region should be defined in order to guarantee modal interchange between personal cars and transit services. In addition, bus line services should be designed to convey transport demand to the railway and metro services from the surrounding territory, and express bus lines must be identified in the corridors where rail services are not present.

⁴² For a comprehensive description of intermodal mass transit, see Jarret Walker's book "Human Transit" <http://islandpress.org/book/human-transit>.

The whole public transport system in the urban areas and the region must be transformed into a thoroughly connected network scheme, based on radial and transversal connections. The success of this strategy depends on several factors that affect both personal and collective transit. The following technical and organizational actions are suggested:

- Dimension the collective services in terms of frequency and daily service span and its capacity to serve the transport demand both in the peak and off-peak hours as well as in the late evening. Travelers choose the transport modes, taking into consideration the entire round trip. In this sense, a service based on high frequency has to be preferred over a service based exclusively in reaching high travel speed.
- Offer a variety of mobility services at the interchange nodes in addition to collective transport. Carpooling, e-car, e-bike, and bike sharing areas (especially in the cities) will be designed with charging stations directly supplied by solar energy on rooftops. Even if managed by different operators, all these services should appear to the user as being part of a single system with an integrated payment service, a coordinated information system, and the same visual graphics and platform.
- Take care of the efficiency of the interchange and how well the nodes work. The success of mobility based on intermodality and sharing is strongly dependent on efficient management and convenient interface with users (ease of use), as well as by an appropriate fare structure. This refers to the frequency of the rides, reliability (in respect to timetable), integration of costs (same ticket for a given trip, regardless of which modes are used), ease of transfer between modes (clear way-finding and information at the interchange stations, and very clear apps to guides users through the interchange), easy planning of the trip, not only during the access and interchange, but also before the trip is made. Both stages (positive experience in pre-planning and positive experience while making the trip) are critical for the success of the system.
- Avoid single-function interchange nodes designed exclusively for transport use. The nodes should provide other services such as cafés, shops, professional meeting facilities, parcel delivery lockers, and grocery delivery, which will contribute to making the intermodal infrastructures a lively place, adding value to the overall travel experience as well as to the urban environment. A multifunctional interchange node enhances its level of attraction and fosters the perception of personal safety and security by providing adequate surveillance. A parking area should not be merely a place to park cars, but also a real Mobility Hub with a complete urban ecosystem living around it.

- Provide high quality pedestrian infrastructure: walking is a necessary complement of public transport. There is plenty of evidence that people are more willing to walk, and will walk over longer distances if the environment is safe, pleasant, direct, and well-connected.⁴³
- Develop ICT in order to provide real time information on the best travel options to enhance the reliability of the system, facilitate the interchanges and, in general, promote the use of sharing and intermodal systems.

Implement last mile solutions for passengers - It is difficult, in the short run, to establish more balanced density and land use patterns for MRDH. Proper urban planning must be initiated immediately, but will show its results only in the long run. For this reason, it will be important to implement a flexible and modern transport system policy able to increment the capillarity of public transport and bring citizens nearer to their final destination (last mile solution).

This system can be realized through the implementation of personal transit: public transport able to satisfy personal travel that collects people that live in suburban and rural areas and transports them to specific intermodal points that are well-connected with the economic center by means of efficient, frequent, and reliable massive public transport services.

Technology will play a central role in reaching efficient system utilization by optimizing the fleet necessary to satisfy the needs of mobility with the minimum number of circulating vehicles. Last mile systems can exploit transport automation technologies capable of adapting – in real time – the transport supply to the transport demand, along with providing shared compact electric vehicles that users can pick up and drop off at station points distributed over the territory. To be efficient, this system requires a high development of ICT solutions for the management of the shared vehicles and the booking system.

Last mile systems can be achieved by means of hectometric systems (tapis roulant, escalators, and lifts) especially in high demand contexts, and by using shuttle type public transport. Solutions based on shared vehicles, or “micromobility” systems integrated with the PT schedule and tariff system, should also be prioritized. These vehicles must be able to satisfy personal travel and be non-polluting, sustainable, and compatible with the urban fabric. This system can

⁴³ There is ample consensus that quantity and length of pedestrian trips are very sensitive to the quality of the pedestrian environment. See for example Jan Gehl: “Life Between Buildings: using public space” Island Press 2011; Jarrett Walker: “human transit” Island press 2011; <http://humantransit.org/2011/04/basics-walking-distance-to-transit.html>; Jeff Speck: “walkable city” North Point press 2013.

be realized using electric micro vehicles (e-quadracycles, e-scooters, e-bikes) or traditional bikes that can be picked up in dedicated stations near the collective transport system and not far from the final destination. Micromobility trips should not last longer than a few minutes. Micromobility allows passengers to reach destinations five times more distant from PT stops than the ones that can be reached on foot.

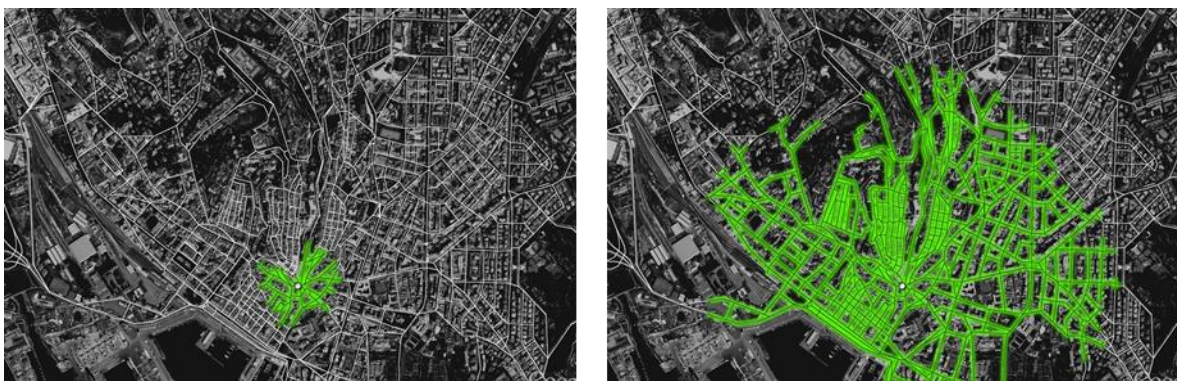


Figure 20 - Area reachable in 5 minutes from a Public Transport Stop by foot (left) and using a last mile solution (right)

A program for a short time implementation of automated last mile public transport in six locations is provided in the Region. Each of these sites has its own specific features, but the common objective is to create a critical mass and a steep learning curve by means of a standardized approach and cooperation between the sites. These sites will become “Field Labs for Last Mile Automation,” with the goal of extending the experience gained to the entire public transport network both in urban and suburban areas.

Synergy of this technology with automated guidance passenger cars is foreseen. Automated last mile (public) transport could enable flexible access in time and place; a concept like Go Join⁴⁴ could be an interesting option. The relocation of last mile vehicles could benefit from the progress of platooning techniques as well, where one vehicle with a human driver is followed by several platooned vehicles, without a driver on board.

⁴⁴ See: <https://www.tno.nl/en/focus-area/urbanisation/mobility-logistics/reliable-mobility/go-join-realizing-multi-brand-cooperative-automated-driving/>



Figure 21 - Locations of the six automated last-mile systems in MRDH

Advanced Last Mile Logistics - In its 2014 review of the Port Vision 2030 strategy, the Port of Rotterdam Authority noted the trend to import more volumes on fewer shipment trips, which is increasing the higher peaks of demand and capacity. So it is increasingly important that the Port can shift cargo at speed and with the lowest associated emissions. This is particularly urgent given the increasing competition in the European port sector, and has been identified as an even greater priority for the Port of Rotterdam going forward.

The increasing virtualization of logistics has highlighted the bottlenecks incurred by last-mile delivery in urban centers. Reducing the impact on congestion and emissions and speeding delivery times depends on the deployment of clean transportation and better analytics for route planning and logistics management. In the short- to medium- term, electric and hydrogen vehicles, on-demand services, and the use of more sophisticated planning and integration tools can improve the efficiency of local logistics. Integrated smart port mobility and transport management—covering vehicle monitoring and routing and smart parking systems—can be linked into regional and national systems to improve the flow of logistics through the region.

In the future, automated vehicles and even drone technologies will offer alternative modes for last-mile delivery. In addition, the emergence of decentralized on-demand models for energy, mobility, and manufacturing (based on 3D printing) means that supply chains will become even more complex at the local level, presenting new challenges and opportunities for the Port as an intermediary in a global network.

“Drones” are unmanned vehicles that do not transport persons but carry objects or perform tasks either autonomously or under remote control. Drones capable of vertical flight are an interesting technology for delivering small parcels. Flying drones could also perform useful roles in monitoring the environment and transporting emergency apparel.

Road equipped drones are essentially level-5 autonomous vehicles and face the same regulatory and safety limitations of driverless vehicles. It is forecast that this technology will not be feasible in non-controlled environments before 2050, but road equipped drones may be already available by 2025-2030 in controlled environments like pedestrian areas and cycling lanes.

These developments will also usher in new thinking about warehouses and distribution centers. Automated, on-demand fulfillment will be coordinated through hub-and-spoke central and local net-zero energy distribution centers that are deployed in alignment with regional transportation and land use planning regulations.

The Erasmus Research Institute of Management (ERIM) has established a program to examine innovative solutions to the challenges of delivering sustainable and efficient last-mile logistics. The Port of Rotterdam and MRDH can build on the work of ERIM to explore closer integration between logistics management within the port boundary and the optimization of logistics across the region.

The combination of large-scale logistics experience in the port and local innovations around clean and efficient transportation can enable MRDH to be a world leader in the development of integrated logistics solutions.

Develop an intelligent street lighting network – Street lighting networks have the potential to support other applications, such as air quality monitoring, parking management, and public safety applications. Interest in smart city programs and applications is on the rise – from intelligent traffic controls, to networked security cameras, to distributed renewable energy generation, and more. A networked street light control system can provide an ideal backbone

for these applications, given that street lights are on an existing network of poles with power throughout a city that are then endowed with network communications. The growing demand for smart city applications will drive the adoption rates of smart street lighting networks, and the growth in street lighting networks will in turn drive a broader use of smart city applications.

1.2.2 REGULATORY

Regulatory measures are critical to ensuring the transition to a Third Industrial Revolution model of mobility, especially in the field of automation and data exchange.

1.2.2.1 Establish a new Commissioner on Security and Resilience - Increasing the capacity to generate Big Data and mine it with analytics, creating algorithms and apps to increase aggregate efficiency and productivity is a radical change in mobility that will need to be carefully regulated. A Commissioner for Security and Resilience will be charged with the task of securing data, avoiding cyber-attacks, and adapting to extreme weather events brought on by climate change.

1.2.2.2 Define new norms for driverless vehicles - The practical implementation of autonomous vehicles is limited by the absence of laws that allow them to travel on public roads; the current scenario is characterized by a “normative void,” since no laws exist that can classify and regulate this new technology. Driving technologies already allow vehicles to travel autonomously in a controlled environment; tests are being carried out with low speed vehicles that travel in pedestrian areas or on cycle infrastructures. Typically, the rules applied are those that relate to railway operation, which are clearly inadequate to govern small, free-moving vehicles. Enacting adequate laws will allow operators to expand this technology to bigger, faster public transport vehicles travelling on dedicated lanes, but allowing some controlled interference with traffic (for example: crossings with activated traffic lights).

The norms will have to be continually updated within an international and European legislative framework. The recent Declaration of Amsterdam, signed by the EU Transport Ministers in April 2016,⁴⁵ aims to remove the legislative barriers that hinder the roll out of vehicle automation. The Declaration of Amsterdam also represents a great step forward in the development of

⁴⁵ See: <https://english.eu2016.nl/documents/publications/2016/04/14/declaration-of-amsterdam>

vehicle automation, and will speed up the advent of fully autonomous, driverless road going vehicles.

1.2.2.3 Data exchange - Autonomous vehicles will require a heavy amount of data exchange: V2V and V2I and, in some cases, from vehicle to control center, and vice-versa. This significant exchange of data raises critical issues: the adoption of adequate protocols, privacy of data, security against hacking, robustness against transmission errors or loss of communication and the capacity of transmission channels to handle the volume of data required by a widespread adoption of automation. Accurate studies and continuous monitoring of the systems are needed to verify the requirements for data transmission that will be necessary for a massive adoption of autonomous driving technology in transportation. The vehicles may be controlled by a central control center – especially public transport vehicles – but they must retain a degree of autonomy to guarantee robustness against loss of communication.

1.2.3 POLICY

1.2.3.1 Coherent transport plans in the TIR - The growth in population and goods in transit projected over the next several decades in the region, together with the strategy to make optimal use of the current transport infrastructure, reinforces the necessity to define coherent transport plans in order to avoid an uncontrolled development of mobility.

A Mobility and Logistic Internet framework, based on the exploitation of the new technologies and renewed sustainable systems, must involve all transport modes:

- Cyclists
- Pedestrians
- Public Transport
- Private vehicles and parking spaces
- Transport of goods and warehousing

All these modes must be comprised in an integrated connected, collaborative and shared network where massive public transport will cover the main role in satisfying the longer trips.

Throughout the 20th Century, the car was the key concern of planners since it is the mode of transport that provides the greatest freedom of movement. Not surprisingly, cars receive the highest share of space and infrastructure.

Having recognized that the Second Industrial Revolution infrastructure has not often led to good planning and optimal use of scarce resources, a new paradigm is necessary to guide the planning of mobility for the 21st Century – one that prioritizes the pedestrian over the personal car.

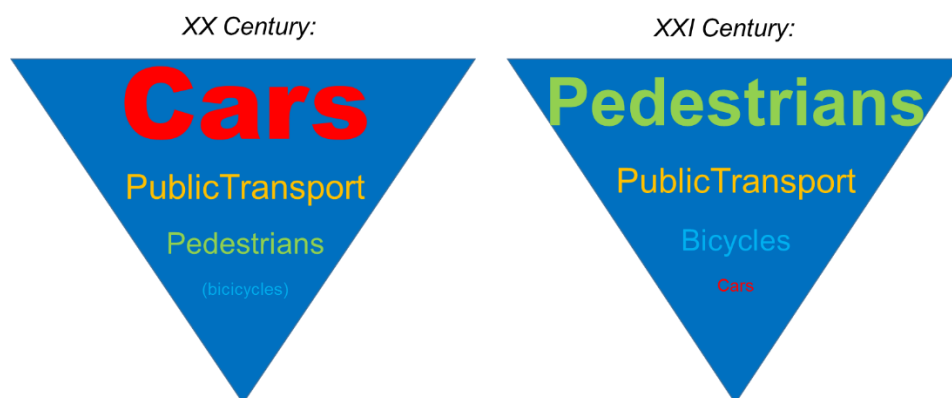


Figure 22 - A new paradigm of priorities in transportation for the XXI Century

1.2.3.2 Standardize the movement of goods and services between modes of transportation -

Increase aggregate efficiencies and productivity and reduce marginal costs and ecological footprint, identifying such ongoing opportunities through a quadruple helix knowledge innovation network.

1.2.3.3 Prepare road, rail, water, and air corridors for automated driverless transportation and logistics - Member States and the European Union will need to establish common codes, regulations, standards and modes of operability, as well as promulgate statutes governing safety and liability.

1.2.4 EDUCATION

1.2.4.1 Promote educational initiatives for addressing vocational and professional training needs in the transition from combustion-based mobility to battery electric-based mobility. A smooth and effective transformation in the electrification of the mobility sector requires new skills and competences along the supply chain, including auto suppliers, post-sales services and maintenance, end-of-life recycling requirements, new business models (e.g., car-sharing

ventures), and vehicle-to-grid interconnectivity technical issues. A quadruple helix innovation network can help identify and prioritize the many aspects and facets that should be incorporated into educational courses and curricula.

1.2.4.2 Promote educational excellence and competences in the field of Multi-modality. The government includes logistics among the top nine sectors, with a 2020 goal of being a global leader in processing of cargo shipments and inter-modal logistics. Vocational and professional competences are essential to sustain the nation's innovation climate in the shipping and logistics sectors. Emphasize development of skills essential for engaging in partnerships among and between education, research institutes, entrepreneurial businesses, and government agencies.

1.2.4.3 Integrate new curricula on mobility thinking - The dramatic innovations unfolding in the mobility and logistics sectors necessitate new learning resources and practices for students and teachers. New curricula need to illuminate the myriad of implications that accompany the expansion of the Internet of mobility, driverless vehicles, wireless charging of electric vehicles, renewable sources of hydrogen fuels, and fuel cell systems. Emphasis should also be placed on deepening the concept of mobility as “access” in smart cities, achievable through means other than vehicles, e.g., mobile phone communication, and spatial planning facilitating pedestrian and bicycle friendly transport modes.

1.2.4.4 Establish a field lab in hydrogen-powered fuel cells for vehicles. Leverage the existing network of research and development occurring through such entities as the Netherlands Biohydrogen Network, as well as the EU initiative, “Roadmap for the first EU-wide Guarantee of Origin scheme for Green Hydrogen”.⁴⁶

1.2.4.5 Establish a field lab for lightweight vehicles. Leverage the expertise being developed at related field labs and research institutes, such as the Field Lab for Maintenance & Repair of Composites (Development Center for Maintenance of Composites, DCMC), the Automated Composite Manufacturing (ACM) Pilot Plant, and the Institute for Composite Development (Instituut voor Composiet Ontwikkeling (ICO)).

1.2.4.6 Continue to foster public-private partnerships (PPPs) in vocational-education training in the field of mobility and logistics - Sustain innovation in learning competences including

⁴⁶ See: <http://ec.europa.eu/research/index.cfm?pg=events&eventcode=6C885754-CC3F-ED0D-45249815790ABECO>

generation, storage, use of hydrogen fuels, lightweight electric vehicles, and the burgeoning field of Internet of mobility and logistics, carried out in institutions such as the Centrum voor Innovatief Vakmanschap Onderhoud Mobiliteit (center for innovative craftsmanship in maintenance mobility), and the centers of expertise in higher vocational education (HBO) and senior secondary vocational education (MBO). Incorporate relevant programs and initiatives at the various vocational and educational institutions such as: Hogeschool Rotterdam (Rotterdam University of Applied Sciences); LEVV (Netherlands Centre of Excellence in Nursing); Albeda College (regional training center (ROC) for secondary vocational education and adult education, and apprenticeship training in the Rijnmond region), Zadkine (secondary vocational education school in Rotterdam).

1.2.4.7 The emergence and expansion of driverless vehicles requires public education and consumer information to help ensure a smooth transition - The unfamiliarity with driverless cars, including concerns of safety, security, operation, and other issues likely to emerge with the scaling of driverless mobility options, should be communicated to the citizenry through various venues. With these concerns in mind, the government should set up an open access platform to enable citizens to participate, interact and engage on identifying, defining, discussing, and recommending ways to educate the public.

1.2.5 FINANCIAL

1.2.5.1 Incentivize electric vehicles – A review of accumulating evidence indicates that financial incentives, a dense infrastructure for battery charging, and production facilities sited locally are important and strongly correlated with a nation's EV market share. The charts below indicate the various financial incentive pathways used in the U.S., Europe, and China.

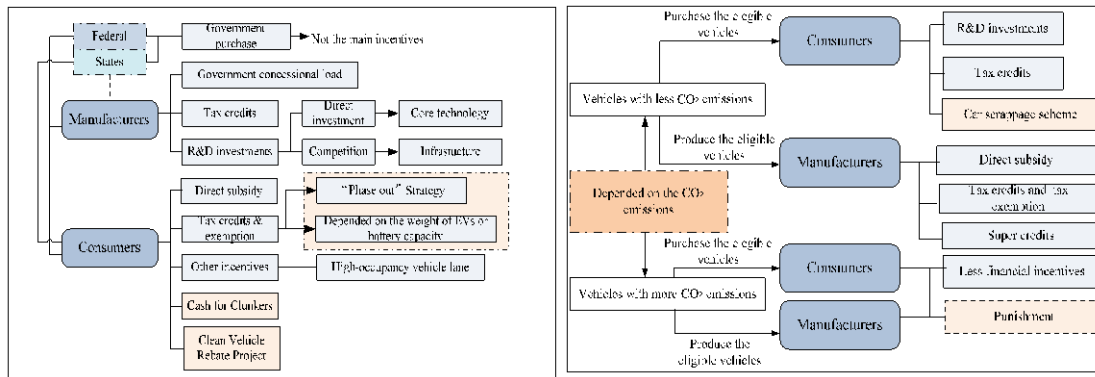


Figure 23 - Financial incentives pathways for promoting electric vehicle purchases (USA Left, Europe Right)⁴⁷

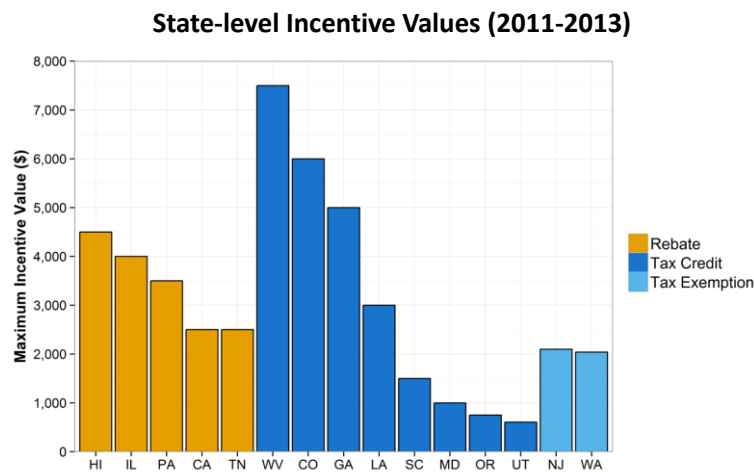


Figure 24 – State-level Incentive Values (2011-2013)

It is important to implement the subsidy policy for a limited period. A significant subsidy should be given initially, but only made available for a short period and, most importantly, it should be under the condition that the beneficiaries will eliminate their fossil-fuel car and not buy a new car within the next five years. The policy can include a reduction or elimination of the purchase tax, road tax, and/or a subsidy for the purchase, given in exchange for a fossil-fuel vehicle that is removed from circulation. Taxes favoring emission-free vehicles are also effective. The

⁴⁷ Source: Xingping Zhang et al. (2014) Policy Incentives for the Adoption of Electric Vehicles across Countries, Sustainability 6, 8056-8078; doi:10.3390/su6118056

Netherlands introduced an aggressive incentivization plan in favor of PHEV and BEV which appears to be successful.⁴⁸

Moreover, incentives (not only for EV) raise the question of how long they will/can stay in place and what will happen when they are removed. There are studies⁴⁹ that show that when the incentive is removed, many people go back to their previous behavior. It is therefore recommended to also promote changes in behavior (for EVs and any other sustainable modes) based on “hard” interventions.

1.2.5.2 Periodically review the various ways that leading cities and regions in the world are promoting and incentivizing increased demand for Electric Vehicles - Cities are using a variety of benefits and preferential policies to spur demand and ongoing expansion of the EV market. Monitoring the results being achieved in these other cities allows gleaning innovative approaches that may prove useful in MRDH. These include different levels of subsidies, promotion of EV car sharing services, and public and corporate preference policies for procuring EVs.

1.2.5.3 Create a workplace charging incentive program and employee outreach program to encourage EV adoption. Workplace charging has proven highly effective in encouraging individuals to purchase EVs by showcasing the technology and reducing “range anxiety” by providing a consistent charging location that effectively doubles the commuting range of an EV. The federal incentive could include greater financial rewards for employers who install solar carports (also protecting the vehicles from the elements) and reducing the cost of trenching as power is produced onsite, or if the location has rooftop solar.

The vehicles can be “trickle charged” during the day using lower cost equipment and the charging rate can be matched to solar production to reduce the need for grid operators to load balance due to solar intermittency. Having an “EV day” at the workplace, featuring the latest models for test drives, will promote familiarity with the technology, and any employees with EVs will be critical for “word of mouth” persuasion of colleagues. Local electrical laws should be

⁴⁸ See: <http://www.eafo.eu/content/netherlands> ;
<https://www.rvo.nl/sites/default/files/2015/04/Electromobility%20in%20the%20Netherlands%20Highlights%202014.pdf>

⁴⁹ Fujii, S. & Kitamura, R. (2003). What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation* 30, 81-95.

streamlined to simplify the installation of clean energy, solar PV canopies, and solar charging stations.

1.2.6 R&D

1.2.6.1 Establish a quadruple helix knowledge innovation network that focuses on the range of R&D issues related to the scaling-up of the interconnections between the Internet of Mobility and Logistics and the Internet of Buildings as Nodes, Internet of Communications, and related sectors. Innumerable R&D efforts and initiatives are currently driving ongoing developments in the adoption of IoT tools and technologies in various sectors of the economy. To prevent missed and lost opportunities and avoid unwitting and unintended consequences, as well as to foresee opportunities arising from crossovers between sectors, a quadruple helix knowledge innovation network should be tasked with addressing these issues. The convergence and synergisms between the IoT explosion and the exponential growth in GAIN technologies (genetics, auto-robotics, informatics and nanoengineering), necessitates all the sectors sustaining ongoing conversations on emerging opportunities to work together in achieving win-win results and benefits.

Delft University of Technology is currently starting a 5-year research program SURF STAD (Spatial and Transport Effects of Automated Driving) together with knowledge partners like Erasmus University, TNO, SmartPort, Rotterdam University of Applied Science, private partners and practice partners like MRDH, and the province of South-Holland with a €2.5 million budget. Together with the concrete ambitions above, the SURF STAD-research provides the basis to develop MRDH as a world leading region in knowledge and business in the field of autonomous driving.

Ranking of Proposals

The graph shows a ranking of the proposals listed in the report. Ten proposals for mobility in MRDH have been ranked using a two-dimensional view, in order to prioritize the TIR proposals based on their ease of implementation (as measured by the expected implementation challenges) and the potential value expected from their realization in the MRDH Region. Six different value factors are scored for each proposal, using the criteria listed in the following tables:

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Potential Value (y-axis)

Value Factor	Low Score	High Score	Weighting
Reduces final energy consumption	Reduces energy consumption by <10%	Reduces energy consumption by >30%	2
Reduces CO ₂ emissions	Reduces CO ₂ emissions by <25%	Reduces CO ₂ emissions by >50%	3
Increases % of renewable energy generation	Achieves >50% of renewables gen.	Achieves >90% of renewables gen.	2
Provides knowledge or results to be used in subsequent projects	Outputs will inform future projects	Outputs are a necessary input to another project	1
Allows for implementation of the cross-axes: circular economy, sharing economy, and smart economy	Allows for implementation of only one of these cross-axes	Allows for implementation of all three cross-axes	2
Builds upon MRDH assets (e.g., ICT, data analytics center, financial standing, university R&D, cyber security, reputation)	Builds upon only one asset	Builds upon three or more assets	1

Note: Medium scores are implied between low and high and are not shown for clarity.

Ease of Implementation (x-axis)

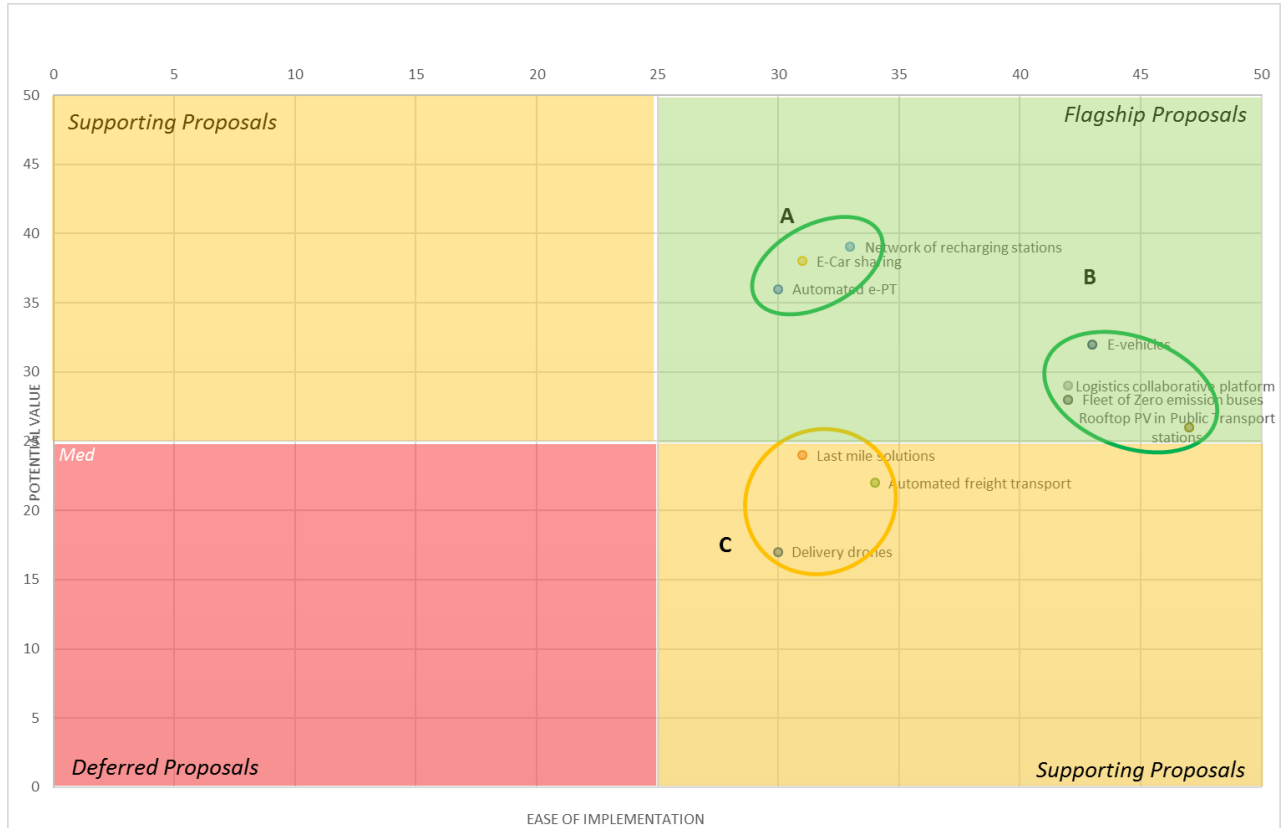
Implementation Factor	Low Score	High Score	Weighting
Technology is commercially available	Technology/application only available in beta or demo format	Technology/application has been implemented at scale	1
Requires specialized skills or partners, rather than local labor	Requires two or more partners, or special training	Requires no partners nor special training, uses local labor	1
Provides an upscaling capacity across multiple geographies	Limited to one or two locations only	Can be scaled across multiple cantons	3
Requires minimal decommissioning effort at project conclusion	Requires decommissioning or equipment removal	Requires no decommissioning and equipment can stay	1
Can be self-funded	Payback period is 7 years or more	Payback period is 3 years or less	2
Requires little start-up time or governance (e.g., regulatory)	Can be started in 6 to 12 months	Can be started in 3 months or less	2

Note: Medium scores are implied between low and high and are not shown for clarity.

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The scores assigned to each proposal are as follows:

No.	project name	X-AXIS	Y-AXIS
		Implementation score	Value score
1	Network of recharging stations	33	39
2	Last mile solutions	31	24
3	Logistics collaborative platform	42	29
4	Promoting E-Car sharing	31	38
5	Promoting E-vehicles	43	32
6	Implementing Automated e-PT	30	36
7	Automated freight transport	34	22
8	Implementing Delivery drones	30	17
9	Deploying Fleet of Zero emission buses	42	28
10	Rooftop PV in Public Transport stations	47	26



The graph shows that the proposals are clearly grouped in three clusters:

- A. Projects with a high potential value (Y-score between 35 and 40) and a relatively high ease of implementation (X-score between 30 and 35). This cluster falls into the “flagship projects” quadrant and it includes: building a network of recharging stations, promoting E-car sharing, and implementing lines of automated electric public transport.
- B. Projects with high ease of implementation (X-score higher than 40) and relatively high potential value (Y-score between 25 and 35). This cluster also falls into the “flagship projects” quadrant and it includes: promoting E-vehicles, building a logistics collaborative platform, deploying a fleet of zero-emission buses, and installing rooftop PV on public transport stations. All four projects in this cluster require very little new network infrastructure.
- C. Projects with relatively high ease of implementation (X-score between 30 and 35) but below-average potential value (Y-score lower than 25). This cluster falls into the

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“supporting proposals” lower right quadrant and it includes: last mile solutions, automated freight transport, and delivery drones. It is worth noting that the “last mile solutions” proposal falls very close to the boundary with the “flagship proposals” quadrant (Y-score = 24).

Action Plan

The transition from a “fragmented, carbon intensive individual transport” to the 2050 vision of a “connected, carbon free shared mobility,” has been framed into an Action Plan that shows the fundamental steps that need to be implemented in terms of Transport and Urban Planning actions (plans, norms, infrastructures, feasibility studies and pilot tests) in order to define a clear and coherent framework for a quick and effective transition. The forecasted time frames of each action are shown at the right.

Actions	2017	2018	2019	2020	2025	2030	2040	2050
<i>Update the transport plans defining updated objectives and action plan coherent with TIR scenario (stakeholder consultation and communication campaign)</i>								
<i>Definition of mobility requirements and specifications for the new urban projects</i>								
<i>Definition of the financial measures (incentives) for the rolling out of electric mobility</i>								
<i>Feasibility studies for automation</i>								
<i>Regulatory norms for Public Transport automation (in controlled environment)</i>								
<i>Regulatory norms for PT automation (in semi controlled environment)</i>								
<i>Regulatory norms for full PT automation</i>								
<i>Establish a Commission for Security and Resilience of Big Data management and AV's transition</i>								
<i>Development of the mobility platform for Rotterdam and the Hague</i>								
<i>Transport and Logistic platform for the Port area (Digital Port) and the cities of Rotterdam and the Hague</i>								
<i>Completion of Collaborative ITS infrastructure in the Port of Rotterdam</i>								
<i>Completion of Collaborative ITS infrastructure across Urban Axis Motorways</i>								
<i>Automated intra-port transport (SAE Level 2-3)</i>								
<i>Truck platooning</i>								
<i>Implementation of a Field Lab for Last Mile Automated Transport (Last-mile automation for passengers in six locations)</i>								
<i>Implementation of a Field Lab in hydrogen-powered fuel cells for vehicles</i>								
<i>Pilot test: automated Group transit system easy demo (SAE Level 3)</i>								

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Pilot test: automated personal transit system easy demo (SAE Level 3)								
Pilot test: small-scale demand-driven transport (Split/Uber like))								
deployment of representative quantities (50%) of truck platooning on fitted corridors								
Cooperative automated driving across Stedelijke As (SAE Level 4)								
Pilot test: two hydrogen buses in line								
Fleet of 50-100 Hydrogen busses								
Fleet of 50 Hydrogen cars								
Implementation of 5-10 hydrogen fuelling stations								

Continue:

Actions	2017	2018	2019	2020	2025	2030	2040	2050
Fleet of 200,000 EVs								
Implementation of the charging stations network								
Implementation of Solar panels in 50 metro stations and 30 light rail stations								
Implementation of a Region-wide car-sharing system integrated with Massive Public Transport System								
Last mile solutions for goods using Drones technology in controlled environment								
Last mile solutions for goods using Drones technology in non-controlled environment								
Intensive awareness campaign to improve acceptance and integration of automation technology								
Representative quantities of last mile solutions for passengers and goods								
Representative quantities of fully autonomous vehicles in non-controlled environment (SAE Level 5)								
Representative quantities of fully autonomous vehicles (Personal Rapid Transit)								

GLOSSARY

Soft mobility: mobility that requires the use of one's muscles and can provide significant health benefits. Typically it includes walking, cycling and e-cycling. May include other means such as skateboards, stand-on scooters and skates

Automated vehicle: a vehicle fitted with automation devices that assist the driver in maneuvers such as speed control, braking, steering, obstacle avoidance. Fits SAE categories II and higher

Autonomous vehicle (AV): a vehicle that can travel without being guided by a human driver, but may retain a driver's seat and controls. Fits SAE categories IV and higher

BEV: battery electric vehicle: electric vehicle with power storage batteries on board

Car sharing: a vehicle whose use is shared in time among many users, who typically pay a participation fee plus a usage fee. The access to the vehicle is exclusive and the users pay for the time they have access.

Driverless vehicle: a vehicle without a human driver. Also driver's seat and controls are missing. Fits SAE category V

Drone: a remotely controlled, automated driverless vehicle that does not transport passengers. It accomplishes tasks such as monitoring, control and transport of goods. Drones can be specialized to travel on land, air or water,

EV: electric vehicle, general definition of a vehicle powered by an electric motor

HEV: hybrid electric vehicle: vehicle with an electric motor and a non-electric motor (generally fossil-fuel powered) that can serve as generator of electric power (serial HEV) but also provide traction directly (parallel HEV)

HECTOMETRIC TRANSPORT: a transport system that can cover a distance of one or more hectometers (hundreds of meters) but typically less than one km. These include continuous systems such as travelators (moving walkways) and escalators, and discontinuous systems with cabins (Automated People Movers).

Hydrogen-Fuel cell (HFC): a device that uses the energy from the oxidation of hydrogen gas to produce electricity. The combustion exhaust gas is water vapor.

MICROMOBILITY: a mobility system based on small, individual shared vehicles that are able to cover small distances of up to a few km. Micromobility can complement public transport, providing rides on the "last mile" from the station of arrival to the final destination, but also travel in compact city centers or districts.

PHEV: plug-in Hybrid electric vehicle; hybrid vehicle with capacity to recharge its batteries through the distribution network, and eventually to release energy to the network.

Platooning: a technique that allows several vehicles to travel at very close distance one behind the other. All the maneuvers of the vehicles starting from the second are coordinated by the first vehicle of the platoon by means of V2V communication

Ride sharing / Ride pooling: various users share a vehicle at the same time along the same route. Users typically register to the service for free and pay the owner for the use of a vehicle which is generally private.

V2V and V2I: vehicle-to-vehicle and vehicle-to-infrastructure communication. The transmission of information between vehicles and with the infrastructure allows vehicles to be informed in real time about the dynamic conditions of traffic and the infrastructure. Allows control centers to monitor mobility and collect and compute data.

SMART ENERGY DELTA

THE RENEWABLE ENERGY INTERNET

The bulk of the energy we use to heat our homes and run our appliances, power our businesses, drive our vehicles, and operate every part of the global economy will soon be generated at near zero marginal cost and be nearly free in the coming decades. That is already the case for several million early adopters in the EU who have transformed their homes and businesses into micro-power plants to harvest renewable energy on-site. Currently, 32% of the electricity powering Germany comes from solar, wind, and other renewable energies. By 2030, a minimum of fifty percent of the electricity powering Germany will be generated by renewable energies.⁵⁰

Kees d'Huy and the Energy Working Group, MRDH

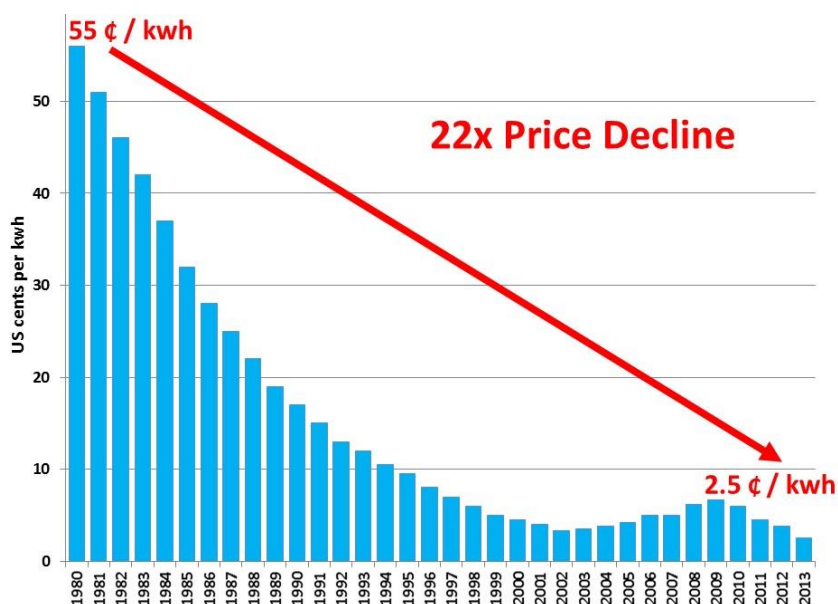
Rob Wilhite (Navigant Consulting), Kathleen Gaffney (Navigant Consulting), Marcel Volkerts (DNV GL), Yvonne Boerakker (DNV GL), Gerhard Stryi-Hipp (Fraunhofer ISE), Andreas Reuter (Fraunhofer IWES Nordwest), and Jeremy Rifkin for TIR Consulting Group LLC

The quickening pace of renewable energy deployment is due, in large part, to the plunging cost of solar and wind energy harvesting technologies. The reduction in fixed costs of solar and wind technologies have been on exponential curves for more than 20 years, as shown in figure 1. In 1977, the cost of generating a single watt of solar electricity was 76 dollars, and by 2017 the cost is projected to be 55 cents/Watt.⁵¹ After the fixed costs for the installation of solar and wind are paid back—often in as little as two to eight years—the marginal cost of the harvested energy is nearly free. Unlike fossil fuels and uranium for nuclear power, in which the commodity itself always costs something, the sun and the wind are free.

⁵⁰ See: <http://www.sueddeutsche.de/wirtschaft/gruener-strom-sommer-sonne-sorgen-1.2638800>

⁵¹ See: <http://www.nwclimate.org/news/solar-panel-efficiency-from-solarcity/>

Figure 1: Wind Energy Product Cost Per kWh (U.S.)



The impact on society of near zero marginal cost solar and wind energy is all the more pronounced when we consider the enormous potential of these energy sources. If we could grab hold of one-tenth of one percent of the sun's energy that reaches Earth, it would give us six times the energy we now use across the global economy. Like solar radiation, wind is ubiquitous and blows everywhere in the world—although its strength and frequency varies. A Stanford University study on global wind capacity concluded that if 20% of the world's available wind was harvested, it would generate seven times more electricity than we currently use to run the entire global economy.

At present, the Netherlands is still heavily reliant on conventional fossil fuel energies, particularly natural gas. In fact, in 2012, the Netherlands was the largest natural gas producer in the European Union, producing 43.2% of all the natural gas production.⁵² The country ranks low among the Western European nations in renewable energy generation. In 2012, renewable energy accounted for only 4.3% of total energy consumed in the Netherlands, and renewable

⁵² See: https://ec.europa.eu/energy/sites/ener/files/documents/2014_countryreports_netherlands.pdf

energy in 2011 made up only 10.9% of the energy used in power generation.⁵³ In fact, the Netherlands is among the EU countries that are woefully behind in reaching its renewable energy targets and is only halfway toward achieving its global greenhouse gas (GHG) emissions goals in the non-EU Emissions Trading System (ETS) sectors.

However, the Netherlands has begun to embrace far more ambitious renewable energy targets in the past year. Solar panel sales alone increased in the first half of 2015 between 70 and 100% compared to the same period a year before, with the installation of more than 2 million panels. While only 0.2% of the electricity generated in the Netherlands is produced by solar, the new data points to a potential leap forward in adoption of solar technology and other underutilized renewable energies. A summary of renewable energy opportunities for the MRDH Roadmap Next Economy can be found in Figure 2.

Figure 2: Netherlands Roadmap Next Economy Domestic Renewables Market Opportunities

60% with offshore wind power: 31% of technical potential; 80 GW nameplate capacity; 16,000 turbines, each 5 MW rated power; 45% average capacity factor; spacing area 10,700 km²; 2050 LCOE (levelized cost of electricity) €cents 11/kWh.

5% with onshore wind power: 17% of technical potential; 8 GW nameplate capacity; 1,600 installed turbines, each 5 MW rated power; 38% average capacity factor; footprint area 722 km² (2.2% land area); 2050 LCOE €cents 7/kWh.

31.4% with utility-scale Solar PV: 73% of technical potential; 137 GW nameplate capacity; 2,740 solar farms, each 50 MW rated power; 14% average capacity factor; footprint area 1,228 km² (3.64% land area); 2050 LCOE €cents 10/kWh.

3.2% with Residential & Commercial rooftop Solar PV: 27% of technical potential; 15.1 GW nameplate capacity; 76,280 commercial rooftop systems, each 100 kW rated power and 1.5 million residential rooftop systems, each 5 kW rated power; 13% average capacity factor; footprint area 73.7 km² (0.2% land area); 2050 LCOE €cents 13/kWh.

The Energy Internet is comprised of four foundational pillars, all of which have to be phased-in simultaneously in the Metropolitan Region of Rotterdam and The Hague for the system to

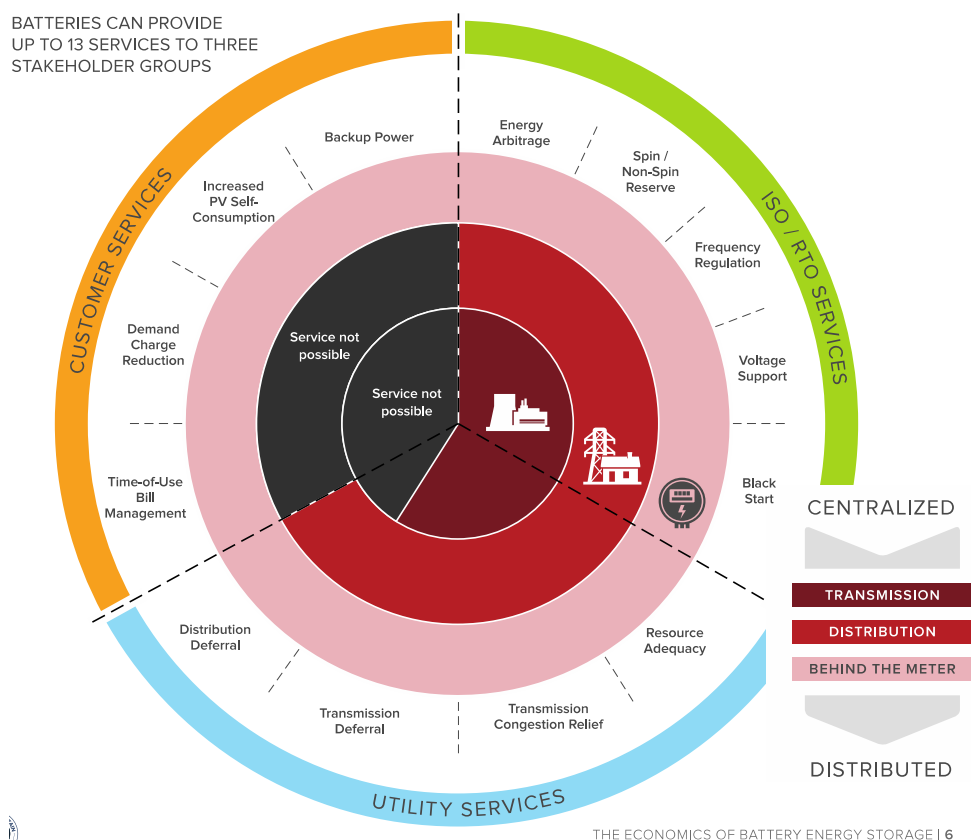
⁵³ *Ibid.*

operate efficiently. First, buildings and other infrastructure will need to be refurbished and retrofitted to make them more energy efficient so that renewable energy technologies can be installed to generate power for immediate use or for delivery back to the electricity grid for compensation. Second, ambitious targets must be set to replace fossil fuels and nuclear power with renewable energy sources. To achieve this goal, various government incentives need to be introduced to encourage early adopters to transform buildings and property sites into micro-power generation facilities. Third, storage technologies including hydrogen fuel cells, batteries, water pumping, etc., will need to be embedded at local generation sites and across the electricity grid to manage both the flow of intermittent green electricity and the stabilization of peak and base loads. Fourth, advanced metering infrastructures and other digital technologies like energy management systems will need to be installed in every building, transforming the energy grid into a fully digitized bidirectional system in order to manage multiple sources of energy flowing to the grid from local generators (smart grid implementation).

The Dutch utility companies have announced the nationwide installation of smart electricity meters with the goal of 100% deployment between 2016 and 2020. This will enable passive consumers of energy in the Metropolitan Region of Rotterdam and The Hague to become active prosumers of their own green energy, which they can then use off-grid to manage their facilities or sell back to the Energy Internet. Fifth, every parking space will need to be equipped with a charging station to allow electric and fuel cell vehicles to secure power from the Energy Internet, as well as sell power back to the electricity grid. Electric and fuel cell vehicles connected to the Energy Internet also provide a massive backup storage system that can send electricity to the grid during peak demand, when the price of electricity has spiked, allowing vehicle owners to be appropriately compensated for contributing their electricity to the network. Figure 3 provides representative battery energy storage applications for further clarity.

The phase-in and the integration of these foundational pillars will transform the electricity grid of the Metropolitan Region of Rotterdam and The Hague from a centralized to a distributed energy system, and from fossil fuel and nuclear generation to renewable energy. In the new system, every business, neighborhood, and homeowner becomes the producer of electricity, sharing their surplus with others on a smart Energy Internet that is beginning to stretch across national and continental landmasses.

Figure 3: Representative Battery Energy Storage Applications (Rocky Mountain Institute)



This massive shift has started to appear in Germany with the establishment of electricity cooperatives. Most of these cooperatives were successful in securing low interest loans from banks to install solar, wind, and other renewable energies on-site. The banks were more than happy to provide the loans, assured that the funds would be paid back by the premium price the cooperatives would receive—via feed-in-tariffs—from selling the new green electricity back to the grid.

The rise of electric cooperatives has forced electricity companies to rethink their business practices. A decade ago, four giant vertically integrated electricity generating companies—E.ON, RWE, EnBW, and Vattenfall—were producing much of the electricity powering Germany. Today, they are producing less than 7 percent of the new green electricity that's taking Germany into a Third Industrial Revolution. Peter Terium, CEO of RWE, the German-based energy company, acknowledges the massive shift taking place in Germany from centralized to

distributed power, and says that the bigger power and utility companies “have to adjust to the fact that, in the longer term, earning capacity in conventional electricity generation will be markedly below what we’ve seen in recent years.”⁵⁴

The Metropolitan Region of Rotterdam and The Hague (MRDH) Energy Context

The Metropolitan Region of Rotterdam and The Hague sits at the crossroads of both challenges and opportunities regarding energy. On one hand, the energy and climate challenges and targets for the region are high. On the other, these challenges also present opportunities for MRDH to become a distinctive, exemplary, and normative energy region, while also creating a competitive business climate and expanded export opportunities.

The Third Industrial Revolution Structuring Document for MRDH has already outlined an ambitious vision for the region’s energy transition. Much can be said about the relevance, applicability, and completeness of this vision relative to the specific energy needs of MRDH, including future economic development. For instance, the vision focuses on electricity and the (smart) electricity grid as the dominant energy commodity and infrastructure. However, as also stated in the energy report “Transitie naar duurzaam” from the Ministry of Economic Affairs, it is believed that all known low-carbon energy resources and technologies are required in order to achieve stated CO₂ reduction targets. Therefore, in addition to its economic ambitions, the energy transition also represents a political aim; one that requires an intervention by society in terms of the decisions that individual energy consumers and producers must make, in order to achieve CO₂ reductions.

Both energy efficiency and renewable energy resources (i.e., biomass, solar and wind power, waste heat, CO₂ capture and storage) are expected to comprise significant elements of the MRDH energy system by 2050. An increased share of fluctuating renewable energy sources, like solar and wind power, requires increased (short and long-term) flexibility, to manage renewable energy intermittency. This energy system will also require – at least in the short term – a hybrid use of fossil-based and renewable energy operating together in a multi-commodity, energy infrastructure network. This system, however, will change over time and

⁵⁴ See: <http://www.reuters.com/article/us-utilities-threat-idUSBRE92709E20130308>

will largely be dependent on the energy demand and supply of numerous energy options, their affordability, and acceptance.

The extraction, transport, and storage of energy have shaped our landscape over the centuries. Think of peat extraction, mining, high voltage electricity pylons, and petrochemical complexes. The emergence of distributed energy networks and renewable energy also has spatial consequences and will compete for the scarce (horizontal) space in MRDH. Renewable energy technologies – solar, wind, geothermal, and biomass – require vertical space, underground and above ground. Given the social issues related to natural gas extraction in Groningen, society expects that energy production issues will be handled in a more integrated way. Spatial integration of renewable energy in the near future will require more attention.

An increasing number of parties are joining the supply side of sustainable energy, including wind, solar, geothermal, and residual sources. This presents new challenges, including the question of how open we want the market to be and which part is a utility function (and public), and which is not? Which policies and rules are needed? How do we keep energy affordable for citizens and businesses? Furthermore, switching to renewable energy sources requires adequate communication and influencing of established behaviors. What can be achieved by a bottom-up movement and to what extent is a top-down approach necessary? Often parties want to switch to a more sustainable energy supply but, lacking sufficient information, knowledge, and trust, they need an incentive to facilitate taking the first steps.

The transition to a cleaner energy supply offers great opportunities for innovation, increasing competitiveness, and the development of new economic sectors. Aligning infrastructure investments and positioning government as a launch customer can accelerate this development. The transition towards sustainable energy requires considerable upheaval. Current technologies lack the ability to meet the demand for renewable energy in an affordable way with continuity and capacity guarantees. Furthermore, our society and economy is not sufficiently set to embed these technologies on a broader scale. The transition path will therefore focus on innovation and the support of rapid scaling of proven concepts. Last, but not least, we have to work on establishing a stimulating and business friendly Smart Energy Delta with respect to policy, law, regulations, fiscal regime, communications, and market opportunities.

A successful transition into a regional, sustainable energy system for MRDH should not only result in an attractive and livable environment, but also in a competitive business climate. With

this in mind, MRDH should aim to create new energy businesses within the region. Using the momentum, speed (urgency), and scale of MRDH, these businesses are developing the aforementioned new and affordable energy options into distinguished products and services for a world market.

The long-term objective for MRDH is to become a zero carbon Metropolitan Region. The ambition is to be powered entirely on sustainable energy, without producing a carbon footprint. The goal is to maintain optimal living conditions while eliminating environmental impacts. This includes decarbonizing the generation of power and light, space heating and cooling, and transitioning into zero-emissions transportation.

Using clean, renewable, and regionally generated electricity will reduce MRDH's dependency on foreign energy supply and will have a positive effect on the environment, health and well-being of the citizens, and overall business competitiveness. Large-scale, applied innovation and new services and products create new businesses, new jobs, and an improved economy. In order to achieve this, MRDH should not only focus on the energy transition itself, but also on exploiting the economic potential of product innovations for the sustainable energy system, as well as organizing and stimulating the ecosystem (including living labs, entrepreneurship, labor and education, finance, and regulations).

Therefore, the transition path "Smart Energy Delta" aims to:

- Advance and promote the use of renewable and future proof energy sources in MRDH for urban brownfields and greenfields, industrial areas, and mobility;
- Develop a highly flexible, clean, affordable, and reliable energy infrastructure and market, as a precondition for a renewable energy region;
- Activate all parties in the triple helix and enable citizens to proactively invest, develop, deliver, deploy, and use sustainable energy;
- Develop a world-wide distinctive, exemplary, normative energy region which provides various export opportunities;
- Exploit the possibilities of innovation and investments in the energy transition for the regional business climate, ultimately leading to new energy businesses;

- Establish a highly-rewarded, living environment and create attractive location factors.

As outlined, MRDH, together with the Province Zuid-Holland and other regional and national stakeholders, should proactively facilitate the required societal transition towards an affordable and future-proof energy supply. For the longer term, the aim is a “Zero Carbon Metropolitan Region” which, in turn, means that for the coming decades, MRDH will have to focus on reaching at least energy neutrality in the built environment, zero-emission mobility, the deep decarbonization of energy intensive industry, usage of renewable energy sources, and CO₂ compensation. Although reaching zero carbon will likely not be achievable within the timeframe of the Roadmap Next Economy (2016-2035), it still should be the long-term objective influencing all choices and prioritizations regarding the energy transition in the MRDH roadmap, as it should be for the rest of the Netherlands and the European Union.

The Perspective for Action

Smart Energy Delta’s Leitmotiv

*In order to not only successfully finish the energy transition but the regional economic transition as well...we need to move **faster, further, smarter, and cheaper!***

According to the 2013 “Energieakkoord,” the Netherlands needs to generate 16% of its electricity from renewable energy sources by 2023. Currently, MRDH produces only 4% of its energy from renewables. For the period following the “Energieakkoord”, the Dutch government is bound by the agreement to reduce CO₂ emissions by 40% by 2030, and by 80-95% in 2050. More than €3 billion are invested annually in the Dutch energy infrastructure and it is expected to grow considerably in the coming two decades. The regional system operators expect between €20-70 billion additional investments in the regional grids until 2050, depending on the choices made by the region.⁵⁵

The Zuid-Holland Province has also set targets for the energy transition (e.g., 1.5% annual energy savings, 100 PJ savings in 2020; sustainable energy production of 16% in 2023). It is clear that MRDH at least has to comply with these targets. The annual CO₂ emissions in Rotterdam

⁵⁵ Netbeheer Nederland – Net voor de toekomst, ontwikkelingen tot 2050

are 30.4 Mton (2014); 90% of these emissions are a result of industry and energy production in the Port. Rotterdam's contribution to CO₂-emissions in the Netherlands increased from 16% to 19% in just 10 years. Comparing the CO₂-emissions in Rotterdam to the EU goals for reduction of greenhouse gas emissions, it is clear there is a considerable gap between current and predicted emissions and the reduction norms.

In the built environment, for instance, the potential for energy savings is considerable. Nevertheless, the amount of net-zero energy buildings delivered to date is only a few hundred, where it should be several tens of thousands per year (or more). Renovation of existing housing stock is proceeding too slowly, due to uncertainties with respect to the return on investment.

In order to not only successfully finish the energy transition, but also the regional economic transition, MRDH will need to move **faster, further, smarter, and cheaper!**

Faster... as a first mover to gain a competitive advantage compared to other regions. This will allow MRDH to achieve regional (next) economic development, export potential, and the launch of customership and scale for settlement of companies who want to grow and be innovative in this field. The window of opportunity for scaling new energy products and services in a developing market that is marking up quickly, is relatively short.

Further... by going beyond the European or national consensus of energy and climate objectives. This will not only distinguish MRDH from its competing regions in the international arena, but will also continuously challenge companies and knowledge institutions to develop and introduce better products that distinguish themselves in a world market.

Smarter... by stimulating the development and use of innovative smart technologies and the Internet of Things, for the entire energy supply chain. This will also align current and future planned investments in infrastructure, urban regeneration, mobility, and industry. Facilitating living labs and campuses that bring together interdisciplinary experts to develop, deploy, and test - in actual living environments - new technologies and strategies for design and implementation, that respond to this continuously changing world.

Cheaper... by lowering the costs for energy-related technologies, products, and services for the energy transition, which are often still perceived as too costly. Financial and fiscal arrangements can be used to stimulate market adoption. However, the phenomenon of lower prices through economies of scale for energy products and technologies will be important for the energy transition. For instance, investing in renovating residential real estate targeting

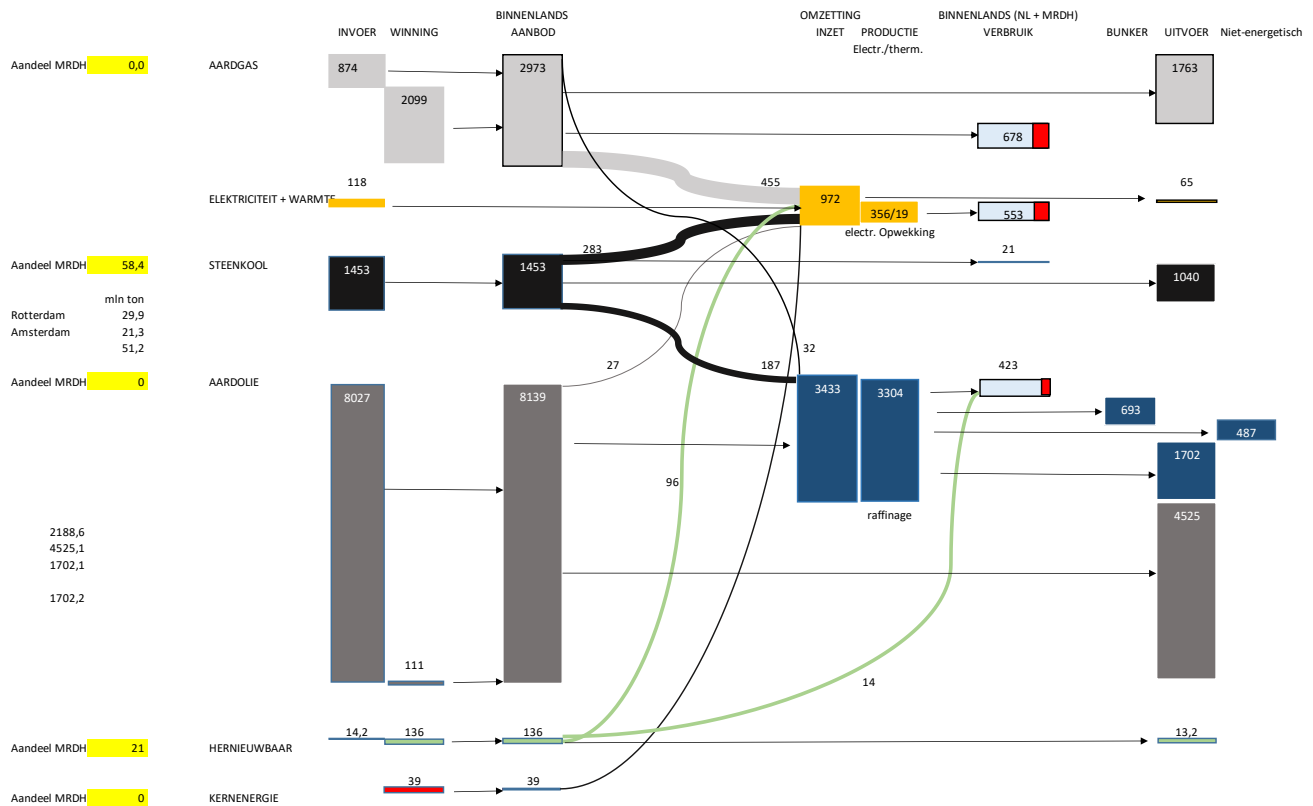
200,000 or more near-zero, net energy households, will contribute significantly to lowering costs for homeowners. This will lead to an intrinsic and more rapid adoption rate by individuals willing to invest in sustainability, without waiting on additional incentives and financing mechanisms.

Energy Flows

In order to scope the Smart Energy Delta for the MRDH Roadmap Next Economy, energy flows into and out of the region must be fully explored and quantified. Figures 4 and 5 outline these flows in petajoules equivalents for the Netherlands and for MRDH, respectively. In terms of total energy volumetric flows, the import and export (including domestic supply) of natural gas, crude oil, and oil products fill the energy streams (vertical flows). With the Port of Rotterdam in MRDH, these diagrams can also be used as a basis for scoping maritime energy initiatives.

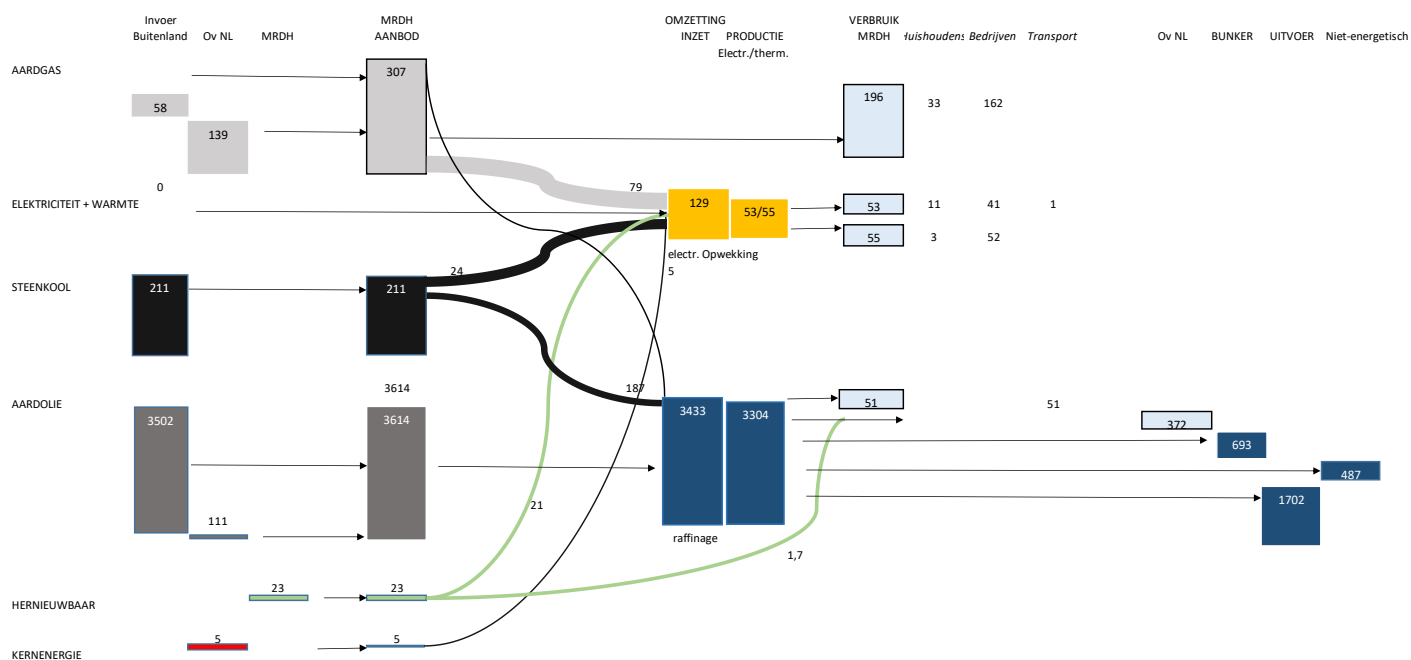
Figure 6 also illustrates that more than 80% of the supply of domestic energy resources, however, are exported. This export business is human intensive and the income from this import/export business is believed to only marginally contribute to overall regional consumption and services. Therefore, the TIR focus is primarily on the right side of this diagram, covering energy uses and horizontal flows in particular, including refineries.

Figure 4: Sankey Diagram for the Netherlands⁵⁶



⁵⁶ Netherlands Economic Observatory.

Figure 5: Sankey Diagram for the MRDH⁵⁷



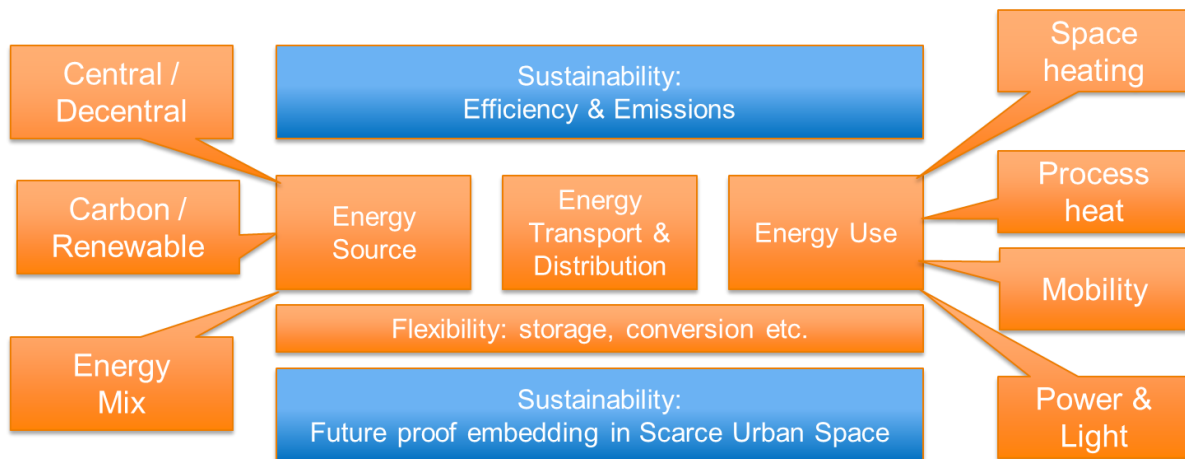
⁵⁷ Ibid.

Energy Supply Chain

The next step in scoping the Smart Energy Delta is to agree upon a common language and terminology in order to assess the energy supply chain and how it is affected by geopolitical, societal, and technological developments and interventions.

The MRDH energy supply chain, as illustrated in Figure 6, consists of all energy sources, transport, distribution, and use. The energy sources can be centralized or distributed, carbon-based or renewables, along with a varied energy mix. Energy uses include space heating, process heat, mobility, and power and light.

Figure 6: MRDH Regional Energy Supply Chain



Revisiting the energy supply chain, four key components can be distinguished:

- The energy sources: central or distributed generated energy, renewable or carbon based and the mixture of different energy sources (e.g., CHP, co-firing biomass) and modalities (e.g., electricity, heat, gas). Transport and distribution of energy, comprising the (long haul) transport of energy in order to efficiently mitigate the physical distance between where the energy is (centrally) created, and locations where it is finally used, and the local and regional (re)distribution of energy in modalities that are fit for final usage.

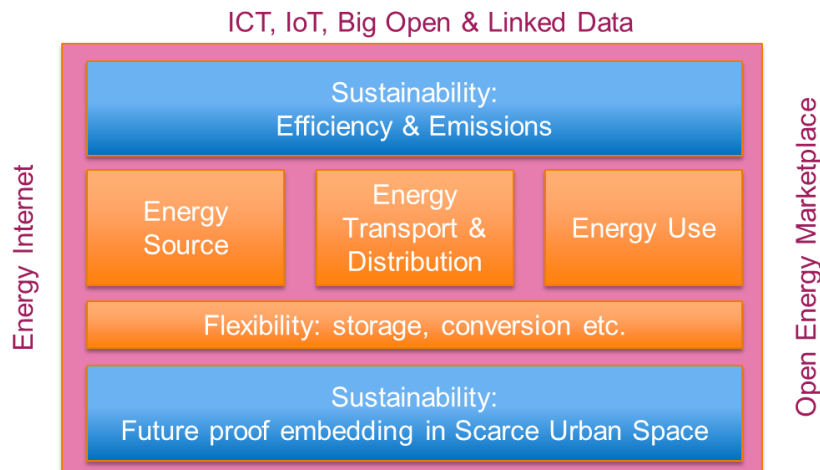
- The energy usage functions: low temperature space heating, high temperature process heating, mobility, and power and Light. With respect to the dominant role of ICT in the Next Economy, one could state that there is even a fifth energy function “ICT & Data” relating to the energy intensity of datacenters and the need for cooling. For now, we have included this in the Power & Light function.
- The energy transition increases the importance of flexibility in the energy chain. Flexibility can be obtained and developed at various points within the energy chain. It consists of various concepts like storage and conversion, demand response, flexible energy sources, system integration and import of energy. With respect to storage, we differentiate between short-term (intraday) storage and long-term (seasonal) storage. Conversion of renewable energy is often required for long-term, seasonal storage.

Sustainability will affect all of the four components of the energy chain. Not only in terms of achieving energy efficiency and reduction of unwanted emissions, but also in terms of safeguarding future-proof solutions, avoiding disinvestments and risks of over- or under dimensioning infrastructure. Furthermore, sustainable energy options come with different spatial requirements than the current energy infrastructure. In MRDH, Urban Space is scarce (literally), but also from a landscaping, livability and safety point of view, we need to carefully embed these options in the environment.

The traditional sequence of the energy supply chain is from left to right: from energy source to energy usage. The organization and composition of the energy chain is predominantly derived from the type of energy sources (centrally) available. This will change dramatically. It is not the source but the energy usage that will be the dominant factor for the organization and composition. In fact, the chain will be mainly bi-directional. Some consumers will be producers as well (think of decentral PV), and storage and conversion nodes will be introduced at central energy generation, in the distribution network, and at the locations where energy will be used. Energy management systems will steer the use of these storage and conversion nodes and will also influence the direction of energy flows in the system.

Another important aspect is the introduction of Digital ICT in every part of the energy supply chain, as shown in figure 7. Making it smarter in terms of how the underlying infrastructure is used on a daily and real-time basis (think of demand-response systems, distributed energy management etc.) will be essential. In more strategic terms, as its usage develops over time, decisions will have to be made where to invest and with what kind of functionality, etc. Digital

ICT will also enable new kinds of business models and digitally enabled marketplaces.



Smart Grid, Demand-Response, Virtual Power Plants, Distributed Energy Management

Figure 7: MRDH Regional Energy Supply Chain

The energy transition will require substantial investments and goes along with numerous other changes in the economy and the built environment. The obligation to save energy will affect how houses, offices, and utility buildings are built and renovated, and how we – assisted by ICT – will use energy-consuming devices. Distributed energy generation has to be integrated in the energy system as well as into building construction and building components.

Electrification of transport requires a new infrastructure as well. Natural gas for heating buildings will be gradually replaced by other sources of heat, such as (green) electricity, ambient heat, geothermal energy, industrial waste heat, and biogas. Local characteristics will determine the options for renewable energy and, therefore, the components of the local energy system. In MRDH, the presence of different geographical and functional areas leads to five different districts: urban brownfield and urban greenfield, the harbor industrial cluster, food and flowers, and mobility. It is a fact that not every city or district within MRDH will be able to fulfil its own energy demand. Some locations, like the old city centers or the large industrial complexes, have only limited possibilities or require too much energy. Hence, some districts will become energy producers while other districts will use more energy than they produce. A regional energy balance will guide these choices, leading to a mix of central and

distributed energy supplies.

Looking at the transition from the perspective of the four energy functions, it is reasonable to conclude that they will not transit at the same time, in the same way, nor at the same pace. The same transition structure could be followed, as found in the Raad voor de Leefomgeving (RLI) report “Rijk zonder CO₂”, but faster and further by capitalizing on the regional momentum and innovative sustainable energy products and services which MRDH has already offered to 300,000 households.

The RLI distinguishes two periods: before 2035 (including Energieakkoord and EU goals) and 2035-2050. Both periods are dependent, because infrastructure investments in the shorter term need to contribute to the goals in the longer term. Lester & Hart⁵⁸ distinguish three waves of innovation as follows:

1. Saving Energy, improving energy efficiency, and improving possibilities and reducing costs for use of sustainable technologies;
2. Implementation of existing technologies and incremental improvement of the efficiency of these technologies;
3. Implementation (long-term) of radically new technologies, for which development time may be relatively longer, thus requiring earlier commencement in the development cycle.

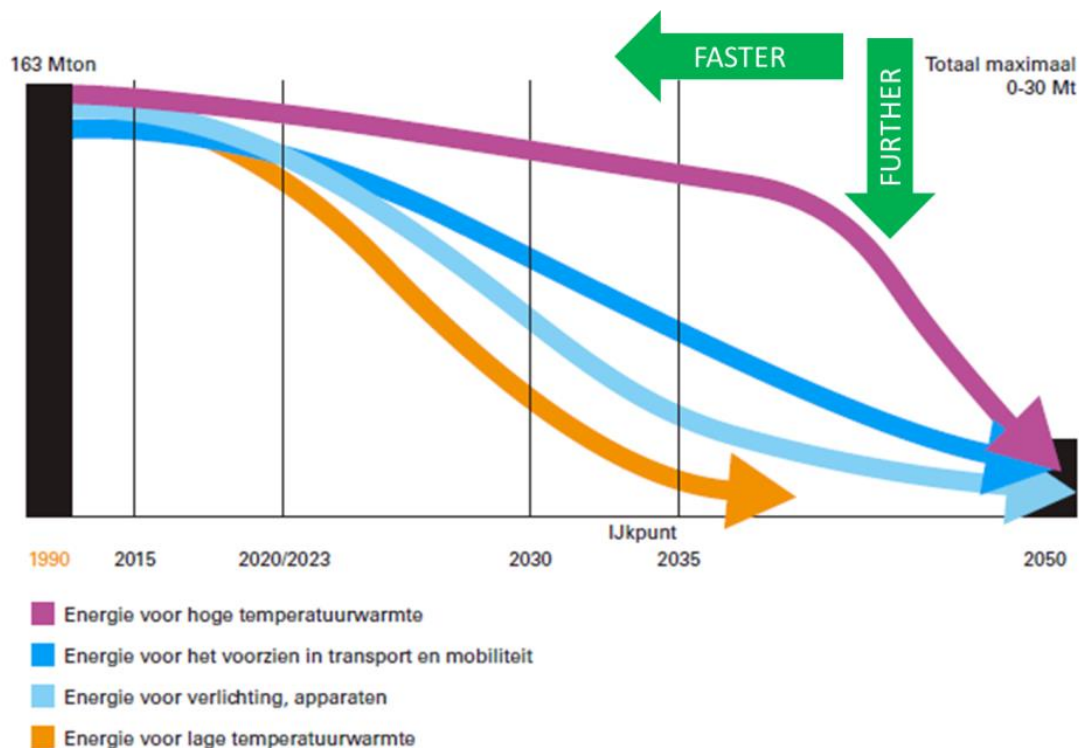
Given the previous context, a coarse structure can be developed that identifies the outlines of how the transition, per energy function in time, might develop. In every period, innovation will play an important role, but it may not be as radical for every energy function. For instance, for low temperature heating, the challenge will primarily be in social innovation, innovations in processes and financial arrangements, and learning by doing. For high temperature heat, on the other hand, there is still a need for some fundamental technical innovations. Moreover, there are also some sequential prerequisites. Delivering heat to homes necessitates infrastructure that can deliver the heat at required quality levels.

The diagram in figure 8 outlines the energy transition in terms of CO₂ reduction per energy function. For low temperature heat, progress will need to occur at a faster pace. For the

⁵⁸ Lester, R.K., & Hart, D.M. (2012) *Unlocking Energy Innovation: How America Can Build a Low-Cost, Low Carbon Energy System*. Cambridge, MA.: MIT Press.

transition of high temperature heat, progress must still be made after 2035, while the required technology must be further developed. For each of the functions, the goals and the speed will differ.

Figure 8: MRDH Energy Transition



Energy Transition – Economic Impacts

The Dutch labor market related to energy is relatively small (0.7% of total economic activity in the Netherlands, CBS 2012), however, it is highly capital intensive. The labor productivity is, at €550,000 per FTE, seven times higher than the national average. However, this is only the case for labor regarding conventional activities and energy-related activities (e.g., energy trade). A considerable portion of these activities take place in MRDH, especially in the Port of Rotterdam.

Employment regarding renewable energy is already higher than conventional activities and lower than related activities, but the labor productivity regarding renewable energy is only

€84,000 per FTE (CBS 2012). Because of the variations in capital intensity of conventional activities (high) and sustainable energy (average), the energy transition seems to have more of a financial rather than employment character within MRDH. The shift from fossil-fuel energy to increased use of sustainable energy will imply job losses on the fossil-fuel side within MRDH, if the Port isn't able to make a major shift to bio-based or manufacturing industries. The aim of the Smart Energy Delta transition pathway is not only to recover job losses, but to also create more renewable energy jobs within the region.

Key players from MRDH are already facilitating the construction of offshore wind parks around the world. There is a strong diverse cluster with many players, including not only maritime companies (e.g., offshore, engineering), but also advanced business services, specialized insurance, and financing of offshore wind parks. By 2030, MRDH will also be highly specialized in engineering and construction of clean ships, including the development of fully-electrified vessels and related infrastructure.

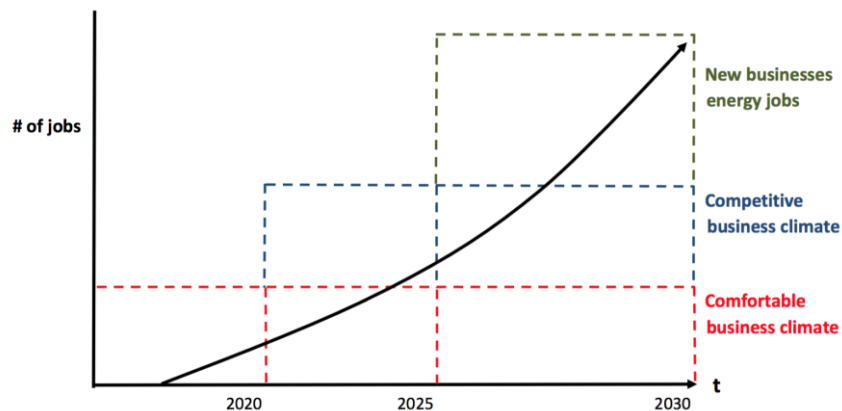
The National Energy Survey forecasts that the energy-related labor market in the Netherlands will increase from 153,000 FTEs in 2013 to 170,000 FTEs by 2020, and that employment in the renewable energy and energy efficiency sectors will increase by 80,000 FTEs. The question remains to what extent those jobs are only created by the transition (direct effect) or have a more permanent character through impacts on other markets and investments (indirect), and additional effects of these investments (reverse effects).

The direct effects of the Smart Energy Delta include jobs in installation (e.g., ICT, smart appliances, heat pumps, solar panels), infrastructure (energy grids, smart charging), and energy efficiency (Net Zero buildings/districts). A recent Facton study estimated that through the so-called "The Hague approach" for districts with a high share of social housing, approximately 800 structural jobs will be created for energy efficient renovations alone. Reverse effects are mostly related to maintenance jobs regarding energy infrastructure and energy efficiency hardware.

Indirect effects include jobs in new energy management, services, and ICT technologies (e.g., apps, algorithms). Jobs can be created by new businesses around the development and supply of energy technology components related to energy infrastructure (e.g., storage, conversion, and systems integration), mobility (EV), and home engines of Net Zero Energy houses. The *faster, further, smarter, and cheaper* approach will create "customership" and scale for companies who want to grow and be innovative in this field. Finally, energy efficiency can become part of an attractive living environment and thus help to create a competitive business

climate. Figure 9 illustrates the expected trends.

Figure 9: MRDH Energy Transition



Education levels in the energy field will increase due to the growing complexity of the system and the digitalization of the sector. The minimum level will be Management Buyout+ jobs. Leveraged Buyout jobs in this sector will be more difficult to create in the future and are most likely to be found in the industry that assembles supporting infrastructures (e.g., mounting and suspension constructions).

To enable the transition towards net zero energy, educational institutions should focus on the following areas:

- Integrated energy education by creating mid-level (MBO+) education across the current apparent silos of energy infrastructure, installation and construction, ICT, and innovation;
- Closely connect education and labor markets through the development of short, intensive, and flexible courses for both practical implementation of renewable energy strategies in brownfields and greenfields, and evidence-based learning of pilots and technologies;
- Stimulate good entrepreneurship by organizing master classes, InterVision sessions, and serious gaming for (would be) engineers;

- Develop permanent Smart Energy Delta education routes based on cooperative principles, with a focus on business, manufacturing, and ICT skills;
- Create (physically and virtually) experimentation, demonstration, and training campuses for the sustainable built environment, close to or integrated with education and research facilities (e.g., RDM Concept House Village Green Village, Zadkine/ZH Infra Park).

The Renewable Energy Internet

Depending upon actual energy usage scenarios and potential efficiency gains by 2050, the Netherlands is expected to have an overall energy demand of about 900 to 1000 TWh across the three sectors of electricity, heat, and mobility.⁵⁹

Assuming a similar pace of technology development found in other regions of the world (e.g., Germany, Denmark, Norway), the majority of the demand for energy will be met by the use of electricity. E-mobility and electric heating are expected to be the standard solutions. The basis for such development is the rapid build-up of renewable electricity generation capacities, in order to address rapidly growing demand.

Since wind energy is one of the least expensive sources of renewable energy today, it is assumed that it will still be a major contributor in the future. Ongoing technology improvements are expected to drive continuous cost reductions over the next several decades. Table 1 provides a forecast regarding estimated cost components for wind, both on- and offshore, in 2050.

⁵⁹ Exploration of pathways towards a clean economy by 2050, PBL Netherlands Environmental Assessment Agency, The Hague, 2011.

Table 1: Projected Ranges of the Levelized Costs of Energy (LCOE) for Wind in 2050⁶⁰

LCOE Components	Onshore		Offshore	
CAPEX in €/MWh	22.2	49.7	28.4	88.9
Fixed OPEX in €/MWh	2.0	4.0	4.0	6.0
Variable OPEX in €/MWh	10.0	15.0	10.0	20.0
Lease in €/MWh	5.0	9.0	0.0	0.0
Total LCOE in €/MWh	39.2	77.7	42.4	114.9

Currently, the wind market is differentiated between the much larger and more mature onshore market, and the younger and less competitive offshore market. Both markets require specific technologies. On the onshore side, the priority is the further levelized cost of electricity (LCOE) reductions that would enable exploitation of less windy sites closer to consumption centers (e.g., U.S. East Coast, Southeast China). This translates into 2-3 MW turbines with extremely large rotors, up to 140 meters in diameter, to harvest the energy of even very low wind patterns.

The offshore wind energy market is developing as a completely independent industry, using technological approaches adapted from onshore wind, from the marine industry, and from the oil and natural gas industries. The resulting technologies are still in an early phase of maturity, but have the potential for significant cost optimization.

For densely populated countries with long coastlines and shallow waters, offshore wind is the perfect solution for satisfying growing energy demand with large volumes of less costly and cleaner energy supplies. More specifically for the Netherlands, approximately 60% of the total energy demand can be met by offshore wind energy, requiring a total of about 9,000 turbines of 10 MW rating each.⁶¹

Assuming a linear capacity build-up, 260 wind turbines have to be erected annually until 2050, in order to reach this target. Reaching this scale of wind capacity seems quite daunting, but it is within the current capacity of one single original equipment manufacturer (OEM) supplier and within the realm of today's technological capabilities. Offshore wind energy costs will further decrease over the next several years, most likely reaching €5 cents/kWh, as the waters along

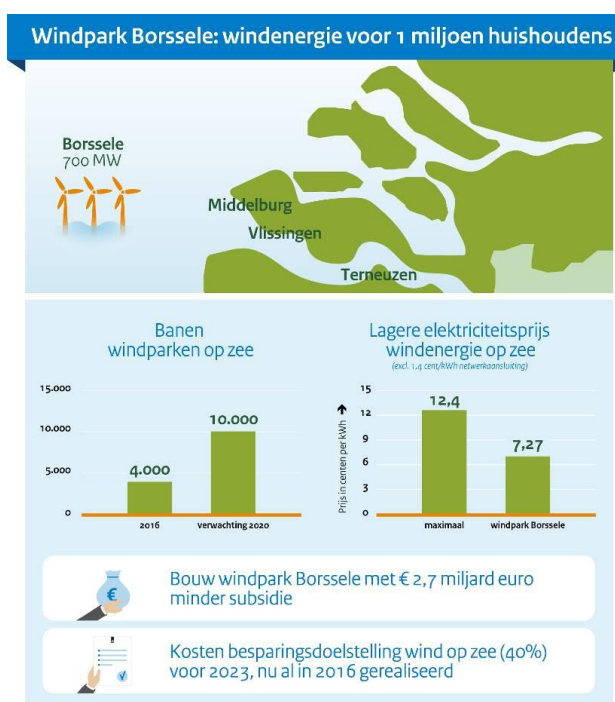
⁶⁰ Windkraftanlagen, Technologiesteckbrief zur Analyse „Flexibilitätskonzepte für die Stromversorgung 2050“, Andreas Reuter | Peter Elsner (Hrsg.), acatech 2016.

⁶¹ Based on the data from MRDH Transition Pathway document p. 54

the Dutch coastline are relatively shallow and projects are not far from the energy consumption centers of MRDH.

As shown in Figure 10, the results of the last tendering process for the Borssele offshore wind farm (where DONG was the successful supplier with a €7 cents/kWh project), demonstrate clearly how far costs can be reduced for scalable project sizes.

Figure 10: Borssele Offshore Wind Farm Tender Results⁶²

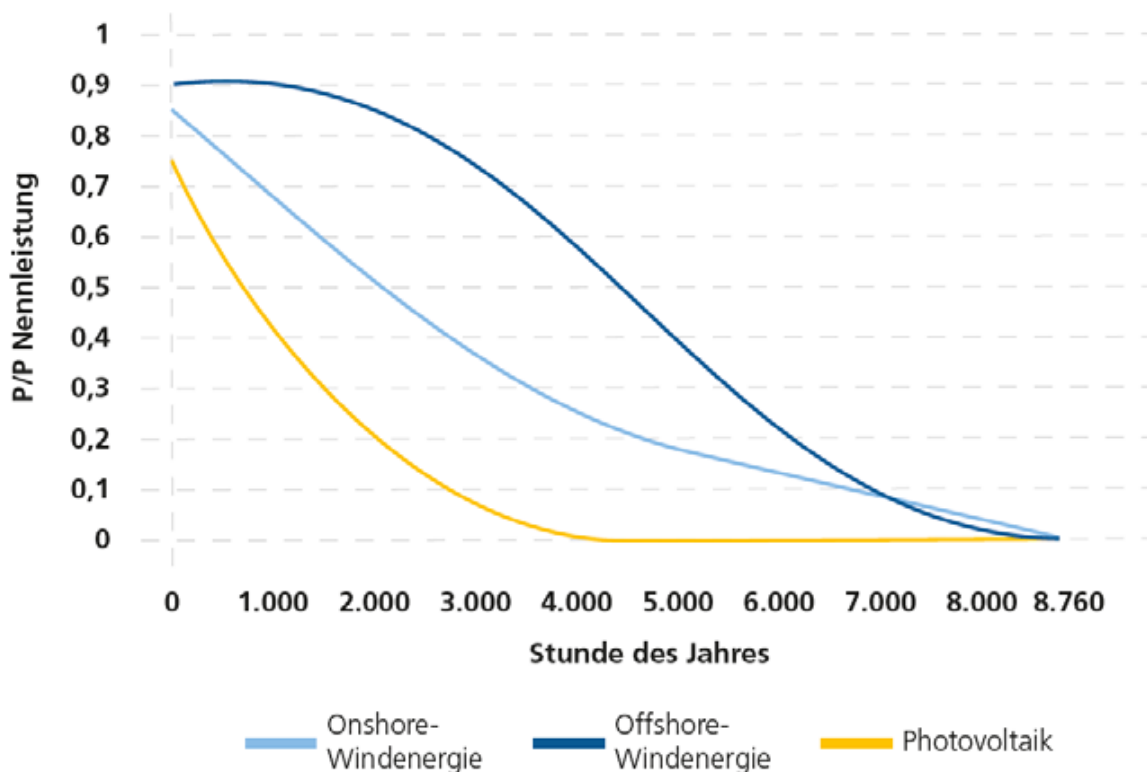


Although geographically close, offshore wind is by nature a more centralized source of electric power generation. By 2050, it is realistic to assume that most of the offshore wind farms in the North Sea will be interconnected by a super power grid, enabling nearly unlimited amounts of cheap wind energy to supplement near-shore wind that will be generated along the Dutch coast.

⁶² Ministerie van Economische Zake, juli 2016

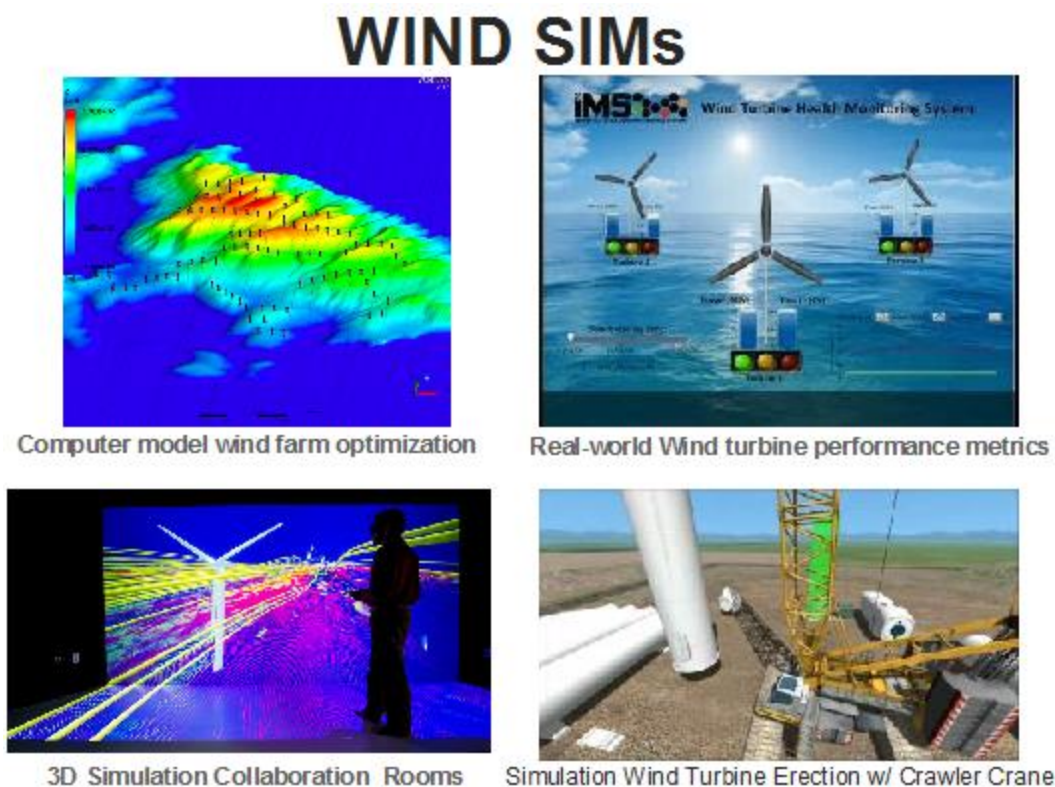
Additionally, offshore wind is a renewable energy source with a high capacity factor, based on the total number of full load electric production hours, as shown in figure 11. This means that when intermittent renewable energy sources are at low capacity, which is often the case for solar and onshore wind power production, offshore wind can still deliver nearly full capacities of electricity supply. Furthermore, advanced designs, standards, and wind simulation models are improving the capacity factors for new projects, as illustrated in figure 12. Therefore, in addition to its lower relative production cost, offshore wind can provide a net positive impact on the broader energy system, partially offsetting the need for energy storage.

Figure 11: Capacity Factors of Solar, Onshore Wind, and Offshore Wind⁶³



⁶³ Windkraftanlagen, Technologiesteckbrief zur Analyse „Flexibilitätskonzepte für die Stromversorgung 2050“, Andreas Reuter | Peter Elsner (Hrsg.), acatech 2016.

Figure 12: Advanced Wind Farm Simulation Models



Another major advantage of offshore wind is its broad public acceptance. As offshore wind farms are developed far enough in the sea, they are less visible from the shore. The result is described in the following statement from Copenhagen regarding the construction of wind farms off the coast of the capital: *"Public resistance against wind turbines in the landscape is, and has been, one of the largest barriers to the development of wind power - and thus to the development of an environmentally friendly and sustainable energy supply. This counts both for Denmark and other countries. [Still,] at the moment, there is wide support for wind energy in Denmark."*⁶⁴ The experience in Germany also shows that although people are often initially skeptical about offshore projects in the planning phase, they generally become supporters once

⁶⁴ Copenhagen: cities can run on wind energy, Middelgrunden projektinformation.

the projects are developed.⁶⁵ The ABS-classed Seajacks Scylla is the world's largest and most advanced wind farm installation and offshore construction vessel, as shown in figure 13.

MRDH represents about 20%, or 200 TWh, of the Netherlands' total energy demand. Assuming an investment of approximately €3000/kW for offshore wind, MRDH would benefit from an annual wind energy investment level of about €1.5 billion.

Figure 13: ABS-classed Seajacks Scylla (courtesy of Seajacks UK Ltd.)



The erection of a renewable Energy Internet enabling individuals, families, and businesses to generate green energies on-site for use or sale back to the power grid raises a series of critical policy issues. For example, how open should this market be? How do we redefine the relationship between power companies and the public when thousands of families and

⁶⁵ Akzeptanz der Offshore-Windenergienutzung, Abschlussbericht
Prof. Dr. Gundula Hübner, Dr. Johannes Pohl, AG Gesundheits- und Umweltpsychologie Institut für Psychologie
Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), 2014.

businesses take on the role of prosumers and generate renewable electricity on-site for delivery back to the power grid? What new policies and rules are needed to oversee the new relationship between electricity utilities and the public? How do we keep energy affordable for citizens and businesses during the transition from a Second Industrial Revolution to a Third Industrial Revolution energy regime? How will the energy revolution affect consumer behavior? How can the government and industry provide useful information to assist families and businesses in altering their energy practices to accommodate the energy revolution? What government and industry incentives need to be implemented to encourage early adoption and the build out and scale up of the Energy Internet?

The transition to a green energy regime offers enormous opportunities for the introduction of new business models that can strengthen innovation and competitiveness across the economic sectors. The government can play a key role as a launch customer by helping to scale the erection of an Energy Internet across the Metropolitan Region of Rotterdam and The Hague. To facilitate the speedy build out of the Energy Internet, attention will need to be paid to establishing a business friendly Smart Energy Delta, particularly with respect to policy, laws and regulations, and fiscal incentives that can encourage new business models and practices to spur market opportunities.

A zero-carbon region runs entirely on renewable energy and has no carbon footprint.

MRDH is still far away from reaching a Zero Carbon state. Using clean, renewable and locally generated energy will make the region less dependent on foreign energy supplies while providing a clean living environment. Large-scale applied innovations and new services and products create new businesses and new jobs, all of which rejuvenate the economy. In order to achieve this end, MRDH should not only focus on the energy transition, but also on harnessing the economic potential of product innovations for the sustainable energy system.

Therefore, the transition path “Smart Energy Delta” advances the following objectives:

- Promoting the use of renewable and future proof energy sources in MRDH
- Developing a highly flexible, clean, affordable, and reliable energy infrastructure
- Establishing Adequate Spatial Integration of renewable energy sources and infrastructure in the MRDH landscape
- Participating in international agreements with respect to energy savings, the generation of renewable energy sources and CO₂-reduction

- Activating citizens and businesses in the triple helix to proactively invest, develop, deliver, deploy and use sustainable energy.

As outlined above, MRDH together with the Province Zuid-Holland and other regional and national stakeholders will proactively facilitate the required societal transition towards an affordable and future-proof green energy initiative. In the longer term, the MRDH goal is a “Zero Carbon Metropolitan Region” which, in turn, means focusing in the coming decades on reaching energy neutrality in the built environment, zero-emission mobility, the deep-decarbonization of energy intensive industry, and the usage of renewable Energy Sources.

What needs to be done to achieve the Smart Energy Delta ambitions for MRDH? There are a number of steps that should be pursued, including:

- In Urban green fields districts, government should require zero emission districts by setting ambitious regional building codes;
- In Urban brownfield districts, actions need to be taken in parallel. Districts where gas infrastructure needs to be renewed, all options for energy efficiency (including renovation or rebuilding) and usages of commodities will have to be taken into account in the decision making process, together with the stakeholders. New building codes and standards for renovation projects need to be created to establish high performance for renovated buildings;
- Energy infrastructure managers need to build a Smart Multi-Commodity Energy Grid. This can connect the different energy district grids that will arise locally in order to make use of the flexibility of the various commodities and to optimize investments, instead of creating various parallel operating commodity grids. This will be done by starting in those nodal points of existing and transformed districts, and connect them where possible;
- Research and development should be undertaken on integral solar panel building components, on industrialization for energy-efficient renovation, and on local energy storage facilities;
- Housing associations, infrastructure managers, and municipalities will have to collaborate and activate/stimulate citizens to engage in energy efficient behavior and investments. The role of energy cooperatives herein is important and should be further stimulated. Park managers of business parks will need to establish ESCOs to define roadmaps towards energy neutral districts and realize them;

- Facilitate the supply side of renewable energy sources by local, regional and national government. MRDH characteristics fit very well in sustainable power supply of heat and electricity. However, current plans of national, regional and local governments for sustainable energy in the Province Zuid Holland will only result in about 6% of sustainable energy in 2020. To achieve the goal within this transition path of 20% (88PJ) in 2020, an additional 58 PJ should be planned. This energy supply will be realized by;
 - The use of collective heat sources (geothermal heat, ATES and waste heat);
 - Solar power on roofs and facades. Prosumers, energy cooperatives and housing cooperatives play an important role in housing. However, businesses, nonprofit organizations, and government agencies are also important stakeholders in realizing solar power in the built environment;
 - Wind power on sea: Although wind power is a national matter, the national government provides opportunities for the region as part of the fluctuating electricity that come ashore in this region;
 - Wind power on land: from NIMBY to PIMBY⁶⁶ by letting local communities benefit as well;
 - Tidal power, blue energy and biomass;
 - Realize energy savings by insulation and efficient energy installations and appliances;
 - Re-use and cascade heat from industry and the greenport to the built environment;
 - Smartness and flexibility by peak shaving, time dynamics and storage and conversion in order to make optimal use of the energy supply over time and prevent installed overcapacity and dependencies on fossil backup.
- Hydrogen could be the “near zero marginal cost” energy carrier. A long history of hydrogen production, distribution, and use is available in the area surrounding the Port of Rotterdam. In addition, the most extended hydrogen grid in the world is located in the Rotterdam area. An important link can be made between the energy transition in the Port, its industrial complex (HIC) and the built environment. There are several ways of making hydrogen including Power2Gas using power from sustainable or non-sustainable sources using excess energy (or “waste energy”), using biomass as a source for direct hydrogen production, and new developments including production from algae

⁶⁶ from ‘not in my backyard’ to ‘please in my backyard’

and bacteria. Hydrogen can be used as a fuel for ICEs or fuel cells, the latter being preferred due to the high efficiency. Hydrogen is an interesting buffer medium for load-levelling in smart grid systems.

- Establish adequate spatial integration of these renewable sources and infrastructure in the MRDH landscape and scarce urban spaces, and create a regional energy information system to keep track of the energy balance.
- Take the lead in applying and providing opportunities to set and develop **new standards and protocols** (e.g., regarding flexibility, smart grid appliances) and attract related organizations (e.g., USEF, ENTSOE-e, NEN).

To meet the previously outlined requirements and to account for the five identified RNE sectors (i.e., Urban and Residential areas, Greenfields and Brownfields, Food and Flowers, Mobility, Industry) and the building blocks of the energy system, MRDH should set transition targets that are summarized in table 2, using the following codes:

- Quick win projects (Q)
- Accelerator projects (A)
- Framework projects (F)

Quantified outputs have not yet been identified for all of the proposed projects, nor have a sufficient number of projects been identified for all sectors at this stage. This will be addressed in the upcoming months in preparation for the implementation of the roadmap. Designated arrows are an attempt to show how one or more projects enables or leads to a successive project.

Key RNE Sector	2025	2030	2040	2050
Overall MRDH CO₂ reduction	20% (8.6 M tons) RNE contribution: <ul style="list-style-type: none"> Urban brownfield 0.04% Mobility: 0.76% Food & Flowers: Industry: TBD Energy supply: 0.12% 	37% (15.9 M tons) RNE contribution: <ul style="list-style-type: none"> Urban brownfield: 0.48% Mobility: TBD Food and Flowers: TBD Industry: Energy Supply: TBD 	60% (25.8 M tons) RNE contribution: <ul style="list-style-type: none"> Urban brownfield 8.1% Mobility: 8.5% Flood and Flowers: 7.5% Industry: TBD Energy Supply: TBD 	100% (43 M tons) RNE contribution <ul style="list-style-type: none"> Urban brownfield 8.2% Mobility: 8.5% Flood and Flowers: 7.5% Industry: TBD Energy supply: TBD
Use of Sustainable Energy	14%	20%	40%	100%
Urban Greenfields	<ul style="list-style-type: none"> All new districts are net zero energy districts (approx. 40,000 homes) (Q) New districts will be developed as virtual power plants (F) Smart homes and appliances are implemented (A) 	<ul style="list-style-type: none"> New districts can operate as virtual power plants All home appliances are connected to smart grids Nodal smart grid connections are made 	<ul style="list-style-type: none"> All new districts produce energy (energy-plus districts) 	
Urban Brownfields	<ul style="list-style-type: none"> Heat distribution networks partly with sustainable + conventional and waste heat (Q) Three practices of net-zero energy districts have been realized (5,000 dwellings) in order to realize scale in converting 'houses in a row' (Q) 	<ul style="list-style-type: none"> Ten district heat distribution networks operate with sustainable heat and smart grid networks for brown fields Thirty Net Zero Energy districts exist with happy consumers and users 	<ul style="list-style-type: none"> 100% of MRDH residential areas are heated sustainably (biogas, electricity) 300 Net Zero Energy districts exist 	<ul style="list-style-type: none"> All brownfields are CO₂ neutral

Key RNE Sector	2025	2030	2040	2050
	<ul style="list-style-type: none"> • 'Renovation factories' for industrialization of zero energy districts/houses (together with TKI HTSM) (A) 			
Food and Flowers	<ul style="list-style-type: none"> • CO₂ infrastructure with multiple sources (towards greenhouse district) (Q) • Smart Energy Greenport: Local Smart Energy System - Greenport (exchange, local market, energy hub, governance) (F) 	<ul style="list-style-type: none"> • Storage and conversion for flexibility and use of cheapest energy 	<ul style="list-style-type: none"> • CO₂-neutral Greenhouses in MRDH to remain leading position • Integrated heat and solar roof panels 	
Mobility	<ul style="list-style-type: none"> • Optimal facilitation of sustainable fuel blending (Q) • 300,000 PEVs within MRDH (A) • Digital platform for Mobility-as-a-Service (Q) • All EV charging points are bi-directional and smart (A) 	<ul style="list-style-type: none"> • Urban logistics is fully electric (excl. harbor) • Public transport is 10% hydrogen • XXX? amount of vehicles are vehicle to grid ready 	<ul style="list-style-type: none"> • Standardization of vehicle to gridUrban logistics and mobility is fossil free 	<ul style="list-style-type: none"> • Urban logistics and mobility is fossil free • Rotterdam is electricity hub of Europe
Industry	<ul style="list-style-type: none"> • Max Flex through Port-City Balancing • Ten practice projects on fossil energy efficiency with an ROI of 2-5 years with a volume of TBD MWh (Q) • Industrial energy efficiency fund (A) 	<ul style="list-style-type: none"> • Maximal reuse of waste heat for urban areas • Ten practice projects on fossil energy efficiency with an ROI >5 years and with a volume of TBD MWh 		
Smart Multi-Commodity Grid (SMCG)	<ul style="list-style-type: none"> • No replacement of gas grids (Q) • Default of new 	<ul style="list-style-type: none"> • Heat networks become public asset and 	<ul style="list-style-type: none"> • All flows through energy networks are sustainable 	<ul style="list-style-type: none"> • All sustainable energy sources are included in,

Key RNE Sector	2025	2030	2040	2050
	districts: all-electric unless other situational opportunities (Q) • Standard framework for exchange of flexibility within SMCG (A)	connected to the SMCG • Storage and conversion become included in the grid (A) • New and renewed districts connected to SMCG • Provisioning of attributed energy and energy-related services to connected households (e.g., platform, data layers, apps)	• All sustainable energy sources are included in, and connected with, the SMCG and used optimally in urban areas with the lowest social cost	and connected with, the SMCG and used optimally in the entire MRDH with the lowest social cost
Intensifying Renewable Energy	• Two practices of PIMBY wind power next to regional wind parks (F) • (Sustainable) heat situationally applied • Twenty new practices of geothermal debits (3 PJ) (Q) • Off/Nearshore wind park MRDH • Percentage sustainable imports: TBD	• Solar parks and wind parks on land and sea • Sustainable electricity production by geothermal heat • Percentage sustainable imports: TBD	• Maximal use of geothermal heat (and power) • Percentage sustainable imports: TBD	• Percentage sustainable imports: TBD

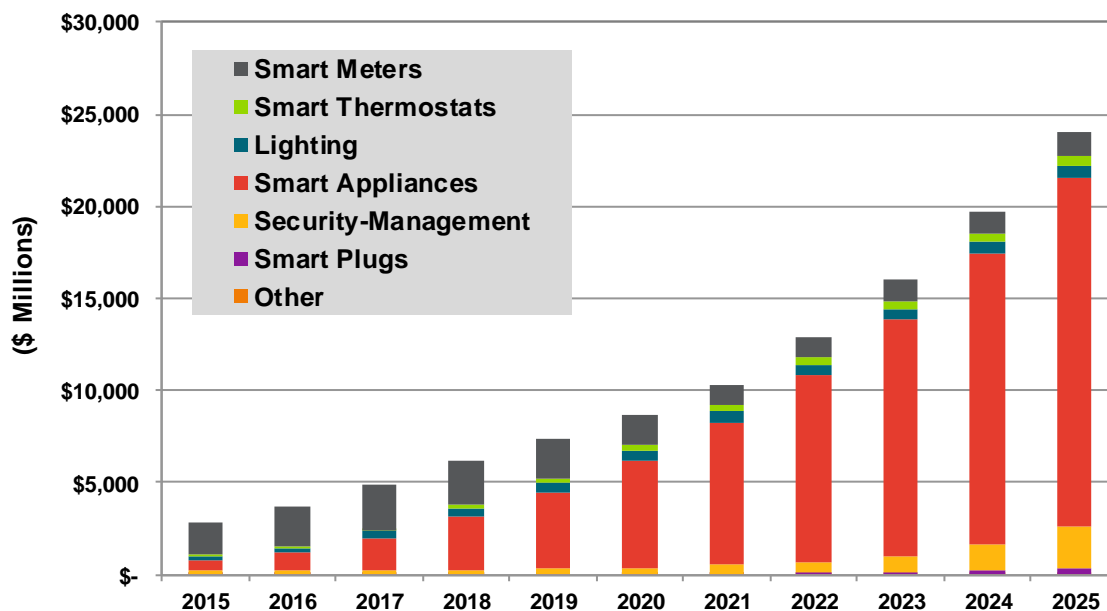
Internet of Things (IoT) and Cyber Security

The scaling of the Renewable Energy Internet will require MRDH to actively pursue and promote IoT infrastructure across the region. This will generate new business opportunities, increase productivity, create jobs, and facilitate a circular green economy. The employment of thousands of workers will stimulate purchasing power and generate new business opportunities and additional employment to serve increased consumer demand. Infrastructure investment always creates a multiplier effect that reverberates across the economy as a whole.

The market for the IoT is emerging and is being driven by a desire to enable devices to communicate and share information for the purposes of greater efficiency, automation, security, and comfort in homes and businesses. Many different companies are providing the products and services for this Third Industrial Revolution technology infrastructure, and they foresee a thriving market well into the next decade.

Leading industry research suggests that global revenue attributed to residential IoT devices will grow from \$7.3 billion in 2015 to \$67.7 billion in 2025, which represents a compound annual growth rate (CAGR) of 25%. As shown in figure 14, European IoT device revenue is anticipated to increase from \$2.9 billion in 2015 to \$24.0 billion in 2025. Shipments of smart meters, smart appliances, smart thermostats, and security and management systems are expected to be among the main revenue drivers.

Figure 14: Residential IoT Device Revenue by Type, Europe: 2015-2025⁶⁷



The establishment of the Third Industrial Revolution IoT infrastructure in MRDH prompts the need to actively engage the commercial and industrial sector with regards to innovation. The

⁶⁷ Source: Navigant Research, IoT (Internet of Things) for Residential Consumers

power and electricity transmission companies, the telecommunications industry, the construction and real estate industries, the ICT sector, the electronics industry, transportation and logistics, the manufacturing sector, the life- sciences industry, and retail trade will all need to be brought into the process. Critical digital infrastructure, value chains, and security protocols will need to be developed to form the foundation from which the Energy Internet will emerge.

Recent reports have raised the awareness of inadequate security for utility mission-critical systems. Smart grid cyber security must address not only deliberate attacks, such as those from disgruntled employees, industrial espionage, and terrorists, but also inadvertent compromises of the information infrastructure due to user errors, equipment failures, and natural disasters – especially stemming from climate change disruptions.

The Hague has already established itself as a major hub for cyber security in Europe. The city is home to the European Cybercrime Center Europol (EC3), the National Cyber Security Center, NATO Communications and Information Agency, and the Cyber Security Academy, and has attracted some of the world's top cyber security businesses, such as Fox-IT, Redsocks, and Authasas. The city also hosts The Hague Security Delta (HSD) Campus, which has grown into the Dutch security cluster's national innovation center, offering living labs, training facilities, flexible office space, and meeting rooms. Here, businesses, governments, and knowledge institutions collaborate on innovative security solutions.

To prepare for the massive build-out of IoT infrastructure, MRDH will need to educate and skill-up its workforce to ease the transition into the new business opportunities. The region already has a head start with the establishment of the HSD.

Developing Resiliency in the Roadmap Next Economy

Resiliency Challenges and Benefits

Introduction

Urban areas are important for decision-making, as they constitute financial, political, media, academic, and industrial centers. Additionally, cities serve as hubs for innovation and are important drivers for the global economy. The majority of energy is consumed in urban areas, which are expected to increase in importance in the coming decade, due to a continuing trend

of urbanization.

At the same time, city operations are increasingly reliant on critical infrastructure. In metropolitan areas, various types of infrastructure come together and are integrated in supporting the functions of the urban system. As the demand for infrastructure services grows, infrastructure disruptions will have greater negative impact on comfort, convenience, mobility, and labor productivity for the population.

As a result, the local urban area is a very relevant scale for the implementation of measures for strengthening resiliency. Managing risks and adapting to minimize the impacts of unforeseen events are central themes in making cities better prepared for disasters.

Resiliency Defined

From an urban perspective, resilience can be defined as the *“capability to prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to public safety and health, the economy, and security”*⁶⁸ of a given urban area.

Strategies to effectively prepare, respond, and recover typically contain the following elements of the “four Rs of resiliency”⁶⁹:

1. **Robustness:** *“strength, or the ability of elements, systems or other units of analysis to withstand a given level of stress, or demand without suffering degradation or loss of function.”*
2. **Redundancy:** *“the extent to which elements, systems, or other units of analysis exist that are substitutable - i.e., capable of satisfying functional requirements in the event of disruption, degradation, or loss of functionality.”*
3. **Rapidity:** *the “capacity to meet priorities and achieve goals in a timely manner in order to contain losses and avoid future disruption.”*
4. **Resourcefulness:** *“the capacity to identify problems, establish priorities, and mobilize resources when conditions exist that threaten to disrupt some element, system, or other*

⁶⁸ Thomas J. Wilbanks, ‘The Research Component of the Community and Regional Resilience Initiative (CARRI)’, Presentation at the Natural Hazards Center, (University of Colorado-Boulder, 2007).

⁶⁹ Michel Bruneau et al., ‘A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities’, *Earthquake Spectra* 19, no. 4 (2003): 733–752.

unit of analysis; resourcefulness can be further conceptualized as consisting of the ability to apply material (i.e., monetary, physical, technological, and informational) and human resources to meet established priorities and achieve goals.”

In summary, resiliency refers to “reducing failure probabilities, reducing consequences from failures and reducing time to recovery.”⁷⁰

While resilience is frequently considered in the context of a sudden occurrence, such as an earthquake or a cyber-attack, it is increasingly relevant in relation to climate change and related extreme weather events. Extreme weather events are weather conditions that differ substantially from more common weather conditions and, consequently, might not have been taken into account when designing a city, its infrastructure, and its buildings. Given that infrastructure is a prerequisite for a well-functioning city, MRDH should prioritize critical infrastructure.

Climate change

The intensity and frequency of extreme weather events have significantly increased on a global scale, partially due to human-induced climate change. While the role of natural variability is still a major factor in forming extreme weather conditions, it is undeniable that climate change has shifted the odds and changed the natural limits. As a result, relatively small shifts in the average of a distribution of climate variables can cause substantial changes in extreme weather.⁷¹

Each rise in temperature of 1°C results in a 7 percent increase in the moisture-holding capacity of the atmosphere. This causes a radical change in the way water is distributed, with more intense precipitation but a reduction in duration and frequency. The consequences are already being felt in eco-systems around the world. We are experiencing more bitter winter snows, more dramatic spring storms and floods, more prolonged summer droughts, more wildfires, more intense hurricanes (category 3, 4, and 5), a melting of the ice caps on the great mountain ranges, and a rise in sea levels.

⁷⁰ Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M. [...] & von Winterfeldt, D. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra*, 19(4), 733-752.

⁷¹ Hunter Cutting, Sandra Chung, and Susan Hassol, 'Current Extreme Weather and Climate Change' (Climate Communication, 2011), <https://www.climatecommunication.org/wp-content/uploads/2011/09/Extreme-Weather-and-Climate-Change.pdf>.

The Netherlands, with a considerable part of the country below sea level and some major rivers running through it, is particularly vulnerable to shifts in the water cycle brought on by climate change. Rotterdam and The Hague, lying mainly below sea level (up to -6m), are well aware of the urgency to prepare for and adapt to climate change. Not surprisingly, Rotterdam already has a Chief Resiliency Officer and seeks to be fully climate resilient by 2025.

Rotterdam is chairing the 'Rijnmond Drechtsteden' program, a sub-program of the National Delta Program. Rotterdam is also a member of the Rockefeller Foundation 100 Resilient Cities initiative, and has established the Connecting Delta Cities (CDC).

For MRDH, higher sea and river levels will mean an increased risk of flooding, while more intensive rainfall will result in implications for the drainage system and higher risk of disruptions and flood damage. Longer, hotter periods will especially affect urban districts and impact the health and well-being of the inhabitants, while the likelihood of damage to flora and fauna will rise. Longer periods of drought can result in lower water tables, affect the water quality, increase the likelihood of damage to built-up areas, flora and fauna, and obstruct shipping activities.

Climate change mitigation and adaptation

There are two main approaches to address climate change: mitigation and adaptation. Mitigation is an intervention *"to reduce the impact of human activity on the climate system, primarily through reducing net greenhouse gas emissions"* or enhancing the sinks of greenhouse gases.⁷² Adaptation can be defined as *"the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities"*⁷³ and involves measures to manage the impact of extreme weather and reduce vulnerability. *"Measures include improvements such as strengthening and hardening infrastructure"* against storms, floods, and other events *"or controlled shut-down procedures, awareness campaigns, and disaster relief and emergency response programs."*⁷⁴

⁷² DEFRA, Adapting to climate change – UK Climate Projections, June 2009.

⁷³ IPCC, 'Glossary of terms'. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, (Cambridge, UK, and New York, NY, USA, 2012): 555-564.

⁷⁴ <http://www.petroleum-economist.com/articles/events/wec-istanbul-2016/2016/energy-gets-smarter>

While the focus to date has been primarily on mitigation measures, both mitigation and adaptation are relevant. Climate change mitigation remains important to limit future greenhouse gas emissions and consequential global warming while, at the same time, adaptation is needed to prepare for the consequences of climate change.

Mitigation and adaptation have been flagged in The Paris Agreement (2015) as critical initiatives in the goal of reducing global warming. The Paris Agreement is an agreement within the framework of the United Nations Framework Convention on Climate Change (UNFCCC), negotiated with representatives of 195 countries and adopted by consensus on December 12, 2015. The aim of the Agreement is *"(a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; (b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; (c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development."*⁷⁵

Action is urgently needed, both with respect to mitigation and adaptation. We have seen average temperatures changing. The National Oceanic and Atmospheric Administration (NOAA), a US meteorological agency, reported that heat records have been broken in each of the fourteen months leading up to June 2016. NASA registered July 2016 as the warmest month ever measured. Compared with July months between 1950 and 1980, July 2016 was 0.84°C warmer. NASA predicts that 2016 will become the hottest year ever.⁷⁶ Climate change thus leads to changes in "average" weather conditions, which we will need to accept as the "new normal." Additionally, climate change leads to more extreme weather events. Recently, we have noticed an increase in the severity and frequency of extreme weather events globally and locally. In June 2016, three events of different types (storm, hail, and extreme rainfall) occurred in a period of about a week in different regions in the Netherlands, each of which caused millions of euros of damage.⁷⁷

The Rotterdam Climate Initiative (figure 15) addresses both mitigation and adaptation. While

⁷⁵ 'Paris Agreement - <http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf>

⁷⁶ Nos.nl, accessed 16 August 2016.

⁷⁷ 'Miljoenenschade Door Hagel in Zuid-Nederland | Binnenland | AD.nl', accessed 17 August 2016, <http://www.ad.nl/binnenland/miljoenenschade-door-hagel-in-zuid-nederland~a1afd343/>.

the City of Rotterdam is showing clear leadership in relation to adaptation, there are several critical challenges related to this topic that need special attention.

Figure 15: Rotterdam Climate Initiative Logo



First, there is insufficient awareness of climate risks and opportunities in large parts of society, including utilities and in the business community. Consequently, there is little desire to invest in understanding climate risks because of a perception that these lie too far into the future.

Secondly, resiliency of a city should build upon action undertaken by citizens, the private sector, and the public sector. However, the majority of activities to develop decision support tools such as serious games, dashboards, and computational models, has focused primarily on the public sector. The private sector, which is responsible for some of the critical infrastructure including telecommunications, food, and financial services, needs to be equally engaged in setting resiliency targets if MRDH is to reach its goals for mitigation and adaptation.

Third, most existing climate services/decision support tools are science-oriented and do not align sufficiently to user needs and decision-making structures. Without more fit-for-purpose tools, designed with end user needs in mind, it will be difficult to engage stakeholders and embed resiliency in investment decisions and day-to-day operations.⁷⁸

Fourth, the interaction between mitigation and adaptation to this point has largely been ignored, as they are traditionally seen as two different topics.

Benefits

Costs due to extreme weather events can easily run into high numbers. For example, superstorm Sandy, which hit the US East Coast in 2012, caused an estimated USD \$65 billion in

⁷⁸ CS4B, 'Climate Services for Business', (2016).

economic losses to residents and the owners of businesses and infrastructure. **Error! Bookmark not defined.** But, in addition to reduction of costs, there are other benefits of making cities more resilient, such as opportunities for economic growth and improved quality of life for the residents, which boosts the attractiveness of the city.

Implementing resilience can also offer opportunities for improved transportation systems, energy security and flexibility, access to smarter technology, business opportunities, and green growth. It becomes clear that building a more resilient city will bring added opportunities for the citizens, assist the city in becoming a more attractive place to live and satisfy the needs of its inhabitants. In the long term, resilience investments contribute to minimizing financial losses, *"it costs 50% more to rebuild in the wake of a disaster than to build the infrastructure to withstand the shock."*⁷⁹

Infrastructure

Critical infrastructure and buildings

Urban systems are typically defined by heavily built-up environments and extensive infrastructure to meet the needs of the residents of the city. Infrastructure systems are particularly vital because they are means to social ends. The reliability of infrastructure systems and the continuity of the services they support are essential for the social and economic stability of modern cities and for the health and safety of community residents.

Climate change and extreme weather events pose risks to the provision of critical services. Most existing infrastructure and buildings have been designed based on known, historic, and relatively stable climate data, not taking into account climate change. However, with climate change now a reality and increasingly leading to changing weather patterns, design guidelines, technologies, and materials need to be updated to reflect this new reality and ensure resilience. New design criteria should be required for all new buildings and infrastructure. New safety standards for dikes have been developed, but new standards should also be developed for building design and operations, and for individual assets and infrastructure at a system level. Standards for buildings, for example, can include green roofs and facades (e.g., sponge capacity,

⁷⁹ 'How Can We Build More Resilient Cities?', World Economic Forum, accessed 17 August 2016, <https://www.weforum.org/agenda/2014/01/can-build-resilient-cities/>.

reduction of heat island effect), self-generation, and storage capacity requirements, and no key electrical equipment (e.g., no heat pump, micro CHP), or storage units at ground level. While standards can be made mandatory for all new buildings/ investments, a key challenge will be to upgrade existing assets.

Understanding Interdependencies - A multi-stakeholder approach

Resilient design and operation of infrastructure is challenging, due to the nature of infrastructure: they are complex systems consisting of a great number of components, which interact in a network structure. Furthermore, modern critical infrastructure systems can be privately owned and operated, which requires cooperation between the private and public sector to optimize resiliency. What makes the task even more challenging is that the digital Third Industrial Revolution infrastructure is increasingly coupled and interdependent in complex ways. As a consequence, failure of nodes in one network may lead to failure of dependent nodes in other networks, and vice versa, leading to a cascade of failures of infrastructure systems and related services. The total impacts of an event may be amplified by these interdependencies, eventually impacting the community and the broader economy.^{80,81}

Obtaining an understanding of the interdependencies between various critical infrastructures lies at the core of urban resilience. Measures to increase resilience should be discussed and shared among different stakeholders, as measures taken by one stakeholder can impact the effectiveness and, therefore, also the financial benefits of measures taken by other stakeholders. Addressing resilience requires a multi-stakeholder approach that can build trust among all the players, encourage sharing of data and information on risks and vulnerabilities, and foster detailed insights into interdependencies between infrastructures.

The Netherlands defines critical services (see figure 16) as *“A product or service... that provides an essential contribution to society in maintaining a defined minimum quality level of (1) national and international law & order, (2) public safety, (3) economy, (4) public health, and (5) ecological environment, or when loss or disruption impacts citizens or government*

⁸⁰ Baichao Wu, Aiping Tang, and Jie Wu, ‘Modeling Cascading Failures in Interdependent Infrastructures under Terrorist Attacks’, *Reliability Engineering & System Safety* 147 (March 2016): 1–8, doi:10.1016/j.ress.2015.10.019.

⁸¹ Frederic Petit et al., ‘Analysis of Critical Infrastructure Dependencies and Interdependencies’ (Argonne National Lab. (ANL), Argonne, IL (United States), 1 June 2015), <http://www.osti.gov/scitech/biblio/1184636>.

*administration at an international or national scale or endangers the minimum quality level.*⁸²” As previously indicated, there are (inter)dependencies between these services. For example, consider the “drinking water supply.” Pumps in many cases run on electricity, and telecommunications are needed to remotely monitor and control the drinking water system.

Figure 16: Energy-Water Nexus

An example of interdependencies - Energy-water nexus

Water and energy cannot exist without each other. Even the world’s most advanced water treatment and delivery system is rendered obsolete without the energy to run it. *“The energy–water nexus has long been recognized as a critical interdependency; water and wastewater utilities need power to operate pumps and treatment operations, while electric power facilities often depend on water for cooling equipment and processes.”*⁸³

In the case of a total electric power failure, *“both water and wastewater treatment facilities will lose operational capability if they do not have backup generation capability. Backup generators can typically reduce the impact of primary power loss to operations by 1 to 33% for periods up to 7 days without refueling”*.⁸⁴

The most innovative and energy-invested utilities are employing different (sometimes multiple) methods of on-site power production, or distributed energy resources (DER), to reduce dependency on the electric grid. Examples of DER cited by the EPA include: microturbines/wind turbines, fuel cells, photovoltaic systems (solar panels), traditional internal combustion engines, and combined heat and power (CHP) systems⁸⁵.

⁸² Eric A. M. Luijff, Helen H. Burger, and Marieke H. A. Klaver, ‘Critical (Information) Infrastructure Protection in The Netherlands.’, in ResearchGate, 2003, 9–19, https://www.researchgate.net/publication/221386927_Critical_information_Infrastructure_Protection_in_The_Netherlands.

⁸³ The Department of Homeland Security Office of Cyber and Infrastructure Analysis, ‘Sector Resilience Report: Water and Wastewater Systems’. July 2014, 1345 EDT.

⁸⁴ The Department of Homeland Security Office of Cyber and Infrastructure Analysis, ‘Sector Resilience Report: Water and Wastewater Systems’, 2014, https://www.massport.com/media/266269/Report_Sector-Resilience-Report-Water-and-Wastewater.pdf.

⁸⁵ ‘Power Resiliency Tips For Water And Wastewater Utilities’, accessed 17 August 2016, <http://www.wateronline.com/doc/power-resiliency-tips-for-water-and-wastewater-utilities-0001>.

Figure 17: The Port of Rotterdam Interdependencies

An example of interdependencies – The Port of Rotterdam

The Port of Rotterdam “is located in a delta area, near the sea and major rivers. The Rotterdam area has a multi-modal transport network connected with the port hinterland, as well as nearby urban areas and industrial complexes.”⁸⁶

Like other European ports, the Port of Rotterdam is vulnerable to extreme weather events – especially storms – that result in disruptions in the flow of logistical traffic in and out of the Port.

In addition to the port facilities, the connecting transport infrastructure (i.e., road, rail, shipping, pipelines) is equally important to ensure the continuous operation of the freight logistics of the port. Indirectly, the whole system depends on other critical infrastructure, such as power supply and telecommunications networks. If these networks fail due to extreme weather events, port operations can be disrupted due to cascading effects, one failure leading to another.⁸⁷

Understanding these vulnerabilities has resulted in steps taken towards adaptation including, the Rotterdam Climate Proof Program. “

⁸⁶ ‘Case B; Port of Rotterdam, the Netherlands - INTACT’, accessed 17 August 2016, <http://intact-project.eu/index.cfm/cases/case-b-port-of-rotterdam-the-netherlands/>.

⁸⁷ Deltares, ‘Impact of Extreme Weather on the Port of Rotterdam’, n.d., https://www.deltares.nl/app/uploads/2015/04/PB_Impact-of-Extreme-Weather-on-the-Port-of-Rotterdam.pdf.

Third Industrial Revolution Consulting Group

Table 3: Products and Services Identified as Critical for the Netherlands⁸⁸.

Sector	Product or service
Energy	<i>Electricity</i>
	<i>Natural gas</i>
	<i>Oil</i>
Telecommunications	<i>Fixed telecommunication networks services</i>
	<i>Mobile telecommunication services</i>
	<i>Radio communication and navigation</i>
	<i>Satellite communication and General Positioning System</i>
	<i>Broadcast services (radio and TV)</i>
	<i>Internet access</i>
	<i>Postal and courier services</i>
	<i>Drinking water supply</i>
Drinking water	
Food	<i>Food supply and food safety</i>
Health	<i>Health care</i>
Financial	<i>Financial services and financial infrastructure (private)</i>
	<i>Financial transfer services (government)</i>
Retaining and managing surface water	<i>Management of water quality</i>
	<i>Retaining and managing</i>
Public Order and Safety	<i>Maintaining public order</i>
	<i>Maintaining public safety</i>
Legal order	<i>Administration of justice and detention</i>
	<i>Law enforcement</i>
Public administration	<i>Diplomacy</i>
	<i>Information provision by the government</i>
	<i>Armed forces / Defense (emergency support tasks)</i>
	<i>Public administration</i>
Transport	<i>Road transport</i>
	<i>Rail transport</i>
	<i>Air transport</i>
	<i>Inland navigation</i>
	<i>Ocean shipping</i>
	<i>Pipelines</i>

⁸⁸ Luijff, Burger, and Klaver, 'Critical (Information) Infrastructure Protection in The Netherlands.'

Key role for resilient energy infrastructure

New technologies and socio-economic developments continuously increase the demand for energy, as well as the societal need for a reliable energy supply. In addition, the dependency of other infrastructure systems on the energy sector increases the importance of its reliable operation.⁸⁹ However, the expected increase in frequency and intensity of extreme weather events poses new risks. According to a National Association of Counties report, *“A severe power outage may mean that people cannot heat or cool their homes; water and wastewater treatment facilities’ electric pumps may not be able to provide potable water or treat sewage and storm runoff; traffic and rail crossing signals may not function; emergency call centers may not be able to process calls or provide communication to emergency dispatchers and first responders.”*⁹⁰

ICT services and electricity services are an integral part of everyday life. Disruptions to these systems can greatly interfere with businesses’ ability to conduct normal commerce, leading to adverse effects on local economies. Furthermore, as electricity grids become smarter, the penetration of IT automation (e.g. smart meters) adds many benefits, but each connected component also brings with it a potential risk for cyber-attacks. This makes effective cyber security critical for electricity grids, as cyber-attacks could render a grid inoperable for long periods, at considerable costs.

Finally, these two sectors, being subject to significant and continually evolving risk-shaping factors, usually trigger disruptions of other infrastructure sectors. Empirical studies have been conducted to analyze the frequency, the originating sectors, and the indirectly impacted sectors during cascading failure events. Analyses of *“a data set of 1749 critical infrastructure failures in 29 European nations, 95% of which post-dated the year 2000, showed that cascades are fairly common and propagate in clear pathways.”*⁹¹ As demonstrated in Figure 18 it is estimated that *“the energy sector accounts for 60% of all cascades, 28% originate in the telecommunications and Internet”* sectors, 5% come from the transportation sector, and 3% are found in the water

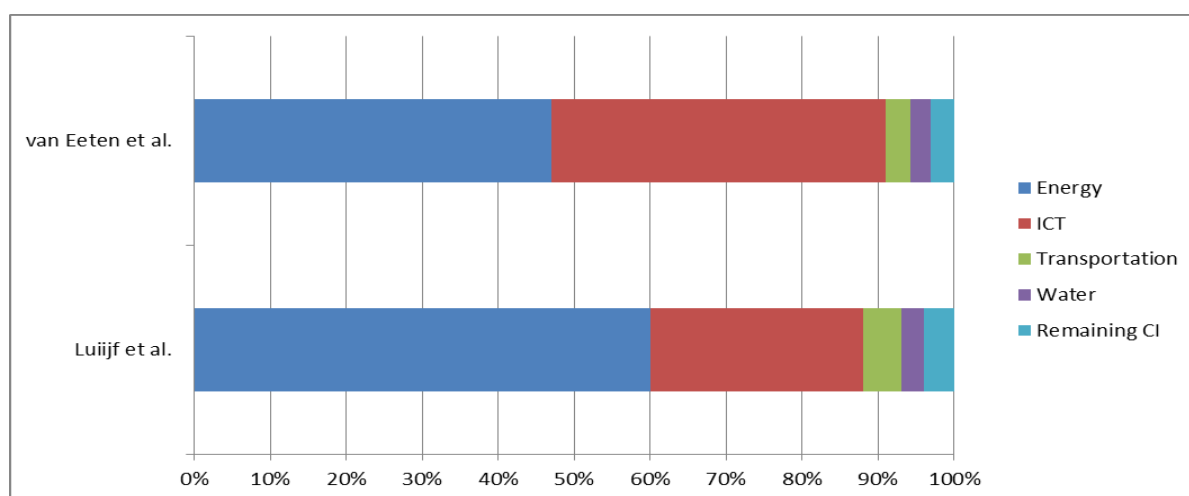
⁸⁹ Ruben Vogel et al., ‘Klimaatadaptatie En Energie-Infrastructuur: Actualisatie van de Risico’s En Kansen Door Klimaatverandering Op de Nederlandse Energie-Infrastructuur’ (The Hague: TNO, 2014).

⁹⁰ Rob Pressly, ‘Improving Lifelines: Protecting Critical Infrastructure for Resilient Counties’, Technical Report (National Association of Counties, 2014).

⁹¹ Eric Luijff et al., ‘Empirical Findings on Critical Infrastructure Dependencies in Europe’, in Critical Information Infrastructure Security, ed. Roberto Setola and Stefan Geretshuber, Lecture Notes in Computer Science 5508 (Springer Berlin Heidelberg, 2008), 302–10, http://link.springer.com/chapter/10.1007/978-3-642-03552-4_28.

sector. Similar observations were found in a second study analyzing 830 reports of incidents in the Netherlands.⁹² In this case, Figure 18 shows that “47% of all cascades originate within the energy sector, 44% within telecommunications and the Internet, 3.2% in transportation, and 2.7% in the water sector.”^{93 94} It is obvious that disruptions, especially in energy and telecommunications infrastructure, trigger disruptions in other critical infrastructure.

Figure 18: Cascading events by affected infrastructure^{95, 96}



Technology

Challenges for the electricity system

Factors that contribute to the previously mentioned double risk trend and make it harder to

⁹² Michel Van Eeten et al., ‘The State and the Threat of Cascading Failure Across Critical Infrastructures: The Implications of Empirical Evidence from Media Incident Reports’, Public Administration 89, no. 2 (1 June 2011): 381–400, doi:10.1111/j.1467-9299.2011.01926.x.

⁹³ Luijff et al., ‘Empirical Findings on Critical Infrastructure Dependencies in Europe’.

⁹⁴ Van Eeten et al., ‘The State and the Threat of Cascading Failure Across Critical Infrastructures’.

⁹⁵ *Ibid.* Luijff et al.

⁹⁶ *Ibid.* Van Eeten et al.

stay in control include the following:⁹⁷⁹⁸

- An increasing decoupling of electricity generation and its use. Large-scale generation (including renewables) takes place a long-distance away from the end-users;
- The increasing age of components, different technological generations - from mechanical to digital - combined with their being put under greater strain;
- Significant differences in the planning procedure for generation and the transmission and distribution infrastructure, enabling local renewable power generation to be realized in a matter of months and larger wind parks in a number of years, whereas the construction of new high-voltage power lines can take decades;
- Increasing power trading between countries leads to more fluctuating transmissions over greater distances;
- A decrease in the availability of balancing power through the closing of large, conventional and other power stations;
- The speed at which new technologies are being introduced, whose effects on long-term reliability are not sufficiently known (e.g., DC connections, power electronics, controls, regulating systems).

The power grid is rapidly changing from a relatively simple, albeit large physical system into a complex, non-linear, digitally controlled system. These changes also involve risks, chiefly in the realm of stability and especially in terms of cyber security, due to the fact that an increasing portion of the power supply is being made accessible via the Internet for the purpose of control, monitoring and even maintenance.

Insufficient resilience of energy systems may lead to blackouts with adverse consequences. Major blackouts are usually caused by cascading contingencies, such as a short circuit, an overloaded single component, or a generator outage with complicated interactions. The vulnerability of the system to these low-probability incidents that expand to a cascading outage

⁹⁷ Olivier Ongkiehong, 'Electricity Grids. Description of the State under the Dutch Energy Research Program', 1 September 2006, http://inis.iaea.org/Search/search.aspx?orig_q=RN:42021006.

⁹⁸ Note: this section is based on an article from Peter Vaessen entitled *De Betrouwbaarheid van Het Toekomstige Elektriciteitsnet Nationale Veiligheid En Crisisbeheersing* and from the DNV GL position paper *Reliability of Future Power Grids*.

(the domino effect) increases when the system is already stressed by other causes. These can include operating close to the limits, or bulk exchange of power between parts of the system through congested transmission corridors. Forces of nature or extreme weather conditions, such as storms, high temperatures, and forest fires, often initiate a cascading outage. The sequence of events leading to a large blackout is diverse, but the result is always the same: an interruption to the electric power supply for many customers.

As an increasing number of people gain access to electricity, overall power consumption increases and the power system becomes more complex and, under these conditions, coupled with the increase in extreme weather events, the risk of disruptive blackouts increases.

In the Netherlands, a large-scale disruption in the electricity supply occurred in March 2015 in a large part of the province of North Holland and in a small part of the province of Flevoland, due to a short circuit at TenneT's 380 kV substations in Diemen. A previous major outage in the Netherlands occurred in 1997 in the province of Utrecht. The March 2015 power outage affected about one million households, a number of large-scale consumers, and vital infrastructure such as Schiphol Airport and parts of the rail network.⁹⁹

Figure 19 provides an overview of the largest global power outages through 2012, and includes the outage in the province of North Holland. Here, the year of occurrence (x-axis), duration (y-axis), and number of people impacted (relative size of the bubbles), are compared. It can be observed that the most common cause of these blackouts was “natural phenomena” (six times), while design and application errors, communications failures, and operator errors were the second largest contributors. These kinds of power outages are usually caused by a combination of technical failures and human errors, where a fault or defect occurs at a critical moment and is then misinterpreted, after which an appropriate, but incorrect action is taken, as was the case with the outage at Diemen.

⁹⁹ Vaessen, ‘De Betrouwbaarheid van Het Toekomstige Elektriciteitsnet Nationale Veiligheid En Crisisbeheersing’.

Figure 19: Major Global Power Outages, 1965 to 2015

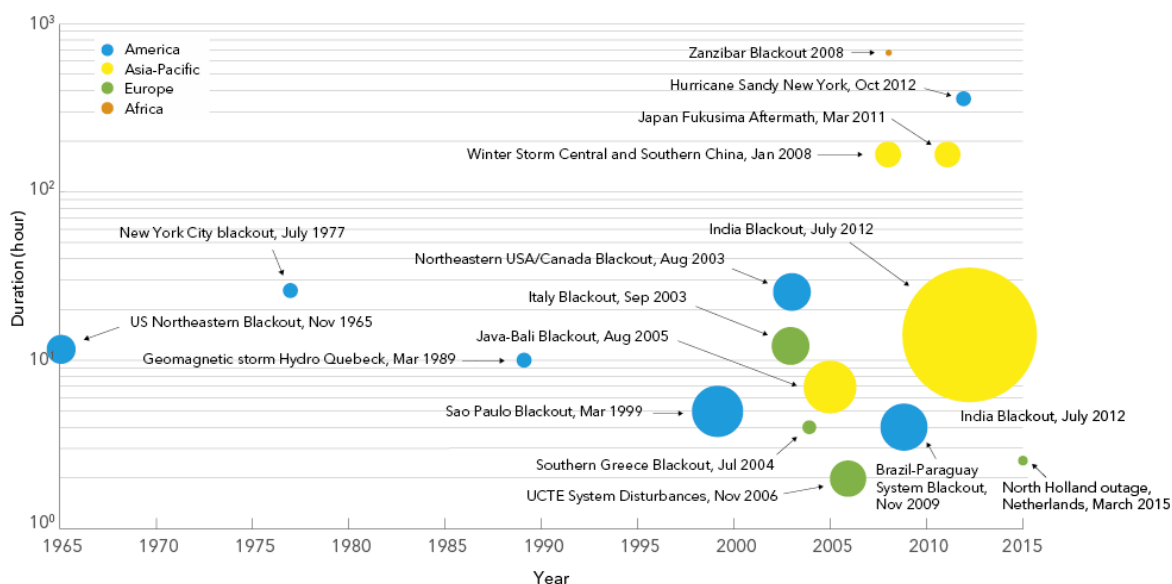
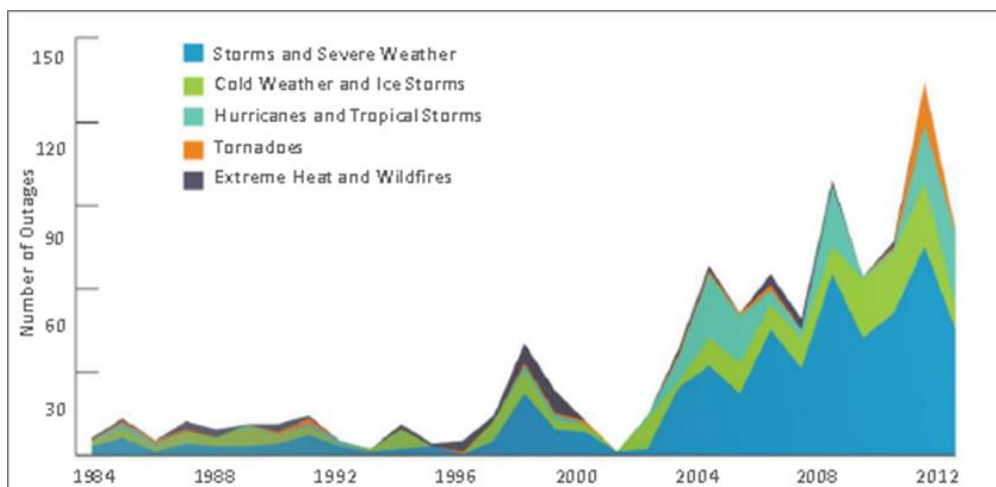


Figure 20: U.S. Power Outages >50,000 Customers Caused by Extreme Weather¹⁰⁰



¹⁰⁰ National Oceanic and Atmospheric Administration.

As shown in figure 20, extreme weather has also become a significant cause of most of the recent major power outages in the United States, particularly along coastal areas. The increased frequency and duration of these power outages is profoundly impacting national and local governmental emergency response programs, infrastructure investment, and the introduction of new policies and funding programs.

Enhancing the resilience of energy systems

In the previous section, some of the challenges in the electricity sector were described. Some of them need to be addressed at the national or international level. The same applies for most of the solutions and technologies contributing to making the power grid more flexible and robust, which includes the following:¹⁰¹

- Expansion of the number of electricity connections between countries. This contributes to the enlargement of transmission capabilities between regions and, therefore, the market, and facilitates the integration of more large-scale, renewable energy;
- More systems that are capable of sending power into the grid in a targeted way to prevent overloads and congestion of the high-voltage power grid due to a shortage in capacity;
- Developing and exploiting the potential of inverters that provide voltage support and improved grid stability;
- More precise forecasting methods for both the supply of and demand for power;
- Determining dynamic load capacity of high-voltage power lines and cables based, for example, on the weather situation, enabling them to be exploited more effectively;
- Installing advanced technologies such as smart grid applications, battery storage, microgrids, fuel cells, and combined heat and power systems (see Smart Energy proposals in section 5);
- Introducing the aggregation of distributed renewable power generation and demand in combination with sufficient grid-linked energy storage with a range of control speeds for better balancing;

¹⁰¹ Ibid.

- Installing flexible connections (via DC) and collaborating with local mini-grids and microgrids, enabling the creation of a partially decoupled and more robust grid.

The latter two solutions have a clear local scope and could fit well in city resiliency activities. For this reason, they will be described in more detail in the next subsection.

The previous measures foster the creation of a hybrid power grid that combines different technologies such as AC (alternating current) and DC (direct current), passive and active controls, and conventional and renewable power generation of various capacities. The Third Industrial Revolution Energy Internet is robust and flexible and is capable of providing consumers with affordable, reliable, and sustainably generated electricity, now and in the future.

Besides the approach aimed at preventing power outages through improvements in technology, procedures, and operational instructions, more attention is being devoted to fast recovery, the creation of fallback/last resort resources and the incorporation of greater flexibility. What is essential here is better coordination and cooperation between all organizations and institutions concerned with power supply, which, incidentally, is gaining a greater European dimension. In addition, better risk assessments, a more systemic approach to evaluating new technologies, and the increased automation of the system as a whole require greater attention at the policy and operation levels.

Reflections on proposed technical local solutions from a social-ecological system approach

Research currently undertaken on social-ecological systems theory aims to learn how to adapt social-technical systems to climate change. Here are some reflections on the extent to which key characteristics of social-ecological systems can be linked to the technical solutions for local resiliency of the electricity system described in the previous section.

Social-ecological systems (SESs) are systems in which both social processes and “*ecological processes are included, and where the ecological and social components interact. For the long-term functioning of a SES in a certain desirable configuration, the biological and social agents in the system need to be able to cope with expected and surprising disturbances.*”¹⁰²

¹⁰² Marco A. Janssen and Erik E. Osnas, ‘Adaptive Capacity of Social-Ecological Systems: Lessons from Immune Systems’, *EcoHealth* 2, no. 2 (June 2005): 93–101, doi:10.1007/s10393-004-0158-7.

There are three characteristics that make social-ecological systems resilient:¹⁰³ *“redundancy, modularity and diversity in agents and interactions.”*¹⁰⁴ *“Redundancy enables a system to maintain its function when a component is lost, and the redundant component takes over the function. Modularity implies a system that has different functional parts or modules which can evolve somewhat independently. The modules might be loosely linked with each other, but a failure in one module does not severely affect the others, as would happen if they were tightly linked. Sufficient links are required since modules might learn from the activities happening in other modules.”*¹⁰⁵ A third factor for resilience is *“diversity, meaning that different components can become specialized in different tasks.”*¹⁰⁶ In systems with low diversity, there is less chance of creating new ideas, components, or connections.

It is possible to build on these three system characteristics when developing resilient cities by modelling urban processes on ecological principles and extracting policy recommendations from these resilience-enhancing features. More specifically, redundancy implies that multiple copies or alternative backup resources must be present in an urban network to sustain its functioning. In that way *“if one system is compromised, there is enough redundancy in the overall system to compensate for the compromised system until it can be replaced or repaired.”*¹⁰⁷ Redundancy is part of the previously mentioned ‘four R’s’ approach to resiliency, and has long been used in the electricity sector (also known as the n+1 principle).

In terms of modularity, resilience capacity will be increased when “system components have enough independence that failure of one part or component will have a low probability of inducing failure of other similar or related components in the system.”¹⁰⁸ Modularity is represented in the concept of micro-grids, where a number of distributed power generators jointly provide the required power. In case there is limited generation capacity due to failure of one of the systems, end users can be asked to switch load to ensure supply and demand match.

¹⁰³ Janssen and Osnas, ‘Adaptive Capacity of Social-Ecological Systems’.

¹⁰⁴ Marleen Schouten, Martijn van der Heide and Wim Heijman, RESILIENCE OF SOCIAL-ECOLOGICAL SYSTEMS IN EUROPEAN RURAL AREAS: THEORY AND PROSPECTS, 2009.

<http://ageconsearch.umn.edu/bitstream/57343/2/Schouten%20Marleen%20cover.pdf>.

¹⁰⁵ Janssen and Osnas, ‘Adaptive Capacity of Social-Ecological Systems’.

¹⁰⁶ http://www.resilientcity.org/index.cfm?PAGEPATH=Resilience/Resilient_Design_Principles&ID=11900, accessed 30-8-2016.

¹⁰⁷ Source: http://www.resilientcity.org/index.cfm?PAGEPATH=Resilience/Resilient_Design_Principles&ID=11900, accessed 30-8-2016.

¹⁰⁸ Source: http://theresilienceinitiative.org/?page_id=1548&lang=fr, accessed 30-8-2016.

Failure of one of the local generators will not lead to failure of any of the other generators. Diversity can be achieved by purposely opting for a mix of generators and storage systems at a local level.

Global Resiliency: International and National Policies and Standards

Policy

Resiliency should be an integral part of decision-making at all levels and across all sectors of society. Policies at the international, national, and local level should be aligned and be complimentary to effectively address climate change. Policy makers at different levels should cooperate to ensure topics are coherently addressed, both within and across sectors, in order to avoid unintentional adverse effects on other levels or sectors.

Additionally, lateral cooperation is important to share best practices. Lateral collaboration across cities and regions can refer both to cities with a similar profile (such as in the Connecting Delta Cities' initiative) and to neighboring cities within MRDH. Several initiatives exist to facilitate peer learning, such as the 100 Resilient Cities Initiatives of the Rockefeller Foundation, and the C40 Cities Climate Leadership.

Policy at the European level¹⁰⁹

The European Union has put climate change mitigation and adaptation high on the policy agenda. With respect to mitigation, there has been a history of policy directives (e.g., Renewable Energy Directive, Energy Efficiency Directive), and standards introduced by the Eco-design Directive.

The European Commission has adopted the 2013 EU Strategy on Adaptation in order to prepare member states for current and future climate change impacts. This strategy features three main objectives:¹¹⁰

¹⁰⁹ 'Resilience - European Commission', accessed 17 August 2016, http://ec.europa.eu/clima/policies/international/paris_protocol/resilience/index_en.htm.

¹¹⁰ 'Resilience - European Commission', accessed 17 August 2016, http://ec.europa.eu/clima/policies/international/paris_protocol/resilience/index_en.htm.

- Promoting action by member states by encouraging them to adopt comprehensive adaptation strategies and providing guidance and funding to help them build up their adaptation capacities and take action;
- Promoting more informed decision-making by addressing gaps in knowledge about adaptation, and further developing the [European Climate Adaptation Platform](#) (Climate-ADAPT) as the “one-stop shop” for adaptation information in Europe;
- Promoting adaptation in key vulnerable sectors through agriculture, fisheries, and cohesion policy, ensuring that Europe’s infrastructure is made more resilient, and encouraging the use of insurance against natural and man-made disasters.

Two other initiatives are critical to establishing a robust resiliency regime: 1) the Civil Protection Mechanism legislation and 2) the Emergency Response Coordination Centre (ERCC). The aim of the ERCC is *“to support a coordinated and quicker response to disasters both inside and outside Europe, using resources from 31 countries participating in the Union Civil Protection Mechanism.”*¹¹⁰ All countries in the world can submit a request for support to the Civil Protection Mechanism.

The EU “Approach to Resilience,” presented in 2012, defines the *“the policy principles for action on helping vulnerable communities in crisis-prone areas.”*¹¹⁰ An accompanying action plan has been created to define the principles for more effective action of EU member states on the topics of *“building resilience, bringing together humanitarian action, long-term development cooperation, and on-going political engagement.”*¹¹⁰

Whereas these actions will mainly be relevant at a national or regional scale, there are also some support mechanisms developed for cities. They include H2020 subsidies, ERA-programs, and Regional Development Investments Funds. These are similar to a “Covenant of Mayors” initiative launched by the European Commission in 2008 to spur local policies and local action regarding energy and climate. Although climate action is the central theme in the Covenant of Mayors, climate change mitigation has received greater attention than adaptation. Consequently, “Mayors Adapt” has been launched to underscore the relevance of enacting resiliency policies and activities at the local level to address climate change adaptation.

Policy at the national level¹¹¹

In the Netherlands, two parallel tracks jointly form the foundation for national adaptation strategies and actions: the Delta Program, focusing on water management; and the National Adaptation Strategy (NAS), which has a wider scope.

The Delta Program focuses on three key themes: the protection of *“the Netherlands from coastal and river flooding, climate resilient urban areas and adequate supplies of freshwater for generations ahead.”*¹¹² As indicated, the National Adaptation Strategy has a wider scope and addresses specific sectors, including *“health, energy and ICT, infrastructure, transport, nature, agriculture and fisheries”*.¹¹²

Other topics addressed in the National Adaptation Strategy include cascading effects across sectors and climate change impacts outside the Netherlands that may impact Dutch society. To track progress and create transparency and accountability, monitoring and evaluation is also addressed in the National Adaptation Strategy.

Policy at the local level

As previously indicated, resilience of a city, including all its systems and services, is key for the safety, security, and well-being of citizens and relevant for all types of economic activities. Although cities cannot always directly determine decision-making regarding investments in the operations of infrastructures and systems, they can certainly have an influence. Domains in which the city can make a difference include spatial planning, including ecological infrastructure, creating water buffers, zoning, construction requirements, and the elevation of roads.

Since 2009, all Dutch provinces address climate change in their spatial planning processes, and most provinces have developed a climate adaptation plan. Whereas most cities have energy policies and mitigation targets and roadmaps, very few have climate adaptation policies. However, some cities show clear leadership in this respect and create visibility with their activities both nationally and internationally. The City of Rotterdam, for instance, has established the [Rotterdam Climate Proof program](#) *“to make Rotterdam climate change resilient by 2025 through, green roofs, water squares, a new rowing course to enlarge the water storage*

¹¹¹ ‘Netherlands — Climate-ADAPT’, accessed 17 August 2016, <http://climate-adapt.eea.europa.eu/countries-regions/countries/netherlands>.

¹¹² Ibid.

capacity of the city, and floating architecture in the old port areas.”¹¹³

Global Resiliency Standards

Standards for Resilient Critical Infrastructure

Many efforts have been undertaken globally to build more resilient cities and communities. However, it is not yet a mature field of expertise. To foster effective sharing of information and lessons learned, it is important that a common taxonomy be used so that actions are well understood and progress is monitored and evaluated. Standardization could support a more holistic approach to resiliency, and should improve the sharing of best practices. Existing standards coming from organizations such as the ISO, NIST, and ANSI, should be carefully assessed to determine universal standards.

EU Standards

The European Commission is integrating climate action in all its policies and actions. Additionally, the Commission supports the development of standards to reduce the vulnerability of European infrastructure to climate change. In the adopted EU Strategy on Adaptation to Climate Change, the European Commission invites *“European Standardization Organizations to contribute to the European efforts aiming to make Europe more climate-resilient. The strategy highlights the key role of standards in securing climate resilience.”*¹¹⁴

A special coordination group, Climate Change Coordination (ACC-CG), was established by the European Committee for Standardization (CEN) and the European Telecommunications Standards Institute (CENELEC) in 2014. The aim of the group is to coordinate and align efforts related to climate change adaptation and critical infrastructure. Standardization activities refer to both revisions of existing standards and development of new standards. Three sectors have been prioritized in the EU Strategy: transportation, energy, and buildings.¹¹⁴

¹¹³ Ibid.

¹¹⁴ ‘Climate Change Adaptation - CEN-CENELEC’, accessed 17 August 2016, <http://www.cenelec.eu/standards/sectors/climatechange/pages/default.aspx>.

Standards and monitoring for resilient cities

An ISO standard has been developed for resilient and sustainable cities (ISO 37120). It “*defines and establishes methodologies for a set of indicators to steer and measure the performance of city services and quality of life.*”¹¹⁵ An initiative is underway to pioneer the ISO standard in 45 cities, which are well-known for their activities to create a climate resilient environment for their inhabitants. The goal of this trial is to distill “*Ten Essentials for Making Cities Resilient*”¹¹⁶ and incorporate them into the standard. This initiative is being led by the World Council on City Data (WCCD) and the UN Office for Disaster Risk Reduction (UNISDR). According to the standard, “*The Ten Essentials focus on issues such as good urban planning, land-use, a risk-informed citizenry, safe schools and health facilities, protection of eco-systems, early warnings and emergency management.*”¹¹⁷

In addition, the ISO has created a subcommittee on climate change adaptation that is exploring a suite of standards. This work is still in its infancy and the goal is to generate a revised ISO 14080 that will describe a framework and set of principles to both make adaptation and mitigation schemes more compatible, and elaborate the different approaches of mitigation and adaptation.¹¹⁸

Monitoring urban resilience

An essential step in developing plans to enhance the resilience of a city is the ability to objectively measure the baseline and the impacts, both positive and negative, of policies and actions. Composite indices are frequently employed by researchers and practitioners as useful tools to accomplish this objective.

There is a wider effort undertaken by the United Nations Framework Convention on Climate Change (UNFCCC), to generate monitoring and evaluation frameworks that track adaptation action, in order to make monitoring results easier to compare. With a large diversity of indicators to monitor and evaluate adaptation policies and actions, it is difficult to share lessons learned and best practices.

¹¹⁵ http://www.iso.org/iso/catalogue_detail?csnumber=62436 (accessed 31-08-2016)

¹¹⁶ ‘Beta Version: Campaign’, accessed 31 March 2016, <http://www.unisdr.org/campaign/resilientcities/home/index>.

¹¹⁷ Ibid.

¹¹⁸ ISO, ‘Practical Tools of Addressing Climate Change’, 2015, http://www.iso.org/iso/climatechange_2015.pdf.

Concluding Remarks

Climate change will lead to “new average” weather conditions and more extreme weather events. While climate discussions previously focused on mitigation, we have recently seen increased attention given to adaptation. Actions on adaptation to climate change are especially crucial for cities. As climate change can affect a city in multiple ways, a resiliency strategy should be an integral part of local government policies and programs.

To provide citizens with a safe and secure living space, and provide financiers and businesses with a stable and attractive investing environment, it is important that critical services such as food, water, and electricity are resilient to climate change and can be delivered at all times. As the delivery of services is heavily dependent on critical infrastructure, city resiliency strategies should pay considerable attention to critical infrastructures and especially the interdependencies between them. To ensure buy-in, strategies and actions should be developed in cooperation with key stakeholders. Furthermore, strategies on critical infrastructure should not be limited to technical aspects, as social and governance aspects are equally important.

To become resilient as a city, it is important that there be a sufficient awareness of resiliency at all levels (public, private, citizens), and that a city start with capacity and capability building. MRDH is well-positioned to become a leading region in respect to resiliency, with Rotterdam already active in this field at a national and international level, and The Hague internationally recognized as a hub for business and innovation regarding safety and security. Combining these strengths will further enable MRDH to strengthen its position as a global leader in resiliency preparedness.

Implementing the RNE Smart Energy Delta

Introduction

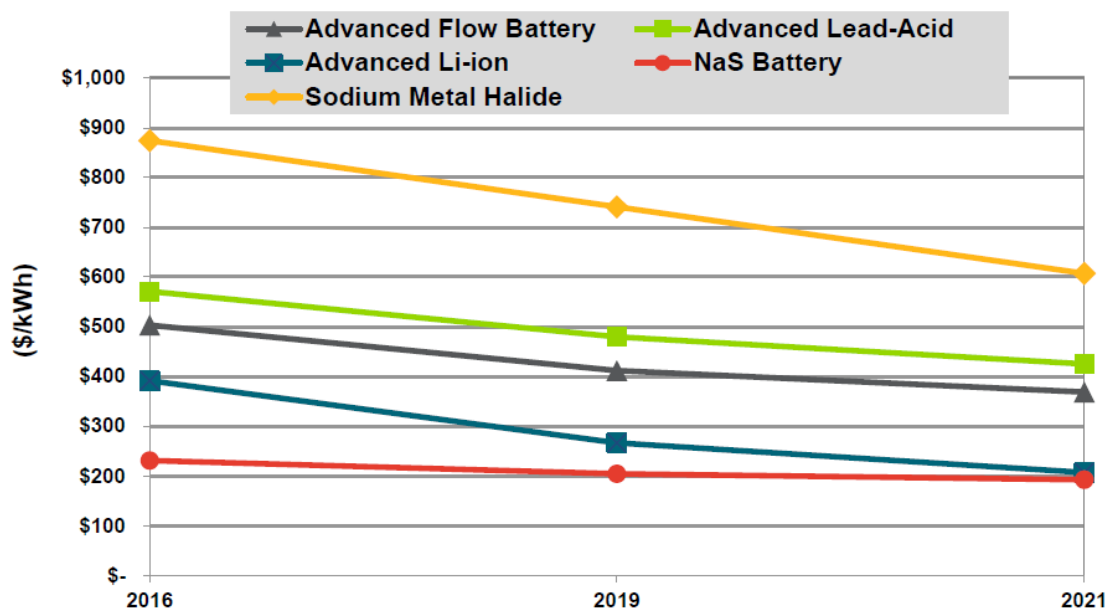
As outlined in this section, the Smart Energy Delta presents a significant opportunity for MRDH to shift to a more productive use of energy in the region. It also presents an opportunity to support additional transition pathways and the transformation of the Port of Rotterdam, as part of the broader Roadmap Next Economy (RNE).

It is understood that MRDH working groups may have some concerns regarding affordability

and proven commercial value for advanced energy technologies and applications. However, vast improvements in technological performance and learning curve effects are significantly reducing energy technology costs (by as much as 15% or more annually) such that solar photovoltaics, battery energy storage, and sustainable hybrid energy systems have all reached parity with traditional power grid and fossil energy sources in many parts of the world.

For example, as shown in figure 21, the costs for advanced batteries used in numerous electric storage applications, are expected to decline steadily and considerably from today's levels.

Figure 21: Forecasted Costs of Battery Storage¹¹⁹



The transition to a fully sustainable Energy Internet in MRDH will introduce invasive processes where many high-impact decisions, with long term consequences for all stakeholders, have to

¹¹⁹ Source: Navigant Research, *Advanced Batteries for Utility-Scale Energy Storage*. Excludes costs from power conditioning systems, bidirectional inverters, software and controls, systems integration services, and other project development costs.

be made. Sustainable energy requires considerable physical space. In a highly urbanized region where space is at a premium, the combination of functions, aesthetics, and concurrent use of space will be important topics to address, when designing a future energy system. Spatial planning and energy system information thus need to be integrated.

Available data is not yet sufficiently tailored to the unique context of MRDH and will therefore need to be adjusted. MRDH's specific combination of a polycentric urbanized area with a large harbor-industrial complex and greenhouse complexes means that existing analyses cannot simply be mapped to the region. Data, when present, is fragmented and located in the various verticals.

To ensure that at any given point during the transition to a Third Industrial Revolution Energy Internet, the best possible decisions can be made, driven by the most complete available data, a modelling and visualization platform should be created that serves as a decision support system for design choices regarding MRDH's future energy system.

This Regional Energy Information System (REIS) should feature components for:

- Detailed, multi-commodity load flow planning and optimization;
- Power grid capacity planning;
- Conversion and storage options;
- Analysis of 'what if' scenarios;
- (Societal) Cost-Benefit Analyses;
- Visualization and analysis of spatial planning aspects;
- Monitoring and evaluation tooling for pilot projects, to assess success and scaling potential;
- Assessment of interventions in the built environment at the national and local level;
- Integration with (open) data sources to power all model components with the best available and realistic data;
- Dashboards and 3D visualizations for easy and effective dissemination of results.

Many models and data sources that could fit into REIS already exist, such as MOTER, PICO, Chess, Go2Zero, CLAIRE, ET-Moses, Koude-Warmte Atlas, Nederlandse Energie Atlas and ZonAtlas.nl. Investing in data-harmonization, API development, and co-simulation can build REIS quickly and cost-effectively.

The energy transition is not a linear process with a predefined and identifiable end status. Throughout the process (while surviving short term political goals) new problems will arise, necessitating a need for continuous change. The different perspectives on the types of problems and options, and distributed and decentralized control, require an adaptive transitional approach. This approach combines characteristics from both the adaptive management and transition approach, such as the ability to develop adaptive capacity, integration of bottom-up and top-down approaches, emphasis on learning from experimentation in complex systems and stakeholder participation, all incorporating feedback and long-term perspectives in socio-technical change (Foxon, 2008).

The path for the energy transition will require MRDH to act faster, go further, be smarter and operate cheaper for an economic transition with new jobs and export opportunities. In some places, quick wins are proposed as “living labs,” fitting into thematic project lines and helping to program the transition path. The lessons of the quick wins can be used to learn about user satisfaction, explore a range of technical issues, contribute to the targets, and obtain other outcomes. The cooperation with local stakeholders, cities, and companies will help to create networks for cooperation and resolve identified problems. The experiments will generate new insights regarding long-term goals and visions. This requires monitoring of performance indicators (using, for example, a Regional Energy Information System or other similar tracking mechanism) as well as learning and evaluation.

As described in the subsequent subsections, a number of demonstration programs and supporting proposals are suggested to facilitate the smart energy transition. Altogether, the TIR team offers a total of 26 Smart Energy demonstration program proposals, as well as seven resiliency program proposals, to immediately launch the RNE. To provide a broader and more systemic perspective, the Smart Energy proposals are categorized into six main dimensions including: new business models and value chains, technical, regulatory, policy, educational, financial, and research and development (R&D). The Resiliency program proposals are outlined in the next subsection.

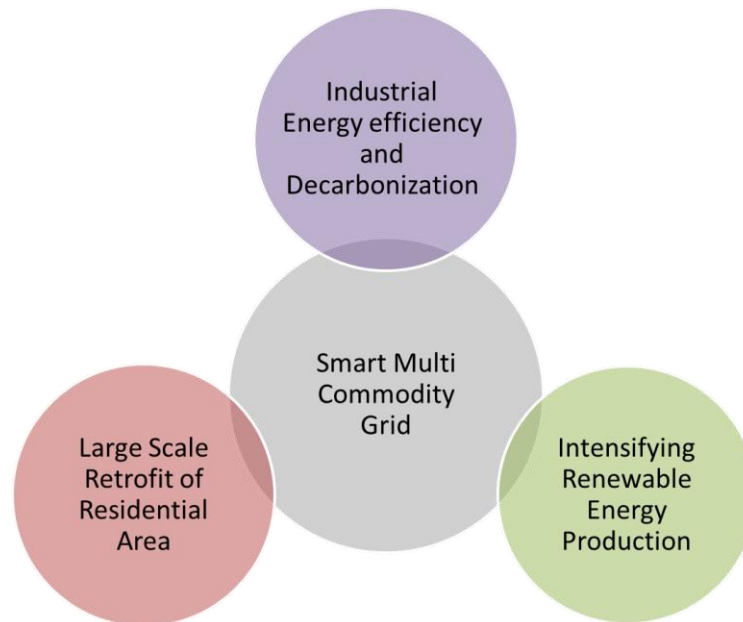
The Smart Energy ambitions for MRDH will be advanced by pursuing three principal routes in parallel, with the proposal dimensions aligned accordingly. In some cases, dimensions are aligned within multiple routes as foundational elements. These routes and dimensional alignments of proposal ideas are shown in Table 4.

Table 4: RNE Smart Energy Delta: Implementation Proposals Summary

Implementaton Route	Proposal Titles/ Prioritization	Proposal Dimensions
<i>Develop and Scale a Clean, Distributed, and Intelligent Energy System</i>	<ul style="list-style-type: none"> • #6 Develop a joint regional plan with TenneT to improve access to imported renewables through interconnections • #7 Nurture and scale community renewable energy projects • #9 Deliver geothermal for the Greenport • #14 Create a testbed environment to demonstrate the concept of an MRDH “Energy Superhighway” • #15 Develop a Smart Multi-Commodity Grid • #17 Explore alternative, performance-based regulatory led schemes that focus on customers and innovation • #22 Pursue Hydrogen for Zero-Emission Public Transport • #23 Continuously strengthen smart grid and smart energy cyber and physical security standards and protocols • #24 Expand the MRDH Energy Superhighway to include the Port of Rotterdam • #25 Leverage geospatial visual mapping to determine optimal sites for wind farms 	<ul style="list-style-type: none"> • Technical: #9, 14, 15, 22, 23, 24, and 25 • Policy: #6 and 7 • Regulatory: #17

Implementaton Route	Proposal Titles/ Prioritization	Proposal Dimensions
<i>Create New Business Models and Innovative Financing Schemes</i>	<ul style="list-style-type: none"> • #1 Mobilize small and medium sized enterprises (SMEs), nonprofit organizations, and homeowners into green electricity cooperatives • #3 Stimulate utility and supplier-based innovation • #4 Implement back to zero in the urban brownfield • #5 Accelerate offshore and onshore wind farm development • #8 Pursue “Dutch in the Urban Greenfield”, where Dutch design meets low carbon net energy producing districts • #10 Implement “Core-to-the-Core Business” Grid • #11 Develop Urban – Industrial balancing act • #12 Accelerate rooftop, community, and utility-scale solar PV systems • #13 Support large-scale sector coupling demonstration projects • #16 Transform the primary role of energy companies • #18 Integrate Blockchains into the promotion of microgrids and cooperative-based Renewable Energy Internet initiatives 	<ul style="list-style-type: none"> • New Bus Models/ Value Chains: #1, 4, 5, 8, 10, 11, 16, and 18 • Financial: #3, 5, 12, and 13
<i>Stimulate Continuous Energy Innovation</i>	<ul style="list-style-type: none"> • #2 Provide cross-sector support for development of innovation engines to accelerate “net zero energy neighborhood” models • #19 Develop energy educational programs based on the Smart Energy Delta platforms and co-operative principles 	<ul style="list-style-type: none"> • R&D: #2, 21, and 26 • Educational: #19 and 20

Implementaton Route	Proposal Titles/ Prioritization	Proposal Dimensions
	<ul style="list-style-type: none"> • #20 Develop a tailored offshore training concept • #21 Integrate wind energy R&D competencies • #26 Advance renewables-sourced hydrogen fuel production 	



Finally, while all 26 Smart Energy proposals represent relevant and focused opportunities for MRDH to pursue, the TIR team provides a recommended sequence for prioritizing resources and enabling initial quick wins and the development of foundational elements for subsequent programs. Therefore, proposal #1 should be implemented ahead of proposal #2, and in subsequent fashion through the list.

Sequencing criteria include consideration of the potential value to be added to MRDH, as well as the feasibility of implementation. Potential value is based on the TIR team's consideration of the following factors: reducing final energy consumption; reducing CO₂ emissions; increasing the percentage of renewable energy generation; providing knowledge or results to be used in subsequent projects; enabling implementation of the other transitional pathways; and building upon MRDH's assets (e.g., renewables experience, cyber security experience, reputation). Feasibility of implementation is based on consideration of the following factors: technology is commercially available; requires specialized skills or partners rather than local labor; provides an upscaling capacity across multiple geographies within the region; requires minimal decommissioning effort at project conclusion; can be self-funded; and requires little start-up time or governance (e.g., regulatory).

Furthermore, we align each of these proposals to the five RNE key sectors identified by the MRDH working groups, namely urban and residential, greenfields and brownfields, food and flowers, mobility, and industry.

2.1.0 NEW BUSINESS MODELS AND VALUE CHAINS

2.1.0.1 Smart Energy Proposal #1: Mobilize small and medium sized enterprises (SMEs), nonprofit organizations, and homeowners into green electricity cooperatives (new business models and value chains). Contributes to RNE sector “Urban and Residential Areas”. The Netherlands economic-engineering potential for rooftop solar PV systems on residential and commercial buildings exceeds 55,000 MW with an average capacity factor of 13%. The onshore wind resource potential exceeds 47,000 MW, with an average capacity factor of 38%. If we include the least cost option in delivering energy services, energy efficiency-productivity gains could potentially match the renewable amounts. Green electricity cooperatives in Germany and Denmark have proven to be the most effective business model for assuring bank financing, early adoption, and rapid scaling of locally generated renewable energies and energy efficiency practices.

The concept of energy cooperatives can also be expanded to offshore wind farms and additionally be supported by tax incentives. The much larger investments compared to onshore projects are a hurdle, but can be overcome, as again an example from Denmark shows:

“Middelgrunden Vindmøllelaug is the largest wind operator of its kind in the world with 8,600 owners. Middelgrunden wind power offshore wind farm is 50% financed by 10,000 stockholders in Middelgrunden Vindmøllelaug and 50% financed by Copenhagen Energy, the municipal energy supplier in Copenhagen.”¹²⁰

To support investments in wind power, families were offered tax deductions if generating their own energy within their own or the neighboring municipality – but still relatively close by. This incentive resulted in the creation of numerous wind power cooperatives. By 2004, more than 150,000 Danish families were members of a wind power cooperative.¹²¹ The challenge for MRDH is to transfer this concept to offshore wind. As the projects are much larger, the individual identification with “my turbine” will be less meaningful. Still, it might be an interesting alternative investment and at least support the required financing.

2.1.0.2 Smart Energy Proposal #4: Implement back to zero net energy in the urban brownfield (new business models and value chains). Contributes to RNE sector “Greenfields and Brownfields.” In order to accelerate the transition towards zero net energy for existing urban

¹²⁰ Copenhagen: cities can run on wind energy, Middelgrunden projektinformation.

¹²¹ Wind Power in Denmark - Economic Impacts - Wind Turbine Cooperatives.

districts, MRDH can demonstrate that even districts and neighborhoods that are perceived as too difficult and too costly to transform can, in fact, be changed for the better.

First, every effort must be made to increase the energy efficiency of the built environment. For the short- and middle- to long-term, this means renovation or demolition and rebuilding of large quantities of current homes. Building and construction technologies are already available, but are often too expensive for the typical individual owners of these houses to invest in, even though the business case is positive in the longer term. Financial arrangements are needed to bridge this gap in the short term. For the middle to long term, MRDH should aim for industrialization of concepts like “Nul op de Meter,” NZEB, and passive home renovation technologies to reduce the cost of renovation from 25 to 50%.

“NZEBs are buildings connected to the existing energy infrastructure that have very low energy demand and are supplemented by renewable energy sources. NZEBs produce as much energy as they consume annually and they can be connected to district heating systems, which distribute heat to a number of buildings through a network of pipes carrying hot water or steam. This enables them to send and receive energy from these systems, for example, where excess heat from NZEBs, generated with solar panels, can provide a benefit to district heating by reducing the systems’ need for energy from other sources, such as combustible fuels.”¹²²

While it may be impossible for some buildings to achieve net zero energy due to site constraints, entire districts can take advantage of economies of scale. It’s important for buildings to be as low-energy as possible with a bandwidth over time (peak demand and peak supply of the building) as narrow as possible, but if the balance of their annual consumption needs can be cost-effectively met with central renewable energy generation from the utility, achieving net zero energy becomes more achievable to a wider population of buildings. For this to work well, the Smart Grid—which promises two-way communications and dispatch between utilities and end use consumers—needs development to balance out a diverse portfolio of distributed renewable generation.

In order to kick-start this industrialization process, we need to organize the joint demand for low carbon or even “Nul op de Meter” renovation, at the level of several thousand homes per year. An important challenge is to industrialize, create economies of scale, and thereby achieve cost reductions without ending up with a “one size fits all” approach that does not appeal to

¹²² Science for Environment Policy Thematic Issue: Green Construction, Issue 38, European Commission, April 2013,

homeowners. Smart industry will play an important role in this roll out.

Building corporations and owners associations play an important role in developing joint demand. In order to accelerate their involvement, MRDH should seek to remove current barriers. The RNE should invest in technologies and product development for zero offset, low carbon districts where local energy storage, micro grids, and net metering mitigate the risk of disruptions of the energy grid. For the longer term, the ambition should be on technologies for energy+ buildings and energy+ districts.

Quick Wins

There are two key areas where these principles may be implemented in a relatively short time.

This would include the following quick wins:

- *Cooperative associations* - Regional and local governments develop energy set-ups/configurations for neighborhoods (e.g., all-electric heat) and approach housing associations to cooperate and make the energy investments happen. Interregional alignment is necessary to prevent suboptimal solutions at higher spatial scale. The City of The Hague has relaunched The Hague Geothermal Heat Project (DAP) in Den Haag Zuidwest, and offers the housing associations an integral energy efficiency plan related to the use of geothermal heat. This requires new heating and cooling systems and is combined with more comfort and affordable energy prices. Den Haag Zuidwest is a district with high and low rise apartment blocks built in the 1950s and 1960s, with a mixed population of Dutch and immigrants with a low- to medium- income, and with low energy interest. This mixture makes the transition towards net zero energy quite difficult, but will become an example for many other districts in the Netherlands.
- *My School Your Energy* - A “Net Zero Energy as a Service” solution for neighborhood schools. School boards must preserve their buildings and save energy. On average, primary school buildings are approximately 42 years old and the housing for secondary education is about 38 years old. Energetically, and with respect to the quality of the indoor environment, large steps can be made. Only 7% of the buildings have an energy label and, of these, more than 75% score a C or lower. About 25% of the buildings do not go beyond energy label G. The indoor environment and energy performance of the schools must be improved. Both factors lead to poor learning and working conditions and unnecessarily high operating costs. A net zero energy building approach can

contribute to this, but MRDH should look a little further. In MRDH, most of these schools are situated amidst residential areas; the same areas where corporations and residents are also challenged to improve the energy performance of their buildings. But, due to the architectural specifications of their houses, these homeowners find it difficult to reach net zero energy on their own. For instance, they often lack enough rooftop space for solar PV, or do not have the possibility for local energy storage.

Introducing a school as a utility building into the equation might provide the means to reach a net zero neighborhood. Schools receive an energy allowance per student which is not enough for renewing and renovation. Storing, delivering, and netting energy at schools on a neighborhood level may turn energy from a cost into a source of income and, at the same time, reduce the energy costs of participating households. It is therefore proposed that MRDH set up a program with some of the boards of the larger school foundations (e.g., BOOR has 82 schools in even more locations), together with local housing associations, industries like Engie or Siemens, and STEDIN that deliver an Energy as a Service solution, that can be rolled out to the majority of neighborhood situated schools in MRDH.

2.1.0.3 Smart Energy Proposal #5: Accelerate offshore and onshore wind farm development (financial, new business models). Contributes to all five RNE target sectors. The upfront capital cost for developing offshore wind farms capable of providing 60% of the Netherlands' total energy needs has been calculated recently at €253 billion (in 2016€), with an energy payback of 5.4 years. Energy, plus air pollution prevention, reduces the payback to 3.1 years, and energy, air pollution, plus CO₂ prevention further reduces the payback to 1.9 years. Onshore wind farms capable of meeting 5% of the Netherlands' total energy needs have a calculated investment cost of €6.7 billion, with comparable paybacks for offshore wind. This economic assessment should be compared with current investment commitments to determine potential savings opportunities.

Offshore Wind Parks Rotterdam - The European offshore wind industry started with the first very small nearshore projects in the early 1990s. The major developments and the start of the industrialization phase have just begun. Therefore, compared to onshore wind, offshore is still a young industry and not all developments regarding turbine production sites, harbor capacities, and O&M centers are finalized and completed.

Assuming a realistic growth scenario for future offshore wind, there is still room for additional industrial initiatives, especially in areas close to the actual wind farms.

An example of how to strategically use this type of opportunity is found with the Green Port Hull on the east coast of England. This project is linked to the growth of the domestic offshore wind market, whereby the region was able to attract major investments, in competition with and in addition to existing capacities in Denmark by Siemens Wind Power.

“Siemens £160 million investment in wind turbine production and installation facilities in Yorkshire will be based at Alexandra Dock. The investment will provide a huge boost to the UK’s offshore wind industry and the Humber region. The combined investment from Siemens and ABP of £310 million will create up to 1,000 jobs directly, with additional jobs during construction and indirectly in the supply chain.”¹²³

The UK is also transforming parts of the existing oil and natural gas industry into an offshore wind industry, leveraging available competencies and infrastructure. This is complemented by major investments in professional training and education.

In the Netherlands, however, there is not yet a defined offshore wind industrial center. The port of Eemshaven has some logistical activity, but not a thorough strategic approach to attract major parts of the value chain.

Therefore, three basic options could be investigated by MRDH:

- Attracting a turbine manufacturer to the region for turbine assembly and/or component manufacturing (e.g., MHI Vestas is limited to their Danish capacities);
- Bundle and attract the existing Dutch infrastructure and vessel companies around the offshore wind business, and create a specific competence cluster at the local port facilities (e.g., van Oord is already present in Rotterdam, Ballast Nedam);
- Develop a port area for specialized O&M services, with the aim of becoming the service harbor for the upcoming capacities in the Dutch waters.

All options can be combined or pursued individually. In particular, the last two are probably easier to execute, as there is an existing competitive basis of companies and an attractive framework for cooperation with these players, which will lead to more timely results.

¹²³ Source: Siemens Wind Power.

To appreciate the size of the market potential for offshore wind, it is worthwhile to review the estimates made by Renewable UK, the local industry's trade association. This group reports that "employment in the offshore wind industry in the UK has more than doubled between 2011 and 2015, adding 3,100 to 6,830 full time equivalent jobs. More than 2,500 (36%) of these jobs are engaged in construction and installation."¹²⁴ This is attributed to the significant rise in commissioned offshore wind projects in the country and the subsequent manpower demand. The basis of these estimates is a local market size in the range of about 1 GW/year of newly installed turbines.

"Jobs within the sector in site planning and development have almost tripled since 2010 to around 1,300, while in operations and maintenance the numbers have doubled to around 1,225. Operations and maintenance bases are needed by each new wind farm and are often built in established harbor sites closest to the offshore wind farms. Engineers and technical experts are required to ensure the permanent monitoring of operations and the production of the turbines."¹²⁵

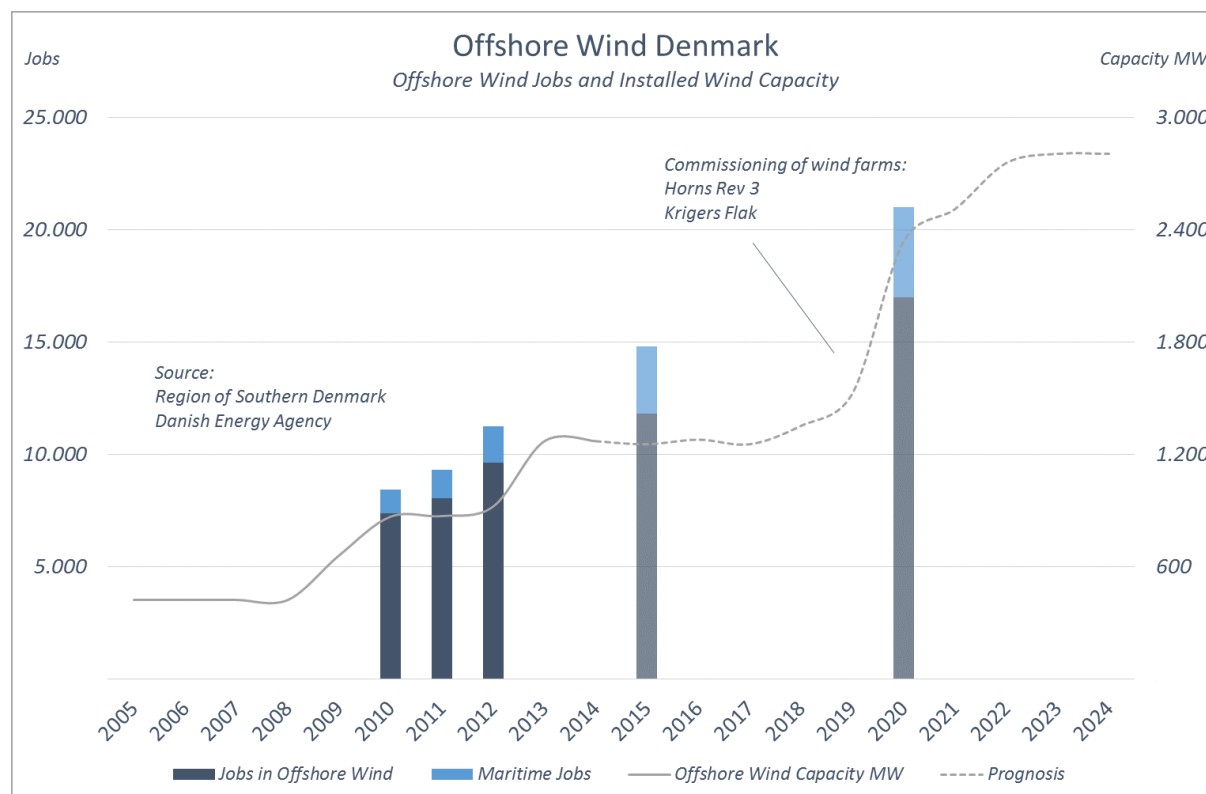
To complete the offshore wind employment picture, additional work of about 10% is typically generated in manufacturing and production design, while the remaining 17% is made up of roles in logistics, specialized transport, and other supporting services.¹²⁶ Indirect job effects are not yet considered in this overview. Figure 22 confirms the impact of offshore wind on the job market for Denmark.

¹²⁴ Source: <http://www.worldwide-rs.com/UK-is-best-place-to-do-business-in-the-offshore-wind-sector#.V9WqxVQrKUK>

¹²⁵ *Ibid.*

¹²⁶ Source: <http://offshorewind.works/offshore-wind-industry-creating-jobs/>

Figure 22: The impact of offshore wind on job creation in Denmark¹²⁷



In summary, approximately 20,000 jobs could be created in MRDH around the potential offshore wind business in the Netherlands, assuming the described capacity increase of about 2,5 GW per year is achieved. In order to draw manufacturers of wind energy plants to the seaside town, other business development agencies will need to make use of specific acquisition measures, such as the provision of knock-on financing and appropriate R&D structures. In addition, companies in the maritime area and in steel production should be encouraged to diversify their activities towards maritime offshore technologies.¹²⁸

¹²⁷ Source: <http://www.job2sea.com/News/58>

¹²⁸ Sauter, E., Treffeisen, R. and Landsberg, H., Konzeptstudie "Klimastadt Bremerhaven" - Analysen, Perspektiven, Empfehlungen, Monographie, AWI Bremerhaven 2010.

2.1.0.4 Smart Energy Proposal #8: Pursue “Dutch in the Urban Greenfield,” where Dutch design meets low carbon net energy producing districts (new business models). Contributes to RNE sectors “Urban and Residential Areas” and “Urban Greenfields”. In an Urban Greenfield, new Net Energy Producing Districts can be developed based on state-of-the-art energy technologies (e.g., renewable energy supply, energy storage and conversion, district energy management). All nodes in the district-wide, Renewable Energy Internet will be digitally connected. All appliances will be integrated into buildings’ construction infrastructure and fully connected to the data network. Appliances are not only engineered to be fully interoperable with the Renewable Energy Internet, but are also designed for comfort and ease of use. It is therefore important to develop a standardized way in which flexibility is unleashed without impacting the freedom of choice of end-users.

If communities organize their common solar panels or windfarm assets into smart microgrids, they can set up a cooperative governance structure that ensures that the benefits from cheaper and more efficient power are reinvested into the community.

The pursuit of energy autonomy for larger groups can bring significant added benefits. For example, autonomous microgrids with the ability to island from the power grid provide greater local resilience in the face of extreme weather events such as Hurricane Sandy in the U.S. in 2012.¹²⁹ A mix of local generators, both renewable and fossil, and both intermittent and non-intermittent, can be combined to jointly provide electricity to a physically-bound grid.

A micro-grid can be characterized by the following four aspects:¹³⁰

- local electricity generation;
- local load management;
- ability to automatically decouple from the grid and operate in “island mode”;
- ability to work cohesively with the local utility.

The value of a microgrid is that even in case of extreme conditions where parts of the greater power grid are damaged, it can ensure security of supply by automatically decoupling from the

¹²⁹ DNV GL Global Opportunity Report, DNV GL, 2015

¹³⁰ ‘Energy Reliability with Microgrids | Storm & Disaster Recovery - NEMA’, accessed 17 August 2016, <https://www.nema.org/Storm-Disaster-Recovery/Microgrids-and-Energy-Storage/Pages/Energy-Reliability-with-Microgrids.aspx>.

grid and operating in island mode. Microgrids are currently often used to ensure power supply to critical buildings such as control centers, hospitals, and army facilities. Microgrids *“not only improve reliability, but may also help to restore power more quickly when the central power grid is down.”*¹³¹ *“However, if major portions of the main grid or the microgrid are torn-down or destroyed in a major weather event, the microgrid capabilities are rendered less effective.”*¹³²

For the first time in the United States, and following the impacts of 2012 Super Storm Sandy (second-costliest hurricane in U.S. history), the New York State Energy and Research Development Authority has implemented a first-in-the nation \$40 million program to help NY communities design and build their own local microgrids. NY Prize is intended to assist communities in reducing costs, promoting clean energy, and building reliability and resiliency into the power grid. It is part of a statewide endeavor to modernize New York State’s electric grid, spurring innovation and community partnerships with utilities, local governments, and private sector. As stated by NYSERDA, *“Our mission is to enable the technological, operational, and business models that will help communities reduce costs, promote clean energy, and build reliability and resiliency into the grid.”*¹³³

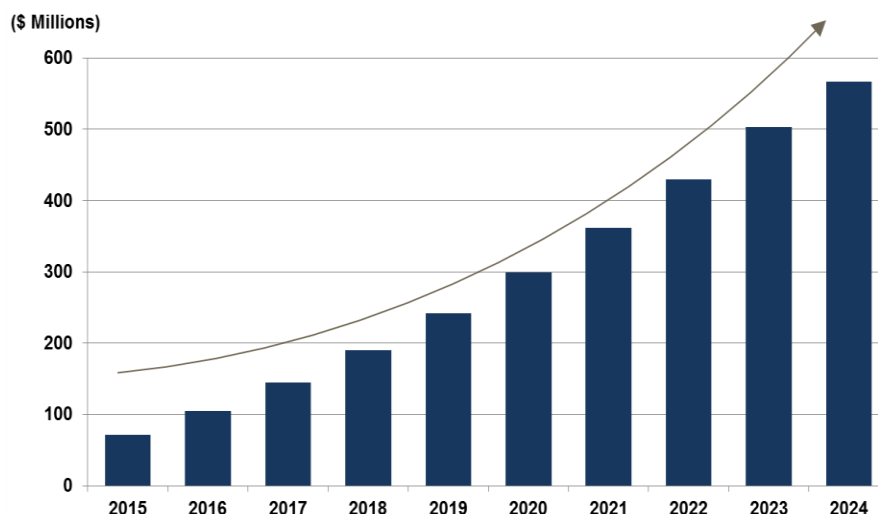
As a result of both public resiliency efforts like the NY Prize and private funding from energy developers, considerable growth and investment is expected in community microgrids, as shown in Figure 23. Over the next decade, North American community microgrid investments are forecast to increase by a compounded annual growth rate of 26%.

¹³¹ DNV KEMA, ‘Microgrids – Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts’, 2014.

¹³² Edison Electric Institute, ‘Before And After The Storm: A Compilation of Recent Studies, Programs, and Policies Related to Storm Hardening and Resiliency’ (Washington, D.C., 2014).

¹³³ <http://www.nysenda.ny.gov/All-Programs/Programs/NY-Prize>.

Figure 23: Community Resilience Microgrids – Annual Implementa



Quick Wins

There are two key areas where these principles may be implemented in a relatively short time.

This would include the following quick wins:

- *The Dutch Windwheel is an icon for a clean, circular, and digital economy.* Fifteen companies and research institutions have joined forces to develop the Dutch Windwheel; these organizations are working together on a program that aims to combine, scale, and market all kinds of promising technological innovations at the nexus of water, energy, and building technology. This program includes R&D projects for local energy production (including the EWICON technology, solar and residual heat, and heat exchange), a closed water system, development of a smart grid, smart skin, and an integrated smart city concept. The use of materials and IoT-based technologies also serves to enhance the experience and attractiveness of the Dutch Windwheel and its environment. All these “products” will be tested and developed in the Rotterdam Region, using field labs like the Green Village¹³⁴ in Delft and the Merwe 4 Harbor in Rotterdam.

¹³⁴ See: <https://www.thegreenvillage.org/about-us>.

- *Green Village is a test site, incubator, and showcase* for state-of-the-art technology in sustainability, and is located on the TU Delft campus. Its main objective is to create a sustainable, vibrant, and entrepreneurial environment to discover, learn, and show how contemporary and urgent problems regarding energy and sustainability can be resolved. Over the next ten years, students, start-ups, SMEs, large businesses, financiers, potential customers, and staff of TU Delft will perform research addressing today's societal challenges, whereby the outcomes can be tested and/or shown one-on-one in Green Village. Current future labs within the Green Villages include “Car as a Power plant,” which is an AC-DC and LED revolution.

2.1.0.5 Smart Energy Proposal #10: Implement “Core-to-the-Core Business.” Contributes to RNE sector “Industry”. The industry cluster in the ports of Rotterdam and Moerdijk is successful because these ports offer companies an ideal location. By sharing infrastructure, logistics, energy, and utilities, and by exchanging raw materials, products and residual and waste materials, companies in the cluster can operate more efficiently than if they were to run in standalone mode. This enables them to reduce their costs and strengthen their competitive position. Over the course of the years, a high level of cost reduction, improved energy efficiency and emission reductions have been achieved through means of collaboration. However, companies and stakeholders broadly share a sense of urgency that this is not sufficient and that more intensive efforts are now required in support of a number of concrete actions designed to retain, reinforce and renew the cluster through means of cooperation within the cluster and with parties outside the cluster.

Phase 1

Attention needs to be paid to producing steam, high-calorie flows (e.g., natural gas, ethylene), cooling water, waste water purification, and sludge treatment. The approach should focus on grouping these non-core activities that are of crucial importance to the core business (“core-to-the-core business”), into regional systems such as Botlek, Central Europoort, Western Europoort, Maasvlakte, and Moerdijk. A major first step is to develop an integrated, robust, and future-proof system for the supply of bio-steam in the Botlek, whereby suppliers and buyers are interconnected. This system would build upon the existing infrastructure and enable innovation of the future steam supply.

A number of interested companies have formulated the following objectives for a system of this nature:

- Cost reductions through means of economies of scale, lower investments, efficient generation, lower steam demand, and shared backup facilities;
- Supply reliability through fuel diversification, optimization of energy flows;
- Sustainability through CO₂ and NO_x reductions;
- Organization models that guarantee a win-win for all parties;
- A business climate that attracts new investments due to competitive advantage;
- Innovation including power-to-steam and biomass as an energy source.

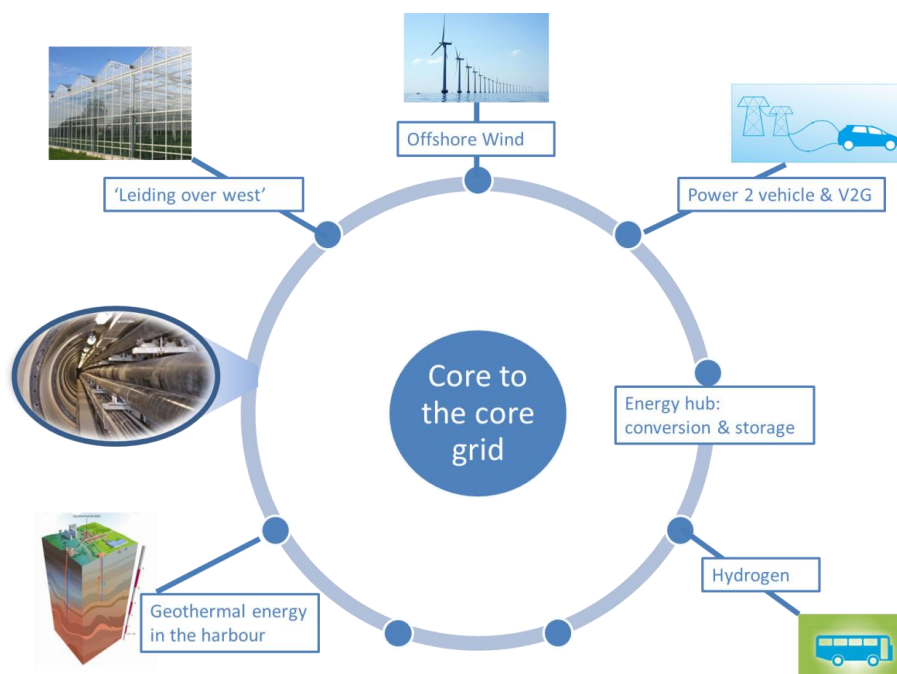
To realize a system like this, the idea is to create a management organization in the form of a cooperative on a cost-plus basis. This means that there is no profit motive and instead there is a continuous drive for cost optimization and efficiency. It is of utmost importance that the permit and grant application processes are approached at the system level by this management organization. This will result in a balanced allocation of CO₂ and NO_x emission rights among the participating parties while at the same time coordinating with the State on the applicability of the Renewable Energy Production Incentive Scheme (SDE+).

Apart from the existing waste heat (AVR) and excess heat stemming from electricity production, there is substantial unused potential for heat recovery and re-use from the existing chemical industry present in the Harbor Industrial Complex. Moreover, there is also potential for geothermal debits within the harbor terrain.

Phase 2

For the mid- to long- term, this core-to-the-core grid (see figure 24) will be enhanced as a true multi-commodity smart grid including electricity (renewable production from offshore wind farms, PV farms on the harbor industrial complex terrains), and renewable heat production from geothermal energy in the harbor. The core-to-the-core grid will not only exchange flows within the cluster, but will further strengthen the energy connections between the harbor and the region.

Figure 24: Core-to-the-Core Grid Concept



Finally the governance, organizational, and financial aspects of the “core-to-the-core business grid” is an important aspect that can be arranged by establishing an energy cooperative within the Port of Rotterdam.

Quick Wins

There are two key areas where these principles may be implemented in a relatively short time. This would include the following quick wins:

- *Pilot at a large scale: CCS Rotterdam Opslag en Afvang Demonstratieproject (ROAD¹³⁵).* “The ROAD project is intended to permanently store captured CO₂ in TAQA’s P18-4 gas reservoir, which is currently still in production but is expected to be available before the ROAD project commissions. An existing well will be used to inject the carbon dioxide into sandstone approximately 3,500 meters below the floor of the North Sea. TAQA’s

¹³⁵ See: <http://road2020.nl/en/>.

P18 gas reservoirs have the capacity to store over 35 million tons of CO₂.¹³⁶ The ROAD project involves the retrofitting of a 250 MWe equivalent of post-combustion capture and compression, to a newly constructed 1,070 MWe ultra-supercritical power plant located within the Maasvlakte section of the Rotterdam port and industrial area in Zuid Holland. Captured CO₂ will be compressed, cooled, dehydrated, and metered onsite. It will then be transported 5 km over land, via a pipeline that commences at the discharge of the CO₂ compressor, and crosses Rotterdam's Yangtze Harbor.¹³⁷ From the coast, the proposed pipeline will run 1 meter below the seabed of the North Sea, transporting the captured CO₂ to depleted gas reservoirs located approximately 20 km off the coast of Rotterdam.¹³⁸

- *Living Lab Smart Metrology (Smart Industry Field Lab)*. The goal of this field test is to facilitate the future deployment of more accurate measurements of liquid volumes, like hydrogen and LNG, as part of the 'Duurzaamheidsfabriek'. The project will develop, prototype, and test new metrology instruments, technologies, and systems with new sensors and ICT technologies. Developing the next generation of precision measuring instruments for liquid measurements is the goal of this field lab test as part of the 'Duurzaamheidsfabriek'

2.1.0.6 Smart Energy Proposal #11: Develop Urban – Industrial balancing act. Contributes to RNE sector "Industry". This proposal recommends the development of a hybrid energy system that utilizes the Rotterdam Harbor Industrial Complex as a balancing agent for Rotterdam City, in order to guarantee enough flexible capacity (MWh/a) for future FEV adoption ambitions. Rotterdam seeks a frontrunner ambition for the deployment of zero emission electric mobility, resulting in cleaner air and less traffic noise. Moreover, electric mobility can substantially contribute to the reduction of road traffic CO₂ emissions by 50% by 2025, compared to 1990 levels. Naturally, the use of clean/renewable energy sources is a prerequisite. By means of the "Stroomstoot" program, Rotterdam can facilitate the growth of FEVs in its region to more than 200,000 in 2025. By then, approximately 15% of all FEVs in the Netherlands may be found in the Rotterdam area.

¹³⁶ <http://ccsnetwork.eu/projects/road-project-rotterdam>, accessed 31-08-2016.

¹³⁷ Ibid.

¹³⁸ The Global Status of CCS, Global CCS Institute, 2014, and references therein.

The energy demand profiles of the Harbor Industry Complex (HIC) versus the Residential Built Environment do differ quite substantially. The energy demand curve for industry is typically flat today, while for residential areas the energy demand curve fluctuates between day and night, and by season. The base power loads of the Rotterdam HIC (including logistics) are about twice as much as the energy demand for the city of Rotterdam. In total, the HIC electricity consumption on an annual basis is about six times the electricity consumption of Rotterdam's built environment. Anticipating the "stroomstoot" ambitions by 2025, charging 200,000 FEVs in the Rotterdam area will require more electrical power than currently used in the city and harbor combined. The required power can be delivered by means of additional deployment of power production assets (i.e., load creation), including renewable energy, augmented through flexibility (i.e., load shifting). Local solar PV energy can be included but, will not be sufficient to meet total energy demand, assuming that 100 MW of solar PV is required to serve the electric needs of approximately 100,000 houses. An integrated combination of central and distributed energy systems is required, forming a hybrid energy infrastructure.

In the built environment of MRDH, demand is about three to four times higher than the supply of renewable energy in the harbor. Hence, additional deployment of centralized conventional energy would be required at high costs. It would also require a high load on the transportation and distribution networks, particularly in the urban environment. With the introduction of a smart renewable energy grid at the local, district, and regional (city, country, harbor) level, these costs and investments can be avoided to a large extent. In addition, the harbor's CHPs ("WKK") can also provide an additional 100 MW of energy supply.

The potential for flexible energy in the Rotterdam harbor for balancing (i.e., switching off) is about 50%. This is about 10% of the electrical power that may be required for charging poles for 200,000 FEVs in 2025. The potential for flexibility in Rotterdam City is about 250 MW, which is equivalent to 20% of the required power. Arranging flexibility in the city through residential load shifting would require millions of electrical appliances in an urban smart grid, as opposed to the limited number of energy consumers and increased complexity found in the HIC.

Quick Wins

There are two key areas where these principles may be implemented in a relatively short time.

This would include the following quick wins:

- *Smart Energy Business Parks.* Smart Energy Business parks can apply brownfield and greenfield approaches to developing business parks. Identifying brownfield business parks (e.g., park management companies) for potential energy efficiency measures, sustainable energy generation, and flexibility options (e.g., balancing, energy storage). New greenfield business parks can become net zero energy districts with smart grids.
- *Bio-based Refineries.* Bio-based refineries can make biochemical and bioplastic, while generating electricity and heat, without using fossil fuels and emitting CO₂. Several types of biomass can be used for bio-based refineries, including the use of wood. By refining wood, instead of burning it, several interesting products arise including lignine and sugars. These sugars can be used to make bioplastics. Lignine can be used to generate heat and electricity, plus chemicals and fuels. The Port of Rotterdam, bioplastics company Corbion, and energy companies RWE and Uniper are working together because of mutual interests in bio-refineries, as part of the circular economy. An extension of the network that includes other partners and public-private finance can contribute to further development while diminishing risks for all the parties.

2.1.0.7 Smart Energy Proposal #16: Transform the primary role of energy. Contributes to all five RNE sectors. The traditional role of electric and natural gas utility companies is shifting as a result of IoT tools and technologies disrupting their business models. Changing customer needs, evolving policy and regulation, and accelerating innovation around distributed energy resources (DER) and digital technology, will drive the creation of more distributed transactions and dynamic business models. These developments will also spur a more democratized and sophisticated grid platform and a rapidly evolving ecosystem of incumbents and disruptors. The ongoing confluence and convergence of the Internets of Communications, Energy, and Mobility and Logistics are creating an expanding pool of exergetic efficiency-productivity gains at the end-use of delivered energy services (demand-side).

New business models are available and essential to capture this vast next economy value chain. The focus is shifting from extracting expensive supplies with large, costly ecological footprints, shipped over long distances, to delivering high-efficiency energy services at the point of use, with the least lifecycle costs and risks. Electric utility companies will need to shift into being aggregators and operators of the Renewable Energy Internet and distributed and delivered energy services. Major utilities like E.ON and RWE are already splitting off their conventional fossil and nuclear generating businesses from the new business models that concentrate on

customer services in the emerging Energy Internet. With an estimated \$1.5 trillion in new annual industry revenue available globally by 2030, new entrants—manufacturers; technology companies (from startups to global powerhouses like Apple, Amazon, and Google); telecommunications and other data, content, and network providers; and even some oil and gas companies (like Total)—have the rare opportunity to disrupt a status quo nearly 150 years in the making. Creating new opportunities for growth across the value chain, new energy and digital technologies are lowering the barrier for entry into a highly regulated industry.

However, the biggest challenge will be balancing ongoing investments in the grid as the total energy volume (and with that, revenue) that flows through core, centralized components decreases over time. This includes mitigating the risk of stranded assets that may become obsolete or financially unsustainable, as well as their costs to incumbent utilities, customers, and society. For MRDH, this transition of the role of energy companies will likely take many years, but it is important to begin to review policy and business model transition paths early in the RNE life-cycle, as these changes are already occurring in many global locations.

2.1.0.8 Smart Energy Proposal #18: Integrate Blockchains into the Promotion of microgrids and cooperative-based Renewable Energy Internet initiatives. Contributes to RNE sectors “Urban and Residential Areas” and “Urban Greenfields”. If communities organize their common solar panel or windfarm assets into smart microgrids, they can establish a cooperative governance structure that ensures that the benefits from cheaper and more efficient power are funneled back into the community. To ensure cooperatives cannot be monopolized by one player, the governance can be organized into an incorruptible distributed autonomous organization (DAO) with smart contract structures built on the blockchain. This is also a means for the coop to instill confidence in social-impact investors that may wish to finance their operations under a benefits corporation (B-corp) arrangement.

A recent example in the United States involved a joint effort between LO3 Energy, a green energy start-up, and ConsenSys, a decentralized applications start-up, in which residents of a Brooklyn, New York neighborhood were producing, selling and buying excess renewable energy from each other as part of TransActive Grid. Using the Ethereum blockchain technology, every unit of energy generated is being counted and logged; programmable smart contracts are then used to make units of renewable energy available for sale on the open market. For example, on one day, 195 credits were purchased for US\$ 0.07. The platform has the potential to scale as it

involves a series of hassle-free transactions, equivalent to purchasing the same amount of energy from the local energy supplier.

2.1.1 TECHNICAL

2.1.1.1 Smart Energy Proposal #9: Deliver geothermal for the Greenport. Contributes to RNE sectors “Urban Brownfields” and “Food and Flowers”. Accelerate the use of geothermal energy in the Greenport by means of facilitating at least 20 new geothermal wells in 2020, connected to the local energy infrastructure. In a recent study of the Province of South Holland, five potential energy routes towards fossil-free, renewable, and sustainable energy were identified:

1. Heat from geothermal sources,
2. Wind on land in areas with low-density population,
3. Bio-based feedstock,
4. Energy supply from green houses, and
5. Temporary use of spare land for solar farms, which can be relocated.

The deployment of geothermal energy requires substantial investments of about €10M to €15M per 4 km of depth, and well up to €20M for 6km depths. At the same time, benefits will not accrue until later project stages. For a horticulture company, this is often a very large investment. In the majority of the geothermal projects, the investment pain is felt mostly at project commencement. Banks do typically require 30 to 40% cash contribution from equity, which often proves to be too much of a challenge in the current entrepreneurial climate.

Currently, the SDE+ scheme supports the operational phase. The SDE+ is an important tool for covering the financial gap found in geothermal energy projects, but this tool does not assist in the financing phase.

Horticulture initiatives that have been previously undertaken (prior to 2012) have usually been able to work with the so-called Market Introduction Energy Innovation fund (MEI-regeling), obviating the problems described above. Stopping the MEI-funds led to project stagnation, with 30 applications in 2012, to 15 in 2013, and to only 4 in 2015.

Quick Wins

There are three key areas where these Quick Wins may be implemented in a relatively short time.

This would include the following quick wins:

1. *Land-based Wind Turbines in the Greenport* - In addition to the harbor, the greenhouse areas of Westland, Oostland, and Waddinxveen form a large industrial landscape where wind turbines can be relatively easily placed.
2. *Rooftop PV for Public Transport locations* – There are four metro stations with solar PV installed, but installation at many others is feasible. Starting with four RET metro stations, each with about 600 solar PV panels, renewable electricity is generated locally for that station's power needs. With a payback period of 10 years, made possible by a state tariff subsidy, a positive business case can be created. Total investment is calculated at approximately €860,000. MRDH has more than 50 metro stations and 30 light rail stations with roof volume (station ceilings, elevator shafts, partly on the infrastructure and the like) suitable for solar panels. There are also depots, workshops, building traffic, and rectifier stations with available rooftop space. The generated power can be supplied back to both the stations, trains, and to the utility to pay for the investment. The investment can be either from own resources (BDU) and loan sources (such as the European Investment Bank), provided that interest rates are reasonable. Any financial gap in the early stage of a major business case would again be eligible to win an additional EU subsidy, due to the project's potential contribution to the National Energy Accord. The RET and HTM, together with MRDH, can decide whether the local spatial impact is limited and what licenses are necessary.
3. *Solar PV on pipeline corridors* - The Harbor Industrial Complex occupies about 450 hectares of pipeline corridors. Altogether, they host more than 1500 km in pipe length, 2500 km in high-voltage power cables, and 800 km in utility pipelines. For safety and maintenance reasons, the pipeline corridors are restricted areas for further building. Nevertheless, the 450 ha offers a considerable opportunity for installing solar farms, as long as these farms are constructed in a manner that does not impede pipeline maintenance. Currently, a solar PV farm exists near the Suurhoffbrug, which is a pipeline corridor installed deeply underground. This 3-hectare solar farm can produce 1,750 MWh on an annual basis, which is equivalent to the power needs for 500+ households.

Together with the building and construction technology present in MRDH, this solution can be installed and scaled within pipeline corridors. In the short-term, this could be developed for at least 100 hectares.

2.1.1.2 Smart Energy Proposal #14: Create a testbed environment to demonstrate the concept of the MRDH “Energy Superhighway” (technical). Contributes to all five RNE sectors. The “Energy Superhighway” is a crucial element of the larger Renewable Energy Internet. The Internets of Communications, Smart Energy, and Smart Mobility & Logistics create opportunities for achieving significant exergetic efficiency-productivity gains (in both capital and O&M expenditures), as well as generating new business opportunities and value streams. The importance of interoperability and coordination with entities and infrastructure, like smart cities, smart buildings, DER, and electric transportation, cannot be understated. There should be linkages among transmission operators, distribution operators, energy suppliers, third parties, and all of their associated systems. It is suggested that MRDH work with national and local stakeholders to establish a demonstration project within the region. This testbed environment will have several foundational components which, when interconnected as a large-scale program, will enable MRDH to move towards the Energy Superhighway.

The first and most immediate component is to accelerate smart meter-enabled, network applications beyond business as usual. As smart meters continue to roll out in 2016, MRDH can work with the energy distribution companies (e.g., Stedin) to facilitate emerging, next-generation advancements in network applications, via the installation of smart meter technologies at scale. Demonstration projects should be situated in MRDH to illustrate how these advancements could accelerate more common applications, such as volt/VAR optimization, conservation voltage reduction, load balancing, outage management, transformer overload detection, high impedance fault detection, and more. Smart meter data exchange platforms can facilitate the development of innovative rate design and related service offerings. Smart meters can enable businesses and homeowners to monitor and adjust their energy use and accrue substantial energy savings, either through near real-time pricing of electricity, or through selling stored electricity (via battery storage systems) back to the grid operator.

In other cases, building owners can go off-grid, using the stored electricity until the return of off-peak electricity prices. Traditional telecommunications firms are now seeking to expand their business into the power market and pursue new opportunities related to electricity data management services. Progressive MRDH electricity distributors will explore ways to position

themselves in the new data-service environment, whether as a market facilitator or partnering with emerging companies. For example, Dutch DSO Alliander has developed a real-time, energy exchange platform (REX) to support flexible tariff monitoring.

In parallel with the smart meter roll-out, MRDH would ideally develop a holistic and scalable Smart Grid 2.0 infrastructure. The smart grid should be capable of dealing with a rising number of distributed energy sources: the provision of detailed information to the consumer to promote their active involvement in energy efficiency; public lighting control; the integration of the electric vehicle infrastructure; and the efficient monitoring of asset conditions. Once the deployment of smart meters is fully rolled out, MRDH could collaborate closely with the TSOs and DSOs to support the advancement into this next phase of the smart grid development. Demonstration projects could be implemented in the region to test new business models and transactive energy exchanges, including active demand response technologies, integration with smart homes, smart metering data processing, integration of DER, automation and control of networks, and integrated telecommunications solutions.

***2.1.1.3 Smart Energy Proposal #15: Develop a Smart Multi-Commodity Grid (technical).
Contributes to all five RNE sectors.*** Smart grids or smart energy systems are enriched with ICT solutions to provide increased control and flexibility. They enable a transition towards a sustainable energy system which is one of the essential pillars of the Third Industrial Revolution. The intermittent character of renewable energy sources requires a system where, instead of a traditional, top-down energy infrastructure, the energy system becomes a true, two-way system that is able to seamlessly match supply and demand under all conditions.

A multi-commodity approach is required as a continuous and undisturbed delivery of power cannot be guaranteed by a system based on separate, renewable energy sources. Moreover, it is attractive to use energy conversion options between various commodities and energy storage facilities, from both a technical as well as a commercial view. These can provide significant optimization opportunities to reduce OPEX and CAPEX on a smart, multi-commodity grid, as well as improve the reliability of the system. This requires a seamless integration of utility networks and requires a coupling of production, energy storage, and demand response, both during the design phase as well as during operation of the system. Importantly, the design of a smart multi-commodity grid should ensure that the comfort level of end-users remains uncompromised to increase acceptance by all the stakeholders.

The energy strategy for MRDH centers on reducing the overall energy demand and flattening the demand curve by reducing peak energy use. A wide range of sustainable energy technologies will be deployed that need to interact with and complement each other, to meet the region's ambitious decarbonization targets, and create an energy neutral region.

Using renewable energy resources effectively and reliably is made possible by dynamically matching supply and demand. This requires a smart electricity grid that enables seamless information exchange between the various components and actors in the system. Energy conversion, storage, and exchanges should be facilitated within the individual utility infrastructure, as well as between them, to mitigate the intermittent character of the various renewable energy technologies and changing user consumption.

The Energy Internet (smart grid) can be operated using a control mechanism for multi-goal optimization of consumption, generation, storage, and demand-response to optimally balance overall energy demand and supply. The control mechanism allows the soft control of connected devices via consumer incentives and user preferences. This includes, for example, low-cost time periods when consumers may want to schedule appliances to run or electric vehicles to charge. Incentives can be part of a pricing strategy or result from immediate operational needs, such as shedding of excess load. Network losses can be minimized by creating similar incentives. Historic and trending data can be incorporated to enhance forecasting and planning.

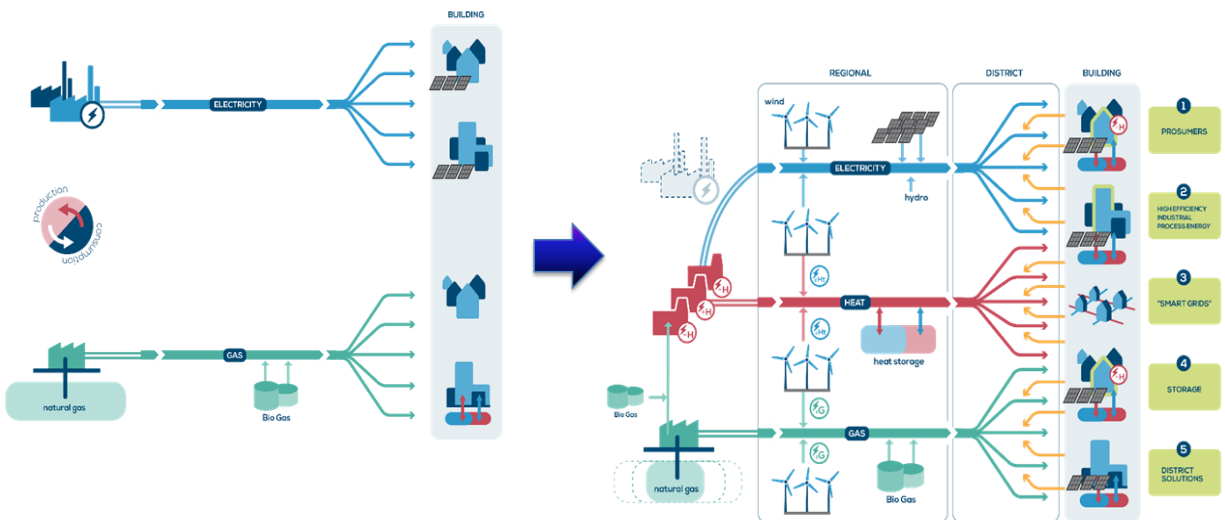
Energy neutrality at the residential, district, or regional level means that the energy consumed is equal to the energy generated. However, it does not say anything about the important aspects of time of use and transportation and distribution. Distributed renewable energy resource technologies also provide possibilities to generate energy close to the local use. Flexibility options such as energy storage, demand response, conversion, and system integration should prevent wasteful transport of energy and extensive upgrading of the energy infrastructure. ICT is becoming part of every aspect of the energy supply chain, requiring a smart underlying energy infrastructure that is used on a daily and real-time basis for enabling new business models and digitally-enabled markets. Finally, with the end of the technical life cycle of the gas infrastructure, zero gas districts may also be present. How may this network be designed? Communities may be self-sufficient, as much as possible, but local circumstances and solutions will vary, thus no common blueprint will likely exist.

A Smart Multi-Commodity Grid would not exclude any energy sources or technologies. In fact, it can reinforce all of them. A Smart Multi-Commodity Grid is a coupled natural gas, electricity,

and heat grid that is optimally adapted to integrate renewable energy, without developing “three golden grids.” A Smart Multi-Commodity Grid is not limited to electricity alone, nor is there a “one-size-fits-all” approach. The set-up varies per district, whether they are all-electric, heat, all gas, self-sufficient /autarky, with or without energy storage (including electric vehicles) and conversion, or have other flexibility options. Different geographical and scale levels can be determined as follows (see figure 25):

- *Macro level* – large-scale network for industrial / harbor / agribusiness activities (high temperature, waste heat, CO₂);
- *Meso level* – medium-scale network for agricultural and farm-producing energy for about 500 households, with biomass, CHP, and other sources;
- *Micro level* - local, small-scale energy network, potentially off-grid or with a hub and spoke system, including solar panels, heat pumps, and local energy storage. Configurations will vary due to local settings and whether they are all-electric, heat/electric, gas/electric, or DC networks.

Figure 25: Illustrative View of SMCG Levels



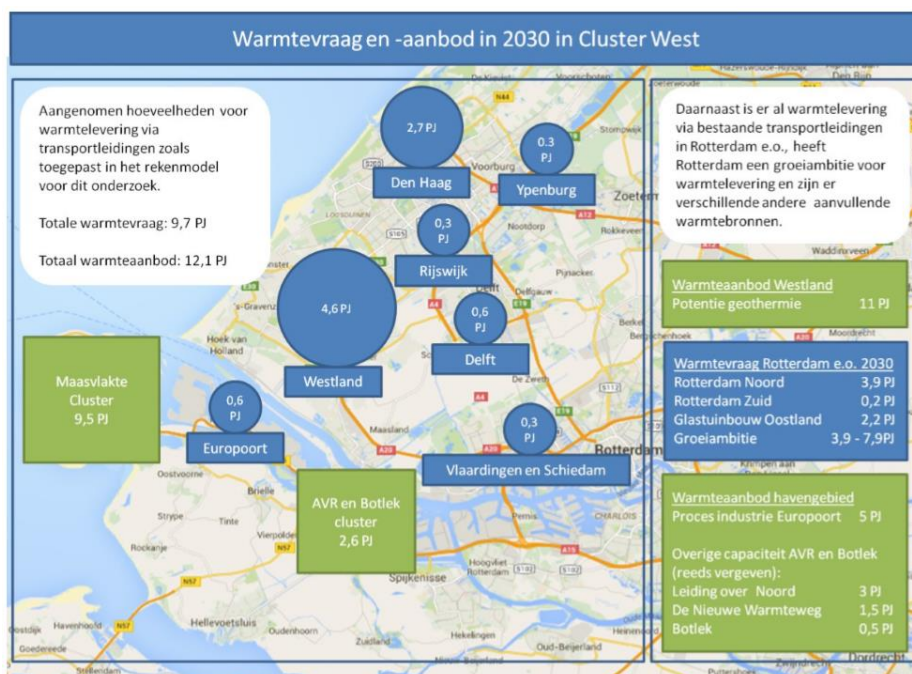
Quick Wins

There are two key areas where these principles may be implemented in a relatively short time.

This would include the following quick wins:

- *Only Vehicle-to-Grid charging poles.* A policy that requires that every new charging pole in MRDH be bi-directional, providing a no-regrets basis for Vehicle-to-Grid (V2G) extension of the power grid. Electric vehicle charging poles are already being installed within MRDH. However, with a small additional investment, these charging poles can be made to be bidirectional. The use of electric vehicles could buffer intermittent, renewable power sources such as wind or solar, by storing excess energy produced during windy periods and providing it back to the grid during high load periods.¹³⁹
- *Western Pipeline - Excess Heat network.* Demand for heat in the southern Randstad is substantial, not only in the cities but also for greenhouses. The total demand for heat in the southern Randstad in the urban areas and greenhouses is approximately 112 PJ. Energy conservation is expected to reduce this demand to approximately 80 PJ by 2050. The Cluster West area (shown in figure 26) has a total heat demand of 68PJ.

Figure 26: Cluster West Area Overview



¹³⁹ Smart grid data analytics for decision support, Prakash Ranganathan and Kendall Nygard, DOI: 10.1109/EPEC.2011.6070218.

The supply of waste heat and geothermal potential is also high in this region. The annual amount of heat alone that is cooled off in the Port of Rotterdam, is equivalent to 12% of the amount of gas used for warmth in the Netherlands. With waste heat and geothermal energy, the potential heat supply of 40 to 60 PJ may be available along the southern Randstad by 2050. This is 50 to 75% of the heat demand in the southern Randstad. The Western pipeline is the most appropriate source to meet the potential heat demand in the Westland region. Extension of the main infrastructure to The Hague – by exploiting the excess capacity of the existing infrastructure (“Pijplijn door het midden”) – is the most logical step to meet the heat demand of the city. The Western pipeline can then be sourced for low temperatures and the other for high temperatures, which can meet differences in local heating needs, especially at desired temperatures.

It should be noted that the viability of waste heat networks is closely linked to the long-term availability of the heat sources feeding the grid. Only when the availability of excess heat can be guaranteed for the economic lifetime of the grid, does a heat grid make sense. Write-off periods and tariffs should be set favorably by the regulator in order to make the business case.

In a global economy where production locations can change quickly when economic circumstances change, the security of supply of excess heat during the typical lifespan of the supporting infrastructure is by no means a given. This is probably even truer for a region embarking on an ambitious deep decarbonization effort like MRDH.

Finally, the creation of waste heat grids impacts the business case for geothermal solutions in the Westland region, so a careful assessment of the optimal application of both technologies is required.

- Quick win – *Power2Hydrogen station*. Construction of Power2Hydrogen stations in the Rotterdam Port area to convert and store excess wind and solar power.

2.1.1.4 Smart Energy Proposal #22: Pursue Hydrogen for Zero-Emission Public Transport (technical). Contributes to RNE sector “Mobility”. By 2020, 50 to 100 hydrogen busses, 5 to 10 filling stations, and 50 hydrogen cars are all expected to be using hydrogen infrastructure. This means that fleets of zero-emission public transport city busses can be realized. A Green Deal for city busses has been agreed to by Rotterdam, which includes both electric and hydrogen-electric pilot programs. A Rotterdam-based pilot with two hydrogen busses will start in 2017.

The province of South Holland is developing a pilot on the island of Goeree Overflakkee, with the goal of developing 10 hydrogen buses and one filling station within 2 years, and 50 to 100 busses and 5 to 10 filling stations within 5 years.

Hydrogen can also migrate to a fully sustainable design within this time period. In parallel, but mid- to longer-term, filling stations can be made accessible for fueling hydrogen-powered cars and expanded to other cities. This should result in a region-wide network of hydrogen filling stations, thus creating critical mass for further investment. In addition, other hydrogen-powered vehicles can leverage this network, where critical mass is insufficient to develop their own network. Heineken, for instance, is currently investigating this approach.

In parallel to these fleets, an innovation and education/training center will be developed. In order to facilitate the learning curve, all available knowledge and experience will be brought together and new skills and businesses will be developed. The developed businesses and skills (e.g. installation, certification, production, service and maintenance, insurance, inspection, firefighting) can be applied to these fleets and networks, as well as exported to other countries. Collaboration with the RDM training plant could also be pursued.

2.1.1.5 Smart Energy Proposal #23: Continuously strengthen smart grid and smart energy cyber and physical security standards and protocols (technical). Contributes to all five RNE sectors. Smart grid and smart energy cyber and physical “security must address not only deliberate attacks, such as from disgruntled employees, industrial espionage, and terrorist actions, but also from inadvertent compromises of the information infrastructure due to user errors, equipment failures, and natural disasters.”¹⁴⁰ Major concerns for energy users with regards to cyber security relate to the integrity of data used for automated applications. Typically, encryption solutions are deployed by utilities to solve this problem. Additional costs to implement cyber security standards can influence the deployment of new IT solutions. The Hague has already established itself as a major hub for cyber security in Europe and its focus should include smart grid cyber security. Physical attacks on critical energy infrastructure are less common, but can have significant consequences, especially where critical electrical components are expensive and time-consuming to replace. The recommendation for MRDH is to build in cyber and physical security testing and validation of protection standards as a required component of all Smart Energy Delta programs and demonstration projects.

¹⁴⁰ See: https://www.smartgrid.gov/recovery_act/overview/cyber_security.html

2.1.1.6 Smart Energy Proposal #24: Expand the MRDH Energy Superhighway to include the Port of Rotterdam (technical). Contributes to RNE sector “Industry” and “Urban Brownfields”.

It is well understood that the Port of Rotterdam is a tremendous potential resource in an extended heat network for MRDH. There is strong potential to build on the existing De Nieuwe Warmteweg (DNWW) project and the proposed Eneco project for Leiding over Noord. It has been estimated that the residual heat from the port could provide heat for some 350,000 homes, saving some 20 petajoules of energy per year. There is, therefore, immense potential for further exploitation of waste heat in the Port of Rotterdam and the surrounding area. In addition, the Port of Rotterdam is already accelerating its use of solar and wind power. There are further opportunities for the integration of renewable energy and industrial combined heat and power (CHP) systems as part of a port microgrid. A microgrid is not a single technology, but rather a system of systems. In the most common configuration, distributed energy resources (DER) ranging from solar PV systems to CHP plants to energy storage are all tied together on a distribution feeder, which is then linked to the larger utility grid at a single point of common coupling. The Port of Los Angeles, for example, plans to install a \$26.6 million solar microgrid in 2016 as it moves toward becoming the first marine terminal to operate solely on renewable energy.

A port microgrid would be a core element of a hybrid energy system for Rotterdam that utilizes the Rotterdam Harbor Industrial Complex for power balancing needs, guaranteeing enough flexible capacity (MWh per year) to meet emerging energy requirements, including a vastly expanded electric vehicle fleet. The hybrid energy system would incorporate active demand management and microgrid technologies and be based on a scalable network of DER technologies that can be monitored, controlled, and dispatched as a virtual power plant.

The Port of Rotterdam is already investing in hydrogen production and technologies. It is the co-founder of the Netherlands’ National Hydrogen Platform and took delivery of the port’s first hydrogen car in 2016. At present, hydrogen is largely generated from natural gas, but the growth in renewable generation offers the possibility for hydrogen to be an important element in a zero-carbon port.

Hydrogen fuel cells also have the ability to offer a clean, quiet, and efficient power source for ports. Fuel cells generally have three broad application areas: stationary, portable, and transportation; they can be deployed in port operations for all three of these applications. The

technology has the ability to help provide electricity for shore power used in cargo and cruise ship applications, to replace diesel or gasoline-powered yard tractors, heavy duty trucks, and passenger cars used at port facilities, and to potentially power forklifts and container cranes.

Fuel cell technology has had several demonstrations in a number of ports around the world. The Port of Los Angeles currently uses over a dozen fuel cell vehicles (FCVs), mainly short haul drayage terminal tractors, but also one Tyrano Class 8 truck with a 200-mile range capability. Most recently, the Port of Honolulu was chosen as the site for a demonstration project by the U.S. Maritime Administration (MARAD), the U.S. Department of Energy (DOE), and Sandia National Laboratories. The aim of the project is to explore the potential cost savings and emissions reductions of hydrogen fuel cells at ports. MARAD is providing \$700,000 in funding to support the construction of a portable fuel cell power system, which will help power onboard systems for ships, tugs, and barges operating between the Hawaiian Islands.

The need to deploy a hydrogen infrastructure is one of the biggest hurdles to the expansion of its use in transport and other sectors. A combined strategy for the port and the MRD harbor and industrial complex, and local bus transport reduces the required scope and therefore the cost of the infrastructure and can accelerate the achievement of significant economies of scale.

2.1.1.7 Smart Energy Proposal #25: Leverage geospatial visual mapping to determine optimal sites for wind farms (technical). Contributes to all five RNE sectors. Visualization is a powerful tool for determining optimal opportunities for harnessing MRDH's solar resource assets, and improving return on investment (see: www.zonatlas.nl).

Greater value can accrue from these mappings by integrating other key algorithms and apps for performing critical analyses of 1) How much energy is available hourly, daily, and seasonally; 2) Economic assessment of the levelized cost of electricity of solar opportunities compared to fossil fuels, including monetization of externalities and price volatilities (e.g., fuels, water, emissions, pollution); 3) Financial engineering calculations selected from a number of available financing options (e.g., bonds, Pay-on-the-Bill arrangements, Power Purchasing Agreements/PPAs); 4) Priority ranking of a city's solar opportunities for implementation over time; 5) Accessing the wealth of knowledge and evidence on best-in-play policies, codes, and regulations aligned to reduce the time, cost and risk of getting these opportunities implemented; 6) In-depth multimedia presentations (e.g., YouTube videos, Flickr visuals, RSA-type animations) of successful case studies, skills development, capacity building, technical training, and other learning tools.

For on- or off-shore wind farm siting, advanced 4D data visualization tools enable lifecycle planning that integrates siting, architectural-engineering-construction processes, virtual monitoring of performance metrics, predictive maintenance, repair and replacement procedures, and related operating data (see: <http://www.awsopenwind.org/>). Ongoing development and use of a suite of virtual reality tools and technologies are projected to help continue reducing costs and improving performance of wind farms. Experience gained in the application of these Internet-based tools (in remote control rooms, with onsite mobile devices, and accessed through smart sensor networks embedded in wind equipment) generate ongoing learning curves that enhance the competitive export of offshore wind farm development in coastal locations worldwide.

2.1.2 REGULATORY

2.1.2.1 Smart Energy Proposal #17: Explore alternative, performance-based regulatory led schemes that focus on customers and innovation (regulatory). Contributes to all five RNE sectors. Utilities are still largely shaped by regulation, and how they respond within the next decade is important to their longevity and relevance. With some exceptions, utilities have generally not been granted much flexibility to assume significant risk when investing in emerging technologies or pursuing new business models. As with any such investment, the risk-reward calculus is important. Given the changing energy environment, alternative performance-based regulatory schemes may be a way forward to incentivize utility focused on customers and innovation. In the UK, the energy regulator has implemented a “Revenue = Incentives + Innovation + Outputs” (RIIO) model which encourages innovation through an emphasis on measurable outputs, funding support and a focus on customer engagement. A similar model could be demonstrated as a pilot in the region.

Energy markets are evolving and volume-based tariffs are becoming less appropriate for cost recovery. More customers are seeking measures to decrease their electricity bills. Users aim for zero energy consumption by generating their own electricity, effectively “presuming,” and even perhaps disconnecting from the grid altogether. Fixed costs for grid infrastructure and operations are being recovered from a shrinking customer base and the higher penetration of renewables is becoming less ideal for DSOs to recover existing integration and operation costs. We suggest that MRDH work with energy distribution companies and suppliers to examine

alternative tariff structures for financing the energy transition. These new tariffs structures will need to incorporate the monetized cost of energy supply externalities, including CO₂ emissions, methane leakage, air pollutants, and waste contaminants. Ongoing research on the social cost of fossil fuel externalities significantly increases the cost of generating a kWh, making end-use efficiency, wind, and solar technologies more attractive commercial alternatives.

2.1.3 POLICY

2.1.3.1 Smart Energy Proposal #6: Develop a joint regional plan with TenneT to improve access to imported renewables through interconnections (policy). Contributes to all five RNE sectors. Taking a regional view on energy supply may be required, given MRDH's limited space to develop onshore renewables and the long timeframe for developing offshore wind. Access to clean energy in the interim could be sourced through interconnections from other European countries with a strong renewables mandate. Building interconnections is the key to managing intermittent renewable sources, especially in addressing security of supply issues and smoothing out volatility in capacity, power quality, and prices. There are already plans underway in the Netherlands to increase electricity imports from other countries. MRDH, along with TenneT, should develop a joint regional plan to determine an optimal transmission pathway to improving the region's access to imported renewables.

2.1.3.2 Smart Energy Proposal #7: Nurture and scale community renewable energy projects (policy). Contributes to RNE sectors "Urban and Residential Areas" and "Urban Greenfields". Community energy projects are a developing trend across Europe, providing groups and communities with sustainable energy and additional collective benefits from the projects. These projects could help MRDH reduce GHG emissions; increase energy security; create local employment opportunities; and engage citizens with energy projects and renewable energy. The European Commission sponsors the European Federation of Renewable Energy Cooperatives, or REScoops, as described below.

There are more than 1,240 individual REScoops all over Europe, where citizens are actively engaged not only in RES electricity production, but also in heat production in district heating cooperatives. REScoops bring benefits to their local economies and are helping the EU to reach its renewable energy and energy efficiency targets. REScoop.eu provides procedures for starting a REScoop, as well as information on business models, financing, and best practices.

More than 90 Dutch local energy cooperatives have been established over the past decade, in addition to 16 wind energy cooperatives established over the past 30 years. Some examples of these local energy cooperatives include the following:

- De Windvogel - an MRDH-based cooperative consisting of 3,300 members and 6 wind turbines generating 7,600 MWh/year;
- Organisatie Duurzame Energie Nederland (ODE) - a Dutch association of renewable energy producers and consumers, consisting of 12,500 members and 15 REScoops. Members include citizens, cooperatives, and businesses.

2.1.4 EDUCATION

2.1.4.1 Smart Energy Proposal #19: Develop energy educational programs based on the Smart Energy Delta platforms and co-operative principles (educational). Contributes to all five RNE sectors. As digital technologies proliferate and new energy stakeholders and business models emerge, the need for new entry-level talent and innovation becomes more critical to achieving MRDH's ambitions for cleaner, distributed, and intelligent energy systems (i.e., Energy Superhighway). Programs should be directed towards secondary and university-level programs, in order to attract and retain millennial candidates into the traditional and evolving energy industry. This would include technical courses regarding power systems and microgrid engineering, renewable energy economics, and alternative policy/regulatory understanding. Emphasis should also be placed on business, manufacturing, and ITC skills. Where appropriate, cooperative principles can also espouse values of self-help, self-responsibility, democracy, equality, equity, and solidarity. Ethical values of honesty, openness, social responsibility, and caring for others are also emphasized. The emphasis should be on developing short, intensive, and flexible, public/private courses and training materials for energy stakeholder staff, which are considered most relevant and pertinent to labor market needs.

2.1.4.2 Smart Energy Proposal #20: Develop a tailored offshore training concept (educational). Contributes to all five RNE sectors. The question of providing for the right skill sets required by the local work force to fulfil new job openings is closely linked to the creation of new jobs. Especially in new and challenging industries like offshore wind, special training is

required. The standard approach is to create training centers tailored to the demands of the local industry or value chain. For example, the National Wind Farm Training Centre offers accredited industry standard training courses to future wind farm professionals.

As an alternative, large actors can be supported to develop in-house training capabilities, a solution preferred especially by the large OEMs as they are often concerned about protecting their intellectual property. Siemens has invested £4 million to establish a facility in the UK (as shown in figure 27), including a 2.3 MW and 3.6 MW training nacelle, training towers, and electrical and mechanical work stations.

Figure 27: Offshore Wind Training Center in the UK¹⁴¹



For less skilled training, the focus is on two core areas: safety and technical skills, replicating as far as possible “real-life” field conditions. Emphasis is put on equipping technicians who are new to the wind power industry with the complete set of skills they need to service onshore and offshore wind turbines.

¹⁴¹ Source: Siemens Wind Power.

2.1.5 FINANCIAL

2.1.5.1 Smart Energy Proposal #3: Stimulate utility and supplier-based innovation (financial).

Contributes to all five RNE target sectors. At the domestic level, some European countries have been active in stimulating utility and supplier-based innovation. For example, in the United Kingdom, the energy regulator (Ofgem) has established two innovation stimulus programs for electricity and natural gas utilities. The Network Innovation Allowance (NIA) funds commercial, technical, and operational research and development projects and enables utilities to spend 0.7% of revenue on innovation projects, 90% of which can be recovered through the incentive mechanism. Network Innovation Competitions (NICs) are run by Ofgem to fund development and demonstration of new technologies, operating and commercial arrangements, and to deliver carbon reduction or improved environmental benefits for customers that are not otherwise funded. Up to €102 million and €34 million is available for electricity and natural gas transmission and distribution-related projects. MRDH and ACM could establish a joint similar stimulus funding scheme to promote grid modernization and utility innovation.

2.1.5.2 Smart Energy Proposal #12: Accelerate Rooftop, Community, and Utility-scale Solar PV systems (financial).

Contributes to RNE sector “Urban and Residential Areas”. The upfront capital cost for developing solar PV power systems capable of providing 34.6% of the Netherlands’ total energy needs has been calculated recently at 232 billion Euros (in 2016€). This includes 31.4% from utility-scale solar PV at €195 billion, and 3.2% from residential and commercial rooftop solar PV at €37.2 billion. This economic assessment should be compared with current investment commitments to determine savings opportunities.

While rooftop solar PV systems are a relatively rapid way of installing renewable capacity close to the point of use by the consumer, these systems are also the most expensive means of installing solar power generating capacity. Community-based systems can provide a greater return on investment for the same solar capacity, and offer several additional advantages including:

- *Less reliance on adjacent technologies* - unlike rooftop solar, community solar systems do not rely on advanced metering and grid technologies;
- *Increased residential access* - only between 22% and 27% of residential properties are suitable for solar;

- *Ease of access for all consumers* - community solar targets green consumers who want access to solar-generated power, but are not eligible to install a rooftop system or do not want to deal with the complexities.

Regulatory stability is of key importance to secure investment in renewable energy sources. Before 2003, renewable energy in the Netherlands was supported through tax exemptions. Then the first feed-in premium scheme (Environmental Quality Electricity Production, MEP) was put in place for the period 2003-06. By 2008, the Dutch government introduced a feed-in tariff scheme called Stimulerend duurzame energieproductie (SDE), which ran until 2011. SDE was then reformed into a market-based, cost-effective premium scheme aligned with EU directives, financed by a surcharge on the final consumer's bill, and renamed SDE+.

In addition to SDE+, other financing schemes are emerging that enable multiple building owners to combine their energy needs and install larger-scale, renewable energy systems on a community-wide basis, thus enabling increased economies of scale and more competitive energy pricing. This also enables residences and buildings that are not suitable for solar energy installations (e.g., roofs that face away from the sun's path) to access renewable energy sources through local infrastructure. These community energy systems are becoming more popular as long-term electricity supply options in Europe (e.g., Spain's solar gardens), Australia, and in North America.

Furthermore, third-party owners are bringing private capital to design, build, own, and operate renewable and microgrid energy systems, often with energy storage embedded. This enables businesses and homeowners to avoid large capital outlays upfront, thereby leasing these energy systems through periodic payments and participating in the conversion to a cleaner source of energy.

In some EU Member States (e.g., Denmark, Germany), more than 50% of renewable energy is community-owned and financed. Under this financial model, local community homeowners and businesses economically share in the development, ownership, and operational costs for these renewable energy systems. Many of these systems are deployed throughout Europe. Germany, in particular, has seen a rising trend of energy cooperatives growing rapidly over the past decade, with approximately 170 municipalities having regained ownership of power generation and distribution facilities. For example, Hamburg purchased its network from Vattenfall and E.ON in 2014. Many remaining city and utility franchise contracts are up for renewal in 2016,

with two-thirds of all remaining German communes are considering repurchases, according to a 2012 report by the Public Services International Research Unit.

2.1.5.3 Smart Energy Proposal #13: Support large-scale sector coupling demonstration projects (financial). Contributes to RNE sectors “Industry” and “Mobility”. One of the key elements to support and facilitate the large-scale integration of wind and solar energy is to deal with the intermittency without having to invest too much in energy storage. One part of the solution is a large-scale link between the three sectors of electricity, mobility, and heat, which enables the transfer of surplus energy from electricity into the other sectors, and using them as a buffer for storage.

A growing number of countries will soon have an excess amount of renewable electricity when the sun is shining and the wind is blowing. At that point, electricity will be inexpensive on wholesale markets, so it will increasingly be used to generate heat for use in buildings and industry. This is the primary approach, as it is highly efficient and does not require expensive infrastructure. Again, it is worthwhile to review how other areas with large amounts of offshore wind energy are dealing with this issue. The City of Copenhagen has set a goal of achieving 100% renewable energy, becoming the first carbon neutral capital by 2025. This includes the ambition to become a test bed and showcase for green solutions, increasing efficiency and renewable energy technologies, and investing in offsets outside the country. Offshore wind today supplies enough power to cover most of the city’s electricity needs. The city has developed some key technology approaches to support the initiative, including the following:

- Heating is being addressed by expansion of combined-cycle plants, as well as using geothermal energy, a plentiful resource in the region. In a first phase, surplus wind energy can be integrated into the heat cycle by using simple immersion heaters;
- Testing and demonstrating large-scale heat pumps to foster wind energy more efficiently;
- Increasing the use of industrial waste heat, waste incineration, geothermal energy supply, and solar thermal energy to diversify the energy mix; and
- Creating a long-term plan for solar photovoltaic, onshore wind, and offshore wind power to enable a clear planning and implementation strategy.

2.1.6 R&D

2.1.6.1 Smart Energy Proposal #2: Provide cross-sector support for development of innovation engines to accelerate “net zero energy neighborhood” models (R&D). Contributes to RNE sector “Urban and Residential Areas”. MRDH should develop a program similar to the XPRIZE competition to stimulate interest in expanding the concept of zero net energy neighborhoods to include a broader set of concepts – including the circular and Sharing Economy, efficient transport, and local entrepreneurship. The intent would be to bring together neighborhood-scale microgrid technologies, smart meter-enabled energy feedback systems, and deep energy efficiency retrofits to neighborhood energy consumption, in order to enhance community-level renewable energy production, community engagement, and new business model development.

Traditional elements might be included such as energy audits and low-cost energy retrofits, but it must also go beyond traditional and include innovative concepts, such as development of a residential microgrid using the local school as an engagement hub. In this example, the approach would generate a replicable, residential microgrid that balances the daytime energy demand of schools and the late afternoon and evening energy demands of households. Reductions in household and school related transportation consumption would also be factored in through the promotion of efficient transport and mobility sharing schemes.

Participation in the scheme might be encouraged through social accountability methods, as well as social norming processes. Limited-time discounts, financing, and other economic incentives will be provided by the government and third-party service providers (e.g., Energy Services Companies) to discount the cost of participation and make implementation more affordable and risk-free. Examples have been implemented in some progressive areas of the United States, such as the geos neighborhood project in Colorado, as well as some of the areas with less prominent “green” agendas, such as a net zero school project in Kentucky.

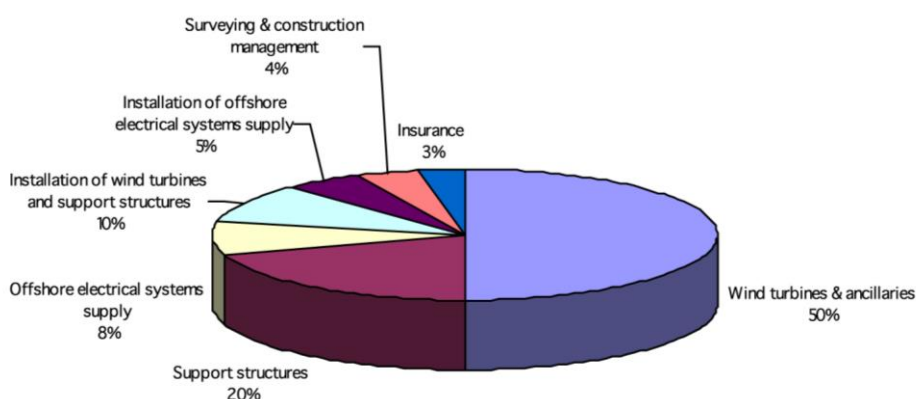
2.1.6.2 Smart Energy Proposal #21: Integrate wind energy R&D competencies (R&D). Contributes to all five RNE sectors. A critical success factor for starting a new industry is the existence of a complete value chain in an identified cluster area. Applied research will play an important role when developing a local wind industry, or parts of it, in MRDH.

DUWIND, one of the strongest global research facilities, is located at the Technical University of Delft. This facility has a track record of more than 30 years in wind energy technology and the expansion of wind power all over the world, through research and education. DUWIND focuses

on large electricity generating wind turbines at the multi-megawatt scale. Both technology development aspects, as well as fundamental aspects of wind energy conversion, are part of the research program. Some of the research activities also address the urban deployment of small scale wind power. Therefore, they are the perfect match for establishing a complete MRDH local wind cluster and strongly contributing to R&D, as further outlined in the following paragraphs.

- *Big Data / Smart Wind Farm solutions.* Following the trend in other industries, the wind energy industry applies the intelligent use of large amounts of data to improve the performance of individual wind turbines and wind farms. Some progress has been made in making wind turbines more productive, starting with better positioning of individual turbines within the array of a wind farm using improved computer simulation models. These models can be used to improve the efficiency of various systems and components, from rotor blades to all parts of the drive train, controlled by various sensors and supported by new software tools to optimize energy output in complex wind regimes. Next to the optimization of output, the same set of sensors and software can be used to improve reliability and reduce downtime.
- *Offshore wind logistic solutions.* The cost structure of a typical offshore wind project shows a much larger percentage of financing in the installation and construction phase, as compared to an onshore project, as shown in figure 28.

Figure 28: Costs for A Typical Offshore Wind Project¹⁴²



Over the past year, the offshore market has developed to a reasonable size, enabling enhanced industrial approaches, especially with construction and installation. However, there is still room for innovative R&D solutions, with the focus on reducing time and costs for the installation process. This topic is on the agenda of local companies, such as van Oord, with their focus on installation infrastructure, but other areas might be added, including access systems, support structure installation methods, and others.

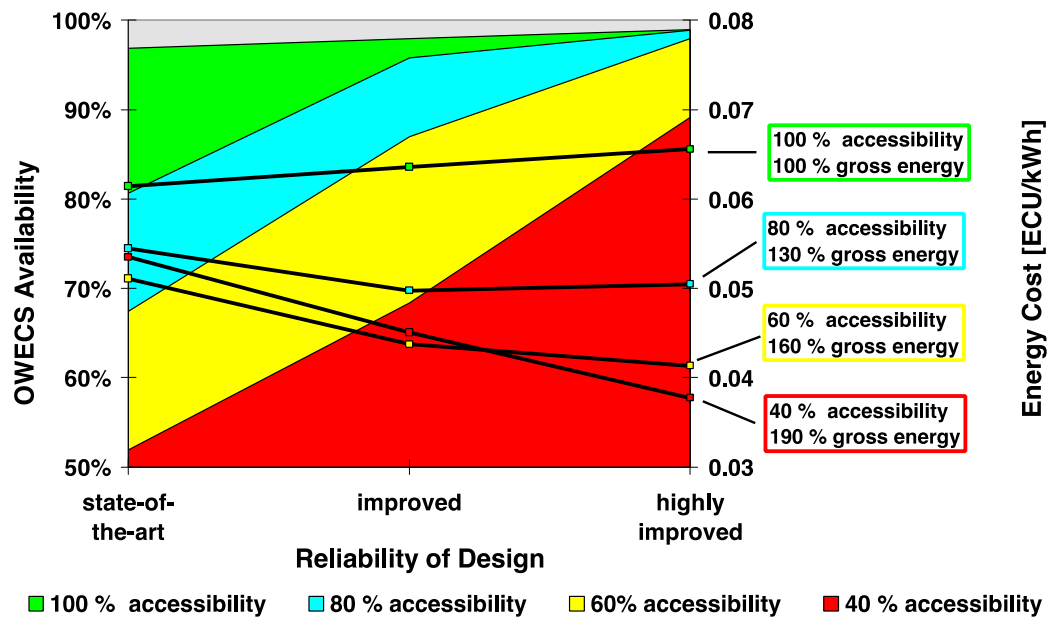
“Maintenance logistics” is also an important competitive factor in the offshore wind energy industry and has a significant impact on the profitability of offshore wind projects. Statistics show that the maintenance support expenditures constitute a major part of the O&M costs. Here, new and innovative approaches ranging from more reliable monitoring systems to improved crew and spare part transport options could be investigated.

- *Offshore wind reliability solutions.* Despite the significant growth in offshore wind power capacity and the specific offshore turbine designs of the last several years, the harshness of the marine environment and rapid changes in weather and sea conditions still result in reduced levels of system availability or reliability. Analyses of field data show that the availability of onshore wind farms is typically between 97% and 99%,

¹⁴² Source: Garrad Hassan and Partners Ltd., now part of DNV GL.

while it is evaluated to be in the range of 70%–80% for offshore wind farms using standard technologies. In addition, the limited availability of supply vessels to transport the heavy spare parts and frequent bad weather constraints are leading to extended lead-times and as a consequence, to increased operation and maintenance costs.

Figure 29: Qualitative Relationship Among Site Conditions



As shown in figure 29, accessibility, gross energy yield, and availability impact energy costs for different levels of reliability of OWECs design.¹⁴³

Therefore, in order to achieve the required cost reductions for offshore electricity, the reliability, availability, and maintainability of offshore wind farms needs to be significantly improved. This is a major R&D effort requiring interdisciplinary work, as the interaction between sophisticated turbine designs and complex environmental conditions is not yet completely known.

¹⁴³ Opti-OWECs Final Report, M. Kühn, W.A.A.M. Bierbooms, G.J.W. van Bussel et al, TU Delft, Technical Report, January 1996 to December 1997.

2.1.6.3 Smart Energy Proposal #26: Advance renewables-sourced hydrogen fuel production (R&D). Contributes to RNE sector “Mobility.” Energy services that are incapable of shifting to electrification and require a fuel source, such as ships, planes, some transport modes, and a number of industrial processes, can take advantage of hydrogen produced from renewable sources like excess wind and solar power. Using excess wind and solar power to electrolyze production of hydrogen is one promising method, given the dramatic drop in wind and solar power generation costs. Additional options are emerging from the R&D pipeline as reported in the journal *Science*: “a recyclable redox mediator (silicotungstic acid) that enables the coupling of low-pressure production of oxygen via water oxidation to a separate, catalytic hydrogen production step outside the electrolyzer that requires no post-electrolysis energy input. This approach sidesteps the production of high-pressure gases inside the electrolytic cell (a major cause of membrane degradation) and essentially eliminates the hazardous issue of product gas crossover at the low current densities that characterize renewables-driven water-splitting devices... a platinum-catalyzed system can produce pure hydrogen over 30 times faster than state-of-the-art proton exchange membrane electrolyzers at equivalent platinum loading.”¹⁴⁴

2.1.7 RESILIENCY PROPOSALS

2.1.7.1 Mainstreaming resiliency in city administration (policy). As climate change can affect many of the services and processes in a city, resiliency should be an integral part of city decision making processes and policies. This requires that resiliency is well integrated across a city’s jurisdiction. In this manner, opportunities for increased resiliency can be included in long-term assets and infrastructure, including new city districts and new buildings. City staff members should not just be well-aware of climate change, but also have a clear understanding of new extremes and related potential hazards. Additionally, it is relevant that departments have an understanding of how their decisions affect issues that are the responsibility of others. Examples include aesthetic requirements in a district development, such as requirements to place all assets underground, that will negatively affect reliable infrastructure operation in case of flooding due to heavy rainfall; or building codes with integrated resiliency requirements that will positively impact the economic value of the properties and the area. Therefore, internal

¹⁴⁴ Source: <http://www.ncbi.nlm.nih.gov/pubmed/25214625>

capacity building and capability building is a key aspect to ensure sound decision making by staff.

2.1.7.2 Actions on resiliency of critical infrastructure at the local level (regulatory). As mentioned earlier, resiliency of critical infrastructure will directly affect the availability of critical products and services. The electricity grid would be a useful starting point to assess vulnerable parts of the infrastructure, and identify potential cascading affects due to interdependencies between critical infrastructures. In this context, the focus should not be limited to the technical or physical aspect, but should also include social, governance, and ecological dimensions.

Critical infrastructure and its interdependencies are most effectively addressed in a multi stakeholder approach to include, for example, city departments, representatives of public health, community or fire services, private companies including banks and insurance companies and representatives from the energy, water, and transportation sectors. The Hague Security Delta (HSD), the security cluster in which businesses, governments, and knowledge institutions work together on areas such as cyber security, national and urban security, and protection of critical infrastructure, should also be involved in a multi-stakeholder working group. Early and frequent engagement not only contributes to positive relationships between the city and the responsible stakeholders, but also creates an environment for data and knowledge sharing, and creating insights that no individual stakeholder can deliver.

2.1.7.3 Develop electricity grid resiliency strategy (regulatory). As indicated, a well-functioning electricity grid is required to deliver many of the critical services, including health services, transport, and telecommunications. This special role justifies specific action, in addition to the actions defined in resiliency proposal #2. The electricity system is in transition. More locally generated electricity is feeding into the grid, smart grid technology is being applied, and the electrification of society is increasing, with key functions such as transport and space heating increasingly being served by electricity. These developments can be both a challenge and an opportunity. Due to the long term impact of investment decision in grid infrastructure, it is critical that the topic of city resiliency be explicitly taken into account at an early stage. It is recommended that MRDH undertake a partnership with the local grid operator, to define scenarios for the future grid architecture. A loosely-coupled and a highly-cohesive infrastructure should be further explored.

2.1.7.4 Ensure buildings providing critical services are resilient to extreme weather events (policy). More resilient buildings should be important components in a city resiliency strategy. They can contribute to reducing the impact of extreme weather events (green roofs and facades can reduce the heat island effect in periods of extreme temperatures and, at the same time, contribute to the water absorbing capacity in times of extreme precipitation) and they will be key shelters during extreme events (e.g., long periods of extreme cold, extreme heat). Well-designed and insulated buildings will have lower demands for heating and cooling, which not only contributes to the reduction of GHG emissions, but also makes it easier to cover energy demand by locally generated energy such as solar and micro CHP, making buildings less dependent on the functioning of the national energy grid.

MRDH should include in its strategy that specific buildings receive a resiliency audit, to understand how resilient these buildings are to extreme weather events and natural hazards while, at the same time, enacting measures to improve resiliency. Buildings that are subject to audits should include those with critical functions (e.g., hospitals, police buildings, buildings of water and energy utilities) as well as buildings owned by the municipality. For new buildings, it is recommended that as part of the permitting process, design requirements are set to ensure a certain level of resiliency. The city should lead by example, making its own building stock more resilient and disclosing the resiliency index of its buildings, similar to publicly showing the energy performance of its buildings. Expertise and experience gained by MRDH on the topic of resilient buildings can, at a later stage, be brought into the process to include resiliency in the building code and building standards at a national level.

2.1.7.5 Sign agreements with public and private entities to encourage increased transparency (new business models). Resiliency increasing measures may require an additional investment compared to business as usual solutions. Without clear insight into current and future climate change related costs, it will be difficult to justify these investments. It is therefore recommended that the city develop an agreement with utilities and larger private companies to disclose, on an annual basis, costs and risks that they faced due to extreme weather events and natural hazards. For the private sector, such initiatives already exist and it is recommended to use the same reporting requirements in order not to overburden companies. The city should lead by example in transparency and in reporting costs and risks (see also resiliency proposal #6).

Requiring private building owners to provide this information voluntarily will not, by itself, be

an effective approach to achieving increased resiliency. Building owners will need to see the value in making commitments to clean energy, climate change, and the well-being of citizens. Many firms today, including Google, Apple, and Amazon, base their strategic investment decisions on many of these factors, rather than economics alone.

2.1.7.6 Implement monitoring and reporting (regulation). If a city sets resiliency goals, it is important that progress of these goals be monitored according to a well-defined monitoring plan. Based on annual progress monitoring, MRDH can identify back logs and define required actions. Monitoring provides an opportunity to delineate best practices, to understand if assumptions made are still valid, and to determine the quantitative impact of the actions undertaken. In this manner, monitoring can support continuous improvement and can function as a decision support system. By sharing the results (annual resiliency progress reporting) the city is held accountable, and can inform the wider community about progress being made and their contribution to it.

2.1.7.7 Increase awareness and public participation (education).

Citizens should be made aware of the risks associated with climate change and extreme weather events and also be sufficiently informed about the ways in which they can contribute to boosting the resilience of the city and of their own properties. Promoting participation by engaging community organizations, local residents, and local community leaders in the development of resilience strategies is also needed within the framework of a multi-stakeholder approach.

RNE Transition Pathways

In the following section, we outline relevant crossovers with the other four RNE transition pathways.

Digital gateway

1. IoT in household appliances and energy installations and connect them to the grid.
2. Digital resilience (cyber security) of the smart grid infrastructure.
3. New Digital Marketplaces that enable local trade and netting of energy augmented with other services.

4. MRDH Digital Intelligence Portal providing an open data platform for every stakeholder to get an accurate and integrated insight in all relevant data for MRDH's transition pathways, including models and forecasting tools that can enrich these data.

Circular Economy

1. Re-use of potential energy sources.
2. Biomass for energy production.
3. Waste incineration.
4. Re-use of process/waste heat.
5. Development of next level of Energy Efficiency measures: CO₂ based (including life cycle of products and use of materials), renovation or rebuilding.
6. Urban Utility Hubs for local Waste, Water, Energy, Resources collection and distribution.
7. Create adequate legislation and experimental zones for circular economy and energy transition.

Entrepreneurial Region

1. To be a world leader in the technology for the customized production of goods in selected specializations, that will produce and export the high tech systems and materials needed to enable the smart Energy Delta.
2. Help Start Ups to be the next big company: Facilitate Energy Start-ups with Venture Capital, Crowdfunding, Regional Revolving Funds and Incubator Yes Delft Energy.
3. Provision of enough Engineering, Installation and Maintenance human resources (skills and competences).
4. Real life testing grounds in terms of Field Labs and Living Labs for maturing products and services in a more controlled or supportive environment (risk reduction, showcases, scaling up, waivers for regulations etc.).
5. Smart Energy Delta campuses bringing together Thought Leadership, Applied Scientific Resources, and Entrepreneurs in this region.

Next Society

1. Maximal stimulation of local initiatives / cooperatives ("Energieke samenleving").
2. Create energy awareness and enable citizens as energy prosumers.
3. Set up local energy trading platforms to realize self-sufficient buildings, streets, or districts that fit in the context of the Sharing Economy and community involvement.

4. Integrated approach and education: Integrated energy instead of siloed commodities of gas, electricity, and heat and construction.
5. Educate enough installers, builders etc. for renovation on industrial scale.

Economic Clusters

With respect to the Economic Clusters, we have identified the following crossovers

Port of Rotterdam

- Port Vision 2030: *“In 2030 Rotterdam is Europe’s most important port and industry complex. It is a strong combination of the Global Hub and Europe’s Industrial Cluster, both leading in efficiency and sustainability. In 2030 the transition to sustainable energy generation and bio-based chemicals is in full swing. Rotterdam is the electricity hub of Northwest Europe.”*¹⁴⁵ The aim for the Smart Energy Delta is to have a Smart Energy Port that is a front-runner in sustainable energy generation. The Port provides storage, transmission and overarching transportation infrastructure (smart grids) for a diverse range of clean and sustainable energy sources. Besides the aim of green energy and reduction of CO₂ emissions, the Port has to safeguard the societal demand for energy at acceptable costs. Diversification of energy sources remains therefore important. The pathways towards deep decarbonization are diverse, and include:
 - Recycling of heat, steam, and CO₂
 - Electrification (terminals, shipping, shoring, and trucks)
 - Replace fossil fuels and chemicals by renewables
 - Sustainable sources (wind, solar, H₂)
- Port Vision 2030: The Port of Rotterdam has set a goal of becoming a state-of-the art circular hub. The size of its flows of goods, products, waste and emissions and the space for experimenting and scaling up, make the Port of Rotterdam by far the most spectacular circular port- and industrial cluster of Europe. With the credo “there is no waste’ in mind, Rotterdam is leading in re-use of materials (by products), water, steam, heat, CO₂ and other emissions. The port offers storage and infrastructure, facilities (such

¹⁴⁵ See: <http://portofrotterdam2030.com/files/downloads/pdf/PortVision-2030-Summary.pdf>

as research), and services needed for the circular economy. “Zero emission” of the port and its businesses is the appealing dot on the horizon. The Deltaplan Energy infrastructure is already on the design table. Furthermore, the Action Plan of the Industrial cluster (march 2016) gives already other actions to be taken towards the integration of industries in Rotterdam and Moerdijk such as:

- Integrated, shared steam infrastructure, and other streams such as wastewater
- Biorefinery
- Recycling of polymers; plastic to methanol production plant
- Game changers (5 years)
 - Big scale, offshore wind parks on the deep sea
 - Solar on roof tops and port infrastructure, plus community-based systems
 - Fully-scaled, regional Deltaplan Energy Infrastructure (heat, steam, CO₂)

Maritime

- With regard to the Smart Energy Delta, the aim is that in 2030 MRDH will extract substantial amounts of energy from the sea by making use of offshore wind and solar (and to a lesser extent of tidal energy), while serving as a hub of renewable energy for other regions. Key players in the region facilitate the construction of offshore wind parks around the world. There is already a strong diverse cluster with many key players, not only maritime companies (offshore, engineering), also advanced business services, specialized insurance and finance of offshore wind parks.
- The first zero emission ship is built and operated in Rotterdam. In 2030 this region is highly specialized in engineering and construction of clean ships. In this region new innovative ways for energy generation and energy storage on ships are developed. This includes the development of fully electrified vessels and related infrastructures.
- In 2030 oil and gas rigs are decommissioned and recycled in the Port of Rotterdam cluster.

Clean Tech

- The RNE Energy pathway will encompass everything dealing with renewables as the main power sources using decentralized solar, on and offshore wind, smart grids, electric or fuel cell vehicles used as storage, etc. This concerns all the actions that need to be taken to erect the renewable energy infrastructure (or energy internet) that will enable the region to increase its energy productivity.

- Vision in relation to clean tech: 90% electrical (mobility but also chemicals), solar + storage + EV aggressive deployment, power to X (heat, chemicals, hydrogen) technologies, every building a power plant, zero waste
- Long and medium term objectives: zero emission households and industry, ambitious targets and strategies (maybe not 100% by 2050 but 80% by 2030), get households off gas, design for recycling,
- Short term scalable projects: Autarkic districts (ex. Feldheim), assembly wind mills platform, bio refinery, smart grids in certain neighborhoods, rooftop and small utility scale solar, energy efficiency buildings, smart grids, demonstration / iconic project (DWW)
- Systems challenges: Smart grids, investment in solar and wind farms, storage facilities, connection to electricity, unknown of autonomous vehicles effect, vested interests versus new solutions.

Circularity

- One-hundred percent renewable-sourced energy. Democratization of energy generation and consumption.
- Five prevailing (scalable) projects and quick wins:
 - Public PV (on all public buildings in MRDH) in local networks.
 - DC Connected LED Streetlights + Individual PV-connectivity + 2-way Mobility Charging Stations.
 - Power to Gas/Chemicals.
 - Delta Potential.
 - Seawater heat plant.
 - Wind Energy Roundabouts/TCMs.
 - Hydrogen Use
 - Exergy Analysis.
 - LED in all lighting

HTSM/IT

This pathway should encompass everything dealing with renewables as the main power sources using decentralized solar, on and offshore wind, smart grids, and electric or fuel cell vehicles used as storage. This concerns all the actions that need to be taken to erect the renewable

energy infrastructure (or energy internet) that will enable the region to increase its energy productivity.

- Vision in relation to HTSM/IT, dot on the horizon to be a world leader in the technology for the customized production of goods in selected specializations, that is to produce and export the high tech systems and materials needed to enable the smart Energy Delta
- Long term actions
 - Branding: clean high tech region
 - Specialization: Smart Grid; energy efficiency in manufacturing
 - Icon: Dutch Wind Wheel = production and storage of renewable energy
- Five prevailing (scalable) projects: Dutch Wind Wheel
- Five quick (potential) wins:
 - Zero emission trucks for the last mile
 - Field lab Smart Integrator for AeroSpace
 - Energy Storage in the harbor

RNE Implementation Challenges

Implementing the Smart Energy Delta will not occur without potential roadblocks and impediments, some of which may be anticipated in advance. In previous portions of this narrative, we have sought to identify some of these challenges, as well as articulated mitigating actions to overcome them. To enable MRDH to initially transition towards a successful outcome for the RNE paradigm shift, we summarize a number of potential risk factors associated with regulations, knowledge gaps, policies, and the positions of relevant institutions and key stakeholders.

- **Regulations**
 - Anticipate continuous change in policy frameworks, new/changing subsidies and regulation, or even weak enforcement of current legislation (e.g., environmental). Often, companies and key stakeholders are not able or willing

to invest while unforeseen or limiting regulations exist, which may need to be directly addressed in advance.

- Regulatory challenges may exist that limit financing schemes and stakeholder involvement. This may occur, for instance, where savings in investments made by the asset manager of gas infrastructure cannot be spent by housing associations in dwellings. The ideal situation is to outline benefit streams for all stakeholders, to avoid NIMBY effects.
- In some cases, direct transactive energy exchanges between consumers (prosumers) may be prohibited by existing regulations, but yet should still be viewed as a means to expand the community-based concepts of sharing economy.

- **Knowledge Gaps**

- A clear and shared picture of the ultimate energy efficiency and environmental goals at various levels (e.g., regional, city, neighborhood) is important to align stakeholder plans, goals, ambitions, and scenarios. This will enable all stakeholders, such as of municipalities, district system operators, infrastructure operators, and housing associations to provide insight regarding common synergies regarding their locations (e.g., linking energy efficiency measures and planned investments in infrastructure).
- Monitoring tools (at various levels) are also needed to provide insights regarding transition progress and success, enabling all stakeholders to connect their share of progress against targets and apply best practices to future project efforts.
- A key industry gap is the need for open source standards for connecting IoT devices and to open access to smart meter data and telecommunications networks.

- **Policies**

- There is currently a need for a national, shared approach for the sustainable built environment. Energy efficiency is not required to be considered in real estate mortgage reviews. Furthermore, incentives are needed for local/regional governments to realize energy goals or stimulate energy efficiency.
- Homeowners need increased access to financing and loan options to provide incentives for investments in sustainable energy. This would also include object bound loans for energy efficiency measures, as well as financing via community ownership associations.

- Current policies are based on informing, motivating, and increasing participation of homeowners; however, they stop short of instilling mandatory steps, thus reducing participation rates to voluntary sectors.
- **Institutional Positions**
 - There is a need for increased transparent and access to the market for energy efficiency, given current difficulties in matching demand and supply for investing in such measures.
 - Increased PPP and funding mechanisms are needed for increasing investments in bio refineries and other bio-based industries, to offset market subsidies and low prices associated with fossil fuel.
 - Increased focus on Intra-European or worldwide cooperation in joint policy, planning and realization, for offshore wind energy development. Current planning is conducted only at the national/regional level, which results in an inefficient use of capital for renewable energy. In particular, the maritime business is highly dependent on world trade and international legislation and European politics.
 - For some large energy consumers, perverse price incentives come into play and reduce their incentive to participate in further RNE investment.

BUILDINGS AS NODES

Every building connected to the Internet of Things infrastructure becomes a Big Data center, green micro power plant, energy storage site, and transport and logistics hub to manage, power, and move economic activity in a smart MRDH. The build out and scale up of a nodal building stock can advance aggregate efficiency from 13% to more than 40% over the course of the next 25 years, dramatically increasing productivity and reducing ecological footprint and marginal costs, making MRDH the most advanced and ecologically sustainable commercial space in the world.

Anke van Hal and the Working Group members from MRDH

Gerhard Stryi-Hipp (Fraunhofer ISE), Claude Lenglet (Co-European Director, TIR Consulting Group LLC), and Jeremy Rifkin for TIR Consulting Group LLC

First, every building, which is not already a Nearly Zero-Energy Building, will have to undergo a complete retrofit to seal its interior, minimize energy loss, and optimize efficiency. Second, smart Internet of Things technology will need to be installed throughout the interior and exterior space surrounding every building. Each building becomes a node connected to every other building across the infrastructure to allow families, businesses, and communities to monitor Big Data flowing along the value chains and use analytics to create algorithms and apps that can increase their aggregate efficiency, dramatically increase their productivity, and reduce their ecological footprint and marginal cost in the conventional market, and increasingly in the emerging Sharing Economy. Third, renewable energy harvesting technologies – solar, wind, geothermal, and biomass – will need to be installed in and around residential, commercial, and industrial sites to generate green electricity and capture heat and cold for immediate use within the buildings or sale back to the electricity, heating and cooling grid. Energy storage technologies, including batteries and hydrogen tanks, combined with fuel cells and thermal storage tanks, will be installed alongside the renewable energy harvesting technologies to store intermittent green energy for use or sale back to the energy grids to ensure a reliable supply of energy. Fourth, electric charging stations will need to be installed in or alongside every building to power electric vehicles for use in the automated, GPS-guided and driverless passenger and freight vehicles of the Transport and Logistics Internet.

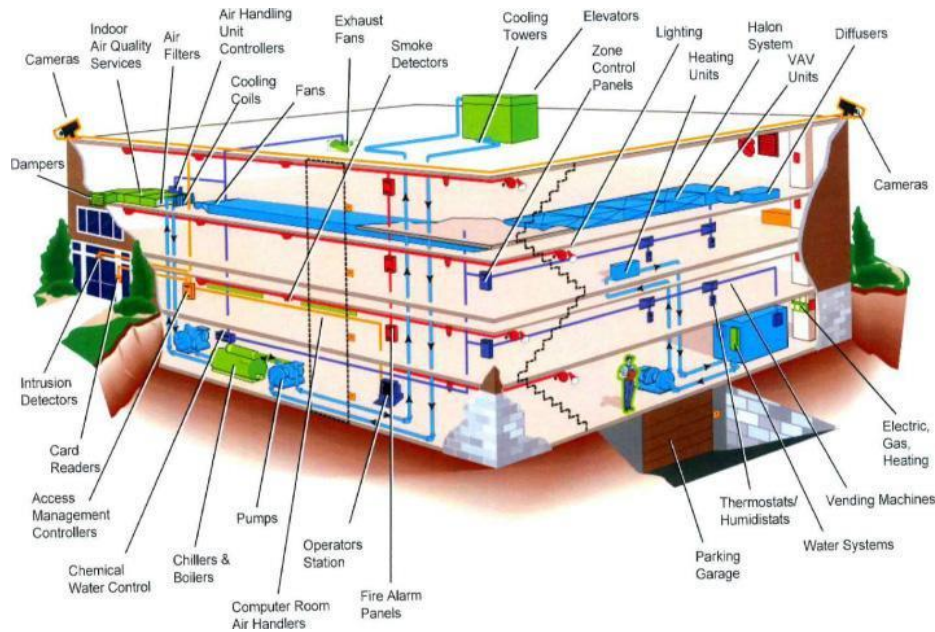


Image Source: Cisco

The return on investment in energy efficiency and energy savings can be as few as four to seven years, after which the owner or renter enjoys a reliable stream of savings on their energy cost for decades. Studies show that retrofitted energy efficient buildings enjoy a higher market value, higher rents, and higher occupancy rates. A typical study of residential buildings across France shows a 40% increase in market value for buildings receiving the top energy performance certificates.¹⁴⁶

More importantly, transforming every building in the region into an Internet of Things Big Data center, green micro power generating facility, energy storage site, and automated transportation hub greatly enhances their economic value by providing a range of high-tech services that dramatically increase aggregate efficiency and productivity and lower marginal cost in the managing, powering, and moving of economic activity. The increase in productivity and reduction in marginal costs, when amplified by thousands of buildings that become nodes linked to an Internet of Things infrastructure, not only appreciates the value of the building

¹⁴⁶ Plan Bâtiment Durable. (2013). Immobilier et valeur verte : État actuel de la réflexion, 2013.

stock but also advances the digital interconnectivity and economic growth of the Metropolitan Region of Rotterdam and The Hague.



Fig. 1: Project “Sleephelling” in Rotterdam shows how a historical building can be renovated to Nearly Zero-Energy Building standard level A++

Photo: Bam Woningbouw¹⁴⁷

¹⁴⁷ See: <http://www.bamwoningbouw.nl/nl-nl/project/3/40/132/sleephelling.aspx> and <http://www.rvo.nl/initiatieven/energiezuiniggebouwd/renovatie-sleephelling>



Fig. 2: The Haagse Hogeschool in The Hague wants to become the most sustainable University and built an energy efficient campus

Photo: Studio Leon Thier Architecten¹⁴⁸

Retrofitting every residential, commercial, and industrial building is a herculean task, but also an essential pre-requisite for transforming the economy into an Internet of Things Third Industrial Revolution. Insulating existing and new buildings, installing new, more efficient HVAC equipment, and introducing highly efficient LED lighting all generate additional GDP while increasing the aggregate efficiency and productivity of the buildings' operations. The introduction of an Internet of Things infrastructure in and around every building to monitor and manage energy efficiency, while still nascent, is expected to grow exponentially in the next few years as MRDH transforms its building stock into smart, digital nodes interconnected in vast digital networks.

Germany's experience in retrofitting provides a metric for the job creating potential in the region as it embarks on a retrofitting project. The German Alliance for Work and the Environment is credited with the most ambitious retrofitting project to date. 342,000

¹⁴⁸ See: <http://studioleonthier.nl/projecten/haagse-hogeschool> and <http://www.rvo.nl/initiatieven/energiezuiniggebouwd/haagse-hogeschool>

apartments were retrofitted, creating 25,000 new jobs and saving 116,000 existing jobs, or more than 141,000 new or saved jobs.¹⁴⁹

Each one million dollars of spending on the manufacture and installation of envelope improvements generates 16.3 jobs when adding together direct employment, indirect employment, and induced employment. Each one million dollars of spending on HVAC improvements generates 13.3 direct, indirect, and induced jobs. Each one million dollars of spending on LED lighting creates 12.9 direct, indirect, and induced jobs. Each one million dollars of spending on Internet of Things technologies fosters 13.0 direct, indirect, and induced jobs.¹⁵⁰

There are tens of thousands of buildings in MRDH that will need to be retrofitted in the coming decades. MRDH is already gearing up to engage in the largest retrofitting project in history. The initiative will create tens of thousands of new jobs while saving tens of thousands of existing jobs in the manufacturing, engineering, construction, and real estate sectors.

Dutch Initiatives on Energy Efficient Buildings

In recent years, the Dutch government has created the framework to implement the European Performance of Buildings Directive (EPBD) for new buildings and transform the existing building stock to Nearly Zero-Energy Buildings (NZEB). A regulatory framework of certification, laws and regulation was implemented, the market stakeholders were motivated to take action and develop innovative solutions, and subsidies are provided.

A sophisticated building certification scheme is essential to systematically improve the energy efficiency of buildings. In July 2012, the Dutch government replaced the existing residential and non-residential building standards with a new Energy Performance Standard for Buildings to make the system easy to apply. The main requirement for new buildings is the Energy Performance Coefficient. The coefficient is the ratio of the calculated primary energy demand per square meter of floor area divided by the reference energy demand per square meter. The coefficient depends on the type of building, e.g. in 2015, the required coefficient was 1.8 for hospitals, 0.8 for office buildings, and 0.4 for residential buildings. The coefficient has been

¹⁴⁹ See: http://warming.apps01.yorku.ca/wp-content/uploads/WP_2011-04_Calvert_Climate-Change-Construction-Labour-in-Europe.pdf

¹⁵⁰ See: Garrett-Peltier, Heidi. "Employment Estimates for Energy Efficiency Retrofits of Commercial Buildings." Political Economy Research Institute. 2011.

reduced over the years. Fig. 3 shows the values for dwellings and offices from 1995 to 2015. Future plans are not included because the Energy Performance Coefficient will no longer be used as an indicator for Nearly Zero-Energy Buildings.

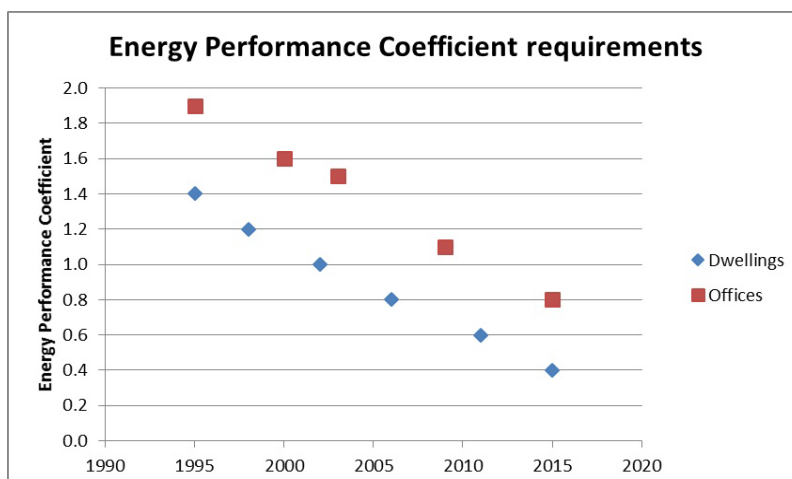


Fig. 3: Change in the energy performance coefficient in new buildings over time until 2015¹⁵¹

The Energy Performance Certificate (EPC) was introduced in the Netherlands in 2008. By the end of 2013, 2.3 million EPCs had been registered. To make the EPCs cheaper and simpler with direct feedback to the residential building owners, the parliament adopted a new system, which entered into force on 1 January 2015. It consists of a user-friendly web-based tool, which allows private residence owners to apply for an EPC for their house. All residential building owners (in total 4.5 million) received a temporary EPC (calculated on the basis of the national cadastral data) by mail. This certificate provides an indicative energy performance of the residence. The owner can digitally add or change information to the intake data of the Dutch cadaster on which the preliminary EPC is based. Both existing and new data are checked by a qualified expert (“energiesdeskundige”), who is responsible for producing the definitive EPC registered in the RVO database.¹⁵²

To motivate the market stakeholders to contribute to the implementation of the EPBD, the national Energy Agreement (“Energie Accord”) was signed by more than 40 market participants

¹⁵¹ van Eck, H.: Implementation of the EPBD in the Netherlands, status in November 2015, Netherlands Enterprise Agency (RVO), 2015

download: <http://www.epbd-ca.eu/outcomes/2011-2015/ca3-2016-national-netherlands-web.pdf>

¹⁵² Ibid.

and other stakeholders in September 2013. According to the agreement, 300,000 existing residential buildings will be refurbished by 2020 and their EPC grade improved by two levels, the existing housing stock will be renovated to the level of energy class B on average, and 80% of the existing houses in the private rental sector will be improved to at least energy class C.

Subsidy programs from intermediary organizations are supported by the government to prepare the market stakeholders for the increased demands of reaching the NZEB level. In 2016, the “ZEN” program (“very energy-efficient new buildings”) started preparing market stakeholders for stricter NZEB requirements. To motivate investors and overcome market barriers, the “Database Energiezuinig Gebouwd” (“Database of Energy Efficient Buildings”) was compiled and today presents more than 400 examples of energy efficient buildings in the Netherlands.¹⁵³

The “Energiesprong” (energy jump) initiative started in 2010 to stimulate demonstration projects, provide information tools for investors and users, and act as an innovation network program to facilitate a large-scale implementation of NZEB in both the private and social housing sectors. Universities, market stakeholders (like technology suppliers, construction companies, housing associations), and the government are working together to lay the foundation for the transition. An accelerated and broadened approach to the built environment has created great potential for employment in the construction sector as intelligent, innovative renovation and new-build systems with guaranteed performance characteristics (energy and indoor environment) are developed and delivered. The program targets clusters of home owners, housing associations, etc., that are willing to implement projects on an energy-neutral built environment. One of the successes of the program is the “Stroomversnelling” deal, which focuses on completion of 111,000 “Nul op de Meter” residences (net zero-energy houses) by 2020. Deals concluded between parties on the supply and demand sides (e.g. construction companies and housing associations) have proven to be an effective way to experiment and tap new market opportunities. Besides the involvement of a coordinating organization, the involvement of (local) governments has proven to be key to the success of the program. Without room for experiments and openness to discuss barriers, the deals would not have been realized.¹⁵⁴

¹⁵³ Source: <http://www.rvo.nl/initiatieven/overzicht/27008>

¹⁵⁴ Energy Efficiency Watch: Energy Efficiency Policies in Europe, Case Study Energiesprong (energy leap) in The Netherlands, 2015, download: <http://www.energy-efficiency->

In Nieuw Buinen, one of the first “Stroomversnelling” projects is being implemented by the Lefier housing association and the VolkerWessels construction company. In 2014, refurbishment of 119 terraced houses from the 1970s to Net Zero Energy houses began with three pilot houses, which were built as test cases. A package of measures is implemented in each building to achieve NZEB status. Insulated façade elements including windows are installed as a curtain wall, an insulated roof is mounted on top of the existing roof and a Smart Portal is installed, including all components such as heat recovery and heat storage (boiler), located in the outer wall or roof elements. Solar panels are also integrated in the roof. Refurbishment can be finalized in just one day thanks to perfectly coordinated logistics. This requires all components to be supplied to the company responsible and highly prefabricated. All materials and components are manufactured based on a fully digital measurement of the building in advance. 3D-BIM (building intelligent modeling) allows the elements to be customized for each property. All that needs to be done at the construction site is the finishing, in particular airtight connection of the construction elements.¹⁵⁵



Front and rear of one terraced house refurbished to the NZEB standard in Nieuw Buinen

Source: <http://www.energiesprong.eu/index.php/our-projects/nieuw-buinen/>



Mounting façade elements on a building in Nieuw Buinen and the Smart Portal (left) including the heating and ventilation equipment, © Photo: Frank Hanswijk, Source: Flickr¹⁵⁶

The Energiesprong initiative is regarded as very successful and has now been exported to other countries like the UK and France.¹⁵⁷ However, the “Stroomversnelling” aspect of the Energiesprong initiative is not growing as fast as expected. By mid-2013, market stakeholders had signed deals to refurbish 11,000 houses by 2017, but by mid-2016, only 700 projects had been implemented. One reason is that the refurbishments are not yet cost-effective. Still, the number of participating companies has risen to 60. According to the president of Stroomversnelling, Leen van Dijke, refurbishment to zero-energy buildings is now mainstream. He expects costs to decrease due to robot-based automation and an increase in employment due to a rise in the number of retrofitting projects.¹⁵⁸ Further cost reduction will be achieved by cooperation of Dutch companies with international companies like Mitsubishi and LG.

¹⁵⁶ See: <https://www.flickr.com/photos/energiesprong/22038140532/in/album-72157657318257173/>

¹⁵⁷ See : <http://www.energiesprong.uk/>

¹⁵⁸ See : <https://www.ensoc.nl/nieuws/stroomversnelling-gaat-te-langzaam?>

MRDH Can Use and Leverage National Initiatives

As described, a number of initiatives are already underway in the building sector nationwide. Ambitious goals have been set to achieve the NZEB level for new buildings and the existing stock; a market oriented certification scheme for buildings has been established; stakeholders in the construction and building sector are being motivated to participate in this movement and develop innovative technologies for fast, cost-effective refurbishment with low impact on occupants; best practice cases have been provided (also within MRDH), and detailed data on the building stock exist and are available in an open data approach to facilitate optimized planning and new digital business models. The basis for a strong market uptake of NZEBs is laid in the Netherlands; however, the implementation rate is not sufficient yet.

Since the framework conditions for building zero-energy buildings and retrofitting existing buildings have already been established, the TIR roadmap recommends that MRDH utilize and optimize the scheme provided by supporting programs that intensify the support of these initiatives and become a frontrunner in implementing the NZEB policy in the Netherlands.

The following measures are proposed for implementation in MRDH:

- An ambitious goal should be set for implementation of the Energiesprong program in MRDH
- Local networks of market stakeholders should be strengthened and supported to accelerate implementation within Stroomversnelling activities
- Additional support should be provided by the MRDH government to make implementing the programs more attractive
- Awareness of the initiative should be increased
- Training and education should be provided to prepare the workforce for the increasing level of refurbishment activities
- The research sector and the construction industry should be supported in developing innovations to reduce the costs of retrofitting buildings

MRDH can distinguish itself from other regions implementing the national initiatives, by adding the following two specific characteristics:

1. Retrofitting buildings and constructing zero energy buildings should be combined with the introduction of a digitalized IoT infrastructure, the installation of energy and data

storage capacities (buildings as nodes), and the integration of buildings as active parts of the Energy and Transportation Internets, to unlock synergy effects.

2. The building projects should be networked to zero-energy-neighborhoods. Flagship projects can demonstrate the benefits of interactions of efficient buildings and networks combining energy efficient refurbishment, renewable energy generation, electricity and thermal energy storage, smart meters and smart grids, smart district energy management systems, electric vehicle charging infrastructures, managed to support grid stability at a neighborhood scale.

Both recommendations comply with the 10 Principles for Smart Buildings, published by the Buildings Performance Institute Europe (BPIE) in June 2016. Principle 9, “Build smart and interconnected districts” emphasizes that buildings are key construction components of urban areas. Smart district energy solutions can make better use of primary energy flows and can cost-effectively integrate renewable energy sources in the heating and cooling sectors. A district-wide approach, including smart technological solutions, demand flexibility and storage that can maximize the uptake of locally produced renewable energy.¹⁵⁹

According to Principle #10 – “Building infrastructure to drive further market uptake of electric vehicles,” – buildings can drive the transition from fuel-based cars to electric vehicles by operating as micro energy-hubs. Buildings are not the only things that are getting smarter – cars and their charging stations are too. Smart charging avoids costly spikes in power demand and can serve as storage to provide valuable services to the electricity system. Intelligent solutions will manage supply and demand between cars and buildings and deploy their separate storage facilities optimally. Combining flexible loads and the distributed storage potentials of both buildings and cars will maximize local integration of renewable energy.

This is why the TIR roadmap for MRDH recommends going beyond the realization of NZEB and implementing nearly zero-energy district pilot projects, including a smart charging infrastructure for electric vehicles (EV) in each building and in the neighborhoods.

¹⁵⁹ Buildings Performance Institute Europe (BPIE): Smart buildings in a decarbonised energy system, 10 principles to deliver real benefits for Europe’s citizens, June 2016
download: http://bpie.eu/wp-content/uploads/2016/06/Broch-10-principles_160624_v4c.pdf

Energy-Plus Neighborhoods: Examples from Germany

In Germany, research institutes are implementing and evaluating several flagship projects for zero-energy or plus-energy neighborhoods. In the city of Landshut, Germany, the Ludmilla energy-plus housing estate, comprising energy-plus single family homes and apartment buildings, was developed by Ludmilla-Wohnbau GmbH. Sixty-eight owner-occupied dwellings were built on a 0.73 hectare site. The single family homes are heated by mini-heat pumps developed specially for low-energy homes, which provide reverse operation for cooling during summer. The multi-family homes are connected to the district heating network with a biogas-powered CHP plant. Most buildings have photovoltaic systems installed on their roofs (see Fig. 4).



Fig. 4: Ludmilla energy-plus housing estate with single family homes and apartment buildings. © Ludmilla-Wohnpark GmbH

The energy-plus housing estate project was scientifically monitored in the EnEff:Stadt research program, financed by the German government. The district energy system was assessed and the impact of energy-plus houses on the energy supplier's electricity grid evaluated. Building

simulations were conducted and a simulation tool for using shallow geothermal energy was developed. Furthermore, guidelines were drawn up for designers and residents. Greater awareness for an energy-saving way of life is fostered among the residents of energy-plus housing estates by showing them how user behavior impacts energy consumption, particularly with highly energy-optimized building types. The knowledge gained from this research project is to be incorporated in future construction projects.¹⁶⁰

In Bad Aibling, Germany, a disused former American military base totaling 70 hectares of residential, commercial, and public buildings, mostly built in the 1930s is being transformed into a zero-energy district. The existing buildings have been or will be renovated and new residential homes have been built. The developer and investor, B&O Wohnungswirtschaft, has decided to fit a solar-powered local heating network with distributed feed-in points in one of the two networks. The zero fossil fuel energy targets will be achieved by means of a woodchip-fired boiler, solar thermal collectors, a large-scale ground-mounted photovoltaic system, and a PV system on the roof of the former aircraft hangar.



Fig. 5: Refurbishment of barracks buildings with prefabricated timber façade elements in Bad Aibling, Pictures: Huber & Sohn¹⁶¹

New four- and seven-story mixed-use buildings are being built with timber load-bearing structures and a high degree of prefabrication, which will reduce construction costs in the future. The use of externally applied timber façade elements with integrated thermal insulation

¹⁶⁰ See: <http://www.eneff-stadt.info/en/pilot-projects/project/details/ludmilla-energy-plus-housing-estate-landshut/>

¹⁶¹ See: <http://www.huber-sohn.de/energetische-fassadensanierung.html>

and pre-installed new windows minimizes interventions inside the dwellings during the refurbishment phase. HVAC equipment is integrated in the external timber refurbishment elements (see Fig. 5).¹⁶²

Smart Meters and Digital Services

In 2014, the Dutch parliament agreed to roll out smart gas and electricity meters in all homes and small businesses by 2020. One aspect of the rollout strategy is to encourage consumers to choose smart meters with detailed meter readings and to use them as efficiently as possible.¹⁶³

Digital services for building owners and the construction sector create new business opportunities. The Netherlands is well prepared in this regard, as Kadasterdata provides Dutch property information and data services on 100% of the residential properties in the Netherlands. Kadasterdata combines public (open) data and unique property information to develop tools and web services.¹⁶⁴

The Waag Society organization uses this data and provides maps with buildings shown in different colors according to their year of construction (see Fig. 6). Maps like this can help market stakeholders identify attractive areas for refurbishment. Kadasterdata has a lot of information about the Dutch residential stock, as it also holds data on the energy performance certificate. The previous calculation method required more than 150 building characteristics to be inputted. The new system requires only 20 building characteristics – which owners can enter on their own – to calculate the energy performance certificate.¹⁶⁵

¹⁶² Source: <http://www.eneff-stadt.info/en/pilot-projects/project/details/a-former-military-base-on-its-way-to-a-zero-energy-city/>

¹⁶³ van Eck, H.: Implementation of the EPBD in the Netherlands, status in November 2015, Netherlands Enterprise Agency (RVO), 2015, download: <http://www.epbd-ca.eu/outcomes/2011-2015/ca3-2016-national-netherlands-web.pdf>

¹⁶⁴ Source: <https://www.kadasterdata.nl/netherlands-cadastre>

¹⁶⁵ van Eck, H.: Implementation of the EPBD in the Netherlands, status in November 2015, Netherlands Enterprise Agency (RVO), 2015, download: <http://www.epbd-ca.eu/outcomes/2011-2015/ca3-2016-national-netherlands-web.pdf>

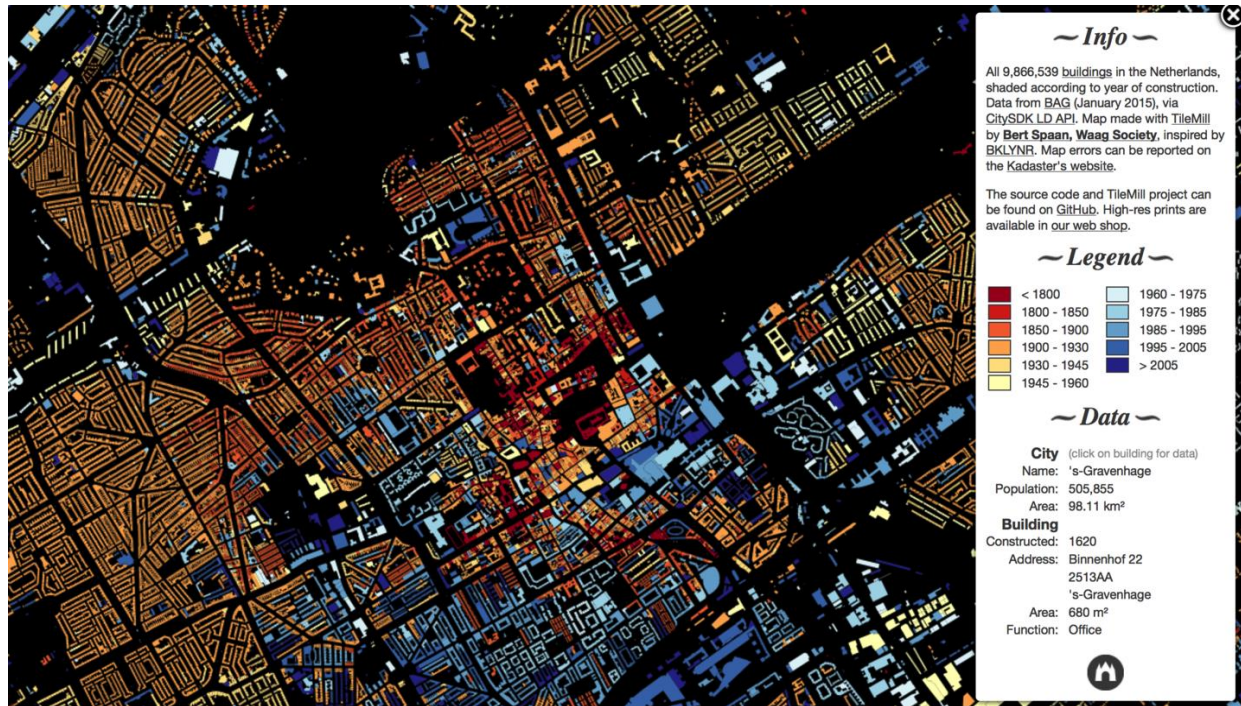


Fig. 6: Map of the city center of The Hague (Dutch: 's-Gravenhage) with the buildings colored according to their year of construction (see legend). Source: Waag Society¹⁶⁶

Further Measures

In addition to these initiatives, legislation is being adopted to entitle reimbursement to owners of buildings ("Energiepresetatievergoeding") who undertake deep retrofits and transition to zero-energy performance, which reduces the energy bills paid by their tenants.

The following recommendations are set forth to facilitate the transition to zero-energy buildings and energy plus neighborhoods:

¹⁶⁶ See: <http://waag.org/en/project/interactive-map-all-buildings-netherlands>

2.2.0 NEW BUSINESS MODELS AND VALUE CHAINS

2.2.0.1 Implement Deep Design practices in all new construction and Deep Retrofit practices in all existing buildings by making intensive use of the Dutch Energiesprong initiative and other NZEB policy measures. Energy savings of 50% and higher are cost-effective, yet most practices capture 20% or less. In addition, energy savings are just one of many accrued values, often ignored, that should also include: 1) Retrofit Capital Costs; 2) Non-energy Operating Costs; 3) Tenant Revenues; 4) Sales Revenues; and 5) Retrofit Risk Analysis. The comprehensive documentation and assessment of the myriad risks allows owners to appropriately price these risks and prevent or minimize their potential impacts. At the same time, this process helps identify, assess, and capture the benefits from other value elements.

2.2.0.2 Foster Energy Service Companies (ESCOs) - Financing the transition of the MRDH building stock to thousands of nodes that serve as data centers, micro power generating plants, storage sites, and automated transport hubs will be financed and executed by a unique business model called Energy Service Companies (ESCOs) and a novel financial instrument known as Energy Performance Contracts, also called Shared Savings Agreements. ESCOs finance the retrofits of buildings, the installation of renewable energy harvesting technologies, energy storage, advanced meters, and electric charging stations with their own capital or bank loans and the investment is paid back by the energy savings over time. The owner or occupant gets a free ride and after the payback period has ended, reaps the full value of the energy savings. ESCOs generally include energy audits, project design, financing, the purchase of equipment, and operation and maintenance.

Given the steep curve in the growth of the ESCOs market and Performance Contracting, it is likely that this mechanism, along with government incentives, will play a critical role in the conversion of thousands of buildings in the region into Third Industrial Revolution nodes to manage, power, and move economic activity across a smart green Internet of Things infrastructure. In the new Internet of Things era, everyone becomes their own efficiency expert and chief productivity officer, continually creating new apps to improve aggregate efficiency and reduce ecological footprint across their respective value chains.

2.2.1 TECHNICAL

2.2.1.1 Stimulate technical innovations to reduce the costs of retrofitting existing buildings by using a high degree of automated prefabrication of wall façade elements, including heating and ventilation equipment to be installed outside the building, to minimize the construction time and the impact on the occupants. This includes using new materials (taking their circularity into account), new production technologies, including robot-based automation and 3D printing, integrating components and technical equipment in façade elements, and improvements in supply and installation logistics. Opportunities for improvements should be evaluated systematically in applied research projects.

2.2.1.2 Stimulate a Zero-Energy Flagship District to demonstrate, evaluate, and improve networking of smart technologies like retrofitting existing buildings to zero-energy buildings, using buildings as energy and data storage, optimizing the generation and use of renewable energy sources at a district level, installing a district energy management system connected to smart meters in each dwelling in the district, integrating electric vehicle (EV) charging infrastructure in buildings and the district, facilitating smart charging and using EV batteries to stabilize the grid, and providing new services in the Sharing Economy by connecting all dwellings and components of the district to the IoT data Internet.

2.2.1.3 Establish an open source library of continuously updated and expanded resources that describe in detail which technical improvements are of value in the design, construction, deep retrofit and real-time operation of buildings. This is essential to ensure integration of ongoing technical innovations offering myriad benefits applicable to deep retrofits and positive power buildings. For example, IoT and ICT technologies help optimize the operation of the energy and security system of the building, enhance thermal comfort, increase energy efficiency, reduce energy costs, optimize operation of energy generation plants (e.g. by solar PV, solar thermal collectors, fuel cells), and electrical and thermal energy storage accumulators. Other aspects that influence building refurbishment solutions should be mentioned, e.g. protection of historical buildings, urban farming as an option, water recycling in the building, recycling of building materials, and the relationship of buildings to the public space.

2.2.1.4 Develop solutions to use wireless smart networks and Big Data building analytics to optimize the operation of buildings by “continuous commissioning.” All buildings suffer decreased efficiency relative to their original designs. The Internet of buildings as nodes addresses this issue by monitoring, in real time, the actual energy performance. Smart control

strategies, e.g. using weather forecasts and artificial intelligence for self-optimization, as well as algorithms for automated control of operating parameters help to optimize the operation and increase the efficiency of new and existing buildings.

2.2.1.5 Upgrade residential information and engagement initiatives - Opportunities to combine smart meter technology with social science and broader marketing tactics are continually emerging. Typically, the goal of these initiatives is to make energy visible and to engage households in smart energy management. Feedback system providers use smart meter data, in-home displays, and web-based and mobile applications to develop and test the impact of various innovative feedback approaches. The aim is to provide real-time and aggregated energy information, comparative assessments (historical and social norms), tips, prompts, and alerts to residential customers, with the goal of reducing energy consumption and maximizing Demand Response efforts.

Local efforts like these should be expanded and upgraded, leveraging models such as Dutch utility Eneco's Toon thermostat. This program enables residential and commercial customers to have access to near real-time energy information to improve energy management and reduce energy consumption. Eneco's Toon Thermostat already allows homeowners visibility of real-time energy consumption and allows the remote control of lighting and heating via smart phones.

2.2.2 REGULATORY

2.2.2.1 Review the existing building-related codes and standards – The novelty of IoT technologies in buildings may raise issues in existing building codes and standards. Identifying possible barriers can help determine resolutions or upgrades required for advancing IoT technologies in buildings. MRDH should implement demonstration projects to illustrate the technical, market and regulatory environment required to codify and standardize these IoT and ICT related building concepts. The goal of these projects would be to demonstrate how buildings as 'information hubs' can help the region, city, or district stay smart. The demonstration projects would need to require all buildings in the pilot area to have the appropriate public or private communication streams, connected to the other key information hubs in the designated area. Data centers could be incorporated into buildings to provide

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services for infrastructure as needed. In addition, Wi-Fi and data center access could be offered as part of the rent, or as a part of the suite of fees-for-service available to users along the system.

2.2.2.2 Establish integrated design principles as requirement for eco-district funding –

Integrated designs involve cohesive and collaborative planning, design, construction, and management of buildings to not only deliver on energy and environmental performance specifications, but to also increase occupant satisfaction and operational effectiveness. Requiring integrated design frameworks for public/private financing schemes will enable the necessary connections between each stage in the building lifecycle, and facilitate a closed loop information exchange between the design vision and ultimate use of the facility.

2.2.2.3 Create TIR standard for public buildings – The principle of first demonstrating smart energy applications on public buildings could be useful in MRDH. The European Commission's EnRiMa decision support system enables public buildings to lower energy consumption by maximizing the potential of the building's existing equipment; it can also support new decision making processes such as the purchase of new equipment and selecting energy tariffs.

2.2.2.4 Establish a new Commissioner on Security and Resilience [See description at 1.1.2.1 above]

2.2.3 POLICY

2.2.3.1 A governance structure is needed to transform the industrial, commercial, and residential building stock of MRDH to thousands of interconnected nodes that serve as Big Data centers, micropower generation sites, and electric and fuel cell transportation hubs. All relevant government agencies will need to be engaged in the planning and deployment of the transition. The government agencies will also need to include the relevant stakeholders in the private sector and civil society in the transformation of the building stock into interconnected nodes in an IoT infrastructure. Construction companies, the real estate sector, electricity companies, the ICT and electronic sectors, neighborhood associations, social and cooperative housing associations, will all need to be included in the governance structure to share expertise and secure buy-in.

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2.2.3.2 Stimulate “Stroomversnelling” deals between market actors and implement partnerships with large businesses to promote ‘energy awareness’ initiatives. MRDH should partner with large companies to create employer-led programs that encourage and support employees to reduce energy consumption through smart energy practices at home and at work and to install renewable energy technologies. Energy savings at work will focus on workplace employee engagement programs. Energy savings at home will focus on the provision of aggregated and discounted technology purchases, specialized payment programs (via the employer), energy information, and energy saving tips and incentives. The UK’s Energy Savings Trust runs an employee awareness program called Carbon Trust Empower. This program targets reduction in energy use, emissions, water, and waste through employee engagement. The program supports the development and implementation of a strategy as well as the monitoring of the program.

2.2.3.3 Pursue actions for achieving both energy neutral or positive power energy buildings with high comfort and the creation of surrounding livable areas - The creation of livable areas requires an integrated urban design of neighborhoods with public spaces, ease of mobility, convenient shopping, accessible schools and work places, diverse social activities and deep participation by the civil society in the creation of social capital in the MRDH community. Living spaces also have to be embedded in rewilded ecosystems to create a sustainable balance between human and natural habits.

2.2.3.4 CUBE 2020 Competition: Commercial building energy challenge - Research indicates that smart building operations and tenant engagement can reduce commercial building energy consumption by 10% or more. This initiative provides a mechanism for leveraging short-term savings through the implementation of competitions (e.g., CUBE 2020 that can help building owners, managers, operators, and tenants rethink their energy use patterns and establish new patterns through shifts in the use of lighting and plug-load technologies). CUBE 2020 is aimed at reducing major users of office buildings to lower energy consumption; it currently involves around 123 candidates across France, Belgium and Luxembourg who are averaging cumulative energy savings of 5.4% and expect to achieve 10% over a full year. Savings are made through better technical operations and the mobilization of occupiers.

2.2.3.5 Foster collaboration which adheres to guidance on buildings as intentional and meaningful spaces. The end use and intention of buildings are often overlooked. Buildings are traditionally designed, built, and occupied, without initially validating that they are meeting the

expectations of owners/occupants, or that they are being optimized for the ultimate end use. The thesis of this concept is that each building is created and developed to the ultimate purpose. Representative sectors might include:

- Schools as the ideal setting for disseminating learning
- Hospitals as the ideal setting for disseminating healing
- Offices as the ideal setting for disseminating collaboration
- Stores as the ideal settings for disseminating commerce
- Turning unused space into used space (power and rooftop farming)

In each case, the building's intention and needs would be matched with a series of appropriate technology solutions that could be leveraged across the city.

2.2.3.6 Develop innovative disclosure and rating tools for the real estate sector – Making energy-related operating costs more transparent to owners, buyers, and renters creates opportunity to make energy more visible and to reshape real estate preferences. Smart real estate markets will use comparative benchmarking and rating systems and ICT-enabled programs to share energy consumption information. In addition, there should be changes in real estate disclosure laws to promote reduced levels of energy consumption through participation in energy audits, retrofits, smart energy management, green leases, and more.

2.2.4 EDUCATION

2.2.4.1 Continue ongoing education and innovation opportunities at Project RDM. The RDM Campus on the former Rotterdam Dry Dock Company site (Rotterdamsche Droogdok Maatschappij) combines innovation and education with the new motto of "Research, Design & Manufacturing." It serves as an incubation center fostering innovation and creative concepts for production industries. Researchers, students and business firms jointly focus on introducing energy and mobility initiatives, and ecologically sustainable solutions. It is important to ensure that these economic sectors derive their aggregate efficiency-productivity gains from the infusion with the Internet of Things platform.

2.2.4.2 Implement TIR in a systemic approach at a University campus with active student involvement. A university can be seen as a small city, with buildings, networks, mobility needs, waste management, energy consumption, and production. It has the great advantage of being largely managed by an in-house team, which is not the case of a small city. With strong student participation, it becomes one of the best places to implement the TIR vision, develop innovations, and contribute to the education of the workforce.

This would also be the best way to involve the young generation and to implement TIR globally, not only in terms of energy, but also in other areas including mobility, urban farming, and 3D printing in technical schools. Students can be involved in the actual program, in making energy measurements for audits or in proposing new designs. For example, they could be part of a zero-waste movement. But to do so, there is a need to build up specific governance, design a multi-annual program, and find the proper financing.

Links could easily be established with the Catholic University in Lille (Hauts-de-France), which is strongly involved in TIR development via its "LIVE TREE" program.¹⁶⁷

2.2.4.3 Leverage and promote insights from the Concept House Village (CHV) & Aqua Dock project, scaling the best performing outcomes. CHV offers the opportunity to undertake and evaluate innovations in a Living Lab where researchers and educators, along with business and government partners, can enhance living, health, and comfort while also achieving significant monetary savings by minimizing the use of energy and the recycling of waste. While transitioning to a commercially independent entity, research and education will remain ongoing at CHV, including preparation with the university of an ongoing research agenda for enhancing and advancing Circular Buildings.

2.2.4.4 Share and promote the ongoing results of the Experimentation and Demonstration areas (Living Labs) for sustainable and circular buildings (experimenter- en demonstratieruimtes voor duurzaam en circulair bouwen). The Living Labs provide the experimental and demonstration conditions in pursuit of circular building construction and sustainable operation. The innovations encompass more ecologically benign designs, material selections, construction processes and operation techniques, and creative funding models, that all advance energy and resource conservation in the built environment. For example, HZ University of Applied Sciences along with the Municipality of Schouwen-Duiveland, developed a

¹⁶⁷ See: <http://www.univ-catholille.fr/decouverte/TRI.asp>

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Lowtech HighTech Campus (HTLTC) in Rijkswaterstaat, with the goal of demonstrating opportunities for enhancing the resilience of economically weak but ecologically rich regions.



Source: Living labs as inspiration and new sources of knowledge and innovation for Schouwen-Duiveland, April 23, 2016, <http://www.bru.nu/living-labs-als-inspiratie-en-bronnen-kennis-en-innovatie-schouwen-duiveland/9622>

2.2.4.5 Communicate the insights and opportunities, as well as lessons learned for further innovation, derived from the Project in Temporary experimental housing in Heijplaat Merwe and 4 Port (Project Tijdelijke experimentele woningen in Heijplaat en Merwe 4 Haven). The joint effort by the Technical University of Delft and several construction firms is demonstrating zero net energy buildings in three experimental temporary dwellings.

2.2.4.6 Continue evolving, fine-tuning, and enhancing the Masterplans for Metal, electric/energy installation curricula, teaching, skills and competences at the multiple Regional Education Centers, ROCs (Meerdere ROC's, Masterplan Metaal-, elektro/energie en installatietechniek). The Masterplans for ROCs provide a platform network where educational institutions and business firms are able to describe and discuss with each other the key issues

related to the field of metal electric / energy and installation and operation techniques. Besides a permanent platform both onsite and online, there are regional profiles, a guidance system, and continuous learning realized for VMBO and HBO. The aim is to standardize a unified approach among all the ROCs in South Holland, while at the same time encouraging ongoing innovation that may necessitate evolving and adapting the standardized unified approach.

2.2.4.7 Disseminate lessons learned from the Project Circulaire Parkkade (Circular Quay park project). The Circulaire Parkkade is an integral design component of the Concept House Village. It is a joint partnership between the Centre of Expertise RDM, Hogeschool Rotterdam, CHV, stakeholders, and the Initiators of the Circulaire Parkkade. The Design is the Netherlands' first totally circular residential area, with the goal of being an entirely self-sufficient district, comprised of circular material constructed buildings, and built to inspire a myriad of stakeholders to replicate the model, including municipalities and developers.

2.2.4.8 Implementation of the Training plant at RDM. Deltalinqs is leading the effort to implement an advanced Training Plant at RDM. Deltalinqs is the association representing the shared interests of more than 95% of all Rotterdam mainport logistic, ports and industrial enterprises, including more than 700 businesses from 14 diverse sectors. The membership accounts for more than three percent of the nation's GDP and employs 180,000 people directly or indirectly. The Plant Training facility is focused on teaching "practical simulations in a realistic way." This will include: serving as a training and testing site on the application of security knowledge; learning from incidents and safety behavior (training managed by the Foundation Cooperation for Safety, SSVV); Deltalinq's trainings; providing retraining, refresher and upskilling courses; as well as simulation and practical environments for education at the MBO and HBO levels.

2.2.4.9 Develop an advanced Research center on Sustainable Bio-based Valorization Opportunities. Since 2007, the nation's key objective has been the development of sustainable biomass valorization ("value pyramid") or production of biobased materials and use residues for biofuels, electricity and heat (cogeneration). Biorefinery technology has been the central focus for achieving valorization. In addition to serving as energy sources for buildings, biomass fibers used in composite plastics and building insulation materials, as well as in developing biobased chemicals merit greater research attention and development.

2.2.4.10 Assess ways to measure the effectiveness of the Zuid-Holland Infra Park: ZIP!, and use these evaluations to evolve, adapt, improve and scale the initiative on a continuing basis.

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ZIP! was formed to bridge the gap between the labor market and infrastructure needs. The training facilities are set up to provide practical modules and ongoing learning for earning the VMBO, MBO, or HBO diplomas. There are test facilities, and programs focused on training pathways.

2.2.4.11 The educational system should undergo a comprehensive study of the existing competences and deficits – In addition, prepare teachers and design curriculum to match the talents and skills that will be needed to transition building stocks, neighborhoods, and urban environments into a digital Third Industrial Revolution economy.

2.2.5 FINANCIAL

2.2.5.1 Perform analyses indicating the conditions under which building owners will be interested to invest in deep retrofits, and the installation of new renewable energy technologies, smart monitoring equipment, and recharging stations and what support they need to undertake the investment (e.g. information, financing, subsidies, and changes in regulatory oversight). To stimulate investments in the refurbishment of buildings and new positive power buildings, as well as the installation of renewable energy technology and smart energy efficiency monitoring technologies, investors must be convinced that their investments will pay off in reducing the cost of operations and maintenance and ameliorating the value of their real estate.

2.2.5.2 Support efforts to scale investment needed to cost-effectively achieve energy efficiency improvements in existing residential and non-residential buildings – The Netherlands, like other EU Member States, will be challenged to reach its building energy efficiency targets. New business models will be needed throughout the country, as well as within MRDH, to supply the scale of investment required to achieve the available energy efficiency potential. Two initiatives are underway in Europe and should be scaled-up through focused, supportive efforts on behalf of the appropriate bodies within MRDH:

- Investor Confidence Project (ICP) Europe. For decades, investor confidence has been a limiting factor in the advancement of the energy efficiency market in Europe. Investors have been deterred by the lack of reliable project data on anticipated energy savings. To address this barrier, ICP Europe was launched as a project jointly funded by the Environmental Defense Fund and European Union's Horizon 2020 program. With its

suite of building energy performance protocols, ICP Europe defines a clear road-map for going from ‘retrofit opportunity’ to ‘reliable, investor-ready energy efficiency.’

The goal of ICP Europe is to reduce transaction costs by assembling existing standards and practices into a consistent and transparent process that promotes efficient markets by increasing confidence in energy efficiency as a demand-side resource. Building owners get a standard they can use to source renovation projects they can believe in, investors achieve reduced due diligence costs resulting from third-party review of each project before certification, and the standardized approach to developing projects enables aggregation of projects into high performance portfolios.

Working with its many active allied organizations, ICP Europe enables a marketplace for building owners, project developers, utilities, public programs and investors to trade in standardized energy efficiency projects. ICP Europe protocols provide investors with the necessary data to enable them to underwrite or manage the energy performance risk of a new building. A first collection of best practices and standards used on actual building energy renovation projects across Europe is now complete and available for use on any building energy renovation project in the 28 European Union countries, Moldova, Norway, Switzerland and all three regions of Belgium. ICP Europe protocols reference the relevant international and European standards, as well as national and regional standards and practices to ensure they are market-relevant.

- Energiesprong is a fully-integrated, market-driven, zero-energy approach to refurbishment, which includes a revolutionary new model for industrial-scale building refurbishment incorporating zero carbon technology. The approach currently focuses on transforming the building stock of housing associations into net zero homes. Energiesprong retrofits take no more than a week to install, come with a long (30-year) performance warranty, improve the home’s indoor climate, comfort, and aesthetics, and are (mainly) financed through the resulting guaranteed savings in energy costs. A not-for-profit market development team also works on alleviating barriers such as regulations and the issuing of permits.

2.2.6 R&D

2.2.6.1 Introduce circularity with the development of a “material bank for buildings” -

Construction and demolition waste (CDW) is one of the heaviest and most voluminous waste streams generated in the EU.¹⁶⁸ In December 2015, “the European Commission adopted an ambitious Circular Economy Package. The EU agenda includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy, boost global competitiveness, foster sustainable economic growth, and generate new jobs. The EU Action Plan for the Circular Economy establishes a concrete and ambitious program of action, with measures covering the whole economic cycle: from production and consumption to waste management and the marketing of secondary raw materials. The proposed actions will contribute to ‘closing the loop’ of product lifecycles through greater recycling and reuse, and bring benefits to both the environment and the economy.”¹⁶⁹

The efficiency improvements in the TIR economy can only be achieved if construction elements and materials are reduced, reused, and recycled after the end of life of the building as required by the circular economy. To reduce the volume of materials, enable the highest share of reuse of construction elements, and improve the quality of recycling of construction elements and materials, knowledge of all materials used in the buildings is needed. Therefore, it is necessary to develop a “material databank for buildings,” which gathers all information on materials (origin, volume, environmental data, etc.) used in a building from construction to disassembly. This will allow automated lifecycle assessments of buildings during the planning phase and the optimization of design based on the assessment of materials used. The information procured will also allow stakeholders to identify the “eco-friendliness” of the buildings.

2.2.6.2 Engage the triple and quadruple helix knowledge innovation networks on an ongoing basis to advance the complex dynamics of an interacting Mobility & Logistics Internet, Smart manufacturing (HTSM/IT) and prosumer sharing and circular economies. Applied knowledge, which grows and changes with experience, and evidence are required in numerous domains: on best-performing deep retrofit construction methods, materials and components, best-performing energy-consuming equipment – appliances, electronics, lighting, etc. – as well as diverse innovative financial engineering options (e.g., private, public, utility, partnerships, cooperatives), best-in play building codes and efficiency standards, state-of-play in utility

¹⁶⁸ See: http://ec.europa.eu/environment/waste/construction_demolition.htm

¹⁶⁹ See: http://ec.europa.eu/environment/circular-economy/index_en.htm

regulatory policies promoting onsite/distributed power, and the best-in-play Internet communication technologies.

2.2.6.3 Focus on methods to cope with the trade-off between future proofing and accelerating innovations. Noted mathematician/philosopher Alfred North Whitehead succinctly noted, “The art of progress is to preserve order amid change and to preserve change amid order.” A challenging task will involve examining how to balance the economy of scales accruing from aggregated procurement opportunities with the reality of a veritable Cambrian explosion of innovation occurring in the IoT realm resulting in ceaseless changes in technologies, apps, and even protocols and standards. Future-proofing is a highly desirable feature, as is robust experimentation with competing systems of technologies to gain experience of what works best, and what fails on some important criteria. In this new world of rapid “speciation” of ever new options, a diversity of egg baskets is more resilient than putting all eggs into one basket.

CIRCULAR ECONOMY

The Circular Economy (also called circularity) is indispensable to the goal of increasing aggregate efficiencies, reducing ecological footprints and, in the largest context, living within biosphere boundaries. The circular economy is designed to mimic the material and energy flows in mature ecosystems where resources are continuously appropriated, used, redistributed, and recycled for future use. Circularity spans three areas: the production and delivery of goods and services, consumption and behavior, and waste disposal. The circular economy performs a valuable function in decoupling economic value creation from resource consumption.

*Peter Luscuere and the Working
Group members from MRDH*

*Michael Totten (Assetsforlife.net)
and Jeremy Rifkin for TIR Consulting
Group LLC*

Circularity is expressed as seven pillars: sustainable supply, eco-design, industrial ecology, functional economy (or functionality), responsible consumption, increase of the life duration, and recycling. *Sustainable supply* concerns the way resources are extracted with the goal of minimizing the environmental impact and optimizing the extraction process. It is valid for energy and minerals, but also for agriculture and forestry. *Eco-design* addresses all the ways to reduce the environmental impact of goods, optimizing the aggregate efficiency of matter used, including life-cycle analyses. *Industrial and territorial ecology* mediates the relationship between the biosphere and human societies through the knowledge of the flows of material and energies across economies. The *functional economy* emphasizes the use of a product rather than its ownership. *Responsible consumption* focuses on making economic choices based on evaluating the sustainable *life cycle and duration* of a product or service. *Recycling* is a well-known process by which waste products are re-introduced into the industrial chain of production. For example, currently, small companies are manufacturing 3D printed products from recycled plastic, paper, and metal objects.

9 Rs

The circular economy has also been described as the 9 Rs:¹⁷⁰

- 1) Refuse: preventing raw resources and materials use;
- 2) Reduce: reducing raw resources and materials use;
- 3) Reuse: reusing products and circulating in sharing economy;
- 4) Repair: repairing and maintenance;
- 5) Refurbish: product refurbishment;
- 6) Remanufacture: producing new products from component parts of used products;
- 7) Repurpose: reuse products in new purposes;
- 8) Recycle: materials reuse through processing; and
- 9) Recover energy: incinerating leftover resources.

The Renault plant in Choisy-le-Roi outside Paris is a good example of circularity across a company's value chain. The Renault plant "remanufactures" automotive engines, transmissions, injection pumps, and other parts for retail. The plant facilities use 80% less energy, 90% less water, and generate 70% less oil and detergent waste in its operations than its competitors, giving it higher operating margins.

Renault redesigns its parts to make them easier to disassemble and reuse. Renault also collaborates in joint ventures with a steel recycler and waste management company to secure the necessary expertise to optimize the lifecycle of their parts. Finally, Renault motivates its suppliers to increase aggregate efficiencies and reduce waste in the supply chain by rewarding them based on performance contracts – paying them for the efficiency gains – rather than simply paying for the purchase of the goods.

Dutch cycling offers a paradigm example of dramatically shrinking the ecological footprints and resource consumption in deriving mobility services (as the photo below illustrates). The Netherlands has more than 35,000 kilometers of bicycling infrastructure, including protected intersections, pervasive bicycle parking, and more direct routes compared to motorized vehicles. Nationwide, 27% of all travel occurs via bicycling. In cities this is even higher (e.g., 38% in [Amsterdam](#), 46% in smaller Dutch cities like [Zwolle](#) (pop. ~123,000), and 59% in [Groningen](#) (pop. ~198,000)), and thought to be the highest modal share worldwide. The fuel

¹⁷⁰ Kramer, Jacqueline (2014) *Milieu: Elementaire Deeltjes: 16*, Amsterdam University Press: Amsterdam, The Netherlands.

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efficiency of a bicyclist is roughly 100 times greater than driving a car (1000 km/liter vs. 10 km/l). The 16 to 20 kilogram bike weight requires just a few percent of the extracted resources, manufactured materials, and converted land into roads required of a 1100 to 1700 kg vehicle. Moreover, riding bicycles eliminate nearly all the greenhouse gas emissions, air and water pollutants, solid and liquid wastes, and toxic contaminants associated with vehicles. New circularity business services have emerged in response to high bicycling rates. For example, Nederlandse Spoorwegen (NS), the Dutch railway company, operates the Dutch Bike Rental Scheme, *OV Fiets*, which provides basic bikes for rent at 250 locations. The OV-Fiets scheme has more than 100,000 members.



It should be emphasized that the circular economy is much more than recycling and restoration of materials. It is also keeping resources in circulation for as long as possible – as, for example, in the Sharing Economy – and exacting the most value from them while in use: in other words, optimizing their aggregate efficiency and productivity. A McKinsey study projects that savings in materials, recycling, and restoration, will likely exceed \$1 trillion by 2025 in the global economy while increasing productivity, reducing fixed and marginal costs, creating net new jobs, and lowering ecological footprint. A recent European Commission study projects that the circular economy can save EU businesses EUR 600 billion.¹⁷¹

¹⁷¹ Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Region: Towards a circular economy: A zero waste programme for Europe

The Netherlands imports nearly 70 percent of its raw materials from abroad, including 90% of 54 raw materials – primarily from China – that are labeled ‘critical’ by the European Commission.¹⁷² Such high percentages of raw materials, and especially critical raw materials, increases uncertainty and vulnerability of secure supplies, as well as exposure to price volatility from increasingly scarce resources. In fact, there was a three-fold price increase in the volatility of raw materials between 2000 and 2013, relative to 1990–2000.¹⁷³

Maintaining the traditional linear mode of designing, constructing and operating society’s physical infrastructure and built environment imposes higher risks to uncertain economic surprises and shocks. Shifting to a closed loop, circular economy model helps avoid opportunity losses and costs, while future proofing against a range of potential social-economic disruptions. Well-crafted circularity governance policies and business practices can augment regenerative and restorative attributes, as well as embed valuable risk-reducing features, notably robustness, resilience, and anti-fragility; qualities that are responsive to uncertainties and surprises in advantageous ways.

An essential component of circularity is undertaking cross- and trans-disciplinary assessments and integrated systems analyses, simulations and scenarios of infrastructure needs and services. Why is this essential? Because the emergence of the Internet of Networks (converging the Internets of Communications, Distributed Renewable Energy networks, and Mobility & Logistics) ushers in symbiotic and multi-functional benefit opportunities and aggregate efficiency-productivity gains that can be gleaned and garnered from intentional, integral designs and integrated actions. Design principles that lead to “feeding products, components, and materials back into the appropriate value chains,” result in “a healthy economy that is inspired by and in balance with nature.”¹⁷⁴

The circular economy principles are eminently applicable and vital to apply to the entire

¹⁷² van Buren, Nicole, Marjolein Demmers, Rob van der Heijden and Frank Witlox (2016) Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments, *Sustainability*, 8:647, <http://www.mdpi.com/journal/sustainability>.

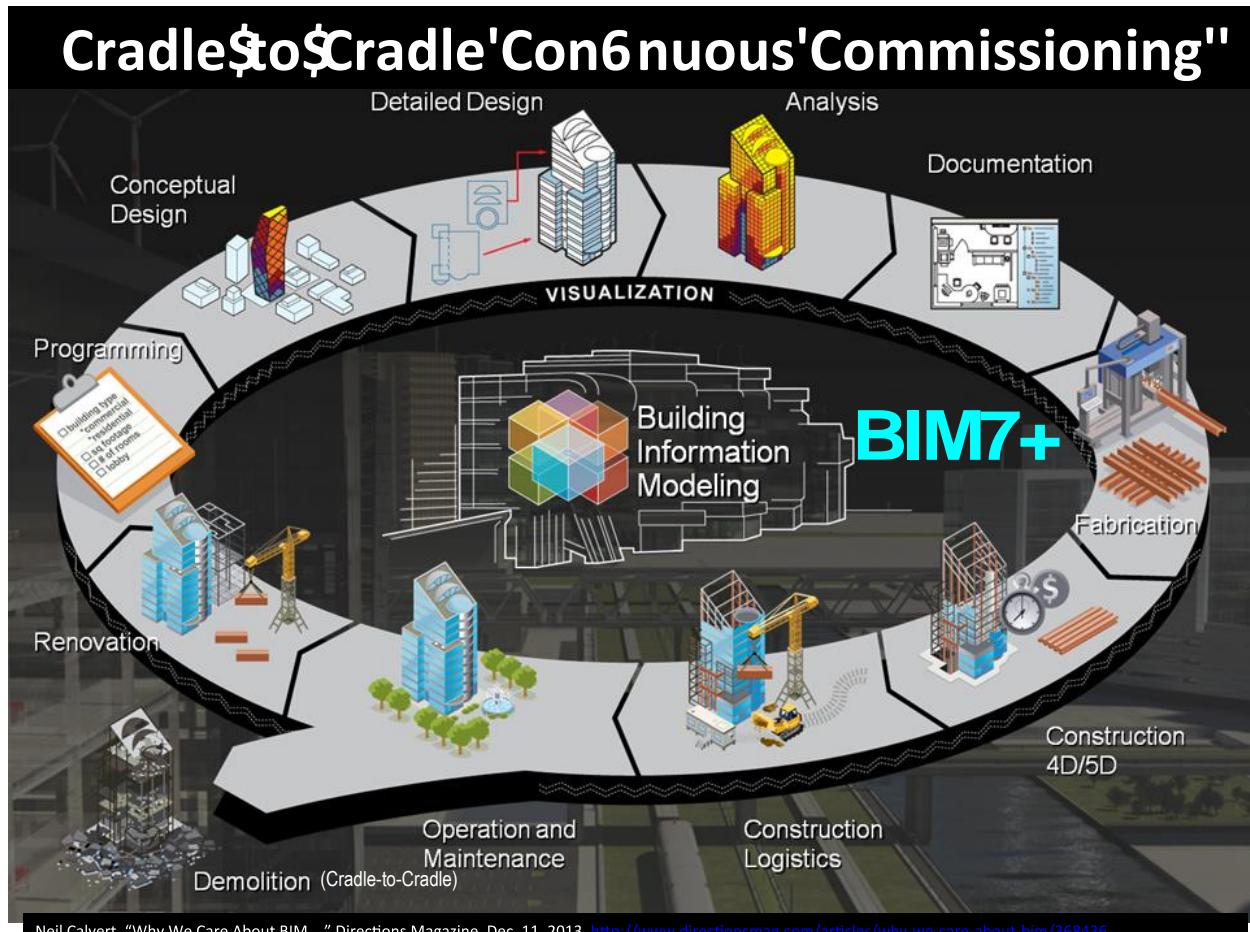
¹⁷³ McKinsey (2013) *Resource Revolution: Tracking Global Commodity Markets*, McKinsey Global Institute, <http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/resource-revolution-tracking-global-commodity-markets>.

¹⁷⁴ Circle-Economy (2014) Designing for a circular world: circular design principles, October 06, 2014, www.circle-economy.com/designing-circular-world-circular-design-principles/.

throughput stream of economic activities, processes, and supply networks, especially given the use of pervasive wireless smart sensor networks, generating big data lakes, assessed by machine intelligence and AI, to perform digital measurement, monitoring, evaluation, and verification. Combined with blockchain technology, these digital measurements can be encrypted in distributed, auditable ledgers, building trust and confidence in transactional flows.

The Netherlands, Denmark, and Sweden, lead the other 25 EU Member States in transitioning into a circular economy. The Dutch government's recycling regulations are among the strictest in the world. The Netherlands has set a goal of reducing waste to incineration by 50%, and aims for 75% of waste sorting and separation at the source. These strict circularity regulations have meant the "landfill has practically vanished."

As mentioned earlier, the maturing of an interconnected digital network composed of the Communication Internet, Energy Internet, and Mobility Internet, enables individuals, small and large businesses, non-profits, and other institutions to use Big Data, analytics, and algorithms to continuously increase their aggregate efficiencies and reduce their ecological footprint in managing, powering, and moving economic activity in a virtuous circular economy. Recall, aggregate efficiency measures the ratio of potential to useful work in every economic conversion. The higher the aggregate efficiency, the less material and energy is wasted in the conversion process. The build out of an IoT infrastructure across the Metropolitan Region of Rotterdam and The Hague provides a technological platform for tightening circularity across every conversion on every value chain. The IoT platform also assists circularity in another way. By reducing the marginal cost of producing and distributing virtual and physical goods to near zero, the IoT fosters the growth of the Sharing Economy. The Sharing Economy is by its very nature a circular economy. Goods and services are redistributed over and over so that nothing goes to the landfill.



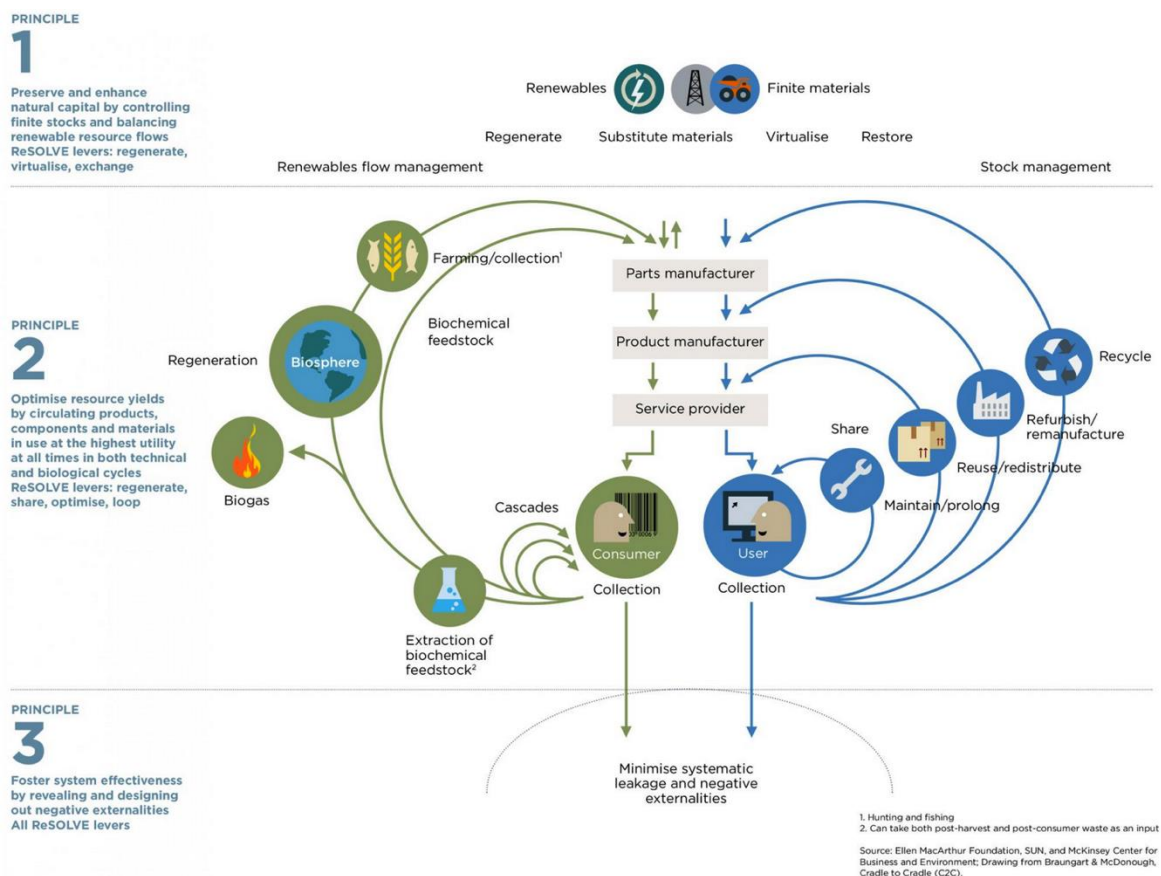
Neil Calvert, "Why We Care About BIM..." Directions Magazine, Dec. 11, 2013, <http://www.directionsmag.com/articles/why-we-care-about-bim/368436>

The depletion of our natural resources has become an urgent global priority. We have to prepare for a post-fossil energy era and need to be able to re- and upcycle our technical and biological materials as they are being depleted or consumed at rates higher than can be grown.

Circularity is the renewability of all natural resources: energy, water, biological and technical materials and topsoil. In this definition, all resources either originate from a renewable source or can be renewed often with the help of energy, whilst preventing negative effects on ecology, economy, and society. This is the ultimate goal – a dot on the horizon for circularity. The overarching premise is that all resources can be renewed and used time after time with little or no waste.

Other approaches to circularity focus more on the reusability of products and resources at the end of the value chain as well as the recuperative power of natural resources. The value of resources is preserved through high value reuse and recycling by which the life span of resources in the value chain is prolonged. Harmful emissions to soil, water and air are prevented as much as possible. In a circular economy, chains are closed and residual waste is either incinerated or left in landfills. This is often graphically represented by the 'Butterfly' schemes (Figure – Outline of a Circular Economy). This is a more pragmatic approach than the ultimate renewability goal above. It consists predominantly of a number of efficiency improvements. The result is often a 'less bad' situation: efficient but not necessarily effective.

Outline of a Circular Economy



Source: Ellen MacArthur Foundation, Circular Economy System Diagram,
<https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram>

A Circular Economy serves both definitions; it holds the dot of 'Renewability for all resources' on the horizon while achieving critical efficiency steps along the way. The definition used by the Ellen MacArthur foundation is:

*"A circular economy is one that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles."*¹⁷⁵

A condensed form of this objective was given earlier by Braungart and McDonough: Waste = Food. Within the context of a Circular Economy, this applies to all economic activities: we have to learn to appreciate that all 'waste' streams are in fact resources, although often for other processes. For the Roadmap Next Economy this applies to all clusters. For each of the clusters, we can apply the basic principle 'Design for disassembly,' which is the very first step enabling society to re-use components and/or repair products. But it doesn't stop there; we should be able to separate materials and even substances so we can recycle them. This will require the use of energy which, in turn, should be renewably generated.

Sustainability has long been viewed as a cost factor. However, it has become clear that sustainable business can be profitable as well. CE is directed at the creation of new business models, based on 'performance based contracting.' This embodies a systems approach that creates new responsibilities for producers and their sales networks. The effect will be that incentives for repair, re-use, remanufacturing and, in the end, recycling will reward the producers. The consumer (both B2B and B2C) will become user of the performances. Through this circular economic strategy, 'loops' will be closed and waste or leakage of materials and energy will be diminished.

Rewilding the Biosphere – Circle of Life

Harvard professor and biologist E.O. Wilson is one of the world's preeminent scientists working to prevent the loss of the planet's irreplaceable floral and faunal species, in what is now labeled as the sixth mass extinction (and the first one caused by human activity). In his most recent and compelling call to action, *Half Earth, Our Planet's Fight for Life*, Dr. Wilson exhorts humanity:

¹⁷⁵ Source: <https://www.ellenmacarthurfoundation.org/circular-economy/overview/concept>

If biodiversity is to be returned to the baseline level of extinction that existed before the spread of humanity, and thus saved for future generations, the conservation effort must be raised to a new level. The only solution to the “Sixth Extinction” is to increase the area of inviolable natural reserves to half the surface of the Earth or greater.

Earth satellite imagery reveals humans appropriate nearly 40 percent of the global terrestrial plant Net Primary Production (HANPP). This level of conversion, combined with record high harvest rates of ocean and freshwater aquatic species, has increased the current rate of species extinction 1000 times faster than the natural background rate. If unproductive and remote lands, plus underground NPP like roots, are subtracted from the total, the remaining available terrestrial NPP amounts to just an additional 10 percent.¹⁷⁶

The historical use of NPP for energy needs was replaced by underground fossil fuels in the First and Second Industrial Revolutions. In recent years, however, the catastrophic threats of climate destabilization and marine acidification has fostered resurgence in large-scale production of bioenergy. The risk with introducing bioenergy is a further loss of biodiversity habitat. For example, it has been calculated that replacing total global consumption of fossil fuels with bioenergy would require more than 400 times the planet’s entire NPP.¹⁷⁷

If the Third Industrial Revolution is to generate a growth period in global economic productivity while simultaneously reducing the massive biosphere impacts associated with First and Second Industrial Revolution technologies, rewilding of the biosphere will need to become an overriding priority. The Internet of Communications, Internet of Renewable Energy, and Internet of Mobility and Logistics that have emerged from the Silicon Valleys of the world will need to be embedded within and throughout *Biosphere Valleys*. Regional and national Biosphere Valleys integrating rewilded nature corridors into the socio-ecological fabric will enhance societal and ecological resilience for future generations.

In the century since protected nature reserves were first established, nearly 13% of the planet’s land surface is now in nature parks, protected areas or wilderness reserves.¹⁷⁸ Roughly 7% of

¹⁷⁶ Running, Steven W. (2012) A Measurable Planetary Boundary for the Biosphere, *Science* 337:1458; DOI: 10.1126/science.1227620

¹⁷⁷ Dukes, Jeffrey S. (2003) Burning Buried Sunshine: Human Consumption of Ancient Solar Energy, *Climate Change*, 61: 31–44, Kluwer Academic Publishers.

¹⁷⁸ Dudley, Nigel, Liza Higgins-Zogib, Marc Hockings, Kathy MacKinnon, Trevor Sandwith, Sue Stolton (2011) National Parks with Benefits: How Protecting the Planet's Biodiversity Also Provides Ecosystem Services, *Solutions*, vol 2, issue 6, <http://www.thesolutionsjournal.com/node/1008>.

coastlines are also protected, as well as 3.3% of the world's oceans.¹⁷⁹ There are a number of countries with notably higher fractions, including the top ten nations with 40 to 60+ percent of their lands protected.¹⁸⁰ However, there are problems with many of the nature parks, with half of them suffering from encroachment and lack of enforcement.¹⁸¹ Unfortunately, 90% of the Earth's identified threatened plant and animal species still remain largely outside these protected areas and face the prospect of extinction in the coming decades.¹⁸²

Rewilding as a protected area design approach emerged over the past half century from ecological research in half a dozen investigative areas— landscape-scale ecological restoration, natural disturbance ecology, species extinction dynamics, meta-population theory, island biogeography, and top-down regulation by large carnivores. Rewilding can be succinctly summarized as comprising three C's: Cores, Corridors and Carnivores.¹⁸³ These independent attributes include vast, well-protected core wild reserves exhibiting connectivity that avoids land fragmentation and patchiness, and contain Keystone species, top trophic carnivores.¹⁸⁴

ARK Nature in the Netherlands was a pioneer in launching rewilding beginning back in the 1980s after a number of floods along the Rhine and Meuse Rivers required re-location of farmlands. The rewilding of the floodplains also led to enhancing ecosystem services, most notably water management and ecotourism. ARK Nature was an original partner of Rewilding Europe, a network now involving 15 nations with more than two million hectares of protected reserves, and a 2020 goal of adding another one million hectares.

Rewilding is now an urgent imperative. It cannot occur in just a few localities, nations or regions. Just as a circular economy cannot fully function if only implemented by a modest

¹⁷⁹ Boonzaier, Lisa and Daniel Pauley (2016) Marine protection targets: an updated assessment of global progress, *Oryx*, 50(1), 27–35, Fauna & Flora International doi:10.1017/S0030605315000848.

¹⁸⁰ World Atlas (2013) Countries With The Most Protected Lands (Percentage Of Area As Reserves), <http://www.worldatlas.com/articles/countries-with-highest-percentage-of-protected-reserve-lands.html>.

¹⁸¹ Laurence, William, D. Carolina Useche, Julio Rendeiro, Margareta Kalka, Corey J. A. Bradshaw, Sean P. Sloan, Susan G. Laurance, Mason Campbell et al. (2012) Averting biodiversity collapse in tropical forest protected areas, *Nature*, vol. 488, September 13, 2012.

¹⁸² Nigel Dudley and Jeffrey Parish (2006) Closing the Gap. Creating Ecologically Representative Protected Area Systems: A Guide to Conducting the Gap Assessments of Protected Area Systems for the Convention on Biological Diversity. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 24.

¹⁸³ Soulé, Michael and Reed Noss (1998) Rewilding and biodiversity conservation as complementary goals for continental conservation, *Wild Earth* 8: 18-28.

¹⁸⁴ Soulé, Michael and John Terborgh (1999) Conserving nature at regional and continental scales - a scientific program for North America, *BioScience* Vol. 49 No.10.

percentage of localities, the same is true with rewilding. Moreover, if rewilding is undertaken mainly by industrialized nations it raises the risk of satisfying demand by shifting production of land-based products and resources to biodiversity-rich developing countries, threatening the further destruction of intact wilderness regions.¹⁸⁵

3.0 NEW BUSINESS MODELS AND VALUE CHAINS

From an entrepreneurial point of view, the way forward for this region is to position MRDH as the lead innovator on circular business models. As such, the region can develop into a world leader in the production and export of knowledge, materials, and systems needed to enable Circular Economies all over the world.

While a rich diversity of business models exist for pursuing market opportunities, from small and medium-sized enterprises (SMEs) to national cooperatives and global corporations, the transition from a simplified linear economy to a complex circular economy poses challenges to all these existing businesses and calls for new extended business models for circularity. In recent decades numerous social enterprise models have emerged from the many initiatives that are complementary with the circular economy: Biomimicry, Blue Economy, Cradle to Cradle, Industrial Ecology, Industrial Metabolism, Industrial Symbiosis, Natural Capitalism, Natural Farming, Performance Economy, Permaculture, Regenerative Design, etc. Researchers have synthesized common components and core elements of these enterprises and circular economy principles, and proposed a number of generic typologies and taxonomies.¹⁸⁶ As an illustrative example, consider the ReSOLVE framework (regenerate, share, optimize, loop, virtualize, exchange),¹⁸⁷ as reflected in the chart below.

¹⁸⁵ Lambin, Eric F. and Patrick Meyfroidt (2011) Global land use change, economic globalization, and the looming land scarcity, *Proceedings of the National Academy of Sciences USA*, vol. 108, no. 9, March 1, 2011, <http://www.pnas.org/cgi/doi/10.1073/pnas.1100480108>.

¹⁸⁶ Lewandowski, Mateusz (2016) Designing the Business Models for Circular Economy—Towards the Conceptual Framework, *Sustainability*, 8:42, <http://www.mdpi.com/journal/sustainability>.

¹⁸⁷ Ellen MacArthur Foundation (2015) *Growth Within: A Circular Economy Vision for a Competitive Europe*; Ellen MacArthur Foundation: Cowes, UK.

Overview of Circular Business Model Types

Classification Criteria	Model	Explanation	Example(s)
Regenerate	Energy recovery	The conversion of non-recyclable waste materials into useable heat, electricity, or fuel	Ralphs and Food 4 Less installed an "anaerobic digestion" system
	Circular Supplies	Using renewable energy	Iberdrola
	Efficient buildings	Locating business activities in efficient buildings	Phillips Eco-Enterprise Center
	Sustainable product locations	Locating business in eco-industrial parks	Kalundborg Eco-industrial Park
	Chemical leasing	The producer mainly sells the functions performed by the chemical, so the environmental impacts and use of hazardous chemical are reduced	Safechem
Share	Maintenance and Repair	Product life cycle is extended through maintenance and repair	Patagonia, Giroflex
	Collaborative Consumption, Sharing Platforms, PSS: Product renting, sharing or pooling	Enable sharing use, access, or ownership of product between members of the public or between businesses.	BlaBlaCar, Airbnb, ThredUP,
	PSS: Product lease	Exclusive use of a product without being the owner	Mud Jeans, Dell, Leasedrive, Stone Rent-a-PC
	PSS: Availability based	The product or service is available for the customer for a specific period of time	GreenWheels
	PSS: Performance based	The revenue is generated according to delivered solution, effect or demand-fulfilment	Philips's "Pay per Lux" solution; the need for new housing model for young starters in Malaysia
	Incentivized return and reuse or Next Life Sales	Customers return used products for an agreed value. Collected products are resold or refurbished and sold	Vodafone Red Hot, Tata Motors Assured
	Upgrading	Replacing modules or components with better quality ones	Phoneblocks
	Product Attachment and Trust	Creating products that will be loved, liked or trusted longer	Apple products
	Bring your own device	Users bring their own devices to get the access to services,	Citrix pays employees for bringing own computers
	Hybrid model	A durable product contains short-lived consumables	Océ-Canon printers and copiers
Optimise	Gap-exploiter model	Exploits "lifetime value gaps" or leftover value in product systems. (e.g., shoes lasting longer than their soles).	printer cartridges outlasting the ink they contain
	Asset management	Internal collection, reuse, refurbishing and resale of used products	FLOOW2, P2PLocal
	Produce on demand	Producing when demand is present and products were ordered	Alt-Berg Bootmakers, Made, Dell Computer Company
	Waste reduction, Good housekeeping, Lean thinking, Fit thinking	Waste reduction in the production process and before	Nitech rechargeable batteries
Loop	PSS: Activity management/outsourcing	More efficient use of capital goods, materials, human resources through outsourcing	Outsourcing
	Remanufacture, Product Transformation	Restoring a product or its components to "as new" quality	Bosch remanufactured car parts
	Recycling, Recycling 2.0, Resource Recovery	Recovering resources out of disposed products or by-products	PET bottles, Desso
	Upcycling	Materials are reused and their value is upgraded	De Steigeraar (design and build of furniture from scrap wood)
Virtualize	Circular Supplies	Using supplies from material loops, bio based- or fully recyclable	Royal DSM
	Dematerialized services	Shifting physical products, services or processes to virtual	Spotify (music online)
Exchange	New technology	New technology of production	WinSun 3D printing houses

Source: Lewandowski, Mateusz (2016) Designing the Business Models for Circular Economy—Towards the Conceptual Framework, *Sustainability*, 8:42.

Business models do not occur in a vacuum, and which ones become successful depend on a number of entangled variables, including motivation, collaboration, human resources,

leadership, business risks, governance and regulatory conditions, socio-cultural acceptance, digital IT capabilities, and customer response. General factors specific to the circular economy also play pivotal roles, including adequate materials and products of value, management of the resource and material supply chain, level of effort to achieve the abovementioned 9 Rs, continuity of product demand over time, and avoiding contamination of resources and materials.¹⁸⁸

3.0.1 Catalyze an incubator/accelerator approach on circular entrepreneurship. Every facet, process, product and service of the economy raises circular opportunities. This richness of entry points for redesigning linear into circular economic activities need to be nurtured and catalyzed through crossover and cross-pollinating incubation centers.

¹⁸⁸ De Winter, J. (2014) Circular Business Models: An Opportunity to Generate New Value, Recover Value and Mitigate Risk Associated with Pressure on Raw Material Availability and Price Volatility. Master's Thesis, University of Utrecht, Utrecht, The Netherlands.

BIM Lifecycle Continuous Commissioning

- 20% reduction in build costs (buy 4, get one free!)
- 33% reduction in costs over the lifetime of the building
- 47% to 65% reduction in conflicts and re-work during construction
- 44% to 59% increase in the overall project quality
- 35% to 43% reduction in risk, better predictability of outcomes
- 34% to 40% better performing completed infrastructure
- 32% to 38% improvement in review and approval cycles



3.0.2 Electrification of mobility should be vigorously pursued and rigorously supported.

Replacing the inefficient combustion engines in the mobility sector with highly efficient electric drive systems helps achieve sharp reductions in ecological footprints. The business models for accelerating and scaling this process have been actively supported to date through positive public policies, with an ambitious 2025 national Dutch target of 1 million electric vehicles. The Netherlands' strong support of incentives and infrastructure measures has lifted it to having Europe's largest fleet of plug-in electric vehicles, as well as ranking among the four largest fleets worldwide (behind the U.S., China and Japan). Roughly one percent of Dutch cars are PEVs. In addition, there are 1.4 million electric bicycles, with electric bikes comprising 20% of new bicycle purchases. Entire city bus fleets, car-sharing fleets, and business fleets are setting targets to advance all-electric status over the coming decade. In going forward, there is value in reviewing and evolving policy incentives to spur business models, resulting in more rapid market uptake of EVs.

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3.0.3 Promote the design and implementation of business models focused on value-leveraging the synergistic convergences between EVs, the built environment and distributed smart grid.

The Second Industrial Revolution operated in sector silos, whereas the Internet of Things, enabling the Third Industrial Revolution, is giving rise to significant productivity gains through the interconnection of these siloed sectors. Buildings with smart wireless sensor networks, Big Data analytics, and onsite power and energy storage systems become nanogrids, linked to other buildings and to distributed microgrids. Attachable/detachable, portable, and interoperable battery-powered electric vehicles (BEVs) become “picogrids” capable of plugging into these nanogrid buildings. With a thriving interconnectivity between buildings, EVs and distributed smart grids, considerable savings accrue in eliminating the need for as much capital investment (capex) in infrastructure, as well as accruing substantial savings in operating expenses (opex) from reduced fuel inputs and waste outputs. This nascent business model requires bringing together experts and specialists from disparate fields to work together in shaping the practices, policies, standards, protocols, and other salient factors for scaling market uptake.

3.0.4 Promote development of new business models for the building sector (architectural, engineering, construction, facilities management) that result in mainstreaming deep retrofits.

Deep retrofits are capable of achieving 50 to 65 percent energy savings, while also improving indoor air quality, comfort, thermal quality, preventing mold growth and water damage, and increasing the property’s value. However, deep retrofits require greater knowledge, enhanced skills, better training, and access to financing. An important aspect is working towards a merger of interests by combining the needs of the people with sustainability ambitions. There are five basic principles of crucial importance in the development of innovations from the Merger of Interests Perspective: broadening scope, identifying interests, collaborating, creating a win-win situation (doing justice to the interests of people here and now, and of people there and later) and creating business opportunities.

3.0.5 Develop business models for harnessing small-scale biological water cleaning in residential areas.

These less resource-consuming grey water circuits can provide distributed systems useful for supporting expansion of Urban Agriculture.

3.0.6 Invest and operate ‘Overseas’ Smart Greenhouses.

The knowledge and expertise of Dutch agro-food-flower technology and know-how in greenhouses offers a vibrant export business model. The Internet of Things tools and technologies allow for locating knowledge-

based smart greenhouses in more favorable climate regions worldwide without the need for extensive heating and intercontinental transportation. ICT innovations like augmented reality, virtual reality, smart sensor networks, intelligent algorithms, machine intelligence, and artificial intelligence (AI) augur for significant “Growth at a distance” overseas greenhouse export business enterprises. These smarter tools will decrease ecological footprints, resource inputs, and waste outputs of operations.

3.0.7 Develop and implement advanced materials, including a 3D printing hub of maritime spare parts from waste material. New materials to deliver sustainable properties should be engineered and used. An integral part of the 3D printing hub is a quadruple helix knowledge innovation network focused on advanced 3D printing practices with a variety of waste materials, and designing advanced systems with decreasing ecological footprints. Not all 3D printing materials are ecologically or environmentally benign.

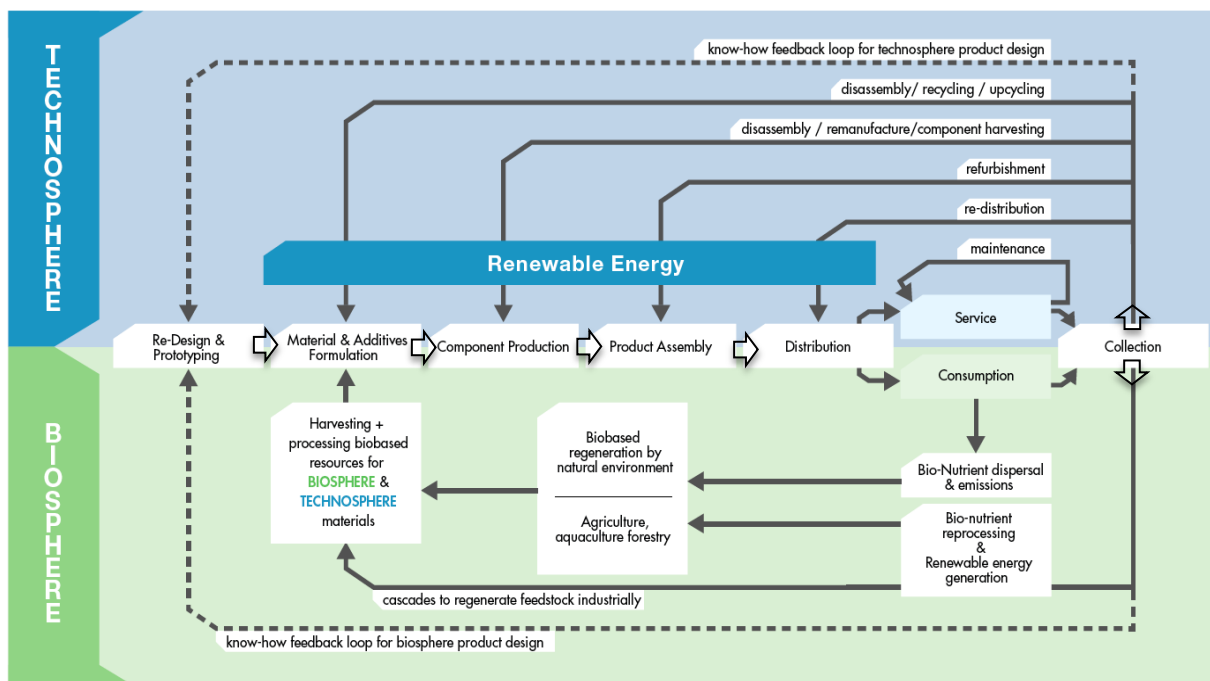


Image source: Circular economy material flows powered by Cradle to Cradle. C2CBizz Guide to C2C-Inspired Business Sites. Diagram EPEA & Returnity Partners.

3.0.8 Establish the Recycling Point. The Recycling Point is a physical Center of the Circular Economy, serving as an accompaniment to the traditional waste collection station, where

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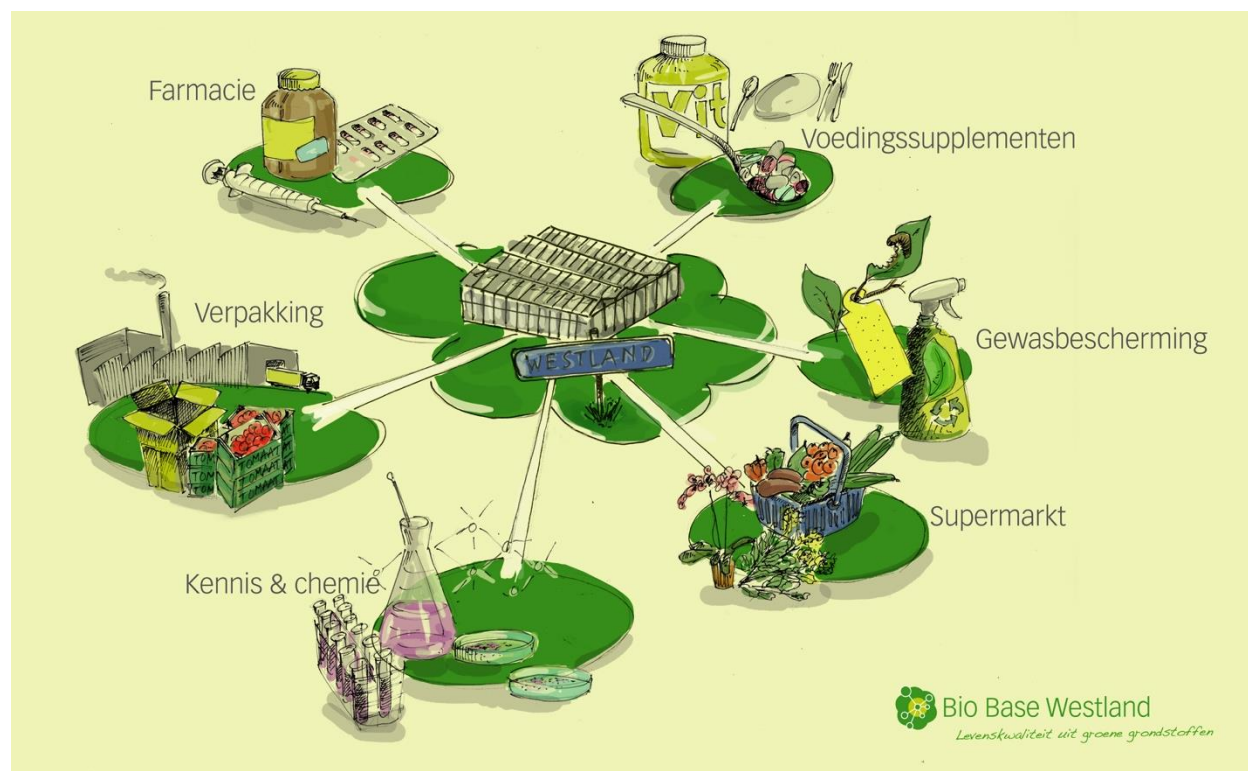
citizens will be paid to bring broken or superfluous products or materials. Nothing is thrown away – everything is repaired or reused. The Recycling Point creates new jobs for appraisers, repairers and makers. The once familiar “milieustraat” will become a “shopping street” of the future, where the makers and creators of the recycled goods sell their upcycled products to the public.

3.0.9 Work with the Clean Tech/ High Tech Smart Manufacturing sector to produce and export high tech systems and materials needed to advance the circular economy. The goal should be to become a world leader in the technology for the customized production of goods in selected specializations. Identifying opportunities can be strengthened and amplified by the use of a quadruple helix knowledge innovation network.

3.0.10 Expand the region’s Urban Agriculture initiatives. Onsite and locally grown food production is the original prosumer activity. Despite a relatively small volume, locally grown food can be a high quality contribution to society. Moreover, a Building-Integrated Greenhouse, where food and fish farming form a synergetic food production facility, can be a highly visible form of the circular economy. The Internet of Communications and the Internet of Things are enriching local food production. Diverse websites are performing innumerable functions: connecting people who want to grow food but have no land with people who have land they will allow others to garden; learning sites on how to design and grow high-yield organic gardens for recreation or vocation with no petrochemical inputs, no machinery except simple hand tools, and a fraction of the water compared to conventional farming; helping school children learn how to use gardens as biological textbooks for learning science, math, and other subjects (geography, history, botanical illustration). This recommendation should build upon the many action recommendations set out in the City of Rotterdam’s fertile ideas publication, *Stimulating urban agriculture in and around Rotterdam*.

3.0.11 Design a business model for manure valorization. The Netherlands is one of the only countries to have a large surplus of manure as a consequence of the high density of the animal breeding industry. As such, manure is seen as a waste and is taxed. Manure, however, can be a valuable resource.

3.0.12 Vigorously pursue new crops for high tech applications: pharmacy, cosmetics, food and crop protection. MRDH should collaborate with growers in determining which plant substances can be produced profitably, as well as expand joint initiatives with the Research Centre on Plant Substances to identify which plant material is in market demand.



3.0.13 Expand the Greenhouse Pharmacy. Maintain and increase the Plant Library with extracts currently from 1,300 plants, with the goal of identifying bioactivity / functionality of specific molecules. Engage the Bio Base Greenport Westland/Oostland (WO), including Wageningen University and the Research Centre (WUR) in Holland, to generate a variety of greenhouse outputs. Bio Base Greenport WO is a network of companies, governments, and civil society organizations working together to deploy biobased business in horticulture. Emphasis should be focused on networking the role of horticulture in the biobased economy, with an eye to transitioning MRDH from a fossil fuels-based economy to an economy using biobased raw material in everything from vegetable colorings and flavoring to pharmaceutical products. Consideration should be given to whether this is open source cooperation based on communal interests, or based on individual interests and patents.

3.0.14 On or before 2030, the shipbuilding and maintenance industry in this region should be organized around the concepts of modular construction design for recycling and more reuse of materials, including the development of material passports. Also, the first zero emission ship should be deployed.

Hydrogen-fuelled container feeder vessel



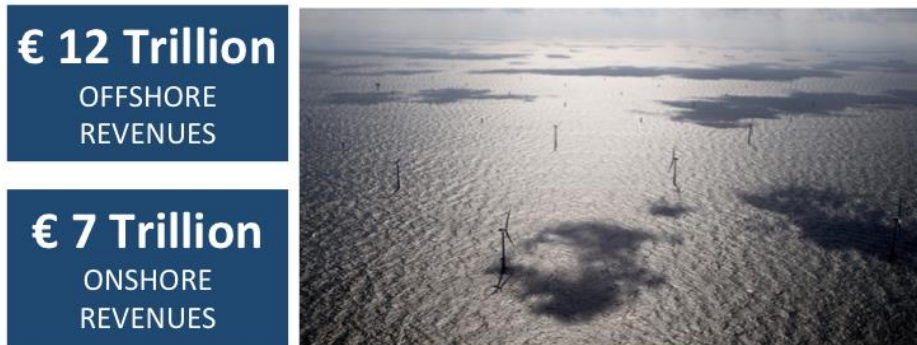
Source: Pierre Sames, vision for a zero emission container feeder vessel, Germanischer Lloyd (GL)

3.0.15 Move from Carbon Capture & Storage (CCS) to Carbon Capture & Usage (CCU).

3.0.16 Pursue quick new initiatives within the next several years, including bio-based refineries, Big scale CCS, Warmtenet (geothermal district heating), and Waste/plastics-to-methanol projects.

3.0.17 Develop new export market opportunities based on learning/experience curves derived from using the MRDH/NL as the Living Lab & Testbed for advancing Circular Economy Enterprise Ecosystems. Transition the Port of Rotterdam from a petrochemical-based business model to a Knowledge-as-a-Service circular economy business innovation model. Leverage maritime expertise and skills to become the profit leader in the global offshore wind platforms – a multi-trillion Euro market opportunity.

Global Market Opportunity WIND



Princess Amalia offshore wind

Source: Jacobson, Mark and Mark Delucchi et al., (2016) 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All- Sector Energy Roadmaps for 139 Countries of the World, April, 2015, <http://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf>

3. 1 TECHNICAL

3.1.1 A combination of sensor technology and ICT must be developed, leading to Intelligent Asset Value Drivers, which will propel the recyclability of all systems, components and materials involved.

3.1.2 In 2030, the dredging industry develops innovative infrastructures for river deltas around the world in the fight against flooding and rising sea levels, including coastal defense and riverbank protection. Use innovative hydraulic engineering as a critical feature of these innovative infrastructures. Employ resiliency and biomimicry processes (i.e., nature-inspired) for coastal and riverbank protection – for example, nature-based designs, such as protection and restoration of sea grasses and mangroves, should be examined and employed as low-cost adaptation opportunities.

3.1.3 The Dredging Industry should develop the artificial and floating islands industry, incorporating ecological design principles and integrative and holistic systems engineering practices.

3.2 REGULATORY

3.2.1 A Circularity Agency should be established by the government. This agency should set up accelerated benchmarks and performance-based outcomes for integrating circularity into every process along an enterprise's value chains.

3.2.2 Establish for all clusters a GPS map-based data visualization tracking system of Intelligent Asset Value Drivers for monitoring and measuring the location, condition and availability of biological and/or technical materials in the form of systems, components and materials in use. Such a system is essential for increasing the rates of reuse and recycling, reducing the rates of waste and disuse, and for determining the status of circularity metrics. Whether it is in shipbuilding, oil and gas rig-decommissioning, electronic wastes, wastes from habitat restoration, or end-of-life appliances, equipment, vehicles or other components of the built environment, material passports and sensor technology should be developed.

3.2.3 Improve the enforcement of existing rules on guarantees and step up the action to tackle false green claims.

3.2.4 Require Pharmafilters to be installed at all Hospitals in the region for effective removal of pharmaceuticals targeting the hormone system, a myriad of medicines, and active substances from major contaminants. Active substances that have been singled out for particular concern include: Doramectin, Ethinylestradiol, Fluorouracil, Fluoxetine, Ivermectin, Tetracycline, and Tylosin. Other medicines encompass a range of antibiotics, microbicides, anti-parasitics, beta blockers, lipid regulators, analgesic/inflammatory medicinal products, anti-epileptic medicinal products, and X-ray contrast media.

3.3 POLICY

3.3.1 Foster a paradigm shift within MRDH to replace the concept of 'waste' into one of perception of 'valuable resources.' This value has to be perceived by the entire community, including government agencies, civil society organizations, and schools and universities. The awareness must result in pertinent integral practice. Continuous learning opportunities must help citizens with this change of mind set, as well as enhancing the skill sets of people needed to redesign products, processes, and services to allow the precycling, recycling, and upcycling of components, materials, and substances. Many skilled and professional workers are needed as

the process of regaining the materials from 'waste' is more labor intensive than creating them from 'virgin' materials. The accumulated experience and learning curves gained through the paradigm shift from the linear to a circular economy should be promoted as a potentially vibrant, robust export business model for MRDH.

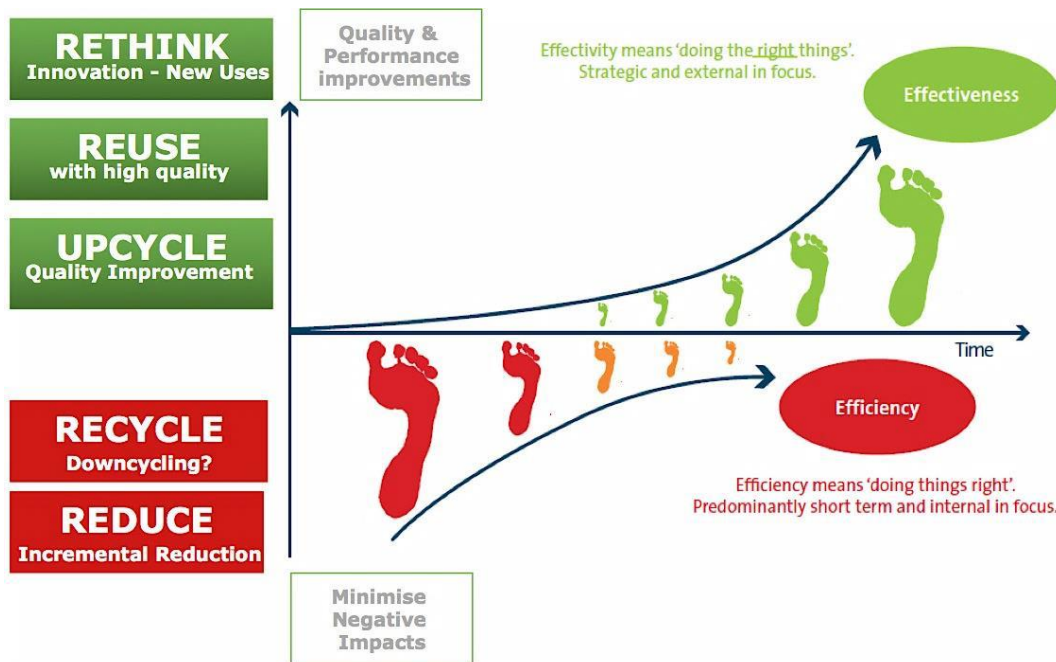


Image source: Environmental Protection Encouragement Agency (EPEA) The road from less negative to more positive. <http://www.epea.com/en/content/about-epea-0>

3.3.2 All Circular Economy limiting laws and regulations already known, or additionally identified in the context of RNE, should be discussed with relevant ministries. A first check can be done by 'Ruimte in regels voor groene groei.' The government is actively pursuing CE as described in a number of documents.

3.3.3 Pursue a total shift to renewables – MRDH needs a more encompassing definition of what circularity requires. The Metropolitan Region should advocate a definition which connects the concept of a positive footprint to all relevant resources in the Built Environment: energy, water, materials and topsoil. In this definition, all resources either originate from a renewable

source or are renewable themselves, while preventing negative effects on ecology, economy, and society. The ultimate goal is 'renewability'. It should be recognized that not all "renewables" are ecologically sustainable when scaled too large and have an impact on other important social and cultural concerns. Moreover, unforeseen and unwitting negative consequences may emerge as different renewables are scaled up. For these reasons, there should be ongoing review and assessment to ensure such issues and potential challenges are recognized.

3.3.4 Incorporate the use of natural processes ('building with nature') and application of ecological principles in coastal and 'urban flood management' including disaster risk mitigation and constructing coastal infrastructure.

3.3.5 Improve consumer information on the environmental impacts of products. Help in enhancing the effectiveness of the EU Ecolabel and addressing possible practices of planned obsolescence.

3.3.6 Establish an integrated set of policies accelerating Deep Retrofits of existing Buildings into nanogrids, and connected into microgrids (ultra-efficient IT-controlled micro power plants), including onsite storage technologies and smart metering instrumentation for performing continuous commissioning. The built environment in the Netherlands accounts for 35% of energy consumption and some 40% of material consumption and is therefore perhaps the most important sector for the Circularity cluster. An integrated set of policies needs to encompass increasingly more efficient building, appliance, equipment and window standards, while continuously improving educational training and up-skilling resources. Innovative financing methods need to be introduced to remove upfront capital barriers. Regulatory changes need to be enacted to remove statutes that impede and inhibit comprehensive, deep retrofits and ICT instrumentation implementation, and other pertinent market-shaping needs (e.g., among trades, associations, consumers, regulators). An open source Internet-accessible platform is crucial for facilitating the ecosystem of interactions within, between, and among these intermingling policy dimensions.

3.3.7 Expand the lateral governance policy of engagement as an integral aspect of the TIR Roadmap Next Economy. The Netherlands has a long tradition of collaboration between government, businesses, the academic community, and nonprofit organizations in the pursuit of economic, social, and cultural goals. MRDH has deepened and expanded on this tradition by bringing together representatives from across various industries, professional associations,

research institutes, and other competencies in a multi-perspective endeavor in partnership with TIR Consulting Group LLC. The joint initiative has transformed the governance model in the metropolitan region to reflect the nature of the new Third Industrial Revolution infrastructure being readied for deployment. The coming together of the Communication Internet, the Renewable Energy Internet, and the automated Mobility Internet, atop an Internet of Things platform, not only changes the way MRDH manages, powers, and moves economic activity, but also the very nature of social engagement among the principal sectors of society. The near zero marginal cost of collaboration across vast digital networks is best advanced in a distributed, collaborative, open, and laterally-scaled fashion, changing the very nature of governance. Recognizing the new opportunities and challenges brought on by this new technological revolution, the 23 municipalities of the Metropolitan Region transformed their traditional role as a centralized overseer and planner to that of a lateral facilitator of a regional network of engaged stakeholders working together as equal partners to advance a new economic, social, and political vision that can take the Metropolitan Region into the new smart digital era.

3.3.8 Catalyze MRDH as a Biosphere Valley – the advanced model of the Third Industrial Revolution. As mentioned in the preface, while the advent of the digital Third Industrial Revolution in the United States focused largely on new technologies, products, and services – the Silicon Valley model –, MRDH has taken a more inclusive and globalizing approach by framing the relevance of the new products, technologies, and services to the emerging global interconnectivity and accompanying planetary stewardship of the Earth’s ecosystems – the Biosphere Valley model. In the Biosphere Era, MRDH and every other political jurisdiction becomes responsible for its 19 kilometers of the biosphere stretching from the stratosphere to the sea, which makes up the life force of the planet and constitutes the indivisible community to which we are all beholden and whose well-being determines our own quality of life. Biosphere stewardship becomes the essential mission of each region and locality in reducing ecological footprint and addressing climate change in the coming era. The Third Industrial Revolution narrative proposed in the Roadmap Next Economy introduces an innovative approach to biosphere stewardship based on ushering in digital ecosystems that mirror the dynamics of natural ecosystems, with the intention of pursuing a seamless symbiotic relationship between the circular flows of nature and the economic activities of Dutch society. The Roadmap Next Economy continually hones in on critical ecosystem features including self-organization, mutualism, co-evolution, diversity, emergence, resiliency, and adaptation in

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modelling the metropolitan region's new digital ecosystems and accompanying business practices and regulatory regime.

3.3.9 Establish a new Commissioner on Rewilding.

3.3.10 Expand the Green Metropolis initiative by combining and integrating efforts between the structural green areas around the Randstad and the network of protected areas. The Staatsbosbeheer (forestry commission), for example, is commissioned by the Dutch government to manage a substantial share of the nature reserves in the Netherlands. The agency operates many former 'buffer zones,' and structural green areas around the Randstad (the collective area of the major cities in the West of the Netherlands), which are primarily recreational areas. Although technically outside the network of protected areas in the Netherlands (Natuurnetwerk Nederland), Staatsbosbeheer believes that these areas can serve as a vital green resource for the Randstad in the 21st Century. Also, taking into account the nationally important cultural history of these protected areas, including their role as part of the Netherlands' system of flood defenses, they can play a vital role in creating an excellent metropolitan environment in which to live and work.

3.4 EDUCATION

3.4.1 Promote a New mindset about Wastes as Nutrients - In order to understand the value of the resources at hand and not to diminish or even destroy it by mixing, contaminating etc., it is imperative to educate and retrain all involved, not only the existing garbage collectors.

3.4.2 Develop educational resources for the skills and competency needed by specialized workers - The industries and companies who will be shaping new business models based on these newfound values will need specialized workers – semi-skilled, skilled, and professional – to develop and operate technologies for re- and upcycling as well as redesign of products and processes.

3.4.3 Redesign modes of continuous learning by taking advantage of the anytime/anywhere nature of the Internet of Communications. New modes of continuous learning are rapidly evolving with the significantly expanded portfolio of opportunities created by powerful smart phones (pocket supercomputers) connected to endlessly vast repositories of knowledge and

3.4.4 Actively pursue Crossovers (and “cross-insemination”) among and between Pillars – Circularity is integral to all the other RNE pillars and clusters and requires integration with circularity actions being examined and proposed in these other pillars.



3.4.5 Continuous education should play an important role in both needed paradigm shifts: 'From waste to resource' and 'Beyond the Fossil Fuel Era.' The ubiquitous smart phone should be leveraged in delivering continuous education, providing easy access and rapid retrieval of relevant resources, tools and know-how and, most importantly, engaging each learner through creative apps, and participation in collaborative learning networks. Smart phones are projected to have highly intelligent personal agents (e.g., an ultra-smart SIRI) within the decade that will greatly enhance a personalized continuous learning process. ICT tools such as augmented reality, virtual reality, and online gaming, also provide strong visual orientations that enable many individuals to learn better and faster.

3.4.6 Implement continuous links between universities and knowledge institutes to safeguard the development and implementation of needed techniques. MBO, HBO and Universities should take full advantage of the Internet of Communication tools and technologies to work together, focusing on the interconnected themes of the circular economy and Third Industrial Revolution. As noted in previous proposals, the myriad of IoT tools and technologies provide rich venues for individual and group learning processes, augmented with visualization techniques, intelligent algorithms, and smart phone “pocket supercomputers” loaded with apps for performing field research and data gathering.

3.4.7 Implement communication projects with citizens in MRDH to deliver a sense of urgency and an inviting perspective. Through a storyline of how people live, work, or recreate, we can identify the coming changes to our society and indicate the sense of urgency. The action matrix developed by circular economy pioneer Walter Stahel (below) provides a conceptual model for developing and communicating narratives.

Implementation of Strategies

	CLOSING MATERIAL LOOPS (technical strategies)	CLOSING LIABILITY LOOPS (commercial/marketing strategies)
RESOURCE EFFICIENCY STRATEGIES		
Reduce the VOLUME of the resource flow	ECOPRODUCTS <ul style="list-style-type: none"> ▪ dematerialized goods ▪ multifunctional goods 	ECOMARKETING <ul style="list-style-type: none"> ▪ Shared utilization of goods ▪ Selling utilization instead
Reduce the SPEED of the resource flow	REMANUFACTURING <ul style="list-style-type: none"> ▪ long-life goods ▪ product-life goods ▪ cascading, cannibalizing 	REMARKETING <ul style="list-style-type: none"> ▪ de-curement services (used & discard exchange) ▪ away-grading goods/components ▪ new products from waste
Reduce the VOLUME and SPEED of the resource flow	SYSTEM SOLUTIONS <ul style="list-style-type: none"> ▪ engineering systems 	SYSTEMIC SOLUTIONS <ul style="list-style-type: none"> ▪ selling results instead of goods ▪ selling services instead of goods

Source: Walter Stahel (1997) "The Functional Economy: Cultural and Organizational Change." National Academy of Engineering. The Industrial Green Game: Implications for Environmental Design and Management, National Academies Press, 1997. doi:10.17226/4982

3.4.8 Expand the Het Groene Brein/Circular Economy Science Lab, to include both onsite and online actions. Combining onsite activities with an Internet-accessible platform, enabling an ecosystem of peer interactions (i.e., collaborative innovation networks) can greatly leverage the network of more than 100 scientists offering support to Green Brain entrepreneurs who want to take steps towards the Third Industrial Revolution. Such interactions can include individual companies searching for answers to questions at the sector level, Het Groene Brein peers working on achieving the right framework conditions for the new economy by generating usable knowledge, and ushering in future-proof education and other system changes that lead to an ecologically sustainable economic paradigm.

3.4.9 Implement an Urban Mining Prospecting initiative at Haagse Hogeschool (The Hague University of Applied Sciences). Leverage the knowledge resources and findings from several relevant initiatives such as the EU's ProSUM project (Prospecting Secondary raw materials in the Urban mine and Mining wastes), the EU-UMKDP (Urban Mining Knowledge Data Platform),

as well as MICA (Minerals Intelligence Capacity Analysis), the European Raw Materials Intelligence Capacity Platform (EU-RMICP), and PUMA (Prospecting the Urban Mines of Amsterdam).



3.4.10 Set up a work-learning station for material mining and for developing technologies for re-and up-cycling as well as re-design of products and processes.

3.4.11 Develop living labs to help foster circular communities, leveraging and building upon the rapidly expanding knowledge resources about both living labs and circular communities.

The Netherlands Circular Hotspot campaign is positioning the nation as the global circular hotspot. Best practices and accumulated insights are already being shared with public and private organizations worldwide. As emphasized at the launch by Prince Carlos de Bourbon de

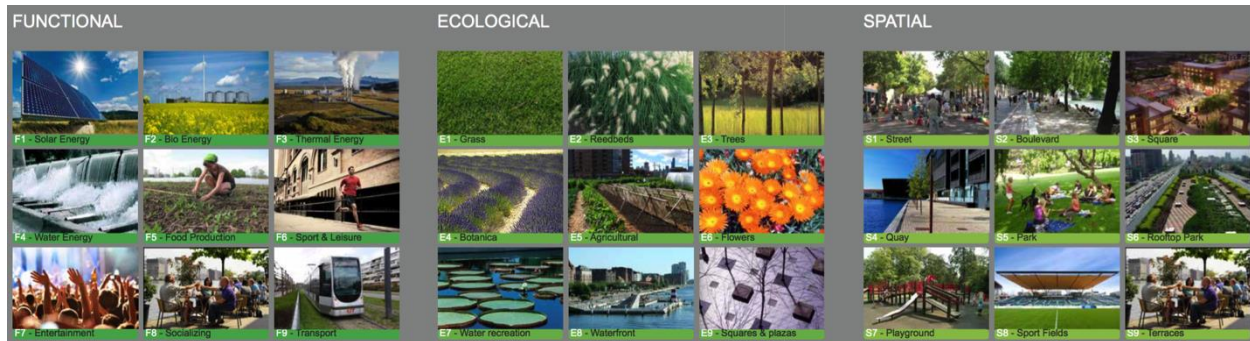
Parme and the initiators (Social Economic Council, SER, Delta Development Group, Circle Economy and INSID), “the vision will be shaped based on input from Dutch and international thought sector and industry leaders and representatives of younger generations.”¹⁸⁹ The implementation of living labs in MRDH helps advance this vision by sharing successes with other communities through such mechanisms as the European Network of Living Labs (ENoLL).

3.4.12 Bring to fruition Urban development in MERWE-VIERHAVENS (M4H). According to the M4H narrative, “the vision for Merwe Vierhavens site is to become a world class art, research & technology hub for the Netherlands, promoting and nurturing local and regional creatives, researchers and entrepreneurs. The site is strategically located within the Randstad and in close proximity to the TU Delft, Den Haag-Rotterdam Airport and the Erasmus University, M4H is positioned to become one of Europe’s premium knowledge and creativity hubs.”¹⁹⁰ The goal is to foster a vibrant waterfront living district where diversity and creativity form the basis of community life. The M4H initiative should use innovative design and advanced technological strategies, in conjunction with social-ecological theory, to create a best-in-show Biosphere Valley.

¹⁸⁹ See: <https://www.theguardian.com/sustainable-business/2016/apr/27/the-netherlands-puts-itself-on-the-map-as-a-circular-economy-hotspot>

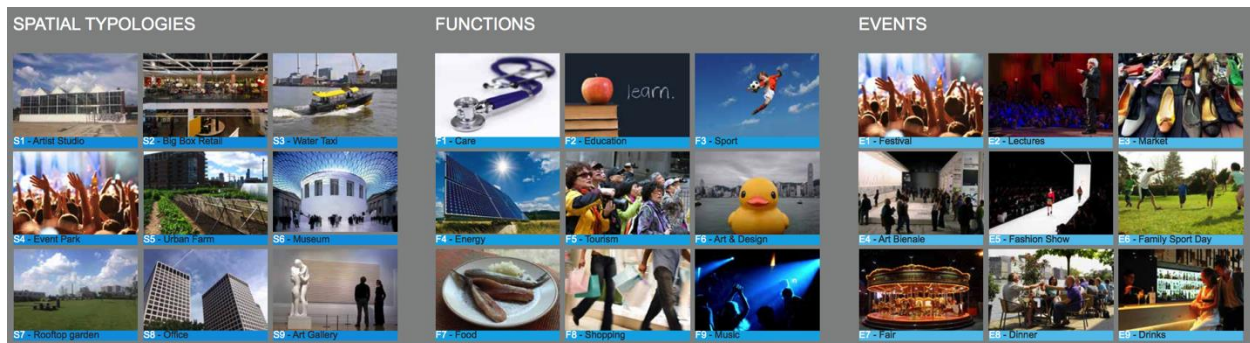
¹⁹⁰ See: <http://www.dutchurbansolutions.com/lab-05---urban-choreography>

M4H Landscape Network Toolbox



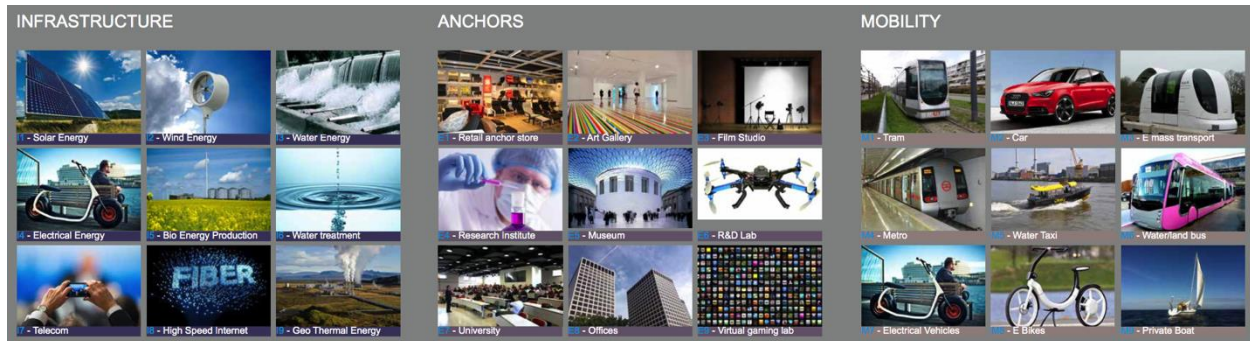
The landscape network toolbox is an annually reviewed set of development tools agreed upon by the Urban Task Force, aimed at meeting the objectives of the landscape development framework. Through nurturing the existing open spaces and developing new quality green spaces, the landscape is to become a unified green network. The application of the different tools is flexible and allows for adaptability over time in its implementation. The toolboxes have been arranged in 3 groups: functional, ecological, and spatial.

M4H Social Network Toolbox



The social network toolbox is an annually reviewed set of development tools agreed upon by the Urban Task Force, designed to meet the objectives of the social development framework. Nurturing existing and developing new THIRD places is an important component in establishing a socially sustainable community. The toolboxes have been arranged in 3 groups: spatial typologies, functions and events.

M4H Economic Network Toolbox



The economic network toolbox is an annually reviewed set of development tools agreed upon by the Urban Task Force, aimed to meet the objectives of the economic development framework. The aim is to provide a set of tools that can activate and enforce the economic network and help to establish nodes of economic development. The toolboxes have been arranged in 3 groups: infrastructure, anchors and mobility.

Source of Images and Text: Dutch Urban Solutions, URBAN CHOREOGRAPHY, M4H VISIONING & DEVELOPMENT STRATEGY, August 2014, <http://www.dutchurbansolutions.com/#!lab-05---urban-choreography/c1wk4>.

3.4.13 Establish the Experience Center in Airborne Composites. The Airborne Group – designer and manufacturer of composite structures – has joined with Siemens in developing a Digital Flexible Manufacturing Factory FieldLab in Ypenburg. The innovation hotspot will enable researchers, educators, government agencies, and companies to engage at the plant in the digitization of all aspects of composite materials development. This includes the entire production chain in one virtual environment: design, simulation, production, planning, feedback, testing, as well as supply chain management.

3.4.14 Accelerate integration of the National Ecological Network (NEN, formerly EHS, also known as Nature Network Netherlands) into an unbroken network of nature areas on land and in water, and connect to the Pan European Ecological Network. The Netherlands' Environmental and Nature Planning Bureau makes an annual inventory of the state of the Dutch nature areas and advises the government on further policy development. The concept of a National Ecological Network, now known as Nature Network Netherlands, dates from 1990. It is a joint network of important existing and new nature areas. Agricultural areas with possibilities for ecological nature management and the coastal zone of the North Sea, the IJsselmeer, and the Wadden Sea all belong to this network. By combatting the splitting up of

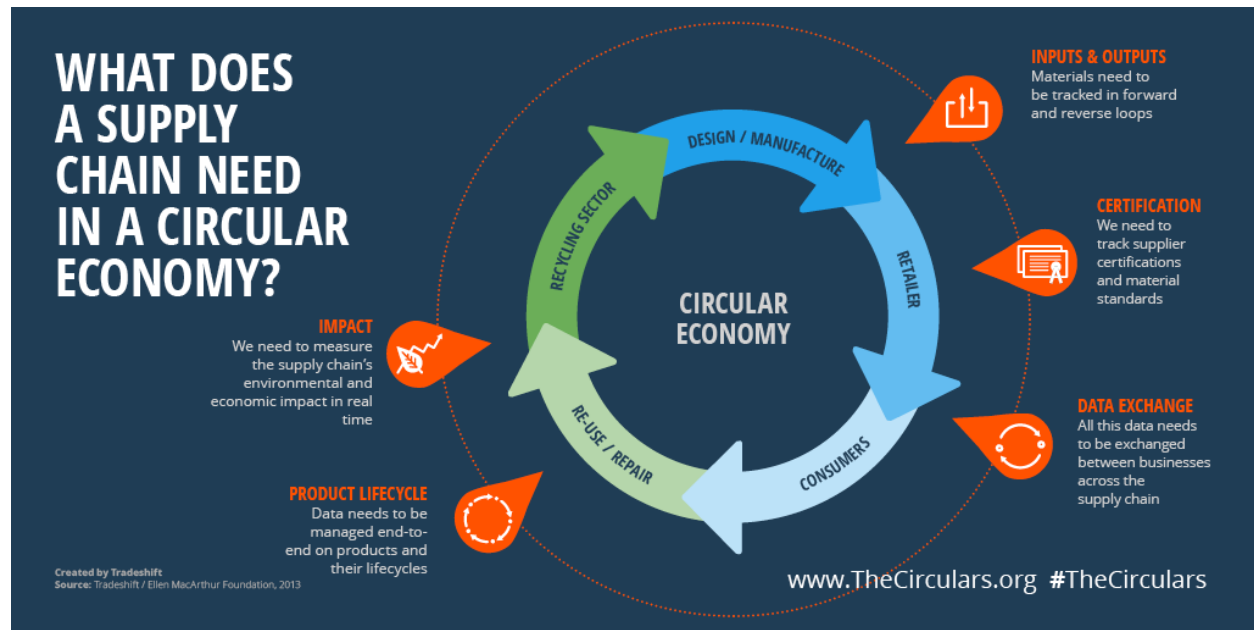
nature areas and linking them together, animals and plants are afforded larger territory to spread out and more opportunity to reproduce with others across terrains that were previously cut off by human development. However, the pace of developing the NEN has slowed down. The rewilding planning was initially scheduled to take place by 2018; this has now been deferred to 2027. The current policy is to slow down the loss of biodiversity, but that is not enough. The Netherlands should work on recovery of biodiversity both within and outside the NEN by catalysing a different attitude towards land use along the lines of the rewilding model. This directly addresses climate challenges such as peat-oxidation (carbon dioxide emissions through peat oxidation, water storage, capturing carbon dioxide in biomass, etc.), while also creating an attractive living and tourist area (the Green Metropolis). The core regions now consist of twenty National Parks in the Netherlands. National Parks form the core regions of the NEN, as well as the coastal zone of the North Sea and the Wadden Sea. Corridors between nature areas can be woodlots, banks, meadows, grain fields and grasslands. Viaducts and tunnels allow wild animals to cross transecting motorways. In policy documents concerning nature, it has been agreed to create approximately 728,000 hectares of NEN by 2027 (originally by 2018), which means another 275,000 hectares are necessary.

3.5 FINANCIAL

3.5.1 Providing financial subsidies, incentives and subventions to promote renewable energies while phasing out subsidies and incentives on fossil fuel energy production and consumption.

Tax-incentives should promote renewable energy development and support newly built communities based smart grids like connected DC streetlight systems, where individuals can easily connect their PV systems and 2-way car charging station.

3.5.2 Promote the higher uptake of green public procurement and increase the focus on issues related to the circular economy. Promote the purchase of products that achieve energy savings based on full life-cycle costs, as well as include features of reparability, upgradability, durability and easy recyclability.



3.6 R&D

3.6.1 Establish Quadruple helix knowledge networks to address circularity issues. TNO researchers have identified a number of pertinent circular economy questions: “How circular are we? How can we assess the level of circularity of companies or client portfolios? How should we account for external effects of economic activities? How is Research, Development and Innovation (R&D&I) policy related to the transition towards a circular economy? How can we prioritize between different feedback loops of the CE framework in public investment decisions?”¹⁹¹ Quadruple helix knowledge networks need to consider these challenges in order to determine experimental approaches and preferable solutions to an array of complicating aspects: rebound effects, creative destruction, risk aversion, IP ownership, path dependencies, privacy needs, value chain interdependencies, personal vs. general utility, winners and losers (e.g., rapid product innovation vs. product lifetime extension), and insufficient micro and macro quantitative data to make informed judgments.

¹⁹¹ See: <http://www.wrforum.org/wp-content/uploads/2015/10/SS4-Rietveld.pdf>

3.6.2 Need for greater focus by industry on Eco-design & Design for Environment -

“Technological materials and especially the way [industries] mix, alloy and indissolubly mingle substances is a problem of its own.” Avoidance of using toxic substances in products and production processes is another essential practice, whenever possible and feasible, noting the EU’s Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) and McDonough & Braungart’s more stringent cradle-to-cradle certification process.

3.6.3 Circularity Metrics Needed – Circularity is an advancing and evolving field, and requires circularity indicators and metrics to be assessed, tested against ongoing evidences, and refined, to be increasingly effective. The Implementation Center for Circular Economy (ICCE) in Belgium, the Luxembourg Institute for Science and Technology (LIST), and TU Delft, Lateral Thinking Factory, getZED, all are looking into the possibility of improving on existing circularity indicators. The existing indicators are actually quite linear, not taking the quality of various flows into account. For energy, this can be done through the use of exergy. For the other resources like water, biological, and technical materials, similar parameters will have to indicate the quality level of various flows.

3.6.4 Inventory the Urban Mining opportunities – Important metals are increasingly accessible from urban waste streams, especially electronic equipment. The business case should be examined regarding urban mining in MRDH. For example, one kilogram of gold can be obtained from 200 to 1,000 tons of ore, depending on the richness of the mine. In 2009 one could find one kg of gold in 3.3 tons of used mobile phones, alongside 471 kg of copper, 10 kg silver, 0.4 kg palladium and 10 grams of platinum. In Japan it is estimated used electronics hold an estimated 300,000 tons of rare earth elements.¹⁹²

3.6.5 Undertake research, development and innovation (RD&I), and create an accompanying roadmap to advance the 2030 transition and transformation goals for MRDH’s shipbuilding and maintenance industry. The expressed goals are to organize the Port of Rotterdam around the concepts of modular construction, design for recycling, and more reuse of materials, including the development of *material passports*. In addition, the Port of Rotterdam should commission the first *zero emission ship* by 2030.

3.6.6 Investigate the use of supercritical CO₂ for selective extractions from algae. Supercritical CO₂ is being applied for selective extraction of food, fuel, and nutraceuticals from algae. For

¹⁹² Materials and the environment, Michael F. Ashby

example, in contrast to conventional methods of extracting lipids from algae that require toxic solvents like hexane and petroleum ether, supercritical carbon dioxide extraction avoids these harsh chemicals, while also enabling higher selectivity and less time-intensive extraction periods.

3.6.7 Leverage the research efforts at TU Delft on the exergy of waste – 'Ex Waste' – to develop effective tools useful for determining the value of waste streams. In an analogous manner, as exergy is used to determine the richness of energy for performing work, there is also an intrinsic richness available in waste. The method entails obtaining parameters that best describe the potential value of exergy of waste, for example the level of accessibility, recoverability, reusability, and circularity.

3.6.8 Develop RDI initiatives to advance biosphere stewardship based on establishing digital ecosystems that mirror the dynamics of natural ecosystems. The goal is to establish a seamless symbiotic relationship between the circular flows of nature and the economic activities of Dutch society. Hone in on critical ecosystem features including self-organization, mutualism, co-evolution, diversity, emergence, modularity, resiliency, and adaptation in modeling MRDH's new digital ecosystems and the accompanying business practices and regulatory regime.

3.6.9 Establish an Internet platform around a Circular Economy Quadruple Helix knowledge innovation system that enables ongoing interactions among and between citizen stakeholders, government agencies, businesses, and academia. Successful mainstreaming of CE involves effective implementation of transformational business models, cultural willingness to adopt new practices, promotion of lateral governance, fostering continuous RDI throughout academia, and supporting education and life-long citizen learning in entirely new areas. In addition to the numerous proposals outlined above, there is a growing body of CE evidence, experience and evaluation to continually draw new insights and ideas (see Manifesto on Circular Economy Policy in EU, below). An IT platform is vital for sustaining citizen engagement, bridging the silos that separate professions, market sectors, and societal niches, and leveraging the tremendous value that Internet connectivity, networks, and apps – all accessible by hand-held smart devices – offer for accelerating the scaling of the circular economy.

**Circular Economy Recommendations from
More prosperity, new jobs, Manifesto on Circular Economy Policy in the EU**

This is a joint manifesto from De Groene Zaak Sustainable Business Association, MVO Nederland and Circle Economy describing our view on Circular Economy Policy in the EU. Our three organisations together represent over 2300 companies from all sectors, including both multinationals and SMEs, striving for implementation of sustainable and circular business models. Our recommendations focus on how governments can create conditions in which circular *business* models will thrive rather than struggle uphill.

Strong government policies to mainstream circular business are crucial to reap the benefits of a Circular Economy: To maximise the potential for long-term competitiveness and the resilience of EU businesses requires leadership from the European Commission as well as member states governments to support the transition to more resource secure business models.

Extend the existing targets to cover the full circle: We recommend keeping the original binding targets for recycling and the landfilling ban, and extend them to binding targets along the full circle, including maintenance, repair, reuse, refurbishment and cascading.

Make sure you steer the EU economy towards circularity: We recommend using The Raw Material Consumption (RMC) per capita as a key indicator for resource productivity, while monitoring other indicators for e.g. biodiversity or the *positive* impact of economic activities

Be a launching customer: To accelerate the transition towards a circular economy, we ask for widespread implementation of green public procurement by the European Commission and national governments, provinces and municipalities as launching customer.

Invest in circular innovation beyond traditional measures: An ambitious circular economy policy in our view means that the European Commission and governments take action beyond their traditional approach. Mainstreaming the circular economy requires policies supporting circular innovation within companies and full-cycle supply chains.

Implement EU-side measures and harmonisation where possible: While acknowledging the political reality and importance of subsidiarity, we ask the European Commission to try and prevent the emergence of a new patchwork of national and regional measures leading to additional red tape for companies.

Ask the Member States for National Action Plans for circular economy: National policy of the EU Member States is essential to boost the circular economy in Europe.

Further substantiate the circular economy benefits: The circular economy will create new jobs and add value. We recommend further substantiating the number of additional jobs in 2030 and financial benefits.

Find clever solutions for the 'losers' of the circular economy: Front-running business and the EU economy as a whole will benefit and become more resilient from effective circular economy policies. However, there will also be losers, such as lagging manufacturers.

Define what circular products and services are: We recommend developing a concise definition of circular products and services, so that they can be targeted by economic incentives

Fiscal incentives for circular business: A tax shift from labor to raw materials.

Extended Producer Responsibility schemes: We recommend expansion, improvement and harmonisation of existing extended producer responsibility (EPR) schemes in the direction of waste avoidance and prevention.

Stimulate integrated reporting: Encourage member states to give incentives through tax breaks for (voluntary) externally audited integrated reporting as a replacement for the current financial reporting.

Extend the Ecodesign Directive to one for Circular Design: While preferring economic instruments, regulatory tools can help mainstreaming the circular economy as well. We therefore recommend expansion of the existing EU Ecodesign Directive into a directive for Circular Design.

Source: De Groene Zaak Sustainable Business Association, MVO Nederland and Circle Economy (2015) More prosperity, new jobs, Manifesto on Circular Economy Policy in the EU, <http://dutchsustainablebusiness.com/cases/>

ENTREPRENEURIAL REGION

The European Union is potentially the largest internal market in the world, with 500 million consumers, and an additional 500 million consumers in its associated partnership regions, stretching into the Mediterranean and North Africa. The build-out of an Internet of Things platform for a Third Industrial Revolution, connecting Europe and its partnership regions in a single integrated economic space, will allow business enterprises and prosumers to produce and distribute their own virtual goods and their own renewable energy, use driverless electric and fuel-cell vehicles in automated car sharing services, and manufacture an array of 3D printed products at low marginal cost in the conventional marketplace, or at near zero marginal cost in the Sharing Economy, with vast economic benefits for society.

Hans Scheepmaker / Anton Duisterwinkel, and the Working Group members from MRDH

Michael Totten (Assetsforlife.net), Harilaos Psaraftis (Technical University of Denmark), Sofie Van Volsem (DNV GL), Rob Wilhite (Navigant Consulting), Kathleen Gaffney (Navigant Consulting), Rik Willard (AGENTIC), Michael Casey (AGENTIC), Philipp Krüger (Fraunhofer SIT), and Jeremy Rifkin for TIR Consulting Group LLC

The convergence of the Communication Internet, the Renewable Energy Internet, and the automated Mobility Internet atop an Internet of Things platform will transform MRDH into a digital interconnected infrastructure to manage, power and move economic activity across the Metropolitan Region's myriad value chains, with a dramatic increase in productivity and equally dramatic reduction in both the ecological footprint and the marginal costs of doing business.

The architecture of the new smart infrastructure is spawning new types of business models and enterprises that can find value in optimizing its design features. Unlike the First and Second Industrial Revolution infrastructures that were designed to be centralized and proprietary, giving rise to giant *vertically integrated* enterprises to create economies of scale, the Third Industrial Revolution digital infrastructure is designed to be collaborative and open in nature, and is best optimized by the creation of enterprises that are *laterally integrated* to create economies of scale.

In the digitally connected era, the selling of goods in markets is "partially" upended by the providing of services in networks. In the TIR economy, providers and users increasingly eclipse

sellers and buyers. Enterprises retain ownership over what they produce and use their productive assets –technical expertise and equipment – to help manage the operations of other enterprises’ value chains. In return, they are awarded with a portion of the efficiency gains and increased productivity they helped foster in the form of shared savings agreements and performance contracts.

PORT OF ROTTERDAM

The introduction of a digitalized Internet of Things infrastructure across oceans and land masses changes the notion of transportation and logistics. In the smart era, maritime ports become more than drop off and delivery hubs between ocean expanses and landmasses. They increasingly serve as the cognitive node in a digitalized nervous system that connects road, rail, water, and air transport around the world.

In the Third Industrial Revolution era, maritime ports will use satellite and GPS data, cartographic mapping, and real-time information generated by smart sensors attached to ships, trucks, trains, barges, planes, drones, warehouses, distribution centers, retail stores, and end-users, to coordinate the flow, storage, and delivery of goods across the transport corridors of continents.

The Port of Rotterdam and other global ports will need to establish collaborative partnerships with other critical industry players, including Internet companies, ICT companies, electric power and transmission companies, transportation companies, logistics companies, and commercial warehouses. These collaborative efforts will assist in the erection and management of a digitalized and automated Transportation and Logistics Internet across continental and oceanic transportation corridors.

Transforming the Port of Rotterdam: Executive Summary

A trend to larger vessels highlights the inadequacies of current port infrastructure: ports are increasingly a bottleneck in the supply chain, resulting in increasing demands for efficiency. As a result, ports worldwide are making infrastructure investments to remain relevant in an increasingly competitive world. While most ports are making significant investments in infrastructure, a key differentiator is how these investments are made. The Port of Rotterdam

must take a strategic and collaborative approach to its infrastructure investments to effectively respond to the requirements of both its customers and European logistics policies. To that end, a synchro-modal approach is recommended to ensure the Port of Rotterdam's long-term strategy dovetails with wider transport objectives.

Technology – and IoT in particular – will play an increasingly important role in the efficient functioning of a port. While current supply-chains related IoT use cases are narrow, there is a huge opportunity to extract additional value, which will improve operational efficiency and customer service across the supply chain, and create new business models. However, central to this approach is the sharing of data on a common data platform, which requires significant collaboration and cooperation between all supply chain stakeholders.

Port infrastructure investments will extend well beyond IoT technology, and the Port of Rotterdam has demonstrated its appetite to invest in other innovations. Combined, these technology investments will help the Port become more energy efficient, provide a higher level of customer service, and create a number of potential new business models that will position the Port of Rotterdam as a market-leading digital port.

Rotterdam must keep pace with a rapidly changing market to retain its global status

The logistics industry – and ports in particular – is facing increasing pressure to upgrade infrastructure to meet changing demands. The trend to larger vessels size creates additional pressure, from higher peaks of demand, to the need for deeper water, more quay space, more storage space, and more advanced technology to unload ships. Efficiency is increasingly a key differentiator between competing ports, which has not gone unnoticed: ports worldwide are making substantial investments to upgrade infrastructure. Despite its position as Europe's largest port, the Port of Rotterdam is not immune to these stresses, and must invest in infrastructure to maintain its market-leading position.

Substandard port infrastructure leads to substandard service

According to a study¹⁹³ ordered by the European's Commission DG Move, aimed at supporting an impact assessment on "measures to enhance the efficiency and quality of port services in the EU", many European ports today cannot offer the services required by their clients due to lack of suitable infrastructure. For example, limited water depth, insufficient quay/storage space and poor connections for further inland transport are typical criticism from port clients. In addition, the quality of the services offered is perceived as not good enough including, for example, the excess time needed to load/unload cargo or lack of flexibility in port operations.

For most of the large European ports, congestion and matching hinterland development is a considerable challenge. Ports typically make large investments in developing the services and infrastructure in the port itself. However, they should also focus on the complete supply chain - i.e., not only the part "within the port" but also the connection to the hinterland, and thus up to the final destination of the goods in transit.

The trend to fewer but bigger ships will put additional pressure on this infrastructure

The shipping industry has evolved substantially over the past few years and the new fast paced ship designs have resulted in vessels being bigger and better. Large containerships are the norm and the load-on and -off process is further enhanced by improvements in automation, resulting in quick turnaround, which has improved safety and is more cost efficient. This trend is forecast to continue as port authorities seek ways to accommodate larger vessels. "According to industry analysts, almost half of current ship orders are for vessels exceeding 12,000 TEUs."¹⁹⁴

"Larger vessels provide many advantages to liners, shippers, and beneficial cargo owners, not the least of which is the reduction in the per-container cost to transport cargo."¹⁹⁵ In its 2014 review of the Port Vision 2030 strategy, the Port of Rotterdam Authority explicitly noted the trend to more imports on fewer trips, which is increasing the higher peaks of demand and capacity. It is increasingly important that the Port be able to shift cargo at speed and with the lowest associated emissions. This is particularly urgent given the increasing competition in the

¹⁹³ Final report - Study aimed at supporting an impact assessment on: "Measures to enhance the efficiency and quality of port service in the EU" – PwC, Panteia for DG Move, 2013.

¹⁹⁴ 13th ESPO conference proceedings, 2016.

¹⁹⁵ <http://www.polb.com/civica/filebank/blobload.asp?BlobID=12230>

European port sector.

The increasing size of container vessels forces port authorities to invest heavily in infrastructure to accommodate them

The Port of Rotterdam is investing almost a billion euros in new facilities and equipment at the Maasvlakte 2 facility. Globally, other ports are also spending on improvements. For example, the American Association of Port Authorities has reported that U.S. ports plan to spend \$46 billion by 2017. Canada has already invested \$3 billion in 93 projects under the Asia-Pacific Gateway and Corridor Initiative. “DP World is also investing about \$2.3 billion at the London Gateway container port on the Thames, with both facilities designed to support mega ships.”¹⁹⁶

“In addition to port facilities, larger ships may require infrastructure improvements, including expanded railroad and highway capacity, to handle cargo from the ships. It should be noted that investments in infrastructure not only require significant amounts of funding, but also take time to plan, bid, and build out.”¹⁹⁷

“The Port of Hamburg projects that the number of containers passing the port will grow from 9 million in 2013 to 25 million in 2025. Since traffic increases accordingly while space remains limited, it is of great importance for large harbors to maximize utilization and minimize the idle time of every link in the system.”¹⁹⁸

A number of components of EU supply chain policy will help deliver these infrastructure changes. Harilaos N. Psaraftis, professor at the Technical University of Denmark, Department of Transport, highlights a number of these in his “big picture” overview; the most relevant to EU ports and to the Port of Rotterdam, in particular, are as follows:

- Trans-European Transport Network (3.3 billion metric tons in 1985 to 9.6 today);
- Environmental challenges;
- One Belt One Road (OBOR).

¹⁹⁶ Source: <http://www.polb.com/civica/filebank/blobdload.asp?BlobID=12230>

¹⁹⁷ *Ibid.*

¹⁹⁸ Source: <http://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-in-shipping-industry.html>

The Port of Rotterdam is not immune to these stresses, and must invest in infrastructure to maintain its global position

The Dutch government includes logistics among its top nine strategic sectors, with a 2020 goal of being a global leader in processing of cargo shipments and inter-modal logistics.

Currently, the Port of Rotterdam can deal with ships carrying up to 18,000 containers, supported by facilities that are ground-breaking in terms of control, ICT, and capacity. In the next decade, it will be important to remain at the forefront of further developments and, at the same time, to have these developments supported by policy and regulatory requirements that keep pace with the business opportunities.

The combination of large-scale logistic experience in the Port and local innovations around clean and efficient transportation can enable MRDH to be a world leader in the development of integrated logistics solutions.

However, it is also essential that the Port of Rotterdam positions itself as a major digital node in the future supply chain, providing IoT connectivity, a universal data platform, and associated applications. It must reconceptualize its role and function, transforming the Port into the flagship Big Data node of a digitally connected global transportation and logistics Internet.

In the Third Industrial Revolution, the Port of Rotterdam becomes the main digital node and gateway for the European continent. The Port of Rotterdam serves all players in the logistic chains with seamless data, high quality of data applications, and Internet of Things connectivity. Digitalization and 'connectivity of everything' are the foundation of the Third Industrial Revolution next economy. The Port of Rotterdam is a lighthouse for the Digital Europe agenda. The real-time Big Data flow of information about traffic, cargo, and warehousing is of huge value for optimizing transport and port management. Three activities within the Smart Port relate to the Digital Gateway transition:

Nautical efficiency (Port Call Optimization) The core process managed by the port and the coordination of nautical services (towage, mooring) include a long chain of businesses involved in the process of a ship-call. Enhancing data availability and quality control for these businesses along their logistics chains will create a faster and more cost effective and efficient supply chain process.

Enabling Logistics (Rotterdam Logistics Lab) Because of its strategic significance, the Port of Rotterdam becomes the critical Big Data node for thousands of supply chains across Europe. Building a platform for seamless data interchange between supply chain partners in the Port and across the intermodal transport corridors of Europe is essential for transforming MRDH into the logistics center for the emerging automated Transportation and Logistics Internet.

IoT for Logistics (optimizing transport capacity) A market platform with real-time data for cargo capacity can help improve the use of transport capacity and prevent inefficient moves or delays coming in and out of the Port.

A collaborative freight policy that encompasses the entire supply chain will assist the Port of Rotterdam's goal to retain its global status

It is critical that the Port of Rotterdam plans its infrastructure investments in line with wider logistics planning. To that end, a synchro-modal transport model is recommended, as it supports a collaborative end-to-end freight policy that will help ports plan infrastructure developments more strategically. This will require the integration of the Port of Rotterdam's strategic plan with regional and national transportation policies. A synchro-modal approach highlights weaknesses in existing Dutch and European logistics infrastructure, which must be incorporated into the Port of Rotterdam's long-term investment strategy. For example, the underutilized inland waterway network, the inadequate hinterland rail connectivity, and congestion in the last-mile of the current supply chain, particularly in urban areas. Finally, it is vital that the Port of Rotterdam plans now for future logistics modes: drones, driverless vehicles, 3D-printing, and more.

A synchro-modal approach provides end-to-end control of the supply chain

A synchro-modal approach will help strategic planners identify alternative modes of transport to relieve existing bottlenecks. For instance, it is widely believed that inland navigation could help relieve a number of stresses in the European road network, while the current rail infrastructure around the Port of Rotterdam will need significant investment before it can help alleviate congestion around the Port. The synchro-modal approach must also consider bottlenecks elsewhere in the supply chain. As a result, the Port of Rotterdam will need to account for how new modes of transport can alleviate pressure in the last mile of the supply chain, particularly in urban areas. As part of the strategic, long-term plan, new modes of transport should also be incorporated: for example, hydrogen and electric-fueled vehicles,

driverless vehicles, and drones. Companies are also investigating the use of 3D printing close to the point of delivery as a way of making the supply chain more efficient.

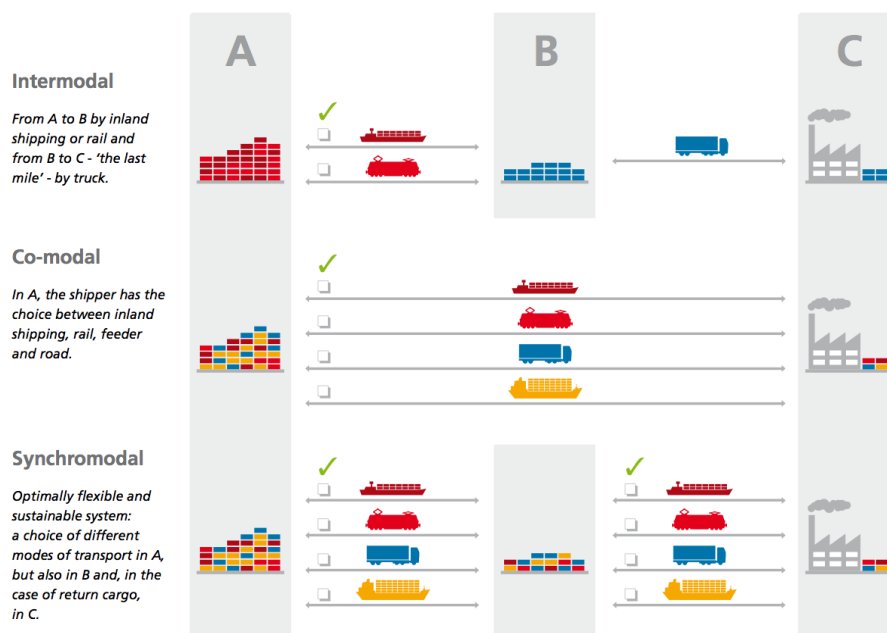
The synchro-modal transport model supports a collaborative end-to-end-freight policy that will help ports plan infrastructure developments more strategically

For most of the big European ports, congestion and matching hinterland development is a significant challenge. Ports typically make large investments in developing the services and infrastructure in the port itself. However, they should also focus on the complete supply chain, i.e. not only the part 'within their port' but also the connection to the hinterland, and thus up to the final destination of the goods.

Synchro-modal transport was introduced in the Netherlands in 2010 by the Strategisch Platform Logistiek, an organization which represents the Dutch logistics sector. Synchro-modal transport can achieve considerable logistical improvements by no longer assigning loads to the same modalities by default. Concepts such as synchro-modality are expected to play a key role in the future. Synchro-modality integrates different transport modes and gives the logistics service providers (LSPs) the freedom to deploy different modes of transportation in a flexible way, which enables better utilization of existing infrastructure capacities. For instance, uncertainties due to weather, port, and canal congestion and dynamically changing information on customer demand and other parameters require ever increasing flexibility in logistical decision-making in terms of routing, booking and consolidation of cargo.

Container terminal operator ECT describes synchro-modality as an extension of intermodal transport (see the illustration in the figure below which shows the transition from intermodal to co-modal to synchro-modal transport).

From intermodal to co-modal to synchro-modal¹⁹⁹



Transportation management within a digital port must be integrated with regional and national transport systems

Integrated smart port mobility and transportation management-covering vehicle monitoring and routing and smart parking systems can be linked into regional and national transport systems to improve logistics flow throughout the region.

Inland navigation is currently underutilized, but will rely on improved access to information across the entire supply chain

The role of ports and inland navigation in de-stressing the European supply chain and moving to greener solutions can be critical. As important elements of the supply chain, ports and terminals need to be able to synthesize information on all components of the supply chain, so as to be able to enhance total efficiency. Inland navigation represents an underutilized component of the European supply chain, and tools to further enhance and exploit its operational capacity are needed.

¹⁹⁹ ECT, 2011.

According to the Dutch government, “It is expected that container transport to and from Dutch ports will grow significantly over the next 20 years. If this growth is to be accommodated by road transport, Dutch roads will become completely congested, but there is a lot of unused capacity in the system of inland waterways and inland shipping is capable of transporting large volumes. Compared to transport by truck or plane, inland shipping produces far less CO₂. New inland shipping engines must meet certain emissions requirements. These international agreements will be even tighter within the EU.”²⁰⁰ MRDH can optimally benefit from its geostrategic location in Europe with regards to the inland waterway connections that are already well-developed.

Development of hinterland rail connections will be critical for the Port of Rotterdam's future development.

One of the biggest challenges faced by MRDH is pacing the development of the hinterland rail connections to support the Port’s growth. Such infrastructure developments typically are difficult to fund and start up if the necessary break-even volumes are not guaranteed, even though a well-running and well-connected transport infrastructure is essential to maintaining competitiveness.

Ports are not the only bottlenecks in the supply chain; synchro-modal planning must also consider the changing face of last-mile delivery in urban centers

The increasing virtualization of logistics has focused attention on the bottlenecks presented by last-mile delivery in urban centers. Reducing the impact on congestion and emissions and speeding delivery times depends on the deployment of clean transportation and better analytics for route planning and logistics management. In the short- to medium- term, electric and hydrogen vehicles, on-demand services, and the use of more sophisticated planning and integration tools can improve the efficiency of local logistics. Integrated smart port mobility and transport management—covering vehicle monitoring and routing and smart parking systems—can be linked into regional and national systems to improve logistics flow through the region.

The Erasmus Research Institute of Management (ERIM) has established a program to examine innovative solutions to the challenges of delivering sustainable and efficient last-mile logistics. The Port of Rotterdam and MRDH can build on the work of ERIM to explore closer integration between logistics management within the port boundary and the optimization of logistics

²⁰⁰ Source: <https://www.government.nl/topics/freight-transportation/contents/inland-shipping>

across the region.

A synchro-modal strategy must incorporate the integration of new business modes of transport and 3D-printing in the long-term

In the future, automated vehicles and even drone technologies will offer alternative modes for last-mile delivery. By 2025, at least some of the shipments on roads, railways, water, and air corridors will likely be carried out by driverless electric and fuel cell transport, powered by near zero marginal cost renewable energies, and operated by increasingly sophisticated analytics and algorithms. Driverless transport will accelerate productivity and reduce the marginal labor cost of shipping goods toward near zero on a smart automated Transportation and Logistics Internet.

In addition, the emergence of distributed and decentralized on-demand models for energy, mobility, and manufacturing (based on 3D-printing) means that supply chains will become even more complex at the local level, presenting new challenges and opportunities for the port as an intermediary in a global network.

The IoT will play an increasingly important role in the port of the future

The supply chain is already undergoing a digital transformation, spearheaded by the deployment of IoT technologies. Warehouses, distribution centers, trucks, ships, trains, planes, and ports are all experimenting with IoT to improve efficiency and develop new business models. Unfortunately, the logistics industry is far from exploiting the full potential of IoT as these use cases are typically narrow, focusing on just one aspect of the supply chain. For example, port-based IoT use cases focus on equipment safety, condition-based maintenance, and operational efficiency. These narrow use cases do not support a synchro-modal approach, which requires end-to-end visibility of the supply chain.

Technology will transform ports into high-tech logistical hubs

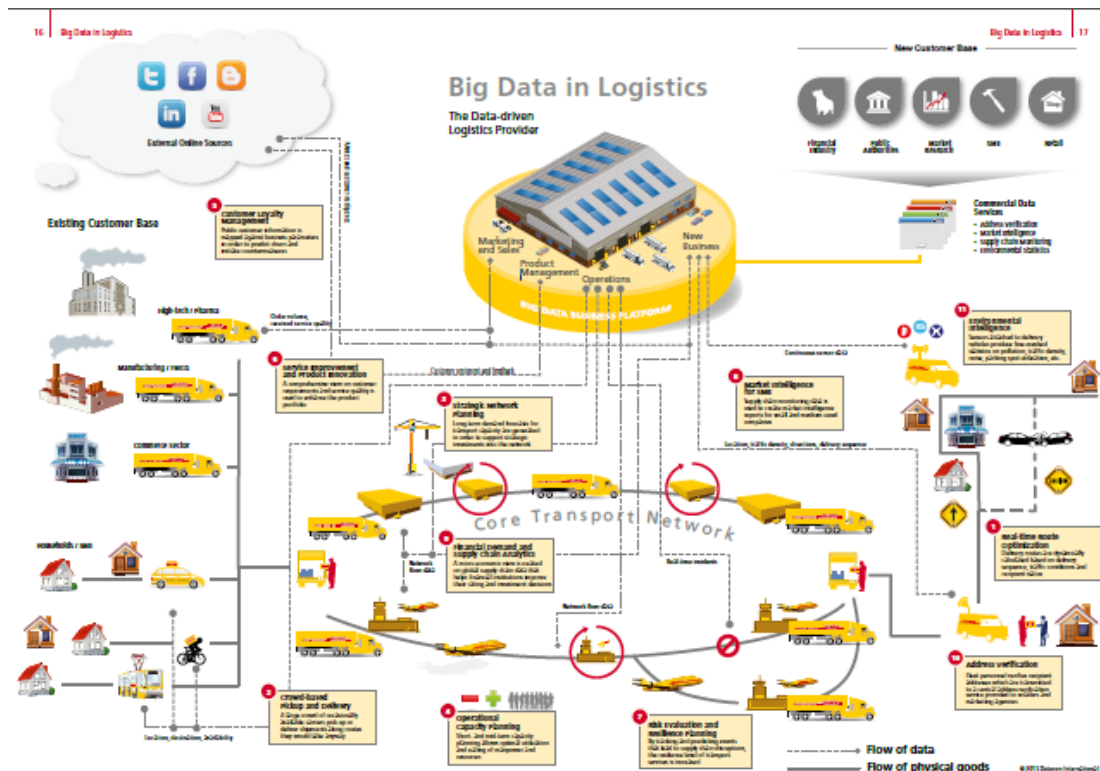
The shipment of goods across oceans increased from 3.3 billion metric tons in 1985 to 9.6 billion metric tons by 2013 – a tripling in global trade brought on by the vast expansion of globalization. The vast growth in the shipment of goods across oceans over the past 30 years has forced port authorities to rethink both their operations and business models. Robotics and automation are transforming ports into high-tech logistical hubs managed by small supervisory

workforces using state of the art software and analytics to increase aggregate efficiencies and productivity and reduce marginal cost and ecological footprint. At the same time, the emergence of the Internet of Things is spawning disruptive new opportunities that are going to change the role of maritime ports. Because of its reliance on visibility across the supply chain, a synchro-modal approach further catalyzes investment in IoT, associated ICT, policy, and collaboration mechanisms. To that end, one would need advanced information systems including e-Freight tools, infrastructures, smart coordination mechanisms, policies, and other means to be able to use different transportation modes flexibly to deliver maximum value to the shipper or end customer. Concepts such as virtual arrival, that can achieve both economic and environmental benefits, critically depend on the proper use of such systems.

Ubiquitous IoT will play a lead role in the 21st Century supply chain

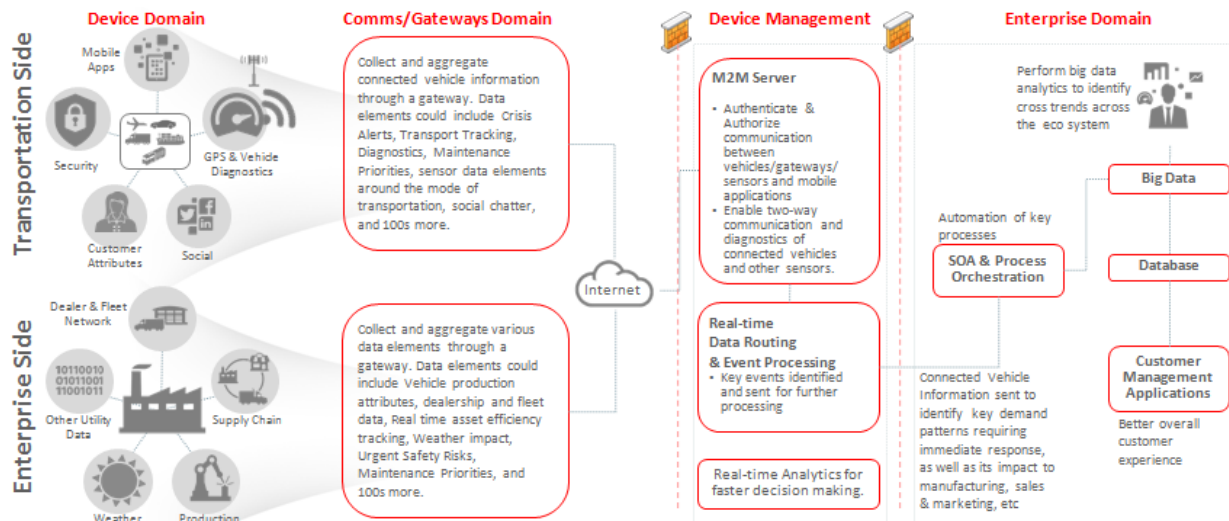
The IoT is enabling us to see, hear, feel, and act more than ever before. This revolution is allowing us to operate machines more safely, with greater efficiency, and with less environmental impact, not just individually, but as complete systems, such as power grids, but also fleets of ships and port terminals. The logistics industry is not immune to the IoT phenomenon. The technology is already being deployed across the value chain. Freight carriers – trucks, ocean cargo ships, rail, inland water transport, airplanes, and drones – are increasingly outfitted with sensors, transforming them into mobile data centers that can collect Big Data in real-time across land, sea, and air corridors. DHL's illustrative vision is shown below.

DHL's View of Big Data in Logistics



Thus far, transport and logistics companies have implemented IoT technologies mostly as track-and-trace applications, intending to decrease network complexity. For example, GPS asset tagging can be used to optimize routes by plotting the real-time locations of trucks and deliveries and using analytics to draw the shortest or most fuel-efficient route between them. Similarly, GPS tagging of shipping containers and other demand-side goods can help manage the flow of those goods through transit nodes. Together, these applications allow for faster movement through the network with fewer transitions, as illustrated in Oracle's vision shown below.

Figure 3: Oracle's View of Transport and Data Management



However, there are a number of untapped opportunities:

- **Big Data:** The logistics sector is ideally placed to benefit from the technological and methodological advancements of Big Data, where there is huge untapped potential for improving operational efficiency and customer experience, and creating useful new business models;
- **Predictive analytics** is used with data warehouse solutions today to optimize routing and improve maintenance scheduling;
- “Sensor driven data will increasingly provide more information about vehicles and goods. In some cases, monitoring this data and taking automated actions (such as stopping a locomotive too close to another train) will be mandated by government regulations.”²⁰¹

²⁰¹ See: <http://www.oracle.com/us/technologies/big-data/big-data-logistics-2398953.pdf>

Warehouses and distribution centers

Warehouses and distribution centers are investing in innovative ways to optimize flow and reduce waste to improve cost efficiency and eco-friendliness. There are many use cases for IoT in warehousing. Some of the most important include the following:

- Driverless trucks, wearable technology and glass windows that provide auto shading are some of this century's inventions that will shape the future of warehouses;
- An increasing number of materials handling systems (MHS), and even components of the larger systems, are gaining both sensors and intelligence;
- Smart telematics: vehicle tracking and fleet management used to minimize overhead, vehicle wear, overhead cost, and to create fuel efficiencies;
- Radio Frequency Identification (RFID) technology helps track inventory and increase workflow efficiency, resulting in lean logistics;
- "Hydrogen fuel cells offer greater productivity because they can be rapidly refueled—in several minutes versus several hours for electric forklifts—eliminating the need to change batteries."²⁰²

Ships

Today, vessels can be tracked by their operators and owners via the improved satellite connectivity and information that is shared via IoT. Large shipping companies are following their vessels and giving information to the captains to optimize their route and speed and, in this way, significantly reducing fuel consumption and emission of greenhouse gases.

In a next phase, this information can be shared not only within the company itself, but also with other third parties and service hubs globally. Making the information available to a wider range of stakeholders has a number of advantages: the risk of information being lost is lower; it allows quick access for the relevant parties; and subsequently leads to swift decision making. For example, combining the voyage and energy data with the monitoring of mission critical equipment on board provides real-time decision-making support during operation that can be

²⁰² See: http://www.raymond-nj.com/pdfs/library/Article%20Reprint_IUV_Fuel_Cell.pdf

used for optimizing planned maintenance of the equipment and having the right intervention teams ready in the next port.

Other port services such as the provision of onshore power supply can also be scheduled more efficiently. For new crews, connection to the IoT is an advantage, as it allows them to receive information on how to operate their vessel more efficiently and more safely. As an example, ABB and Dutch weather forecasting specialist, MeteoGroup, recently won an order to outfit 140 container vessels from the Maersk Line with advisory software to optimize routes, based on factors including the hull design, loading conditions, and the weather. Routes will be optimized continuously and automatically to skirt adverse conditions that could be harmful to the ship, its crew, or its cargo, ensuring all arrive safely and on-time at the destination port.

Another example is DNV GL's ECO Insight portal on how the utilization of Big Data helps to enhance transparency and improve fleet performance. The portal is a hybrid solution, combining manual and sensor-based data collection.

The aggregation of these data onshore and enrichment with data from other sources like satellite weather, AIS, or bunker quality data, is a prerequisite for the type of systematic analysis required to gain deep insights into bunker consumption and route causes. This would lead to insights in how big the performance gap really is and to set targets for improvements.

Unfortunately, the logistics industry is far from exploiting the full potential of IoT

"New applications retain a focus on networks but also aim to make better use of the information captured to create new value and even new revenue... few companies in any industry, however, have discovered how the IoT can create novel business models or new revenue, but logistics companies may be uniquely well positioned to quickly adopt just such models. Using the IoT to create new revenue requires applications that not only include the company's operations but also integrate its customers into a service ecosystem."²⁰³

"Logistics companies traditionally have close ties to customers, which can come to rely on them for core business functions. Therefore, logistics companies can rely on those ties to more quickly introduce customers to a potential IoT application offering new benefits for which they are willing to pay. In fact, where other industries are struggling to progress beyond the "killer

²⁰³ See: <https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/energy-resources/deloitte-nl-er-the-iot-of-shipping.pdf>

app” and discover how IoT technology can generate revenue, several logistics providers have already begun to do so.”²⁰⁴

“In a shipping port, many companies and multiple modes of logistical transport jostle for space in a small area. Every large shipping port has problems aligning different stakeholders in order to optimize the port’s utilization. Moreover, the expected turnover of containers in ports continues to increase dramatically.”²⁰⁵

Port-based IoT use cases are narrow, focusing on equipment safety, condition-based maintenance, and operational efficiency

IoT value for the port environment is all about managing, monitoring, controlling, or effectively utilizing the largest assets of terminals, in particular mobile equipment. Equipment safety is a good business case for an IoT application; collecting information, processing it, and using it for optimizing performance and making crucial decisions quickly and appropriately to avoid mishaps or accidents due to malfunction or equipment failure during terminal operations. For example, the spreader ropes in the gantry crane are a key failure point. If it is possible to fit relevant sensors to detect the position or other characteristics of the spreader rope, the sensor readings can be analyzed in real-time and also compared to historical data. Potential problems can then be flagged to the operators and/or the maintenance team, who can then decide whether the problem requires immediate intervention, or can wait until the next maintenance stop.

IoT can be a major support in the evolution from a reactive maintenance environment to a predictive and preventive maintenance environment, making the terminal and ultimately the port safer and more efficient at the same time.

To maximize the value of IoT, ports must integrate data from across the supply chain

A synchro-modal approach requires an integrated, common IoT platform that can be accessed by all stakeholders within the supply chain. This platform is a prerequisite for any port wishing to undergo a full digital transformation. Port Community Systems can provide that common

²⁰⁴ *Ibid.*

²⁰⁵ *Ibid.*

platform, aggregating data from multiple stakeholders. However, this approach relies on the integration of data from multiple and often competing stakeholders. Bridges must be built between different stakeholders to ensure they are comfortable sharing data with other stakeholders. It is therefore vital that the Port of Rotterdam brings together a group of like-minded partners to collaborate towards this common goal. The task is not impossible: The Port of Hamburg has already successfully launched a common data platform for all of its stakeholders.

Port environments have a key role to play, due to their inherent multimodal nature

Shore-based IoT business models in a port environment need to tackle the integration of IoT data created by the other elements of the supply chain: warehousing, logistics, and transportation systems. Being able to analyze the data captured at each step to enable not only smart inventory management, but also predictive asset maintenance, and advanced supply-chain risk management, adds value in each step of the supply chain. This allows integrating not only logistics firms and suppliers and distributors in their supply chains but also customers and possible business partners. But deploying and expanding IoT capabilities requires more than just technological breakthroughs—making a system work requires both an understanding of the industry dynamics and a strategic approach to using the available data.

The Third Industrial Revolution platform of the digital Communications Internet, the digital renewable Energy Internet, and the digital Transportation and Logistics Internet riding atop an IoT platform, fundamentally alters the way ports manage, power, and move economic activity between oceans and land masses.

While the digitalization and greening of ports around the world is inevitable, it is only the beginning of a far more disruptive change that will necessitate a rethinking of the very function of ports. The introduction of a digitalized Internet of Things infrastructure across oceans and land masses changes the notion of transportation and logistics.

Port Community Systems – a common platform for all stakeholders – are central to the synchro-modal approach of the port of the future

Integrating data from multiple – and often competing – sources is vital for a port's digital transformation

“With multiple companies operating various different types of equipment, each with unique data requirements, integrating all of that data can be a challenge. Moreover, many of the Port’s users are competing firms reluctant to share information with competitors. The bottleneck typically lies in the difficulty of aggregating information, due to the number of disparate parties involved. Without proper data aggregation, it is much more difficult for a system to analyze and redistribute data about the port to the relevant stakeholders so that they may make better, more efficient use of the available supply of logistics, including cranes, trucks, and warehouse space.”²⁰⁶

All of the operators along the logistics corridors will need to aggregate into collaborative networks to bring their collective assets into a shared logistical space to optimize the shipment of goods, taking advantage of lateral economies of scale.

Port Community Systems provide a common data platform to all stakeholders

In terms of advances on the ICT front, port community systems (PCS) are neutral and open electronic platforms. Their users are public and private stakeholders with interest in an airport, seaport, or inland port, and therefore make up a “port community.”²⁰⁷

Usually PCS are either tailored to a specific port or are designed as nationwide services. Some systems even offer a generic solution. This leads to differences in the offered functions ranging from basic information handling and EDI exchange through messaging with embedded databases to import/export services such as customs declarations, tracking, tracing, and processing maritime and other statistics. Common to all, however, is that they facilitate an efficient connection of the platforms’ users and thereby foster a direct time and energy-saving approach to support transportation management.

PCS often includes a “Single Window” functionality. As defined by the United Nations Economic Commission for Europe (UNECE) a Single Window is “a system that allows traders to lodge information with a single body to fulfil all import- or export-related regulatory requirements”.²⁰⁸ Within a PCS, the services, which are combined by a Single Window, have to be defined by the involved regulatory agencies. They build up the Single Window

²⁰⁶ See: <https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/energy-resources/deloitte-nl-er-the-iot-of-shipping.pdf>

²⁰⁷ Geiger, C. (2015), *ICT in green freight logistics, chapter 6 in Psaraftis, H.N. (ed.) Green Transportation Logistics: The Quest for Win-Win Solutions, Springer International Series in Operations Research and Management Science.*

²⁰⁸ United Nations Economic Commission for Europe, 2013.

environment²⁰⁹ and include customs, transport, agriculture, and health agencies.²¹⁰ For traders, Single Windows facilitate communication and data exchange with the involved regulatory agencies, resulting in a quicker settlement of regulatory issues.

“PCS applies to nodes of air, inland waterways, and sea transportation networks. These nodes include interfaces to all modes of transportation. A PCS network comprises a broad range of parties, such as terminal operators, carriers (ocean, road, and rail), freight forwarders, enforcement agencies (e.g., customs), port authorities, and various lobby groups, including workers’ unions, environmentalists, and other policy makers.”²¹¹

Within the above general framework, the Port of Rotterdam is very well placed to contribute toward the fulfilment of EU goals, for at least the following reasons:

- Being the largest seaport in Europe, it has a serious potential to contribute to further attracting traffic from land based modes to other modes that are more environmentally friendly than road, such as short sea shipping and inland navigation;
- It has made serious commitments to a spectrum of advances on the ICT front, as outlined in the Structuring Document;
- It has a “green” philosophy regarding port and other maritime emissions (e.g., infrastructure for LNG and other clean fuels, cold ironing);
- It can become a governance example for other EU ports, large and small.

MRDH can create a SCM platform to support the synchro-modal approach

MRDH is advised to establish a Supply Chain Platform that can bring together the stakeholders to pursue freight strategies that encompass the entire supply chain. IoT systems could support automated business transactions and information exchanges between the different actors in the transport chains. This is fully supportive of the European transport policy, making greater use of intermodal transports with more emphasis on waterborne transport. The MRDH Supply Chain Platform should envision testing and development of the following:

- Generic business models for transport chain management;

²⁰⁹ WCO, 2011.

²¹⁰ United Nations Economic Commission for Europe, 2013.

²¹¹ Geiger, C (2015) in H.N. (ed.) *Green Transportation Logistics: The Quest for Win-Win Solutions*, Springer International Series in Operations Research and Management Science.

- Open data models covering all aspects of intermodal transport.

Port Community Systems are difficult to achieve, but not impossible

Collaboration is required between multiple stakeholders

The Smart Port initiative is a collaborative partnership between the Rotterdam Port Authority, the City of Rotterdam, the companies on-site at the port, and Erasmus and Delft universities, designed to bring together expertise from a range of disciplines to explore innovative new ways to link maritime logistics with inland road, rail, water, and air transportation and logistics networks. In effect, it expands the spatial and temporal role of the port in the management of a seamless digital Transportation and Logistics Internet across Europe. The Smart Port Initiative will play an important role in helping to define the opportunities that lie ahead for the Port of Rotterdam in an emerging Digital Europe.

A common data platform needs a common language

Matching real-time space availability and truck availability will require that the storage and transit of all physical goods be standardized so that they can be efficiently passed off by any truck to any warehouse and retail node operating across the logistics system in the same way that information flows effortlessly and efficiently across the World Wide Web.

The port of the future will integrate new technologies with existing legacy solutions

A digital transformation does not occur overnight, and rarely is there a blank sheet from which to work: new technologies will have to work with older technologies, and existing infrastructure will have to be retrofitted with smart equipment. All this will take years to complete; still, a number of legacy systems can help deliver a digital transformation, and significant value can be extracted using existing IoT technology. The Digital Port will be a showcase of the technologies required to enable the TIR, including digital connectivity, Big Data platforms, smart logistics, smart mobility, IoT networks, sensors, and others. However, there are a number of mature technologies which will provide visibility across the supply chain. The most important are:

- Port Community Systems (PCS)
- Electronic Chart Display Systems (ECDIS)

- European Rail Traffic Management System (ERTMS)
- Automatic Identification Systems (AIS)
- Long Range Identification and Tracking (LRIT)
- E-freight systems
- E-commerce systems
- E-customs systems
- River Information Services (RIS)
- Single windows systems
- Big Data
- Cloud computing
- Physical internet
- Platooning systems.

Of these, five ICT systems will play the most important roles in the digital transformation of ports:

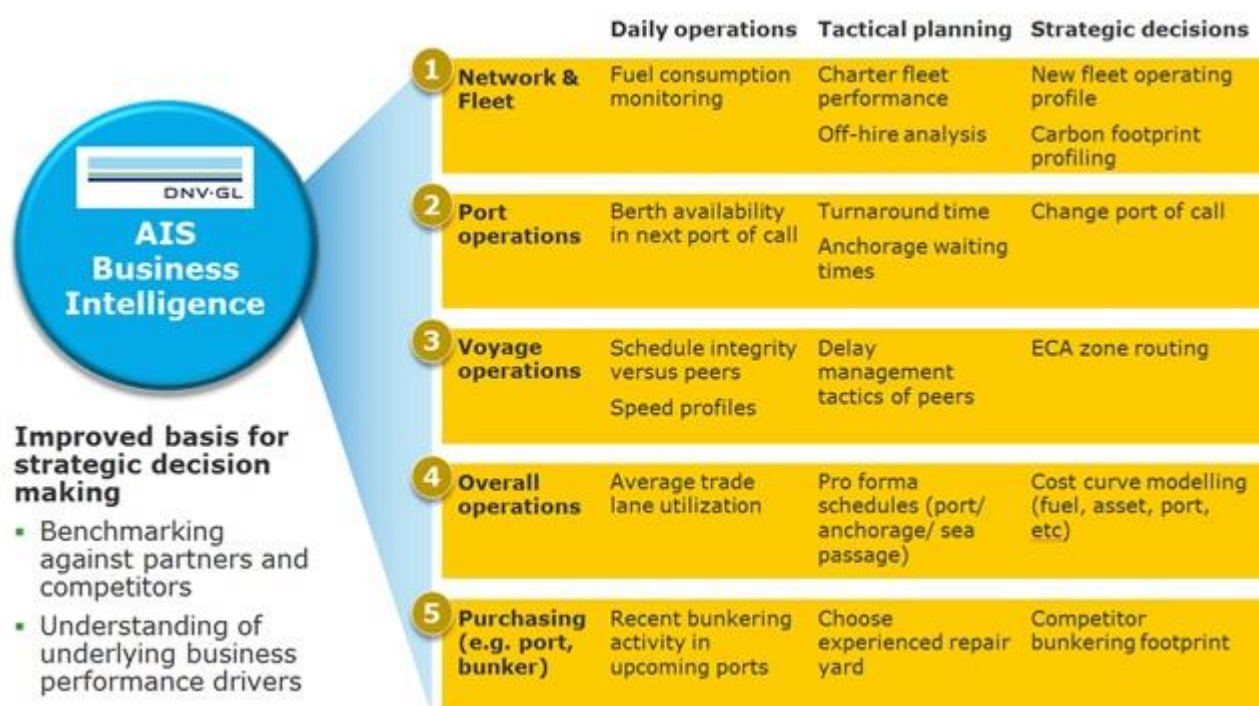
- Port community systems, e-freight and single windows
- European Rail Traffic Management System (ERTMS)
- Platooning systems
- River Information Services (RIS)
- ICT systems in OBOR

Significant value can be extracted using existing IoT technology

Not all IoT is new, and using existing IT assets, wherever possible, should not be overlooked. RFID & GPS have been around for years. Ports and terminals are already using Terminal Operating Systems, WMS, and BI infrastructure in places that can handle large volumes of data. While certain problems may require an overhaul of the fundamental building blocks, significant value can be extracted by using existing technology accompanied by newer standards that facilitate added value.

For example, more than 400,000 ships worldwide are equipped with transponders. By analyzing and merging Automatic Identification System (AIS) data with other data sources, shipping

companies can create new strategic and economic benefits.²¹² These include monitoring emissions, managing container ship delays, and voyage management.



AIS Business Intelligence

The example previously described may be implemented in the Port of Rotterdam as follows:

- Use AIS and RIS data for port and vessel emissions monitoring and reporting, and for providing integration with ESI, Ecoport – PERS (Port Environmental Review System), and MRV regulations;

²¹² DNV GL Position Paper (2014), Big Data - the new data reality and industry impact.

- Delay management;
- Voyage management.

Ports must take a value chain-wide view of IoT investments

As discussed previously, current port-based IoT use cases are limited to just the immediate environs of the Port. A synchro-modal plan requires ports to share their data with a much broader set of stakeholders. For example, port data can support much wider transportation projects: Dutch investments in smart transportation infrastructure are currently limited to commuters, but more far-reaching measures are expected for public transport, in the Port itself, and for autonomous road trains. These efforts will rely on data from the Port's common data platform, which will need to be designed to integrate with other external sources.

The Port of Rotterdam's common data platform should integrate with wider smart city platforms, following the model of Copenhagen's City Data Exchange

Today, ports are digitalizing their operations to enhance performance, efficiency, and productivity and reduce marginal cost and ecological footprint "only in the last mile" leading in and out of the ports. But, with the build out and scale up of the Internet of Things across continents, the opportunity exists to collaborate across industry sectors in the erection and management of an automated, GPS-guided, and driverless road, rail, water, and air Transportation and Logistics Internet that spans the world's landmasses and oceans.

The port and MRDH could develop a data management and exchange platform that enables multiple stakeholders from the public, private, and academic sectors to share and access data. Such a platform can accelerate innovation and open up new forms of funding. A number of cities are expanding their data platforms to allow broader integration. In Denmark, Copenhagen's City Data Exchange is one of the first offerings to explore the possibilities of a commercial model for data sharing across a city region.

Digital transformation relies on investment beyond IoT

The Port Authority is on the constant lookout for innovative ideas. To this end, it works together with universities and commercial partners, among others, to explore and elaborate new (technological) opportunities. The Port of Rotterdam is investing in a number of R&D

projects. For example, the Port Authority's research department is collaborating with container transfer company APM Terminals on the development of a sustainable terminal. It has investigated the concept of collapsible containers. There are numerous opportunities to use digital technology to reduce the Port's carbon footprint. Finally there are a number of use cases for blockchain technology to support efficiency and flexibility in the port environment.

The Port of Rotterdam's APM terminals place it ahead of the competition in digital transformation

The Port of Rotterdam has already taken the lead in the digital transformation. It is the largest terminal in the European Union and 11th largest terminal in the world and has jumped ahead of much of the competition with the roll out of its new APM terminals in 2015. Inside the 212 acres of terminals that comprise the Port of Rotterdam is an automated operation designed to speed up the efficient handling of shipments, while upgrading the safety of the work environment and reducing environmental footprint.

While the new automated terminals at the Port of Rotterdam cost €535 million, the Port Authority expects the return on investment – in the form of increased efficiencies and productivity – to more than warrant the upfront costs. The new facilities are expected to improve productivity by a stunning 40% in the near future.

The new terminals are equipped with automated ship-to-shore crane operations that are expected to improve the performance in the movement of containers over manually operated cranes by 50% when fully vetted. After hoisting the containers off the ships, they are automatically loaded onto driverless automated guided vehicles (AGVs) that are electric and run on batteries, and transferred to the storage yards to await loading by automated stacking cranes onto trucks, rail, or barges. The new automated facilities have cut the transfer time from ships to trucks from 45 to 30 minutes.

Collapsible containers

The Port Authority, together with Delft University of Technology, is examining whether it is possible to make containers that collapse - like a shopping crate. According to Delft University of Technology, this is possible, which is why the Port Authority has now commissioned a number of companies to develop prototypes that can be tested in practice.

Numerous technologies can assist the Port of Rotterdam to meet its ambitious carbon reduction targets

The expansion in global shipping has led to a significant increase in global warming emissions and focused growing attention on the need to make ports greener around the world. The Port of Rotterdam has established a high bar with the goal of reducing carbon dioxide emissions by 50% by 2025 and has set its sights on being the leading green port in the world. To reach this objective, the Port will need to transform the electricity grid powering its operations from fossil fuels and nuclear generated power to solar, wind, and other renewable energies. Already, the quay and yard cranes are electric and powered by locally generated wind. The cranes even generate their own power on the downward cycle of their movements.

Reaching zero emissions in operating the port will require a qualitative expansion of offshore and onshore wind and the addition of solar PV energy at port facilities. Electricity power and transmission lines feeding into the port will also have to reach renewable energy generation targets comparable to those in Germany, to meet the Port's expectations.

A significant portion of the costs of operating ports like Rotterdam is in the energy bill. The shift to a Third Industrial Revolution renewable Energy Internet will enable the Port of Rotterdam to operate on near zero marginal cost energy – the sun and wind are free. Operating the port with near zero marginal cost renewable energy means a significant increase in aggregate efficiency and productivity, and a steep reduction in ecological footprint in its day-to-day operations.

Geothermal energy use in the green port can be accelerated through the drilling of 20 new wells

The deployment of geothermal energy requires substantial investments of about €10 to 15M per 4km depth well up to €20M for a 6km depth well. While upfront fixed costs of installing the geothermal technology are often considerable, delaying the payback schedule, the marginal cost of harvesting geothermal heat is nearly zero. MRDH will need to provide the appropriate tax and credit incentives to encourage horticulture enterprises to introduce the geothermal harvesting technology. The goal is to have the new geothermal energy online and connected to the local energy infrastructure by 2020.

Ports are already investing in microgrids

The Port of Rotterdam is accelerating its use of solar and wind power. There are further opportunities for the integration of renewable energy and industrial combined heat and power

(CHP) systems as part of a port microgrid. A microgrid is not a single technology, but rather a system of systems. In the most common configuration, distributed energy resources (DER), ranging from solar PV systems to CHP plants to energy storage, are all tied together on a distribution feeder, which is then linked to the larger utility grid at a single point of common coupling. The Port of Los Angeles, for example, plans to install a \$26.6 million solar microgrid in 2016 as it moves toward becoming the first marine terminal to operate solely on renewable energy.

The Port of Rotterdam is also investing in hydrogen production technologies. It is the co-founder of the Netherlands' National Hydrogen Platform and took delivery of the Port's first hydrogen car in 2016. At present, hydrogen is largely generated from natural gas, but the growth in renewable generation offers the possibility for hydrogen becoming an important element in a zero-carbon port.

However, the need to deploy a hydrogen infrastructure is one of the biggest hurdles to the expansion of its use in transport and other sectors. Hydrogen fuel stations and electric charging stations will need to be installed at existing fuelling outlets stretching from the Port of Rotterdam to all of the major transport corridors across the EU and partnership regions to provide clean near-zero marginal cost renewable energy fuels for the thousands of trucks travelling the roads and expressways. Since the major transport corridors cross rural areas, regions along the routes will need to set up electricity cooperatives on adjacent open land to harvest solar and wind energy. The energy can be sent by micro-grids directly to the fuelling stations for storage and delivery to the vehicles.

Blockchain can revolutionize transactions across the supply chain

The many partners that comprise the Mobility and Logistics Internet – ocean ships and inland barges, trucks, rail, air transport, factories, wholesalers, warehouses, retailers, electricity cooperatives, filling stations, and others – will need to establish blockchains to secure their networks and provide up-to-the-moment accurate data on all transactions flowing through the system to ensure a proper distribution among the partners of the costs incurred and income generated from the activity.

Blockchain can be used for IoT device identification, adding security to stakeholders sharing data within a Port Community System

Blockchain introduces the Device Identity Model, a revolutionary approach to digital identity. Traditional digital identity systems rely on shared secrets and institutional endorsements. Under this model, when a user creates an account with a service, the service asks the user to choose a secret password, and then attempts to verify an email address by sending it a shared secret link or code. Banking, and other services that have identity-based regulations also request verifiable personal secrets like previous addresses, mother's maiden names, and even a taxpayer's ID number or a state issued ID such as driver's licenses and passports. These systems build large, centralized databases of personal information that are used to verify identities.

As centralized repositories, these become single-vector targets (referring to one single point of entry), inherently vulnerable to increasingly sophisticated cyber-attacks. Importantly, this means that at the same time that the value of the information contained in them increases over time, they also become less secure over time. One paradoxical result is that identity theft, fraud and other breaches of the identity system are easier to perpetrate against older people with identities that have accrued more value.

With blockchain, instead of tying blockchain-related transactions to accounts with usernames and passwords, transactions are controlled by a collection of related encryption certificates tied to user devices. This is the device identity model and, when combined with the immutability of the blockchain ledger, it has major benefits for security and privacy.

Digital transformation enables a number of new business models

The digital transformation of the Port of Rotterdam opens up a host of potential new business models. These include extending the Port's common data platform to become a pan-Eurasian data aggregator, offering a port-as-a-service model to smaller but technologically advanced ports, introducing concepts such as shared capacity between rival warehousing or transport companies, and monetizing investments in blockchain.

There is an opportunity for the Port of Rotterdam to position itself as the aggregator of data across the Eurasian landmass

A robust discussion is currently underway between the People's Republic of China and the European Union on the build-out of a digital infrastructure across Eurasia over the next half century – the 'Belt and Road' initiative – to create a seamless smart Internet of Things platform for carrying out commerce and trade, from the Port of Shanghai to the Port of Rotterdam. The Port of Rotterdam is the critical global node that connects the Americas to Europe on the Atlantic Ocean side, while Shanghai connects Asia to the Americas on the Pacific side.

The Port of Rotterdam can position itself as an aggregator of a digitalized intermodal transportation and logistics platform stretching across Europe and into Asia, fundamentally changing the Port's conception, role, and business model.

The Sharing Economy can help improve efficiency within the Port of Rotterdam

Thousands of trucks, warehouses, and distribution centers might establish cooperatives to share unused spaces, allowing a wide range of carriers to drop off and pick up each other's shipments, using the most efficient path en route to their next destination.

By also sharing thousands of trucks, different companies can carry, drop off, and pick up each other's goods en route to specific neighborhoods and locales, eliminating partial loads and deadheading, with a vast increase in aggregate efficiency and productivity, and dramatic reduction in marginal cost and ecological footprint.

TENESO Europe SE is a great example of a cooperative that utilizes innovative logistical processes to increase efficiencies and quality of service:

- Eleven of Europe's leading distribution and logistics companies have joined forces to create an organization they believe can improve the penetration and reach claimed by the larger global specialist transportation companies;
- Launched in May 2009, TENESO Europe SE (TEchnical NEtwork SOLution) aims to combine the resources, expertise, and know-how of its partner companies to produce a fully-integrated and superior logistics service they believe the market is seeking;
- TENESO Europe SE has secured a fleet of over 700 fully equipped, two-man vehicles as well as 70 high-security storage centers at strategically placed points throughout the UK and Europe.

Monetizing tokens from blockchain-related activities can be used to fund innovation

Tokenized assets derived from the various processes concerning blockchain efficiencies and proofs could be monetized to help develop an ecosystem of sustainable economic support and innovation for the Port and surrounding area.

These tokens can be viewed essentially as “community currencies” used by consumers and the growing start-up community for local goods and services, thus making the Port a unique player in their support of home-grown, ongoing innovation in port-related technologies.

The Port can use these tokenized “meta-assets” through renewable energy credits, to create bonds, and token crowd sales, which can raise significant money for further long-term development.

The Port of Rotterdam can take the lead in the development of Blockchain technologies for the supply chain

The Port of Rotterdam should take the lead in developing distributed logistics services around blockchain technology, providing it as a service for manufacturers, importers, shippers, and freight companies. By establishing its own certification systems as the trusted “oracles” feeding data into the blockchain, the Port will retain significant control and the ability to monetize the system. In a more fluid, dynamic supply chain environment, where shipping routes start to become even more substitutable than they are now, the provision of these kinds of trusted services would likely become a deciding factor for companies involved in supply contracts. There would also be licensing opportunities for the port, including the provision of certification services to financial institutions that deliver trade finance based on the Port’s information.

Additionally, Port “tokens” derived through the pegging of the tokens to predicted and real cost efficiencies can create new paradigms in sustainable growth and holistic community development through local currencies, growth bonds, crowdfunding and other mechanisms.

SMART MANUFACTURING: High Tech Systems and Materials/IT

The Metropolitan Region of Rotterdam and The Hague hosts diverse industrial sectors including maritime and logistics telecommunications, electricity power and transmission, the construction and real estate industry, manufacturing, agriculture and food, health and life sciences, cleantech, and the Sharing Economy. The Netherlands GDP topped €540 billion in 2012, and manufacturing contributed €68 billion to the total. Ten percent of the Dutch workforce – 825,000 people – works in the manufacturing industry. The Dutch manufacturing sector enjoys high productivity among EU nations, contributing €51.90 of additional value added per additional hour worked. Still, the Netherlands ranks in the second of four tiers in the European Commission Innovation scoreboard for 2015. Denmark, Finland, Germany, and Sweden rank in the top tier as “innovation leaders,” while the Netherlands, Austria, Belgium, France, Ireland, and Luxembourg are listed as “innovation followers.”²¹³

While the manufacturing industry was in continuous decline across the EU member states in the 1990s and the first decade of the 20th Century, the decline in manufacturing output stopped and has even reversed in recent years. The European Union has set a goal of increasing the industrial share of GDP from the current 15.3% to 20% by 2020. The smart manufacturing revolution is viewed as the key to a manufacturing renaissance, and the Dutch manufacturing industry is beginning to lead the way. While its manufacturing sector is still less developed than some of its neighbors, the Netherlands now ranks third behind Austria and Germany in growth.

MRDH’s leading industries will explore the vast opportunities brought on by the convergence of the Communication Internet, Renewable Energy Internet, and the automated Transportation and Logistics Internet, and the build out of a smart Internet of Things infrastructure. Cross-industry collaborations, the development of open-source platforms, the lateralization of value chains, collaboration between conventional market-based companies and startups in the Sharing Economy, and new distributed business models, will draw MRDH’s industrial sectors into the emerging digital business culture. Every industry will be tasked with exploring new ways to utilize the Internet of Things to increase its aggregate efficiencies, raise productivity, reduce marginal costs, and lower its ecological footprint in a smart green region.

The transformation of the Metropolitan Region of Rotterdam and The Hague’s industries into the new digital economic paradigm will be assisted by a number of world-class scientific and

²¹³ See: <http://bookshop.europa.eu/en/innovation-union-scoreboard-2015-pbNBAY15001/>

technical institutions. Virtually every industry in the region will be transformed by the Internet of Things platform and the ushering-in of a Third Industrial Revolution. For example, a new generation of info-facturers in the Metropolitan Region of Rotterdam and The Hague are beginning to plug in to the incipient IoT, and dramatically increasing their productivity while reducing their marginal costs, enabling them to compete in a highly competitive global digital marketplace. 3D printing – also called fabrication technology - is the manufacturing model that accompanies an IoT economy. MRDH hosts a large FabLab called Stadslab Rotterdam. Engineers, architects, and designers use the technology at Stadslab Rotterdam to erect urban models, create prototypes for components and products, and repair broken parts.

Renewable Resources Substitutes for Petrochemical Products

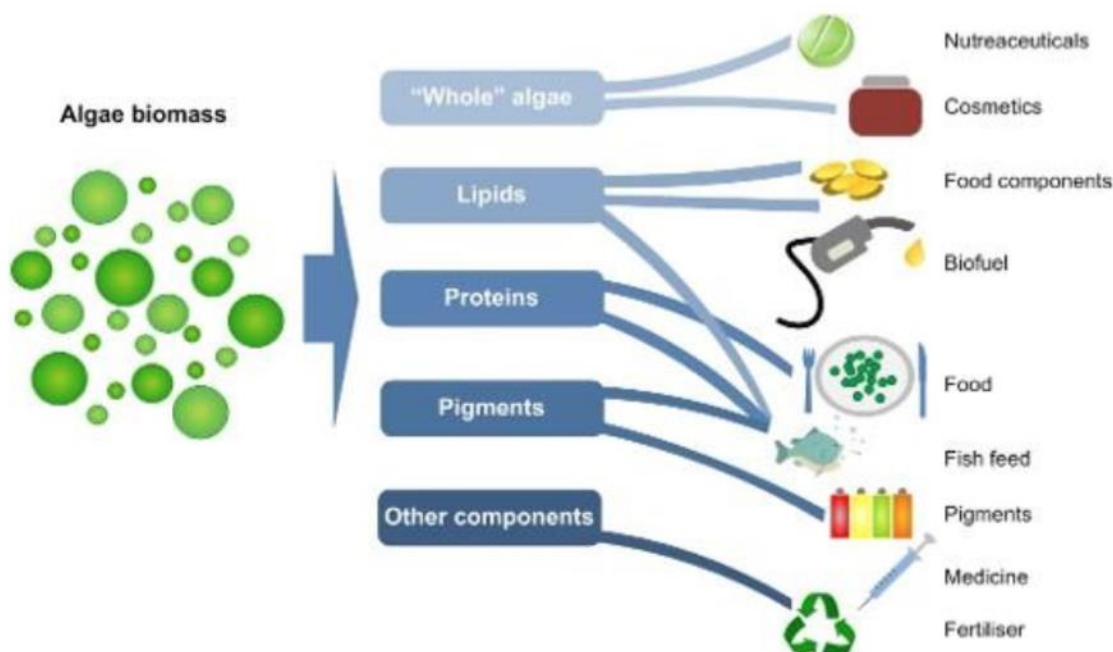
Today, most organic chemicals are derived from petrochemicals. A number of estimates have concluded that about two-thirds of those chemicals can be generated from renewable raw materials, rather than from oil. This suggests a market size of about €1 trillion. Currently, just seven percent of organic chemicals are produced from renewable resources.

The convergence of the chemical, agro-food, and life sciences will be particularly important in transforming the business models and product lines of the large petrochemical industries in the region. The digital and ICT revolution is now combining with the chemical, agro and life sciences through the genomics and bioinformatics revolutions.

MRDH is already in this market. Cutting edge research and development in biomedical materials is currently taking place at Brightlands Chemelot Campus in Sittard-Geleen. The Dutch Chemistry of Advanced Materials Council of the Top Sector Chemistry approved nine projects in 2015 in the Biobased Performance Materials (BPM) program. Wageningen Urban Research Centre's (WUR) Food & Biobased Research Institute, in collaboration with two-dozen partners, are concentrating on plant-based renewable materials. The research is focusing on roofing and carpet materials made from 100% non-petroleum, biobased bitumen binder. Other examples include biobased alternatives for 2D and 3D digital printer inks, as well as conversion of natural waste materials into particleboard.

Algae to fuels and plastics

Microalgae (microscopic unicellular species) are believed by researchers to be a vast pool of economically viable resources for producing renewable substitutes for products and fuels currently produced with petrochemicals. More than 125 tons of biomass can be produced from microalgae per hectare per year. Algae consist of energy-rich oils that enable conversion into mobile fuels. Continuing research is moving this promising algae resource to competitive status with fossil fuels. Crop production and harvesting techniques and oil extraction processes are all being advanced to increase oil content and productivity. The GAIN technologies are playing instrumental roles in achieving these advancements, especially bioinformatics, molecular, genetic, and synthetic biology techniques. The conversion of algae lipids into hydrogen production offers one of the most promising pathways to a 100% renewable fueled and powered economy with a diminishing ecological footprint.



Fermentation to Rubber

Petrochemicals currently produce all synthetic rubber materials. However, scientists are at work constructing a high-efficiency fermentation process for producing a biobased monomer that can serve as a substitute for petrochemical rubber. DuPont, in collaboration with the Goodyear Tire & Rubber Company, is co-developing this product, called BioIsoprene™.²¹⁴

Microbes to Acrylics

Acrylic is an exceptional petrochemical product widely used by industry, comprising an \$8 billion market. Acrylic is used to enhance paint durability and eliminate odors. Acrylic is also instrumental in improving the adhesive performance of diapers, their longevity, absorbent capability and leak-resistance. Acrylic helps produce cleaner clothes by making better detergents. Renewable biobased acrylic is now under development that will reduce CO₂ emissions by 75%, while providing the same performance and cost criteria of current petro-acrylic products. This new product, which is being researched at OPX Biotechnologies (OPXBIO), offers a reduction in petrochemical demand, while sustaining stable prices. The BioAcrylic product is now being scaled up to large demonstration size. Dow Chemical Company, one of the world's largest producers of petro-acrylic, has entered into an agreement to commercialize BioAcrylic in 2016.²¹⁵

Renewables to Fertilizer

Ammonia production, principally used in fertilizers made with the Haber-Bosch process, consumes two percent of the world's fossil fuels and releases one percent of the world's GHG emissions. Renewable energy production of ammonia for fertilizer can be done through electrochemical reactions without generating any CO₂ emissions. Hydrogen is produced in the electrochemical reaction by splitting water, which is then combined with nitrogen taken from the air through an electro-catalyst to produce ammonia. This low energy conversion process can be entirely powered by wind or solar energy systems.

²¹⁴ See: <http://biosciences.dupont.com/about-us/collaborations/goodyear/>

²¹⁵ See: <http://news.bio-based.eu/opxbio-raises-36-5-million-to-accelerate-commercialization-of-renewable-chemicals/>

A plethora of bio-based products are in development, including bio-based paint, adhesives and solvents, bioplastic, bio-packaging, bio-based fertilizers, and additives. However, standards have not kept pace with technological innovations. Wageningen Urban Research Centre's Food and Biobased Research Institute has been researching standards for the myriad of biobased products, instituted through the EU's Open-Bio project. A host of functional properties are vital for the commercial acceptance of biobased substitutes for petrochemical based paints, adhesives, plastics, additives, and fertilizers. The various products must exhibit key qualities of resilience, permeability, flexibility, recyclability, and degradability. Moreover, when reaching the end of their life, additional issues arise, including their ability to be composted, biodegraded, and recycled. These qualities need to be captured in easily explained and understood standards. Numerous research organizations across the European Union are currently partnering in the Open-Bio initiative, including FBR, ECN, and LEI in the Netherlands. The end goal is to arrive at a global harmonization of testing methods.

SMART AGRO-FOOD-FLOWERS

Approximately 200,000 people are employed in the agriculture and food industry in the Netherlands. There are 70,000 agricultural holdings in the country. Utilized agricultural land makes up over 1.9 million hectares, or 45% of Dutch land. ²¹⁶

²¹⁶ See: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_census_in_the_Netherlands#Agricultural_holdings

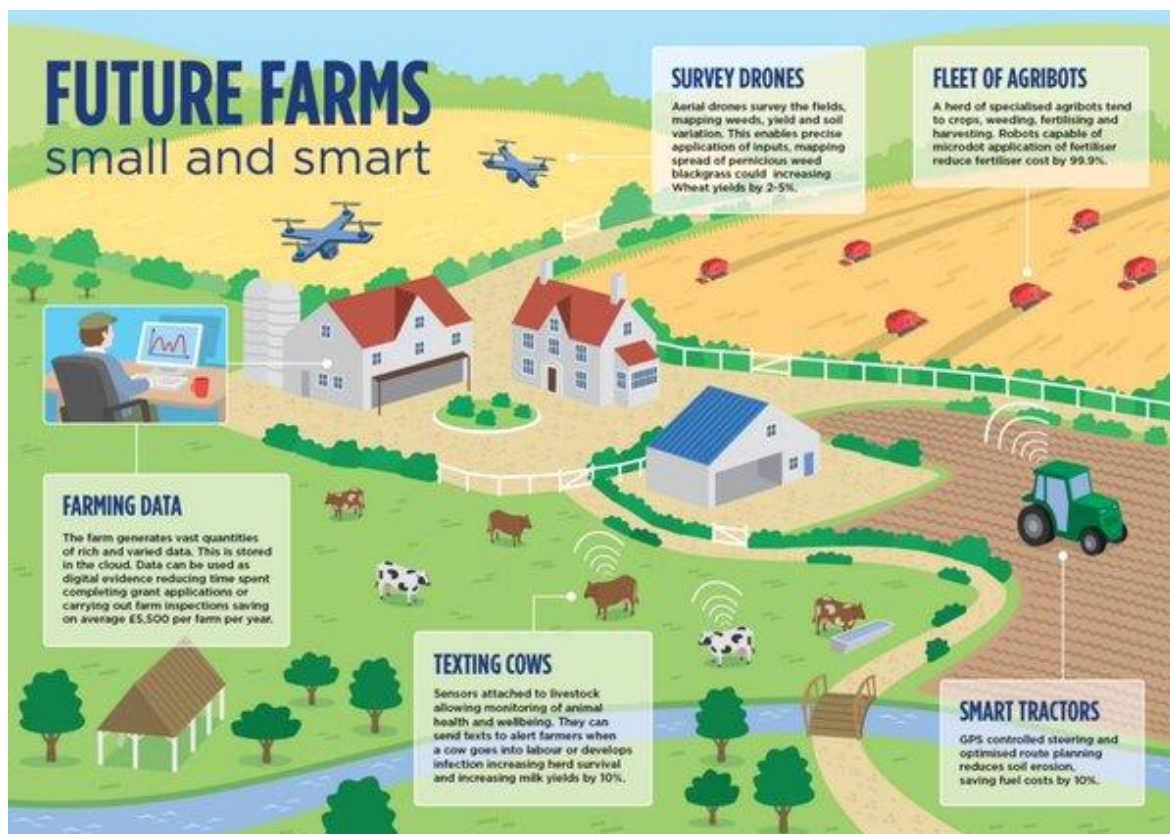


Image source: NESTA, <http://www.nesta.org.uk/blog/precision-agriculture-almost-20-increase-income-possible-smart-farming>

The phase in of the Internet of Things infrastructure for a Third Industrial Revolution portends vast gains in aggregate efficiency and productivity for MRDH farmers, food processors, wholesalers, and distributors. Farmers are already utilizing the emerging Internet of Things with sensors to monitor weather conditions, changes in soil moisture, the spread of pollen, and other factors that affect yields, and automated response mechanisms are being installed to ensure proper growing conditions.

The agricultural Internet extends beyond the harvest to include the distribution of food to wholesalers and retailers. Sensors are being attached to vegetables and fruit cartons in transit to both track their whereabouts and sniff produce to warn of spoilage so shipments can be rerouted to vendors.

As the IoT infrastructure is phased in, farmers, processors, wholesalers, and distributors in the region will be able to mine the Big Data flowing across their value chains. They will be able to use increasingly sophisticated analytics to create algorithms and apps, allowing them to dramatically increase their aggregate efficiency and productivity, and reduce their marginal cost and ecological footprint in the managing, powering, and transporting of food, taking the food industry out of the chemical era and into an ecological era mediated by smart, new digital interconnectivity.

The Ag Internet introduces a new era of agriculture. It's called prescriptive planting and it is being heralded as a potential productivity leap in agricultural yields. Early trials boosted yields by approximately 5% over two years, marking an extraordinary jump in productivity. Prescriptive planting combines remote sensors and cartographic techniques to map millions of acres of agricultural land and overlays the information with Big Data on climate across the regions. Analytics are used to mine the Big Data and provide precise times for planting as well as selecting the appropriate seed varieties best matched to the prevailing conditions.

While a promising new technology, the agricultural Internet of Things is not without controversy. Farmers worry that global life science companies might misuse the Big Data they are collecting to buy underperforming farms or that the Big Data might be sold to third parties or be used to trade on the commodity markets, undermining the price farmers receive for their harvests. In the United States, the American Farm Bureau, the nation's largest organization of farmers and ranchers, is introducing a code of conduct declaring that farmers own and control their data and that life science companies cannot use the information except for the purpose intended and cannot sell the data to third parties.



Image source: *Polydome*, High Performance Sustainable Polyculture Agriculture, www.except.nl/en/projects/1-polydome

The food sector is a major consumer of energy in the Netherlands and across the European Union. The cultivation, harvesting, storing, processing, packaging, and shipping of food to wholesalers and retailers use massive amounts of energy. Petrochemical fertilizers and pesticides account for a significant portion of the energy bill. Operating farm machinery is also a major energy expenditure. The cultivation of crops – especially the electricity bill used in irrigation – and animal rearing use the most energy in the food value chain, making up one third of the energy bill. The industrial processing makes up another 26% of total energy use, while packaging and logistics uses another 22% of the total energy expended. Final disposal of food waste makes up about 5% of total energy use. Animal-based food production and refined food products require more energy than fruits and vegetables.

When all the energy costs of food production, distribution, and recycling are added up, EU agricultural food production is a whopping 26% of the EU's total energy consumption annually, making it a major contributor to greenhouse gas emissions. The food sector has lagged woefully behind other commercial sectors in increasing renewable energies, with only 7% of total energy used coming from renewable sources, in sharp contrast to 15% in the overall energy mix.

Weaning the region's food sector off of petrochemical based farming is a formidable task. "The food sector is beginning to turn its attention to the challenge. Replacing petrochemical farming practices with organic ecological based farming practices is spreading across Europe and especially in the Netherlands. Approximately 49,000 hectares of land in the Netherlands are currently being used to grow organic food crops. Consumer demand is pushing the transformation. An increasing number of Dutch consumers are willing to pay premium prices for organic and sustainable foods. Farmers are also joining together in the creation of electricity cooperatives and beginning to install solar, wind, geothermal, biogas, and small hydro renewable energy technologies on spare land, creating a second business as micro power generators.



Changes in consumer dietary preferences are forcing a rethinking of farm practices. For example, rearing cattle and, to a lesser extent, pigs and sheep, requires massive amounts of energy and is the most inefficient means of providing food in the agricultural system. It takes up to eight pounds of feed to create a pound of beef, making cattle production and related animal

husbandry practices even more inefficient than automobile transportation. A younger generation in Europe is beginning to wean itself off of a heavily meat-oriented diet and is consuming more fruits and vegetables.

Community Supported Agriculture (CSA) is a good example of the impact that new TIR business models are having on how food is grown and distributed. After a century of petrochemical-based agriculture, which led to the near demise of the family farm and gave birth to giant agribusinesses, a new generation of farmers is turning the tables by connecting directly with households to sell their produce. Community supported agriculture began in Europe and Japan in the 1960s and spread to America in the mid-1980s. Shareholders, usually urban households, pledge a fixed amount of money before the growing season to cover the farmer's yearly expenses. In return, they receive a share of the farmer's crop throughout the growing season. The share usually consists of a box of fruits and vegetables delivered to their door (or to a designated drop-off site) as soon as they ripen, providing a stream of fresh, local produce throughout the growing season.

The farms, for the most part, engage in ecological agriculture practices and utilize natural and organic farming methods. Because community supported agriculture is a joint venture based on shared risks between farmers and consumers, the latter benefit from a robust harvest and suffer the consequences of a bad one. If inclement weather or other misfortunes befall the farmer, the shareholders absorb the loss with diminished weekly deliveries of certain foods. This kind of peer-to-peer sharing of risks and rewards binds all of the shareholders in a common enterprise. The Internet has been instrumental in connecting farmers and consumers in a distributed and collaborative approach to organizing the food supply chain. In just a few years, community supported agriculture has grown from a handful of pilots to nearly three thousand enterprises serving tens of thousands of families.

The CSA business model particularly appeals to a younger generation that is used to the idea of collaborating on digital social spaces. Its growing popularity is also a reflection of the increasing consumer awareness and concern about the need to reduce their ecological footprint. By eliminating petrochemical fertilizers and pesticides, CO₂ emissions from long-haul food transport across oceans and continents, and the advertising, marketing, and packaging costs associated with conventional Second Industrial Revolution food production and distribution chains, each shareholder comes to live a more sustainable lifestyle.

Finally, as mentioned in the previous section, new cutting edge developments in the life sciences are opening up vast new opportunities for the agricultural sector. The fiber industry is introducing new biological based products as substitutes for petrochemicals in packaging, construction materials, enteric coatings for pharmaceutical products, and filaments for 3D fabrication and manufacturing, raising the prospects of a second life for farmers, growing specialized fiber-based materials that can replace petrochemicals in a range of commercial fields.

SMART LIFE SCIENCES AND HEALTH TECHNOLOGIES

The Netherlands was one of the first eight countries to digitalize health records. The Dutch government mandated that electronic health records be available for all children in the country. With this precedent, the Netherlands is likely to emerge as an early adopter in establishing smart health care and health disease networks in the coming Third Industrial Revolution era.

Millions of people are open sourcing the personal details of their medical history and current conditions, sharing information on symptoms, diagnoses, and treatments; collaborating in research to find cures; joining in support groups to provide solace, comfort, and encouragement to one another; and spearheading advocacy groups to push governments, insurance companies, and the medical community to rethink medical-health assumptions and protocols across every aspect of the health-care field. In the United States, where health-care costs represent 17.9% of GDP, patients are becoming their own advocates on a giant health Commons that's paralleling the market economy and shaking up the theory and practice of medicine.²¹⁷

Health care, which was traditionally a private relationship between doctor and patient— in which the physician prescribed and a passive patient followed the physician's instructions— has suddenly been transformed into a distributed, laterally scaled, peer-to-peer relationship in which patients, doctors, researchers, and other health-care providers collaborate in open networked Commons to advance patient care and the health of society.

²¹⁷ See: <http://www.bloomberg.com/news/articles/2012-06-13/health-care-spending-to-reach-20-of-u-s-economy-by-2021>

Healthcare trends and opportunities



Image source: TI Medical, <http://destinhaus.com/the-healthcare-internet-of-things/>

Patient-driven health care began organically as increasing numbers of people started to search for their symptoms on the Internet to pinpoint a diagnosis of their medical condition. In the process, they came across others on the Web who had similar conditions and began sharing notes. Those who had already been diagnosed began to share their personal histories of a disease or illness on various health-care websites in hopes of eliciting feedback from individuals with similar case histories. Still others, unhappy with the treatment prescribed by their physicians, began searching for likeminded individuals who had similar misgivings in hopes of learning about alternative treatments. Individuals also began comparing notes on the side effects they were experiencing in taking certain drugs, especially if they were being taken in tandem with other drugs.

People with chronic or life-threatening illnesses for which existing treatments were either inadequate or nonexistent began to band together in search of potential cures. The more activist-inclined started groups to lend each other emotional and practical support and

launched advocacy organizations to bring public attention to their disease and push for more public funds to find a cure.

Today there are numerous social media websites where millions of people are engaging, supporting, and aiding each other in the pursuit of advances in medical care and public health. Some of the most popular sites include PatientsLikeMe, ACOR, the LAM Foundation, Cure Together, the Life Raft Group, the Organization for Autism Research, the Chordoma Foundation, and Sarcoma Direct Research.

Patient-driven research (PDR) is even beginning to penetrate the inner sanctum of science. Some e-patient online communities have erected tissue and specimen banks. Others have created cell lines for testing. Still others have set up patient registries and formed clinical-trial networks.

One of the great benefits of PDR is its speed. Advocates can get lifesaving information out to the people who need it right away, much faster than professional researchers, who must go through many time-consuming steps, which can take several years. So professional research has a built-in lethal lag time—a period of delay between the time some people know about an important medical breakthrough and the time everyone knows.

While double blind, controlled clinical studies are extremely expensive, patient-initiated observational studies using Big Data and algorithms to discover health patterns and impacts can be undertaken at near zero marginal cost. Still in its infancy, this open-source approach to research often suffers from a lack of verification that the slower, time-tested professional review process brings to conventional randomized control trials. Advocates are aware of these shortcomings but are confident that patient-directed research can begin to build in the appropriate checks, much like Wikipedia does in the process of verifying and validating articles on its websites.

Patient-driven Health Commons' advocates remind us that when Wikipedia first came online, academics argued that the democratization of scholarly research would severely compromise the high academic standards that went into compiling encyclopedias. Their fears turned out to be unjustified. The champions of patient-directed open-source Commons health research ask why crowdsourcing of research, with rigorous scientific protocols in place, should fare any worse.

There are currently hundreds of open-source health Commons online. That number is likely to increase dramatically in the years ahead as nations begin to use electronic health records to streamline the delivery of health-care services. In 2009, the U.S. government awarded \$1.2 billion in grants to assist health-care providers in implementing electronic healthcare records.²¹⁸ The Big Data that will be potentially available in the United States and other countries will provide a pool of information that, if used by open-source patient-driven health Commons with the appropriate privacy guarantees put in place, could revolutionize the health-care field.

The potential of using Big Data to address health issues became apparent in the winter of 2013 when a serious flu epidemic spread quickly around the world. Google was able to pinpoint the locations where the flu was breaking out and the intensity of the epidemic, as well as track where it was spreading in real time, by analyzing data of people's searches for flu-related topics on Google. While subsequent analysis showed that Google had overestimated the intensity of the epidemic, in part because of widespread media coverage—especially in social media that drew more people to flu-related searches – its tracking was sufficiently reliable as an early-warning mechanism that the U.S. Centers for Disease Control and Prevention subsequently made Google an official partner in their surveillance programs.

With epidemics, tracking the spread of breakouts in real time is critical to controlling the disease. Being able to mobilize local health-care services, ensure that flu shots are available and quickly administered where needed, and alert the public makes a big difference in the severity of the outbreak. In the traditional surveillance system, it can take between one and two weeks to collect data from doctors around the country based on patients' visits. By that time the flu virus could have peaked or even run its course. Google tracks peoples' first response when they search the Web to see if their symptoms match those of the disease, often days before they call or visit their physician. Twitter is also being looked to as a tracker. Twitter users send more than 500 million tweets per day. People who are not feeling well will often tweet their condition to friends, hours before the flu has disabled them, again providing an up-to-the-moment account of how the virus is spreading. Using Big Data to track global epidemics and blunt contagions will save billions of dollars in health-care costs while the surveillance and reporting system heads to near zero marginal cost.

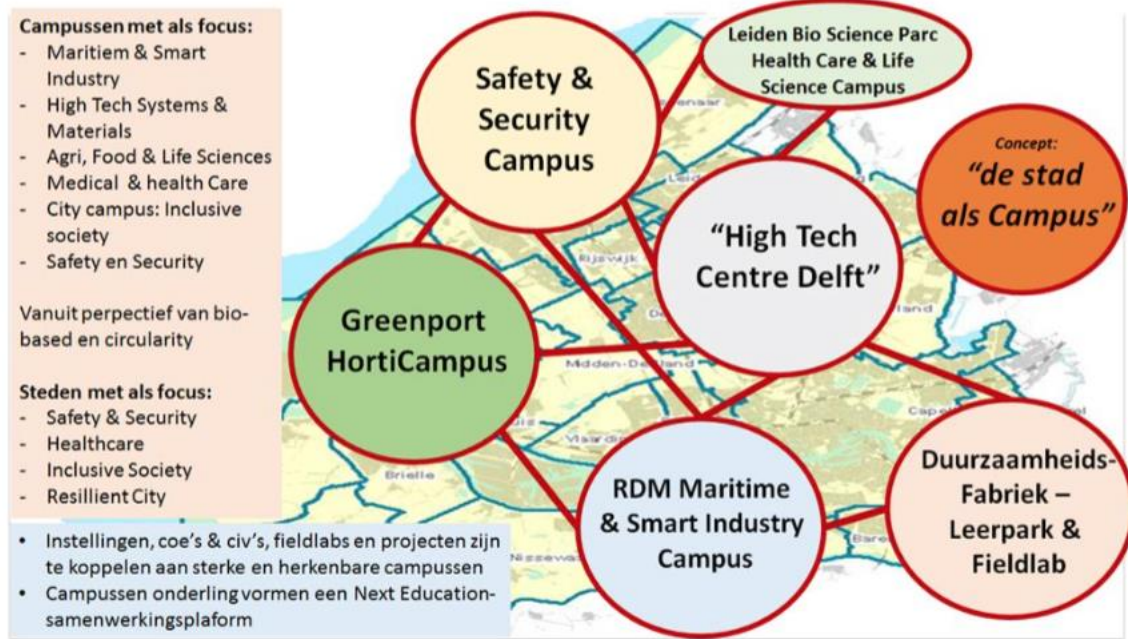
As researchers discover more about the links between genetic abnormalities and environmental triggers in the new field of genomic medicine, they're learning that while illness

²¹⁸ See: <http://www.reuters.com/article/us-usa-healthcare-electronic-idUSTRE57J21J20090820>

can be broadly categorized—for example, breast cancer, leukemia, and lung disease—each individual’s illness is unique, even if diagnosed as part of a generally defined illness. Genetic medicine is at the forefront of a new customized approach to illness that treats each individual’s affliction as an “orphan” disease. The diminishing cost of DNA sequencing is making available a library of Big Data that can be used by individuals to begin connecting with others who share a similar DNA profile. In the future, as DNA databases expand and the full sequence of human DNA becomes available for testing, millions of people will be able to match up with those who share common inherited genetic traits in customized patient-driven health networks, and compare notes on illnesses and collaborate to find cures. These more customized patient- directed health Commons will also be able to create sufficient lateral scale to bring public attention to their disease cluster and encourage increased government, academic, and corporate research into their illnesses as well as raise funds for their own research, clinical trials, and treatment.

These DNA clusters of biologically matched individuals will also be able to use Big Data to cross-reference each other’s lifestyles—eating habits, smoking and drinking, exercise regimens, and work environments—to further correlate the relationship between genetic predispositions and various environmental triggers. Because the matched human clusters will include a chronology of life histories from in utero to old age and death, algorithms will undoubtedly be developed to pinpoint potential disease risks at various stages of one’s life as well as effective treatments. By midcentury or earlier, any individual will be able to access a global health Commons search engine, register their genetic makeup, find a matching cluster of similar genomes, and receive a detailed account of their health risks over a lifetime as well as a rundown of the most effective customized medical treatments to make them well and keep them well, at near Zero Marginal Cost.

Today’s high-cost health care—much of which is primitive, ill-informed, and costly—will be a thing of the past in a Big Data culture and a near zero marginal cost society. Like the democratizing of information on the Internet, the democratization of electricity on the Energy Internet, the democratization of manufacturing with open-source 3D printing, the democratization of higher education with MOOCs, and the democratization of exchange in the sharable economy, the potential democratization of health care on the Web adds one more layer to the social economy, making the Sharing Economy an ever more prominent force in the affairs of society.



SMART FINANCE – BLOCKCHAIN DISTRUBUTED LEDGERS

Because new transactions can be included permanently and immutably in in blockchains for relatively small transaction fees, the entire Internet of Things can use it to securely track certificates, identity, agreements, and other facts of note. Use-cases of this include:

Securitization. The blockchain, when combined with Internet of Things facilities, offers a powerful way to create collateral to attract low-risk, low-cost financing. That's because this technology can establish clear, time-stamped, and verifiable provenance of title and allows for very precise measurement of the revenue or economic activity generation of particular assets. On top of this, kill-switch chip technology, coupled with smart contracts, can give these assets a "smart property" quality that means contracts that are attached to them can be executed with unprecedented, real-time precision and equitable treatment. In essence, the digital money flow stops, and a smart contract will automatically freeze an asset and/or transfer title to the lien holder in a way that neither party is in a position to abuse. That precision, executability and

contractual surety means that we can create localized crypto-assets (either equity or debt) that can be bundled into structured portfolios of asset-backed securities. Through this innovative approach to structured finance, we can bring high-level aggregated financing to bear to a multitude of what are otherwise small, local, decentralized projects.

Moderating private vs. public interest. Social impact investment funds, which seek both financial profits and “impact,” are the ideal funding sources for many of these projects. And to structure the deals so that investors in these funds get to achieve their goals, blockchain-based smart contracts can establish inviolable rules for how target objectives are met. Benefit corporations would be created under blockchain-regulated DAO structure that execute delivery of funds when pre-ordained conditions are met (for example, once the carbon footprint of a certain project reaches X level, renewable energy generated dividends will start automatically flowing to investors). The same structure could be used to regulate government subsidies, where needed, such that they automatically cut out when the cost of production falls to a certain level once a project becomes profitable.

Market mechanisms. By creating native crypto-tokens of value that trade over a blockchain, resource usages can be regulated by a market mechanism that creates the right incentives for efficiency that’s not possible without this system. This is also highly applicable to energy markets. Dynamic, ongoing marketplaces for energy can be created around those tokens, constantly incentivizing producers to compete to produce energy at the lowest cost (measurable in both traditional financial terms and in externalities such as pollution/carbon footprint). Similarly, consumers of energy can design smart contracts that tie their energy usage into whatever value propositions they determine, pre-setting limits so that certain machines turn off if and when the price of energy reaches a certain level or when some other priority needs to be addressed.

Next Economy Quality of Life Indicators

The transition into a smart, sustainable Third Industrial Revolution economy is measured less by the accumulation of market capital and more by the aggregation of social capital. The steady decline of GDP in the coming years and decades is going to be increasingly attributable to the changeover to a vibrant new economic paradigm that measures economic value in totally new ways.

Nowhere is the change more apparent than in the growing global debate about how best to judge economic success. The conventional GDP metrics for measuring economic performance in the capitalist marketplace focus exclusively on itemizing the sum total of goods and services produced each year with no attempt to differentiate between negative and positive economic growth. An increase in expenditures for cleaning up toxic waste dumps, police protection and the expansion of prison facilities, military appropriations, and the like are all included in gross domestic product.

Today, the transformation of economic life from finance capital and the exchange of goods and services in markets to social capital and the sharing of goods and services in the Collaborative Commons is reshaping society's thinking about how to evaluate economic performance. The European Union, the United Nations, the Organization for Economic Co-operation and Development (OECD), and a number of industrialized and developing countries have introduced new metrics for determining economic progress, emphasizing "quality of life" indicators rather than merely the quantity of economic output.

Social priorities, including educational attainment of the population, availability of health-care services, infant mortality and life expectancy, the extent of environmental stewardship and sustainable development, protection of human rights, the degree of democratic participation in society, levels of volunteerism, the amount of leisure time available to the citizenry, the percentage of the population below the poverty level, and the equitable distribution of wealth, are among the many new categories used by governments to evaluate the general economic welfare of society.

The GDP metric will likely decline in significance as an indicator of economic performance along with the diminution of the market exchange economy in the coming decades. By midcentury, quality of life indices on the Collaborative Commons are likely to be the litmus test for measuring the economic wellbeing of every nation.

Many of Europe's global manufacturing enterprises will continue to flourish in the emerging Third Industrial Revolution, but will be fundamentally transformed by the lateralization of industry, which favors a high-tech renaissance for small and medium sized enterprises. Europe's industrial giants will increasingly partner with a new generation of 3D-printing small and medium sized enterprises in collaborative networks. While much of the industrial production will be done by SME's that can take advantage of the increased efficiencies and productivity gains of lateral economies of scale, the global enterprises will increasingly find value in

aggregating, integrating, and managing the marketing and distributing of products and services on a planetary IoT platform.

The transition from the Second to the Third Industrial Revolution will not occur overnight, but, rather, take place of over 30 to 40 years. Many of today's global corporations will successfully manage the transition by adopting the new distributed and collaborative business models of the Third Industrial Revolution while continuing their traditional Second Industrial Revolution business practices.

The establishment of the Third Industrial Revolution Internet of Things infrastructure in the region will necessitate the active engagement of virtually every commercial sector, spur commercial innovations, promote small and medium sized enterprises (SME's), and employ thousands of workers over the next forty years. The power and electricity transmission companies, the telecommunication industry, the construction and real estate industries, the ICT sector, the electronics industry, transportation and logistics, the manufacturing sector, the life-sciences industry, and retail trade will all need to be brought into the process. Many of today's leading companies, as well as new commercial players, will help establish and manage the Internet of Things platform, allowing thousands of others—small, medium, and large sized businesses, nonprofit enterprises, and prosumers—to produce and use renewable energy, automated transportation and logistics, and a panoply of other goods and services at low marginal cost in the exchange economy or at near zero marginal cost in the Sharing Economy.

4.0 NEW BUSINESS MODELS AND VALUE CHAINS

SMART PORT

4.0.1 *Reconceptualize the role and function of the Port of Rotterdam* – Transforming the Port into the flagship Big Data node of a digitally connected global transportation and logistics Internet.

4.0.2 *Digital Port* – In the Third Industrial Revolution, the Port of Rotterdam becomes the main digital node and gateway for the European continent. The Digital Port fully serves logistics and trade between Europe and other continents and within Europe. The Port of Rotterdam serves all players in the logistic chains with seamless data, high quality data applications and internet of things connectivity. Digitalization and 'connectivity of everything' are the foundation stones

of the Third Industrial Revolution next economy. The Port of Rotterdam is a lighthouse for the Digital Europe agenda. The real time Big Data flow of information about traffic, cargo, and warehousing is of huge value for optimizing transport and port management. Three activities within the Smart Port relate to the Digital Gateway transition:

- Nautical efficiency (Port Call Optimization) The core process managed by the port and the coordination of nautical services (towage, mooring) include a long chain of businesses involved in the process of a ship-call. Enhancing data availability and quality control for these businesses along their logistics chains will create a faster and more cost effective and efficient supply chain process.
- Enabling Logistics (Rotterdam Logistics Lab). Because of its strategic significance, the Port of Rotterdam becomes the critical Big Data node for thousands of supply chains across Europe. Building a platform for seamless data interchange between supply chain partners in the port and across the intermodal transport corridors of Europe is essential for transforming MRDH into the logistics center for the emerging automated Transportation and Logistics Internet.
- IoT for Logistics (optimizing transport capacity). A market platform with real time data for cargo capacity can help improve the use of transport capacity and prevent inefficient moves or delays coming in and out of the Port.

Integrated smart port mobility and transportation management-covering vehicle monitoring and routing and smart parking systems- can be linked into regional and national transport systems to improve logistics flow throughout the region.

4.0.3 Port as a Service - Expand the footprint of the Port by providing port (supply chain) management as a service to other ports. The project develops a business plan for remotely managing robotized ports. The initiative includes managing automated vessels, smart maintenance of port infrastructure, and automated supply chains that connect terminal operating systems (TOS), port monitoring systems, logistics platforms etc. Intelligence on how to manage a port is developed and marketed in a similar way that the food & flowers sector commercializes its plant growth models. Major developments are carried out in the areas of:

- Crewless shipping and trucking/smart mobility
- Port monitoring (sensing of all the port infrastructure)
- Scaling up the Maritime Field Lab into a fully-fledged digital manufacturing port infrastructure

4.0.4 To assure a competitive advantage, the port and the various freight and other service providers connected to it will need to have logistics technology that interfaces with blockchain capabilities - Logistics must be a priority for a port city and Rotterdam needs to be at the cutting edge of what promises to be one the most disruptive developments in this field: blockchain-based supply chain management. Whereas the movement of goods and the maintenance of inventories are now typically managed over proprietary systems such as Wal-Mart's famous vendor-managed inventory system, the blockchain lets small suppliers and customers break free of that dependence on the biggest player in the supply chain. Along with RFID chips, smart contracts, and integrated digital payment systems, a blockchain-based supply chain promises full, verifiable visibility of the location and provenance of goods without any one participant in the chain holding control over the information. That changes bargaining dynamics dramatically and so portends a much more distributed and fluid set of commercial relationships. When coupled with 3D printing and drone delivery systems, it means that the flow of goods along a supply chain can shift more rapidly with geographic and corporate consequences. That will have implications for the Port of Rotterdam because the flow of goods will change.

Dubai's Global Blockchain Council (a collaboration between government, local business, and global technology and service providers) has identified shipping as one the core areas for the exploration of the benefits of blockchains. The use case proposed focuses on how different players can combine more effectively in the exchange of goods and financing of trade.

4.0.5 Explore new collaborative partnerships between the Port of Rotterdam and other industries – The Port of Rotterdam will need to collaborate with companies in other industrial sectors in the erection and management of an automated GPS-guided and driverless intermodal Transportation and Logistics Internet across the European Union.

4.0.6 The Port as Innovation Hub – The Port of Rotterdam has already established a number of programs to drive further innovation in the use of new technologies in the port and to support the development of a local ecosystem of developers and startups. It has worked with tech incubator YES!Delft to establish the Port Innovation Lab, which brings together the port industry, port startups, and knowledge institutes to drive the creation of new solutions that can meet the needs of a global port sector.

In the Port of Rotterdam, RDM Rotterdam has been established on the site of the former shipyard of the Rotterdamsche Droogdok Maatschappij (RDM). One important area of

development is 3D printing. A 3D printing pilot project to make spare parts for maritime industries has been led by the Port of Rotterdam, RDM Makerspace, and InnovationQuarter. These partners have also supported the establishment of a new Fieldlab, which uses 3D metal printers for the creation of marine parts.

SMART MANUFACTURING [HIGH TECH SYSTEMS & MATERIALS, HTSM/IT]

4.0.7 Foster HTSM/IT as the economic backbone of the region. Many elements are in place to reach this goal. However, major changes in mind-set are required. MRDH will need to build an entrepreneurial ecosystem where scale-ups can quickly grow. To facilitate this process, sector walls will need to be brought down. MRDH is a high-tech region where all the stakeholders can benefit from each other. This will stimulate new spillover of ideas and business models. New B2B businesses will need to be developed as is now the case in the consumer market. The region will need an investment climate comparable to Silicon Valley. New models are needed in the job market as well. Finally, MRDH can become a testing ground for new legislation to foster the transition.

4.0.8 MRDH will need government assistance in making the transition to a smart manufacturing mode. There are significant smart advanced manufacturing initiatives underway around the world supported by national governments. Germany, the United Kingdom, the United States, and China all have major initiatives. For example, the “Made in China 2025” plan was launched in 2015. China’s massive effort focuses on accelerating the transition from a labor-based manufacturing industry to a machine intelligent one. Smart manufacturing is also being phased in by the German government. Smart manufacturing emphasizes resource efficiency and productivity gains, combined with flexible organizational models of work, through integrations of computation, networking, and physical processes known as cyber-physical systems (CPS). CPS provides corporations with an advantage in attracting and retaining outstanding employees.

The National Strategic Plan for Advanced Manufacturing launched in 2012 by President Obama, emphasizes, “a robust innovation policy that would reduce the gap between R&D and deployment of advanced manufacturing innovations.”²¹⁹ The focus is on a technology’s

²¹⁹See:https://www.whitehouse.gov/sites/default/files/microsites/ostp/iam_advancedmanufacturing_strategicplan_2012.pdf

complete lifecycle to promote advanced, transformative manufacturing technologies, while catalyzing increased public and private investment for the early stages of advanced manufacturing technology infrastructure. The strategy is also designed to achieve rapid scale-up and market uptake of the advances coming out of the development pipeline.

4.0.9 Scale-Up Nation – There has been growing interest in start-ups in recent years. With all the attention on the next ‘darling’ start-up, the importance of scale-ups has been somewhat overlooked, despite the fact that the real growth potential and employment opportunities come with scale-ups. This is now being acknowledged by the Scale-Up Nation initiative, originated in Amsterdam. A regional MRDH program in collaboration with this initiative should be set up to ensure fast growth of many high tech scale-ups in relevant market segments, encompassing the following activities:

- Support programs comparable to YES!Delft, ECE and CIC for scale-ups: flexible space, programming, intervision, ‘vibe,’ good investor climate, etc.
- Collaborate with the Amsterdam initiative to build a Randstad Scale-up initiative
- Establish a program on business model development and internationalization
- Provide flexible prototyping and manufacturing space that can be hired for short terms and on short notice
- Provide cheap locations by retrofitting unused office spaces for use in small series production of high tech products and for use by IT-firms, etc.
- Offer last mile transport for production sites: data driven, well integrated, and electric and automated
- Scale-up the YES!Delft model by creating satellites in the regional business districts as well as a shake-up of YES!Delft to create more ambitious and entrepreneurial start-ups

4.0.10 Field Lab Ecosystem – MRDH needs to further develop the use of field labs to stimulate cross-sector innovation, practical education and quadruple cooperation between end users, companies, R&D and government. Aspects that need to be organized include:

- creating a Field Lab Fund
- building a Field Lab Support System (exportable product)
- devising programs across and beyond sectors

- creating a collaborative network of field labs, makerspaces, innovation districts, multistakeholder living labs and freezones for enabling experimentation and R&D in real world circumstances will contribute to an environment in which the deployment of technological innovations can be stimulated, scaled up and translated into real business (cases) and job opportunities.

Strange Attractors

The combined force of the cross-sector field lab approach may result in 'strange attractors' in the region that will have a strong 'pull effect' on creative pioneers from all over the world and may contribute to substantial clustering of talents. Such initiatives can prove to be the catalysts for new innovations across and beyond sectors (e.g. the high tech 3D printing facility in Bristol UK which has attracted a wide range of pioneering companies developing new and previously uncharted applications). Investments in state of the art technologies and cutting edge facilities should be closely connected to topics that are aligned to the existing economic strengths and knowledge expertise in the region. Some suggestions for 'breakthrough' innovations or potential 'game changers' to be further investigated and/or developed:

- Drones / unmanned valley
- Automated / unmanned, zero emission vessels
- Solutions for vital infra security
- Developing a global Blockchain system for transport and logistics
- Developing circularity metrics for uniform resource handling
- Solutions for energy storage
- State of the art facility for 4D printing
- Zero emission trucks and buses for the last mile
- Health robotics
- Robotics for extreme environments
- Development of off shore wind and solar parks
- Sustainable decommissioning of oil and gas rigs
- Coastal defense, building with nature, climate proof building
- Dutch Wind Wheel (iconic project encompassing various field labs)
- BlueCity 010 (circular accelerator)
- Energy disruptors (e.g. PV from E-waste, seaweed waste and materials, biogas to materials)

- Ocean Clean Up Group (first clean up barrier test as pilot for deployment in the Great Pacific Garbage Patch in 2020)
- Medical Cabinet of Europe (implementation of radical medical approaches developed in various living labs)
- Smart technology for personalized diagnostics & drugs (e.g. electroceuticals / nano implants)
- Rotterdam has prepared a proposal for the Dutch bid for the World Expo 2025, which could showcase the strange attractor Next Economy initiatives spawned in the region.

SMART AGRO-FOOD-FLOWERS

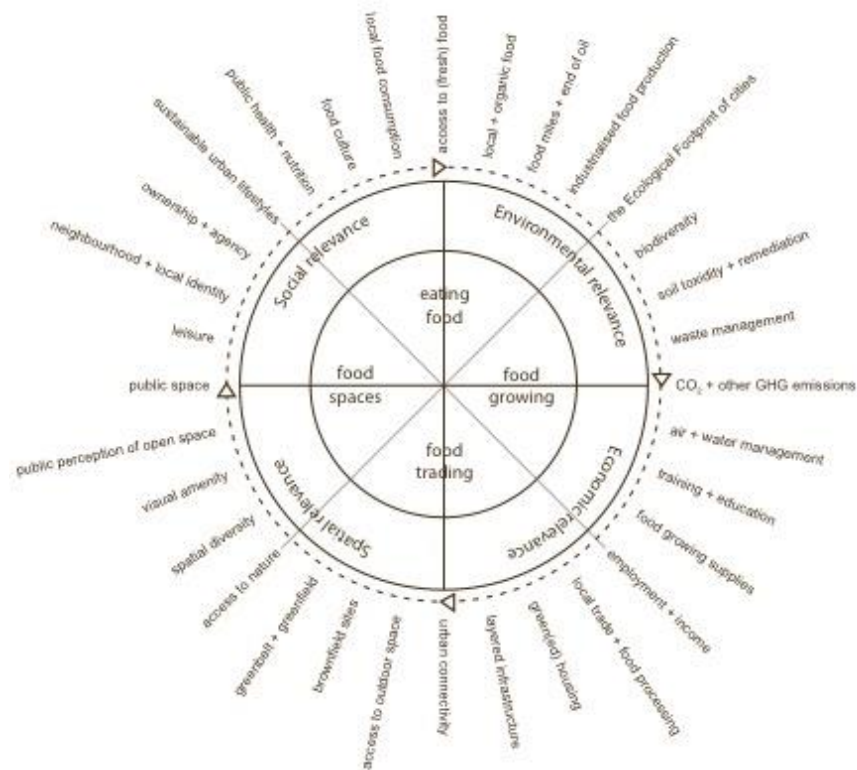
4.0.11 Promote policies and initiatives to engage children from an early age on the rewarding opportunities that horticulture and Greenport offers. Gardening provides an excellent venue of applied learning, potentially catalyzing life-long learning to cultivate food and flowers as a recreation, vocation, profession, or simply instilling an appreciation of the local aesthetics of horticulture and agriculture. The schooltuinen, school garden, is a well-known concept in the Netherlands. It is an educational tool and a voluntary part of the elementary school curriculum. This experience can be greatly enriched by mobile apps and Internet platforms enabling peer-to-peer interaction, and collaborative innovation initiatives.

Rotterdam's citizens and officials have joined together in launching one of Europe's finest urban-wide farming and gardening programs, with the transformative vision of the city as an ecological system. Eetbaar Rotterdam (Edible Rotterdam) offers an excellent example of applied life-long learning experiences that can be leveraged for engaging citizens spanning all ages from pre-school to senior centers (see case examples, next page).²²⁰

Urban gardening and mini-farming encompasses a myriad of social, ecological, educational, and financial benefits; people may participate because one or more of the dozens of positive

²²⁰ See: de Graaf, Paul (2012) Ruimte voor stadslandbouw in Rotterdam, (Room for Urban Agriculture in Rotterdam), Eetbaar Rotterdam, <http://www.pauldegraaf.eu>.

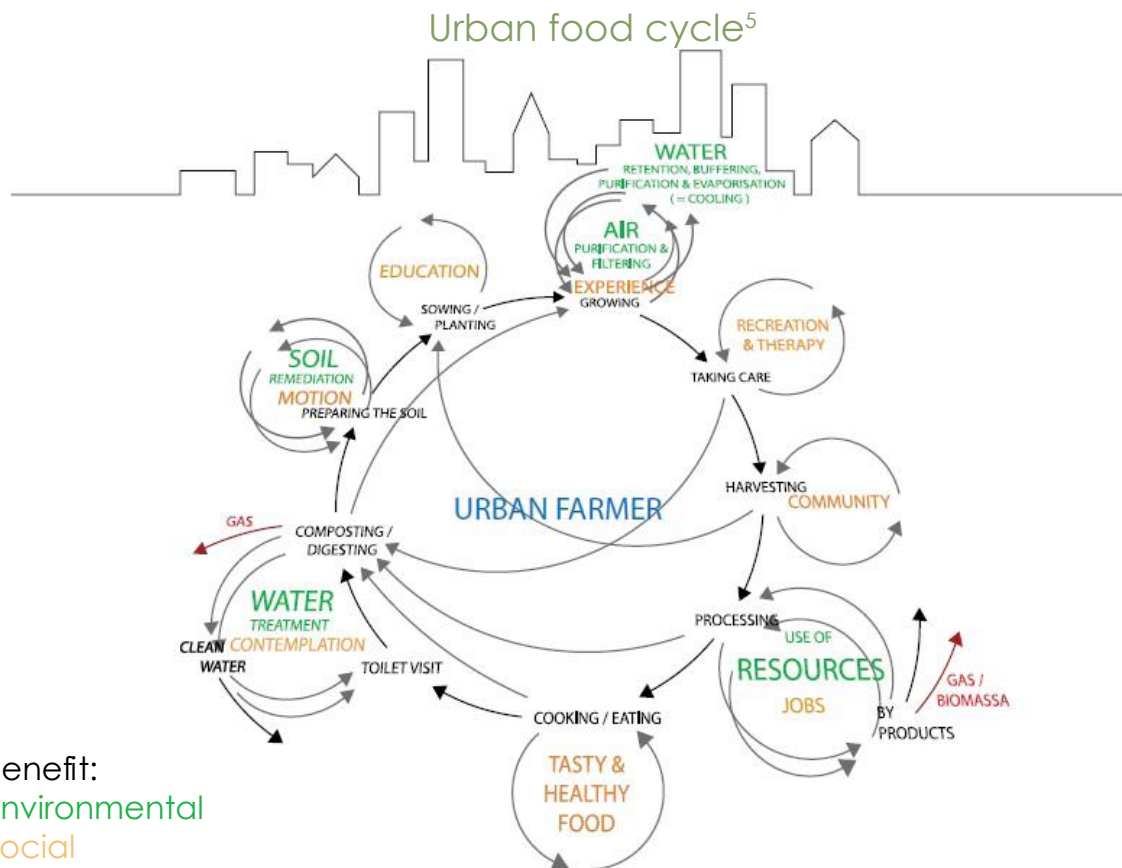
features persuades them. This is encapsulated in the circular visualization (below) based on accumulated research, evidence, and empirical experience.²²¹



Source: Viljoen and Wiske

²²¹ Viljoen, André and Johannes S.C. Wiskerke (2012) Sustainable food planning evolving theory and practice, Wageningen Academic Publishing.

Urban farming and gardening offer a host of city services – applied learning, recreation, aesthetic landscapes, vocations, professions, numerous ecosystem services – and are integral components of both the prosumer Sharing Economy and the circular economy. In addition, the learning and experience curves generated from urban agriculture can be leveraged as key components of an export business innovation model emphasizing Knowledge-as-a-Service expertise. These diverse dynamics are captured in the systems diagram (below) and in detailed GIS mapping (four examples on the next page).



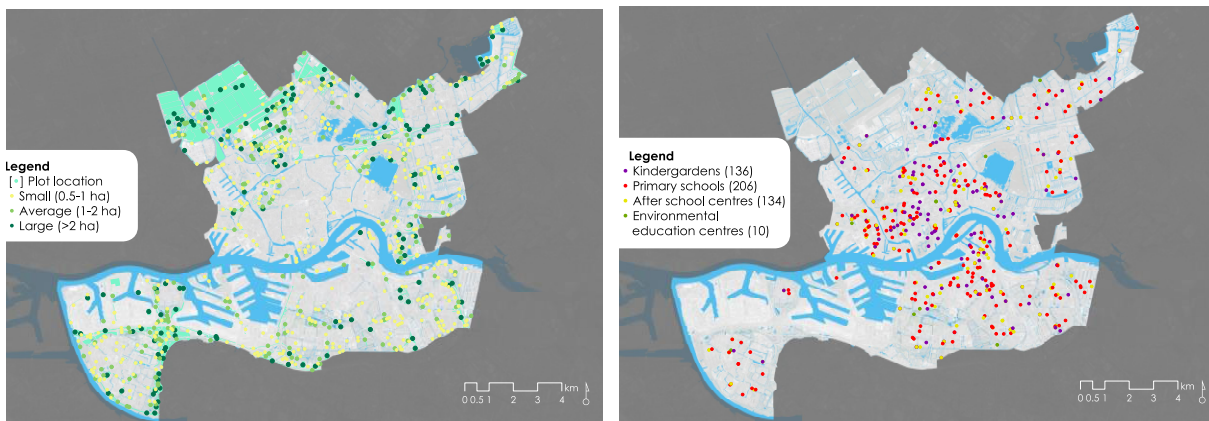
Source: de Graaf (2012)

Urban farming and gardening are essential elements of regenerating the biosphere. Moreover, the IoT-driven Third Industrial Revolution enables IT platforms, allowing citizens easy access to information on all facets of urban agriculture.²²²

²²² Dumitrescu, Vlad (2013) Mapping Urban Agriculture Potential in Rotterdam, Gemeente Rotterdam Ingenieursbureau and Eetbaar Rotterdam, December, 2013.



(Left) Unsealed land use (including allotment complexes); (Right) Soil contamination (0-1m) of unsealed urban areas. Source: Dumitrescu (2013)



(Left) Commercial farm suitable plot location and size (grasslands & derelict lands > 0.5 ha); (Right) Institutions with an incentive to start urban farms. Source: Dumitrescu (2013)

4.0.12 Expand engagement in the quadruple helix knowledge innovation networks by adding six Innovation and Demonstration Centers to the three existing ones, and the Greenport Horti Campus – The competition for talent among sectors necessitates promoting investment in human capital, engaging all stakeholders, to interact, cross-pollinating ideas, and mainstreaming life-long learning competences by being linked and aligned in these networks.

4.0.13 Explore the multiple opportunities for successful crossovers – Cross-pollination of ideas and opportunities with other relevant sectors should be promoted, building on the

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convergence and synergy being created by the Communications Internet, Renewable Energy Internet, and Mobility & Logistics Internet, as well as other pillars and cluster.

4.0.14 Implement real-time auditing of the food chain to identify inputs and outputs of resources - Introduce sensors and monitoring equipment across the farm belt - to create a seamless and comprehensive database for decision-making and identifying new value chains, revenue streams, and cost-saving opportunities.

4.0.15 Establish farmers' green electricity cooperatives - The Netherlands' onshore wind resource opportunity is estimated at 50,000 MW, and the solar resource available for utility-scale solar PV systems is estimated at 187,000 MW. As in other regions of the world, farmers should come together to establish energy cooperatives to become power producers, as a second stream of revenue.

4.0.16 MRDH and the Dutch government should set-up a subsidies program over a 10-to-15 year period to enable farmers to lay their land fallow for detoxification to qualify for organic certification. Petrochemical fertilizers and pesticides are major contributors to CO₂ and nitrous oxide greenhouse gas emissions. In addition, the price of fertilizers, pesticides, and insecticides are volatile and swing wildly with the price of oil, often negatively affecting profit margins. Organic foods are the fastest growing segment of the retail market in Europe, and guarantee farmers a higher price than conventional crops.

4.0.17 Set up an agro-food platform - Tap the citizenry's commonsense and crowd wisdom through an interactive platform mashup of social media and apps where stakeholders can entertain a lively and open dialogue on agro-food issues. MRDH should welcome, use, and leverage the public's wisdom to avoid ending up with tunnel vision.

4.0.18 Assess and pursue state-of-the-art knowledge on agro-food-flower production in the Netherlands and MRDH as a promising Knowledge-as-a-Service export model – Internetization of society and the economy presents the Netherlands with the opportunity of advancing a highly competitive TIR global business model platform based on deep knowledge-infused logistics (KNOW-LOGISTICS) and Knowledge-as-a-Service. Several programs are already underway within Greenport, such as agrologistics, remote growing, and Triple Helix collaborations. Sustainable Urban Delta Cross-overs with other sectors are also underway, including Synchromodaal SMART and efficient logistics, and R&D and market advances of GAINS (Genetics, Auto-robotics, Informatics and Nano science, technology and engineering).

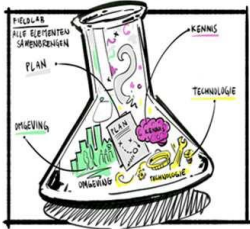
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4.0.19 Continue to foster vocational education and training in smart food and flower competences and skills, carried out in-class, online and in the field. This encompasses a wide range of institutional settings, including: Lentiz [pre-vocational secondary education (VMBO), general secondary education (HAVO), pre-university education (VWO) and senior secondary vocational education (MBO)]; Wellant [largest agricultural institution of vocational education and training in Europe]; Centrum voor Tuinbouw en Uitgangsmaterialen [Center for Horticulture and Propagation Materials]; De Demokwekerij Westland [the leading innovation center for greenhouses, where cultivation and technology innovations for the national and international horticulture sectors are initiated and facilitated]; Demokwekerij als Techno Centrum Glastuinbouw (Technical Center on Greenhouses); Innovatie en Demonstratie Centrum Robotica (Innovation Demonstration Center in Robotics); Food Inspiration Academy; Wellant College Urban Green Development; the Greenport Food & Flower Xperience; and others.

4.0.20 Maintain robust innovations and demonstrations through the Fieldlab SMARTFood. This is essential for sustaining continuous innovation in smart food production techniques throughout the Netherlands' horticultural sector.

Fieldlab SMARTFood

- Making the Dutch industry world leader in smart solutions for fully automated production, cultivation and distribution of fresh fruits and vegetables.







TNO innovation for life

Innovation Quarter

Invest & innovate in West-Holland

SMART INDUSTRY DUTCH INDUSTRY FIT FOR THE FUTURE

Source: Marcel van Haren, FME and Egbert-Jan Sol, TNO, Radboud University, Smart Industry, Dutch Industry Fit for the Future

Fieldlab SMART DAIRY FARMING

- Increasing the sustainability of dairy farming by real-time monitoring of dairy cows and sharing data in the chain.



Source: Marcel van Haren, FME and Egbert-Jan Sol, TNO, Radboud University, Smart Industry, Dutch Industry Fit for the Future

4.0.21 Develop Horti-campus (Doorontwikkeling Horti-campus) and spawn talent through Innovation & Demonstration Centre's (IDC's). Foster basic education through a combination of learning experiences: in-class and online learning (blended programs & MOOC's); Innovation Labs that are multi-level and multi-disciplinary; and through development of an (international) Living Lab Food (LLF). Foster 'Learning for Life' and encourage the development of cooperative education routes.

4.0.22 Develop a Center of Expertise or Academic Maker space for knowledge valorization and dissemination. Knowledge valorization can occur in various ways, such as spin-off companies, start-ups, patents, licenses, patents with third parties, creative commons licenses, etc.

LIFE SCIENCES & HEALTH TECHNOLOGIES

4.0.23 Intensify cooperation between the leading innovation partners in the Medical Delta region. Through the academic institutes, the incubators and existing companies, around 75 innovative startups have been created in five key technology areas: 1) Imaging and Image guided Medicine; 2) Interventions and Care; 3) Molecular and Cellular Technologies; 4) eHealth and Self-Management; and, 5) Vitality. In the coming decade the target is for both the number of joint activities and the number of participants (now 50) to expand ten-fold.

4.0.24 Organize Medical Delta Living Labs where new concepts and products can be developed together with end-users. The testing and thorough evaluation of the effect of implementation in real-life setting is another very crucial feature of the Medical Delta Living Labs. A Medical Delta Living Lab is a real-life physical environment where various healthcare stakeholders develop new solutions for healthcare issues together (co-design or co-creation) and/or where the validity of new solutions is tested.

4.0.25 Expand use of 3D Printers in Medical Delta 3D Labs - Develop software and hardware to offer 3D printers and/or 3D VR models to clinicians and students for training, and also focus on expanding programs for 3D printing of implants and organs.

4.0.26 Expand the My Data My Health initiative - Create Health Data Cooperatives organized around patient-directed healthcare and organize health-focused information and QS meetings (Health café) in cities and for corporations. Build a cooperative virtual data bank used and owned by all the people who are part of the cooperative. Every participant decides what happens with the data and citizen-driven research can be performed on the data. Users can get advice via all sorts of high quality apps. The platform will become a development place for all sorts of open data (software and hardware) companies.

4.0.27 Explore and engage in crossovers with other Pillar and cluster groups – Participate in cross-pollination opportunities with the value chains of the Greenports (healthy foods, medicinal foods etc.), the Hague Security Data (for my data our health / cyber security), the Smart Manufacturing (HTSM/IT) and Maritime sectors (3D printing experiences).

4.0.28 Examine the conceptual and practical implications of crowdsourcing healthcare – Spawning patient-driven and patient-controlled health promotion networks. There are half a dozen sound reasons for pursuing patient-controlled data, as highlighted in the January 2016 issue of the *New England Journal of Medicine*, and shown in the chart below:

Selected Reasons for Pursuing Patient-Controlled Data.	
Need or Purpose	Explanation
Complete data	A patient-controlled health record, updated after each health encounter, would provide a complete view of the patient (in contrast to that available in institution-specific electronic health records).
Data sharing for coordinated care	In the absence of other effective mechanisms, patients may be the best vehicle for making data available to their clinicians and family.
Use of data by intelligent software or apps	Patient-controlled data repositories, properly configured, could be the nexus of patient-facing apps for care management, participation in research, and data sharing.
Support of diagnostic journeys	Patients and families with undiagnosed or difficult-to-treat conditions are now manually assembling complex data sets, including genomic data, to present to researchers and clinicians.
Data donation	Under myriad consent and authorization models, patients are increasingly figuring out how to contribute data to research.
Patients as reporters	The patient is a source of data that are complementary to the information found in institutional records; bidirectional data exchange with patients could become a cornerstone of the medical record.
Additional pairs of eyes	Patients can identify and correct errors in the medical record.
Social networking	Health data are a basis for finding other patients with similar conditions or genomic variants.

4.0.29 Leverage medical research through crowdfunding - The crowdfunding phenomenon of citizens participating in and supporting innovation initiatives has included medical research, as reported in *Lancet* medical journal. For example, David Hawkes of the Florey Institute of Neuroscience and Mental Health, Australia, raised \$12,000 for his research into the use of viral vectors to treat neurological disorders, while Michael Pollastri, Northeastern University, MA, USA, raised his full target of \$25,000 for a project about neglected tropical diseases.²²³

4.0.30 Sustain rigorous and robust innovation in practices, procedures, and knowledge development at the MRDH Research Centers of Innovations in Care. As Rotterdam University of Applied Science emphasizes, the Centers “bring together various professionals, students, and other partners to make this practice-based research and innovation happen. Research Centre Innovations in Care brings together expertise in clinical care, research methods, community healthcare, implementation sciences, health policy, health care delivery, information technology, business and education to address the barriers that prevent high-quality, efficient, and cost-effective healthcare and innovation. By involving the university's students and teachers we contribute to a better education for future professionals.”²²⁴

4.0.31 Promote smart health and welfare best practices, competences and innovative procedures throughout educational and vocational institutions. These include such institutions as Haagse Hogeschool, Technology for health; Zorg Regio Rotterdam-Rijnmond + Zorg Regio

²²³ See: http://www.invivomagazine.com/en/mens_sana/tendances/article/240/the-generous-donors-of-the-internet-community

²²⁴ See: <https://www.rotterdamuas.com/research/research-centres/innovations-in-care/>

Haaglanden; MBO voor Zorg en Welzijn (education for care and welfare); and Hogeschool Inholland: Agro & Life Sciences.

4.0.32 Set up a Care & Cure campus with a Care maker space (A M fieldlab; Vivalib labs).

SMART FINANCE

4.0.33 The distributed ledger technology, Blockchain, has applicability to all the RNE pillars and should be integrated into all discussions. The biggest challenge is that of financing. How do you attract sufficient funds to the development of projects that are a) often going to be structured around distributed systems (such as smart electricity grids of “prosumers”) where there are none of the traditional opportunities for monopoly profits and b) have a public interest attached to them that’s hard to align with a private profit motive? There’s a powerful argument to be made that tokenization, smart contracts, and the creation of distributed autonomous organizational (DAO) structures, all built over a blockchain, can be designed to maximize both private and public outcomes in ways that attract financing. Because new transactions can be included permanently and immutably in the blockchain for relatively small transaction fees, the entire Internet of Things can use it to securely track certificates, identity, agreements, and other facts of note.

4.1 TECHNICAL

4.1.1 Tap major entrepreneurial state benefits by investing early on and participating in the developments as a pioneering test-bed metropolitan platform - 5G will essentially address three markets, all fundamental for the realization of the Third Industrial Revolution: a) ultra-wide band wireless communications, with peak data rates per device which are orders of magnitude larger than those achievable today (up to 1 Gbit/s) thanks to the exploitation of millimeter-wave bands; b) Internet-of-Things services, introducing a capacity leap to allow the interconnection of trillions of devices, maintaining energy expenditure under control (and circularity would be a great cross-sector reflection, here); c) mission critical services, with especially tight requirements in terms of network latency, availability and reliability, to allow real-time operations in very demanding environments, such as automotive, industrial production, remote operational healthcare, emergencies and disaster relief. From the outset, the development of 5G is addressing the interconnection with vertical sectors, such as energy, smart cities, media and broadcasting, automotive and factories of the future, etc.

The deployment of KPN's Low Power Wide Area Network in the Netherlands also offers an opportunity to examine cheaper, easy-to-deploy sensor technologies for asset management, goods tracking, and other purposes.

4.1.2 Enabling Port Logistics (Rotterdam Logistics Lab) - The Port's new role in erecting and managing the emerging Transportation and Logistics Internet across the intermodal transportation corridors of the European Union will enable it to manage the Big Data, analytics, algorithms and apps of the supply chains of thousands of enterprises. Building a platform for seamless data interchange between supply chain partners using the port is one of the main elements needed to help establish MRDH as the foundational node of the automated Transportation and Logistics Internet.

4.2 REGULATORY

4.2.1 Remove and supersede regulatory and policy barriers constraining local renewable energy cooperatives facing unfavorable market conditions against traditional utility companies. Citizen-owned-and-operated energy cooperatives have been instrumental forces in bringing transmission and distribution lines to rural communities without electricity (as in the United States over the past century), and have been at the vanguard in transitioning to wind and solar power in recent decades (as in Denmark and Germany, and in parts of the United States). More than 90 Dutch local energy cooperatives have been established over the past decade, in addition to 16 wind energy cooperatives established over the past 30 years. A recent analysis of the Dutch local energy cooperatives concluded, "Competitors in the energy sectors have the advantage in terms of governance power, financial resources, and the existing energy infrastructures. The balance between competitive advantages and disadvantages [for local energy cooperatives] will probably be influenced by the national government's choices about whether or not to stick with the privatized market regime."²²⁵

4.2.2 Establish "benefit corporations" as legal entities. The "benefit corporation" is an interesting new business model that's attempting a makeover of the conventional capitalist corporation to allow it to be more agile and able to maneuver in the hybrid world of markets and Commons. Patagonia, the California-based global sports clothier, with annual sales around \$540 million, is the most prominent company to date to make the switch to a benefit corporation. Benefit corporations are recognized and regulated as legal entities in 18 U.S. states

²²⁵ Hufen, J.A.M. & Koppenjan, J.F.M. *Energ Sustain Soc* (2015) 5: 18.

and offer entrepreneurs a form of legal protection against outside investors who might force them to give up their social or environmental commitments in return for new financing. Although benefit corporations operate as for-profit companies and are responsible to their shareholders, their new legal status enables them to put their social and environmental mandates up front without risking the wrath of investors interested only in optimizing shareholder value. The benefit corporation is part of a larger wave loosely defined under the rubric of “social entrepreneurialism” that has captured the imagination of a younger generation coming out of business schools around the world. Social entrepreneurialism casts a wide net from the nonprofits that are the mainstay of the Commons to the traditional shareholding *companies* that are the dominant enterprises in the marketplace.

4.2.3 Explore the regulatory changes that need to accompany the shift from centralized healthcare systems to distributed healthcare management.

4.3 POLICY

4.3.1 Establish a new Commissioner on Quality of Life Indicators. The Commissioner will be responsible for identifying, tracking, and compiling the regional and national quality of life indicators. These quality of life social indicators should be fully integrated with government reporting on regional and national economic indicators.

4.3.2 Assess changing nature of employment – The quadruple helix knowledge network of government agencies, universities, think tanks, and civic stakeholders, needs to explore, analyze, and assess how the changing nature of employment – flexible working hours, part time employment, and augmented virtual reality work environments – will affect quality of life indicators, including changes in conception of selfhood, identity, sociability, and cultural affiliations. The migration of employment from the automated market economy to the Sharing Economy and social economy is going to fundamentally change the nature of work.

4.3.3 Entrepreneurial Government - The title for the RNE Transition Pathway ‘Entrepreneurial Region,’ has been deliberately chosen with Mariana Mazzucato's ‘Entrepreneurial State’ publication in mind, which emphasizes the crucial role of public investments in breakthrough technological innovations. If MRDH wants to take a leading position and establish a competitive edge in the deployment of the IoT platform and digital and circular technologies, the government will have to rise to the occasion.

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To ensure that the national, regional and local governments assume their role in the entrepreneurial ecosystem, MRDH should consider the following actions:

- organize innovation contests on very specific innovation challenges
- reward civil servants actively contributing to realizing sustainable solutions in government
- establish extended investment funds for Innovation Quarter
- stimulate cooperation between corporations and start-ups
- stimulate standardization in engineering and manufacturing (e.g. ROD, ODL, SPEMA)
- ensure that universities use the Birmingham approach: 'I don't care about IP'
- create impact economy fund based on targets set in the European Next Work Program

MRDH: testing ground for new legislation

Given MRDH's ambition to become a "real life testing ground," there should be a strong emphasis on removing the legislative and regulatory bottlenecks that prevent the deployment of innovations.

In December 2015, MRDH signed a City Deal with the national government that gives MRDH an experimental 'testing ground' status to temporarily bypass or circumvent existing legislation without having to go through cumbersome legal procedures.

On the basis of this agreement, MRDH should facilitate testing ground pilots on:

- new job legislation, e.g.:
 - a new 'kenniswerkersregeling' to keep high-tech staff employed
 - use a part of lay-off payments for retaining in a field lab
 - offer self-employed engineering a free place in field labs
- new legislation on waste usage
- new legislation for deployment of PV installations on public buildings (fines for unused public roofs)
- incentives for deployment of PV on rooftops on privately owned buildings
- admittance of health claims in relation to fresh food
- accept proof for lifestyle as a medicine via randomized clinical trials
- accommodate new radical approaches to improve pharmaceuticals
- light permit procedures for companies that have demonstrated a commitment to Next Society principles (social entrepreneurship for inclusive economy in neighborhoods)
- change fiscal rules on innovation and entrepreneurship that contributes to RNE targets

- establish protocols to ensure safe open public data transfer in a level playing field
- differentiate tax rates according to sustainability levels of buildings
- enable ESCO constructions and smart grid deployment
- provide tax benefits to inclusive strategies (local employment, local companies, etc.)
- carbon taxation, carbon reduction benefits
- level playing field between seaports in terms of employment regulations, inspections and fiscal incentives

IT4All

To ensure a better match of talents and jobs, MRDH has to make IT happen on a large scale. The following steps should be taken by the government in close collaboration with the academic and business communities:

- attract young people into the fields of engineering and manufacturing and ensure that all pupils and parents visit clean high tech factories
- introduce IT and tech in primary school
- set up courses and organize loans to re-integrate outdated IT experts in modern IT systems
- permanent education using modular courses at MBO, HBO, and other academic levels
- set up a system of accreditation for engineers, e.g. inspired on the system in South Africa
- train more system integrators, who combine know-how of business, manufacturing and IT (e.g. MESA)
- facilitate staff exchange ('collegiaal uitlenen')
- attract foreign talent (e.g. by using strange attractors)
- limit the number of students (numerus fixus) on MBO and HBO education paths where few jobs will be available in the future
- develop a High Tech Maritime and Smart Industry Campus (collaboration with RDM Campus and Schiedam)
- develop a public/private Harbor Internet of Things Faculty (part of KPN IoT Academy)
- facilitate a Circular and Biobased Research and Education Center (related to Circular University Delft)

4.3.4 Using and strengthening regional USP's – The RNE should develop a region-specific deployment strategy that will provide the existing business community the opportunities to innovate and grow, while at the same time nurturing new sectors, new business models, and

products and services emerging from the economic transition. This strategy requires a clear picture of the unique qualities the region possesses and how it can empower them in the next economy. Important traits of effective entrepreneurial ecosystems include the proximity of companies and knowledge institutes with well-known and well-employed strengths (specializations, USP's). In an effective entrepreneurial ecosystem, these strengths cross-fertilize to yield new and surprising products and services. MRDH needs to ensure that these USP's are empowered and employed in the Next Economy that revolves around Big Data and renewable energy rather than fossil fuels. One of the current strengths of the region is the refining of fossil fuels into chemicals with high added value. However, in the future, MRDH's strengths will increasingly come from mining Big Data streams into information and services with high added value.

4.4 EDUCATION

4.4.1 Launch public-funded contests for related entrepreneurial projects – Contests of various kinds and levels of sophistication – for example hackathons - should be held frequently, especially for the younger generations.

4.4.2 Implement reforms of the educational system - Introducing new subjects in secondary schools, trade schools, and universities to foster creative thinking, systemic decision-making, and artificial-intelligence control, from a very early age on. This involves redesigning pedagogy and curricula to be compatible with the interconnected, distributed, open, and collaborative platform of the digital economy and the new business models that accompany it.

4.4.3 Make available executive education seminars - Earmark the conventional industries that will need to transition their business models as well as start-up companies, and provide ongoing executive education seminars at Dutch business school for MRDH enterprises to help them make the adjustment to a Third Industrial Revolution paradigm.

4.4.4 Bridge the gap between the skills asked for by companies and those offered by unemployed staff. A significant effort is needed to boost smart industry skills of many current employees; to reintegrate unemployed ICT-experts; and to ensure that manufacturing and engineering jobs are and remain interesting. Set-up a system of accreditation for engineers, for instance, inspired by the system available in South Africa [<https://www.ecsa.co.za/default>].

4.4.5 Promote Permanent education - Elementary and secondary schools and universities must start providing modular courses for small groups, preferably together with field labs. This allows

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SME's to train personnel at reasonable cost; helps individuals to keep up their trade knowledge and stimulates the building of the ecosystem. See the Technologie clusters of TNO and the vision 'De toekomst van leren' (the future of education) developed by The Haagse Hogeschool together with entrepreneurs.

4.4.6 Stimulate entrepreneurship – Organize master classes, intervision sessions, and serious gaming into the curriculum at Dutch universities to train more systems integrators who can become adept at organizing and managing complex systems that combine multiple professional and technical skills. See MESA (www.mesa.org).

4.4.7 Promote staff exchange – High-tech SME's, offer only a limited scope of job opportunities and experiences. Exchanging staff on a loan basis between companies in different sectors will allow personnel to learn new technologies and be inspired with new ideas. This will enhance spillover and can be used to react to market volatility.

4.4.8 Integrate and continuously upgrade curricula and training materials with knowledge resources that help students and employees develop skills, competences and upskilling in smart manufacturing. This should be done for all the Albeda College Regional Training Centers, Zadkine training center for secondary vocational education, the Shipping and Transport College (STC), the CIV Maintenance & Process Technology Center Rijnmond, the more than 800 companies of the Maritiem Drechtsteden, and Hogeschool Rotterdam.

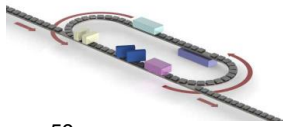
4.4.9 Scale up the RDM Fieldlab for Additive Manufacturing in Internet of Things and smart industry. RDM Makerspace provides makers and developers access to machines, workspace, courses and networks to turn their idea into a real prototype. They also focus on digital fabrication, Internet of Things, 3D printing, Robotics and Drones, and collaborate with partners in those fields (e.g., IoT Academy, Robotics Academy, and Fieldlab Additive Manufacturing). In collaboration with the Port of Rotterdam and Innovation Quarter, RDM Makerspace is setting up the fieldlab 'Additive Manufacturing Center' with a focus on production and certification of large metal parts. ROFFAB (3D printing) has also been set up in Rotterdam to inspire and stimulate young makers.



Metropolitan Additive Manufacturing Architecture (MAMA)

- › Getting manufacturing back to Europe, back to the cities & create/save jobs
- › Old paradigm – one big vendor owned factory in China with economy of scale
- › Future paradigm – 10 vendors share 10 flexible modular fabs in 10 metro area
- › Upon a customer order, download the file to the location closest to the customer, manufacturing with AM, robotic assembly etc the product and deliver it 2 hours latter.





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Source: Marcel van Haren, FME and Egbert-Jan Sol, TNO, Radboud University, Smart Industry, Dutch Industry Fit for the Future

4.4.10 Promote the results from Project RDM Havenlab en Innovation Connector. Havenlab is a co-working and lab space where education can unfold between students, as well as teachers, completely separate from the normal classroom environment. The Havenlab is located near RDM Maker Space, amongst numerous companies in the Innovation Dock, enabling and facilitating collaboration and prototyping.

4.4.11 Foster youth interest in smart maritime vocations and professions. Hogeschool Rotterdam, Project Schiedamse Haven; Maritime Innovation and Education Cluster (maritiem innovatie- en onderwijscluster); Hogeschool Rotterdam, Project Shared facilities; Center for Innovative craftsmanship (CIV Maritieme Techniek & ST); the collaboration between the STC-Group and Da Vinci College, focused on Increasing the innovative power of the maritime sector to encourage a flow of high- qualified employees in this sector; CIV Logisticus van de Toekomst- STC; and the European Cooperation Programs in Sailing (Europese samenwerking opleidingen binnenvaart).


















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4.4.12 Transforming RDM Campus into a High Tech Maritime & Smart Industry Campus in co-operation with Schiedam (high-tech and specialized construction) en Dordrecht (Sustainable Factory). Emphasis should be placed on developing a center of expertise in the Maritime Delta, including development of four fieldlabs: 3D Additive Manufacturing (existing); smart fieldlab (in development); new materials in shipbuilding (composites); and a fieldlab for designing and manufacturing robot systems, aquabots and automation in selected niches in the Maritime sector.

Multi-material 3D Printing – lead applications

- › The **human centric (dental)** and **high-tech** markets are appealing carriers for this FieldLab
- › **Why:**
 - Small series – high volume** – Personalized and customized manufacturing of parts
 - Freeform** – Light weight , no assembly
 - On-demand manufacturing** – No spare parts in stock
- › **What:**
 - Management of data** – Design → manufacturing → after care
 - Advanced process control** – One-time right, certification
 - Multi-material products** – Seamless connected production steps

Source: Marcel van Haren, FME and Egbert-Jan Sol, TNO, Radboud University, Smart Industry, Dutch Industry Fit for the Future

4.4.13 Develop permanent education routes based on the Co-op principles with focus on maritime business services and maritime manufacturing and IT-skills. Investing in education related to the maritime business services sector is crucial. The first steps have been taken, for example, by developing the Anatomy of Shipping and Transport course, which gives professionals in the maritime and shipping industry (lawyers, financiers and other advanced service providers) a knowledge boost on the shipping industry.

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4.4.14 Develop a public/ private Harbor Internet of Things (IoT) faculty based on the Harbor LoraWan (Low Power Wide Area Network) system as part of the IoT Academy of the Dutch landline and mobile telecommunications company, KPN, for connecting “smart stuff “ in port and port transport.

4.4.15 Develop a Circular & biobased Research & Education Center of Applied Science (related to and combined with Circular University at Delft) specializing in high tech construction and systems, e.g. hydrogen fuel cells for ships in maritime industry or/and new business models.

4.4.16 Development of an international Livinglab in Maritime Innovations.

4.5 FINANCIAL

4.5.1 Set up a “government guarantee fund” to stimulate procurement of domestically produced smart products and services - Local, regional and national authorities rarely use the opportunity to act as a launch customer. According to estimates by the European Commission DG Trade’s Chief Economist, in 2012 the size of the Netherlands government’s procurement market amounted to nearly 23% of GDP.²²⁶ The government guarantee fund should prioritize purchases that scale the build-out of the smart TIR infrastructure and the technologies, products and services that accompany it.

4.5.2 Examining entrepreneurial economy investment needs and financial engineering options - There are several ways that the investment in ICT could be taken up in MRDH, and these different strategies may have very different impacts and associated risks. The TIR DEEPER modeling team has identified at least three different future scenarios for transitioning MRDH to a post-carbon smart economy.

4.6 R&D

4.6.1 Invest in field labs. Scale up fifteen field labs in different application fields. These field labs will enable companies to develop prototypes and test and validate them quickly and at low cost, thus bridging the valley of death and reducing time to market. This allows companies, SME’s, and scale-ups, in particular, to invest in product development that would otherwise not be possible. Field labs can become pivoting points in the entrepreneurial ecosystem, promoting

²²⁶ See: http://trade.ec.europa.eu/doclib/docs/2015/april/tradoc_153347.pdf

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spillover, market oriented innovation, smart industry, and smart skills. All of these field labs are associated with the new center for next generation robotics at RoboValley on the TU Delft campus. The tech center promotes interaction and applied research among companies, incubators, knowledge institutes and schools. It is an R&D hotspot in the field of Smart Industry with a focus on the region's specializations. It must be well-connected to application oriented field labs in e.g. high-tech horticulture, composite manufacturing, 3D printing, aero/space integration, and smart maintenance.

4.6.2 Establish a Collaborative Innovation/Collective Intelligence Network (COIN) open source, open access, open device Platform. Many COINs can reside on the same platform. This one would focus on the R&D issues specific to the entrepreneurial state, while also networking with the other COINs for cross-pollinating valuable insights, ideas and feedback. For example, the HTSM/IT cluster emphasizes the need to *stimulate the high-tech entrepreneurial ecosystem*. Entrepreneurial ecosystems are important for economic growth innovations and are stimulated by the presence of specialized suppliers, service providers and institutions, combined with the spillover of ideas and knowledge between companies and sectors. MRDH has all the ingredients for becoming such an ecosystem, but has not yet achieved that end. This appears to be due to a lack of network and trust. Holland Instrumentation, the high-tech platform of Zuid Holland, tries to stimulate this high-tech entrepreneurial ecosystem. The rapidly growing foundation (more than 50 percent per year) is building the network of companies, universities, education, investors and governments that focus on high-tech. The aim is to double high-tech sales and exports in ten years by more and better cooperation and removing obstacles to innovation. This must be brought to the next level: 1) Create a virtual system where people can easily find each other 2) Stimulate the 'connected campus' in Delft where university, knowledge institutes, and companies form the hub of the entrepreneurial ecosystem 3) Create a 'trademark' for this hub; RoboValley may be that trademark. The typical independent mind-set of Zuid-Holland entrepreneurs and scientists needs to make room for a more collaborative, distributed, open and laterally scaled approach to entrepreneurialism that is compatible with the architectural design principles of the IoT platform.

4.6.3 Develop and expand knowledge (ideational) centers, online and onsite - Knowledge and information sharing products and services (commodities) are a *sine qua non* of the TIR, and the real competition will be played out in terms of generative abilities, ideation, and creativity. These new structures could be identified as "Ideational Centers," following the entire process from idea generation, to early prototyping, to enterprise acceleration with business angels, all the way to early incubation.

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4.6.4 Establish a government commission to prioritize subsidies and other incentives and retire stranded assets. Set up a special government commission to oversee the reprioritization of subsidies and incentives to industries. The commission should be tasked with shifting subsidies and other incentives from the mature and sun-setting industries of the Second Industrial Revolution to the new smart industries of the Third Industrial Revolution. The commission should also conduct ongoing studies on stranded assets in sun-setting Second Industrial Revolution industries – for example, the generation of conventional fossil fuel and nuclear power and electricity transmission – to assess their potential, short-, mid-, and long-term negative impacts on the MRDH economy. The commission should also make appropriate recommendations on retiring these stranded assets to mitigate economic losses during the transformation to the next economy.

NEXT SOCIETY

Capitalism is giving birth to a progeny. It is called the Sharing Economy on the Collaborative Commons. This is the first new economic system to enter onto the world stage since the advent of capitalism and socialism in the early 19th Century, making it a remarkable historical event. The Sharing Economy is already changing the way we organize economic life, offering the possibility of dramatically narrowing the income divide, democratizing the global economy, and creating a more ecologically sustainable society.

*Peter Van Lieshout and Bert Hooijer,
and the Working Group members from
MRDH*

*Michael Totten (Assetsforlife.net) and
Jeremy Rifkin, for TIR Consulting Group
LLC*

Like every parent-child relationship, the two economic systems generally cooperate but occasionally are at odds. And while the capitalist parent will need to nurture its child and allow it to mature, the child will also transform the parent in this unfolding relationship. We are already witnessing the emergence of a hybrid economy, part capitalist market and part sharing economy on the Collaborative Commons. To the extent that capitalism can create new business models and practices that will support the development of the sharing economy, it will prosper along with its offspring.

The triggering agent that's precipitating this great economic transformation is zero marginal cost brought on by the digitalization of communication, energy, and transport, and now the introduction of the Internet of Things platform. Businesses have always sought new technologies that could increase productivity and reduce the marginal cost of producing and distributing goods and services, in order to lower their prices, win over consumers and market share, and return profits to their investors. They never anticipated, however, a technology revolution that might unleash "extreme productivity" bringing marginal costs to near zero, making information, energy, and many physical goods and services nearly free, abundant, and no longer subject to market exchanges. That's now beginning to happen.

The near zero marginal cost phenomenon wreaked havoc across the "information goods" industries over the past decade as millions of consumers turned prosumers and began to produce and share their own music via file sharing services, their own videos on YouTube, their own knowledge on Wikipedia, their own news on social media, and even their own free e-books on the World Wide Web. The zero marginal cost phenomenon brought the music industry to its

knees, shook the film industry, forced newspapers and magazines out of business, and crippled the book publishing market.

Meanwhile, six million students are currently enrolled in free Massive Open Online Courses (MOOCs) that operate at near zero marginal cost and are taught by some of the most distinguished professors in the world, and receiving college credit, forcing universities to rethink their costly business model.

While many traditional industries suffered, the zero marginal cost phenomenon also gave rise to a spate of new entrepreneurial enterprises including Google, Facebook, Twitter, and YouTube, and thousands of other Internet companies, who reaped profits by creating new applications and establishing the networks that allow the Sharing Economy to flourish. Economists acknowledge the powerful impact zero marginal cost has had on the information goods industries, but until recently, have argued that it would not pass across the firewall of the virtual world into the brick-and-mortar economy of energy, and physical goods and services. That firewall has now been breached. The Internet of Things platform is emerging, allowing millions—and soon hundreds of millions— of prosumers to make and share their own energy, and an increasing array of physical products and services, at near zero marginal cost.

Digital interconnectivity across virtual, physical, and biological borders and across every sector of society is already challenging some of our most cherished beliefs about economic, social, and political life. In the digitalized Sharing Economy, social capital is as vital as market capital, access is as important as ownership, sustainability supersedes consumerism, collaboration is as crucial as competition, vertical integration of value chains gives way to lateral economies of scale, intellectual property makes room for open sourcing and creative commons licensing, GDP becomes less relevant, and social indicators become more valuable in measuring the quality of life of society, and an economy based on scarcity and profit vies with a zero marginal cost society where an increasing array of goods and services are produced and shared for free in an economy of abundance.

People in the Netherlands and around the world are already transferring bits and pieces of their economic life to the Sharing Economy. Prosumers are not only producing and sharing their own information, news, knowledge, entertainment, green energy, transportation, and 3D- printed products in the Sharing Economy at near zero marginal cost. Forty percent of the US population is actively engaged in sharing homes, toys, tools, and countless other items. For example, millions of apartment dwellers and home owners are sharing their living quarters with millions of travelers, at near zero marginal cost, using online services like Airbnb and Couchsurfing. In

New York City alone, Airbnb's 416,000 guests who stayed in houses and apartments between 2012 and 2013 cost the New York hotel industry 1 million lost room nights.

The exponential growth of the Sharing Economy raises a number of critical policy and regulatory questions that will need to be addressed by MRDH. New regulations will have to be enacted to ensure the social security benefits of a growing freelance workforce. Additional regulatory policies will need to be adopted to promote a level playing field between the market economy and Sharing Economy. Procedures will need to be put in place to track and record shared work and the exchange of goods and services for the purposes of charging taxes, measuring social security contributions, and providing accurate statistics for national accounting purposes. The Sharing Economy will also require new codes and regulations to ensure product safety and protect consumer rights.

The migration of employment from the automated market economy to the Sharing Economy and social economy is going to fundamentally change the nature of work. Government agencies, universities, and think tanks will need to explore, analyze, and assess how the changing nature of employment – flexible working hours, part time employment, and augmented virtual reality work environments – will affect quality of life indicators, including changes in conception of selfhood and identity, sociability, and cultural affiliations.

Recent surveys underscore the broad economic potential of the Sharing Economy. A comprehensive study found that 62% of Gen Xers and Millennials are attracted to the notion of sharing goods, services, and experiences in Collaborative Commons. These two generations differ significantly from the Baby Boomers and World War II generation in favoring access over ownership. When asked to rank the advantages of a Sharing Economy, respondents to the survey listed saving money at the top of the list, followed by impact on the environment, lifestyle flexibility, the practicality of sharing, and easy access to goods and services. As for the emotional benefits, respondents ranked generosity first, followed by a feeling of being a valued part of a community, being smart, being more responsible, and being a part of a movement.

How likely is it that the Sharing Economy will play an ever-larger role in the economic life of MRDH in the coming decades? According to an opinion survey conducted by Latitude Research, "75% of global respondents predicted their sharing of physical objects and spaces will increase in the next five years."²²⁷ Many industry analysts agree with these optimistic forecasts. *Time*

²²⁷ See: <http://www.shareable.net/blog/the-new-sharing-economy>

magazine declared collaborative consumption to be one of its “10 ideas that will change the world.”²²⁸

In a 2015 survey,²²⁹ 26% of the Dutch public said they have heard of the Sharing Economy, and 5% said they are already participating in it, putting the Netherlands among the top 3 EU countries polled. But on the question of whether the Dutch public would likely increase its participation in the Sharing Economy in the coming 12 months, only 20% positively responded, putting the Netherlands below the EU average. Finally, when asked to prioritize their interest in the Sharing Economy, 49% of Dutch respondents ranked saving money at the top of their list, followed by 49% who cited interest in protecting the environment as important. Thirty-four percent of respondents said they were interested in the Sharing Economy because it helps build communities.

The prosumer sector and Sharing Economy continue to expand exponentially. The enabling technologies have been expanding ten-fold, with projections of sustaining this accelerating pace of ongoing innovations over the next half century. The exponential growth of the economy arises from the compounding zero marginal cost opportunities emerging from the network effects of massive adoption of smart mobile technology.

Venture capitalist Benedict Evans, a mobile IT expert with the Silicon Valley VC firm of Andreessen-Horowitz, nicely captures the past two decades’ trends in noting, “On the iPhone 6 launch weekend Apple sold 25X more CPU transistors than were in all PCs on Earth in 1995. Everyone gets a hand-held supercomputer.”²³⁰ The radical miniaturization enabled by ultra-dense chip technology now makes mobile computing available to citizens previously untouched by technology for under \$50. This, combined with the widespread availability of networks results in a truly transformative economic product. Mobile has become, Evans summarizes, the “first universal tech product – completing a journey from one computer on earth to a computer in every pocket and purse.”

The global connected smart phone is a General Purpose Technology (GPT), integral to the exponential growth of productivity in the TIR Next Economy. Exponential growth rates are projected to continue with the ongoing advancements and breakthrough innovations in semantic intelligence, machine intelligence, artificial intelligence (AI), all combined with, and

²²⁸ See: http://content.time.com/time/specials/packages/article/0,28804,2059521_2059717_2059710,00.html

²²⁹ See: <https://www.ing.com/Newsroom/All-news/European-sharing-economy-to-grow-by-a-third-in-the-next-12-months.htm>

²³⁰ See: <http://www.forbes.com/sites/anthonykosner/2015/06/30/meteor-is-the-app-platform-for-the-new-world-of-cloud-client-computing/#7e48679a3eaf>

driving forward, the GAIN technologies (genetics, auto-robotics, informatics and nanoengineering).

The accessory economy of the consumer society is giving way to the 'appcessory' economy of the sharing society. Apps facilitate interactions, and Internet platforms facilitate apps. Platforms enable value creation by generating network effects from the countless interactions of prosumers. The unfolding Cambrian explosion in app speciation has just begun as the IoT percolates through society and market interactions. The following sampling of prosumer apps is just a few among the most used and successful. While not even noticing, we citizens have become networked to the prosumer economy, with new competences. It is what the founder of ZipCar Robin Chase calls the peer economy. We each can claim, ***I am a public good; I am a prosumer of public/social infrastructure***. COINs (Collaborative innovation/collective Intelligence Network) are the global platforms allowing the human race to contribute information and knowledge that comprises the global infrastructure of public goods at zero marginal cost. Millions of people are actively engaged each day in helping to create public goods, as the examples below demonstrate.

Google is the world's largest search platform, retrieving relevant documents and links for more than 1 billion monthly queries. Google has developed a business model based on free access and free content, financed by revenues from screen ads. In 1998, the founders of Google began their start-up while at Stanford University graduate school, beginning with creating and testing the code, then scaling the search and retrieve algorithm, PageRank. Eighteen years later Google has a market value of half a trillion euros.

Wikipedia is a Big Data, open source platform launched in 2000. It is the world's largest free-access free-content Internet encyclopedia. Wikipedia is a premier example of an open source COIN. It is one of the top 5 to 7 daily visited Internet sites in the world with a monthly readership of 1.1 billion. Fifty million volunteers have prepared more than 34 million free usable articles, many being translated into 288 languages. The knowledge would fill 15,000 volumes equivalent to Encyclopedia Britannica.

Those who can access the site can edit most of its articles. Wikipedia constitutes the Internet's largest general encyclopedia and general reference platform. Its business model is non-profit, creating value through the platform. Self-motivated volunteers and users participate by adding, editing, updating, error correcting, and translating to achieve the mission of expanding an open-source encyclopedia. It is an ad hoc, self-organized and maintained, volunteer-fueled platform. Its 51 million euro annual budget is funded through user donations.

Couchsurfing International Inc. is a hospitality exchange and social networking web platform that went online in 2003. The Internet site operates as a platform for individuals to "surf" and locate available couches at a host's home where they can stay. Some 10 million people in more than 200,000 cities worldwide participate in sharing their homes, lives, and travel adventures.

BlahBlahcar describes itself as the world's largest long-distance ridesharing community platform, "Connecting people who need to travel with drivers who have empty seats." BlahBlahcar links passengers seeking rides with drivers traveling to the same destination. Some 25 million people in 22 countries have joined BlahBlahcar.

Waze is a free mobile phone app for GPS-based geographical navigation now used by more than 50 million people worldwide. Waze screens show turn-by-turn information, as well as driver-provided location-dependent travel times and route details. Unlike conventional GPS navigation software, Waze is community-driven, accruing user map data and traffic insights. Waze provides routing and real-time traffic updates based on users' driving times. The app shares other potentially useful user reports such as traffic jams, speed traps, accidents, landmarks, and lowest cost gas stations

The Sharing Economy model promotes a more efficient use of assets, giving access to more opportunities at lower cost and adjusting to the needs of our resources. As the European Sharing Economy Coalition notes, "there are three prominent models: 1) Product-based systems (e.g., car and bike sharing); 2) Redistributing markets (e.g. Freecycle, eBay, and other exchange markets); and, 3) Collaborative lifestyles, where citizens "with similar needs or interests come together to share and exchange less-tangible assets such as time, space, skills, and money."²³¹ For example, workspaces (CitizenSpace), gardens (Landshare) and home stays (Couchsurfing).

Smart Labor Market

The unemployment rate in the Netherlands is among the lowest in the European Union. At the beginning of 2015, the labor force totaled 8.9 million workers, with a 7.1% unemployment rate. However, part time employment is high and made up 40% of the Dutch workforce in 2013. In 2014, more than 800,000 Dutch workers were self-employed, constituting 10% of the labor force, making the Netherlands one of the most highly self-employed workforces in Europe.

²³¹ See: <http://www.euro-freelancers.eu/european-sharing-economy-coalition/>

The very high educational level in the Netherlands may account, in part, for the high level of self-employment – one third of high school graduates continue on to higher education. This highly educated and self-employed workforce is a strong enabling factor in the potentially successful transition into the new Third Industrial Revolution economic paradigm.

However, the Metropolitan Region of Rotterdam and The Hague is facing huge challenges: economic activity in the region is coming under all kinds of pressure. The new economic structure – with its strong emphasis on the transport of goods in Rotterdam, public service provision in The Hague, greenhouse horticulture in Westland, Oostland, and Barendrecht, technology and ICT in Delft and Zoetermeer – is changing. The question is whether these sectors will be able to offer sufficient growth and employment in the coming decades. There are also a number of social issues which need to be addressed – sustainability and an inclusive society are two of the most important.

The current situation regarding the labor market in MRDH is not ideal. Among the top five big cities in the Netherlands, Rotterdam and The Hague are ranked lowest when it comes to the growth of employment: between 2009 and 2014, employment in The Hague fell by 4.7%, in Rotterdam by 5.2%. Compare that with Amsterdam, which experienced a 10% growth during the same period. Rotterdam and The Hague had the least number of sectors with growth. There are many signs that this is a structural development: growth in Rotterdam is consistently lower than in the rest of the Netherlands, for example. In Rotterdam, annual growth between 1995 and 2013 was 1.6%, compared to 1.8% in the Netherlands.

An important reason for this structural deficiency is the sector structure in MRDH. Sectors which have been declining for decades are strongly represented in the region. While elsewhere in the Netherlands, business services have been thriving and acting as an engine for growth, MRDH relies heavily on industry, logistics, and public services – sectors which have in fact been declining. Outside the big cities, the region's fortunes are mixed: there was a significant contraction in Zoetermeer and Rijswijk, but there was growth in Midden-Delfland.

The structural deficiencies in important sectors of the MRDH economy will likely continue for some time. In that respect, there is a phase difference between Rotterdam and The Hague. Signs of declining industrial activity were already becoming visible in Rotterdam in the 1980s, but the decline in public services in The Hague is more recent. Whereas Rotterdam has been struggling for a long time with the demand for the new earnings model, that demand has become particularly acute in The Hague in recent years. In 2014, employment grew in The Hague for the first time since 2009, although at a slower rate than the overall population. That

growth mainly occurred in existing businesses, particularly in healthcare, hospitality, retail and the government, while technology declined. However, three of those four sectors which did experience some growth are expected to shrink in the coming years: the budget for healthcare has been sharply curtailed, retail in the form of physical stores is struggling, and the government wants to further reduce its staffing levels. Sectors with growth potential are tourism and The Hague Security Delta which has grown 4% since 2012 – in total, the region accounts for 23% of the country's security jobs. However, those growth sectors do not have the ability to compensate for the decline elsewhere.

Apart from a quantitative issue (more employment), the region also faces a big qualitative challenge. The labor market is increasingly looking for highly qualified staff. By contrast, many jobseekers have low or medium qualifications. This is apparent, for example, in the development of employment in the Port of Rotterdam: the amount of work there has fallen dramatically in recent decades as a result of ICT and robotization. At the same time, new job opportunities are emerging because many technical activities are shifting from manufacture to technical design, maintenance, and related business services. Growth lies in the indirect jobs which tend to require higher skilled staff than the jobs which have disappeared. We see a similar development in horticulture in Westland, where robots harvest chrysanthemums. This development is also noticeable in classic sectors. In the healthcare sector, there is mainly a need for highly skilled staff, while lower qualified employees are made redundant. In the construction industry, walls and installations are increasingly assembled in factories and installed on-site in a short space of time. This approach also requires different employees.

MRDH is therefore starting from a difficult position where the labor market is concerned. At the same time, there does not seem to be a way back: the use of fossil fuels must be reduced, with consequences for the Port of Rotterdam. The public sector seems to have reached the limits of its growth and the use of ICT will also make many administrative jobs redundant.

But there are also opportunities. As the OECD has shown, not enough emphasis is placed on achieving agglomeration advantages. The region boasts a good physical infrastructure and administrative organization. The conditions are thus favorable for a more targeted search for synergy and connection – factors which are vital for economic growth.

What's more, the region also has a strong knowledge infrastructure. With three universities working closely together (and which have international departments like ISS, IHE and IWS) along with three universities of applied sciences and numerous specific institutes of higher education (music, hotel school, arts) and four Regional Training Centers (ROCs), two Agricultural

Training Centers (AOCs) and specialized education institutes like the Scheepvaart- en Transport College, Hout- en Meubileringscollege and the Grafisch Lyceum, as well as the presence of a number of other knowledge organizations (like TNO and the Asscher Instituut), the conditions are present to leverage specialized education for the Third Industrial Revolution.

In order to be able to systematically reflect on how the region can and must develop, the Roadmap Next Economy initiative was launched. The key is the coming together of three big developments: the shift from fossil fuels to renewable energy; the development of the Internet of Things; and changes in transport and logistics. The idea is that the current linear economic model based on fossil energy is no longer tenable and will rapidly need to be transformed into a circular economy based on renewable energy sources (zero carbon and zero waste). This paradigm shift from linear to circular coincides with a digital revolution, which will radically change the existing economic model. Thus, a new digital technological platform for economic activity emerges, with low to near zero marginal cost information as the dominant production factor. These broad developments form the backdrop against which the region must try and find its own route to reviving the economy.

Everyone can see that the world is changing under the influence of digitization. The classic example is Kodak. At its peak, the company employed more than 140,000 people worldwide and was worth over 28 billion dollars. Today, Kodak is bankrupt. The new icon of digital photography is Instagram: when it was sold to Facebook in 2012 for a billion dollars, it had thirteen employees.

In the coming years, the nature of work will gradually change. Digitization is important, but not the only driver of change. Processes like globalization and individualization also play a major role. The transformation in the field of work has different layers: the daily routines in businesses and the way companies are organized are changing, as well as the nature of jobs and employment contracts, the relationship between employers and employees, and finally the structure of the labor market and employment.

Modern economies are increasingly driven by innovation: growth is mainly the result of the ability to permanently improve products and services. This means that innovation is not just the responsibility of management, but of everyone in the organization. Fifty years ago, the standard model for innovation was based on a strong Research & Development function. Businesses had large research departments (for example the famous Philips Natlab) and, they were able to launch a new product every few years. That product was then manufactured in big factories on long conveyor belts. Today, much of our innovation no longer comes from big – and expensive

– corporate research labs. The time when IBM was awarded five Nobel prizes and General Electrics nine is long gone. R&D still contributes to innovation, but much more innovation comes from the primary process: everyone in a company contributes to the permanent improvement of products and services. Many of those improvements are minor and not at all revolutionary, but the result is a world in which change has become the norm. Innovation is, therefore, increasingly an activity which is not placed in a management organization, but one which fits in the line organization and for which line managers are increasingly responsible.

The direct consequence is that the ability to obtain new knowledge and skills, to take a wider perspective, and to invest in self-development, is becoming increasingly important for the workforce. What's more, knowledge is ephemeral. It's no longer enough to have specialist knowledge in a particular field: that knowledge is soon available in many places and quickly superseded by new knowledge.

This is a stylized picture of continuous disruptive development and certainly does not apply everywhere. However, it is an undeniable tendency. A good indication is the speed with which products, brands and companies come and go. The lifespan of products, as well as brands and companies, has declined dramatically. In the 20th Century, several large companies dominated the market for a long time (Philips, Unilever, IBM). Today, many smaller companies hold a significant market share, but also have a shorter life. Over the past fifty years, the average lifespan of a company listed on the S&P 500 (an important share index in the United States) has fallen from 60 to around 18 years. Conversely, many businesses reach the top faster. It took Facebook six years to achieve a turnover of one billion dollars, while Google only took five years.

Permanent development also has consequences for the internal organization of businesses. The traditional organization model, in which work is structured in the form of fixed jobs with matching salary scales and pay rises is making way for a more dynamic model. Jobs are less and less the organizing principle: employees perform a number of activities. New tasks are added to existing ones – because the work is changing and because the person is developing.

The Internet and digital platforms also offer new ways of organizing work. Via the Internet, flexible work is easier to find and it is easier now to distribute globally. The Internet facilitates new forms of work division and the associated specializations. Work comprises a number of tasks that can be singled out and ultimately individually outsourced. Already, companies are posting specific jobs on the Internet for anyone who wishes to do the job anywhere in the world. This creates a kind of on demand economy where the job provider no longer employs

people in the traditional sense of the word, but only outsources tasks to self-employed people who perform those specific tasks: from employer and employee to client and contractor. Gradually, an approach to work is emerging which is no longer based on position, job, and vacancy, but on “activities, tasks and projects.”

The new genre of activities, tasks, and projects revolve around the build out, scale up, and management of a Third Industrial Revolution Next Economy infrastructure. The erection and servicing of the new infrastructure will involve virtually every industry and sector of MRDH and require large numbers of semi-skilled, skilled, professional, and knowledge workers. The Metropolitan Region of Rotterdam and The Hague communication network will have to be upgraded with the inclusion of universal broadband and free Wi-Fi. The energy infrastructure will need to be transformed from fossil fuel and nuclear power to renewable energies. As alluded to earlier in the section “Buildings as Nodes,” thousands of buildings will need to be retrofitted and equipped with renewable energy harvesting installations and converted into micro power plants. Hydrogen and other storage technologies will have to be built into every layer of the infrastructure to secure intermittent renewable energy. The electricity grid of the Metropolitan Region of Rotterdam and The Hague will have to be transformed into a smart digital Energy Internet to accommodate the flow of energy produced by thousands of green micro power plants. The transportation and logistics sector will have to be digitalized and transformed into an automated GPS-guided driverless network running on smart roads and rail systems. The introduction of electric and fuel cell transportation will require thousands of charging stations. Smart roads, equipped with millions of sensors, feeding real-time information on traffic flows and the movement of freight will also have to be installed.

Workers across the MRDH industrial and commercial sectors will need to be employed over the next 30 years to construct and service the three Internets that make up the digital platform of a Third Industrial Revolution economy. Transforming the Metropolitan Region of Rotterdam and The Hague’s energy regime from fossil fuels and nuclear power to renewable energies is extremely labor intensive and will require thousands of workers and spawn new businesses. Retrofitting and converting thousands of existing buildings into green micro-power plants and erecting thousands of new positive micro- power buildings will likewise require thousands of workers and open up new entrepreneurial opportunities for Energy Service Companies (ESCOs), smart-construction companies, and green- appliance producers. Installing hydrogen and other storage technologies across the entire economic infrastructure to manage the flow of green electricity will generate comparable mass employment and new businesses as well.

The reconfiguration of the electricity grid into an Energy Internet will generate thousands of installation jobs and give birth to cleantech app start-up companies. Finally, rebooting the transport sector from the internal-combustion engine to electric and fuel-cell vehicles will necessitate the makeover of the Metropolitan Region of Rotterdam and The Hague's road system and fueling infrastructure. Installing charging stations along roads and on industrial, commercial, and residential spaces is labor-intensive employment that will require a sizable workforce. The massive build-out of the IoT infrastructure for a Third Industrial Revolution across the region is going to spur an extended surge of mass wage and salaried labor that will run for forty years or more, spanning two generations.

Improvements in aggregate efficiency and productivity across all of the sectors that make up the region's economy will have a significant impact on new employment opportunities. It's important to note the key role that ICT will play in transitioning all of the other commercial and industrial sectors into a digitalized Internet of Things economy. By establishing the critical digital infrastructure to manage, power, and move economic activity across the value chains, ICT becomes an enabler of new job creation throughout the region's economy.

The Metropolitan Region of Rotterdam and The Hague must provide retraining for the existing workforce and the appropriate skill development for students coming into the labor market to ease the transition into the new job categories and business opportunities that come with a massive build-out of an Internet of Things infrastructure.

In summary, the scale up of a smart digitalized Internet of Things infrastructure across the Metropolitan Region of Rotterdam and The Hague will generate new business opportunities, dramatically increase productivity, employ thousands of people, and create an ecologically oriented post-carbon society.

The phase-in of a smart digital region will ultimately lead to a highly automated capitalist market economy by mid-century, operated by small professional and supervisory workforces using advanced analytics, algorithms, and artificial intelligence. The maturing of this smart infrastructure will lead to a migration of employment from an increasingly automated capitalist market to the growing social economy. While fewer human beings will be required to produce goods and services in the market economy in the second half of the 21st Century, machine surrogates will play a smaller role in the nonprofit social economy for the evident reason that deep social engagement and the amassing of social capital is an inherently human enterprise. The social economy is a vast realm that includes education, charities, healthcare, child and

senior care, stewardship of the environment, cultural activity and the arts, sports and entertainment, all of which require human-to-human engagement.

In dollar terms, the world of nonprofits is a powerful force. Nonprofit revenues grew at a robust rate of 41%—after adjusting for inflation—from 2000 to 2010, more than doubling the growth of gross domestic product, which increased by 16.4% during the same period. In 2012, the nonprofit sector in the United States accounted for 5.5% of G.D.P.

The nonprofit sphere is already the fastest-growing employment sector in many of the advanced industrial economies of the world. Aside from the millions of volunteers who freely give of their time, millions of others are actively employed. In the 42 countries surveyed by the Johns Hopkins University Center for Civil Society Studies, 56 million full-time workers are currently employed in the nonprofit sector. In some countries, employment in the nonprofit arena makes up more than 10% of the workforce. In the Netherlands, 55,000 nonprofit organizations account for 15.9% of paid employment. In Belgium, 13.1% of the workforce is in the nonprofit sector. In the United Kingdom, nonprofit employment represents 11% of the workforce, while in Ireland it's 10.9%. In the United States, nonprofit employment accounts for 9.2 % of the workforce, and in Canada it's 12.3%.

These percentages will likely rise steadily in the coming decades as employment switches from a highly automated market economy to a highly labor-intensive social economy. Students will need to be educated for the new professional skills that come with the job opportunities opening up in the social economy. Although a massive effort will be required, the human race has shown itself capable of similar efforts in the past—particularly in the rapid shift from an agricultural to an industrial way of life between 1890 and 1940.

Despite the dramatic growth curve in employment in the social economy, many economists look at it askance, with the rejoinder that the nonprofit sector is not an independent economic force but rather largely dependent on government-procurement contracts and private philanthropy. One could say the same about the enormous government procurements, subsidies, and incentives meted out to the private sector. But this aside, the Johns Hopkins study of 42 countries revealed that contrary to the view of many economists, approximately 50% of the aggregate revenue of the nonprofit sector already comes from fees for services, while government support accounts for only 36 percent of the revenues, and private philanthropy for only 14%. By mid-century, if not sooner, a sizeable percentage of the employed around the world will be in the nonprofit sector, busily engaged in advancing the

social economy, and purchasing at least some of their goods and services in a highly automated capitalist marketplace.

John Maynard Keynes's futurist essay, written more than 80 years ago for his grandchildren, envisioned a world where machines have freed up human beings from toil in the marketplace to engage in deep cultural participation in the social economy in the pursuit of more lofty and transcendent goals. It might prove to be his most accurate economic forecast.

Smart Education

Since 2000, over half the *Fortune 500* corporations have disappeared. Corporate lifespans have also been experiencing steep declines. Companies listed on the Standard & Poor's 500 have seen lifespans fall from 75 years in the 1920s to 27 years by the 1970s, and a further drop to 15 years over the past decade. These indicators mark the rapidity of change coursing through the economy. While due to a multitude of factors, the digitization and Internet-ization of the economy are playing instrumental roles in changing the business and economic landscape. ICT is a breakthrough, general purpose technology, increasingly harnessed as a primary driving force behind myriad innovations and disruptions in society. Nearly one-third of the economic growth in recent decades is connected to ICT.

The times make it incumbent upon citizens to acquire competence in how to sustain continuous life-long learning practices, including cognitive qualities like versatility, adaptability, creativity, and flexibility, as well as becoming well-grounded in, and conversant with, ICT and IoT tools and technologies. Moreover, it is important for students to recognize the shifting and inter-connected roles between producers and consumers becoming prosumers. The rise of prosumer entrepreneurial opportunities and the expanding sharing economy, places an additional commitment on the education system to help cultivate and nourish enterprise skills in students.

Fortunately, the Netherlands has one of the top performing education systems in the world, ranking near the top across most significant indicators: proficiency in pupil literacy and numeracy; experience with computers and basic computer skills; longest number of years in educational institutions; and nearly half the adult population rank at the top levels in problem solving in technology-rich settings.

Personal Pocket SuperComputers



Human & Knowledge Capital

SuperComputer Networkers



Social, Civic & Intelligence Capital

Image source: Michael Totten.

Moreover, as highlighted in the World Economic Forum's 2015 Global Information Technology report, the Netherlands ranked fourth in the Networked Readiness Index (Singapore first, Finland second, and Sweden third). The Netherlands ranked near the top in key categories: soundest political and regulatory frameworks (7th); one of the most enabling business and innovation environments (8th) in the world; highly skilled workforce (6th) including a high degree of ICT uptake. Widespread use by individuals of ICT (7th): virtually the whole population has use of a computer, and a major fraction can connect to hardwired wide bandwidth (broadband) (3rd highest adoption rate in both indicators). ICT tools and technologies are also highly leveraged by the business sector: business-to-business (B2B) and business-to-consumer (B2C) Internet use in the Netherlands has achieved uppermost levels (9th and 4th, respectively). In terms of providing open access to online public services, the Netherlands continues to be a top leader (8th), also enabling the citizenry to e-participate (1st). Digital and Internet technologies are being integrated throughout the Dutch economy to achieve high

impact, including companies' use to generate new goods and innovative services (5th), and also reflected in the fact that Dutch workers rank in the top nations with highest penetration of employees in knowledge-intensive occupations (9th).²³²

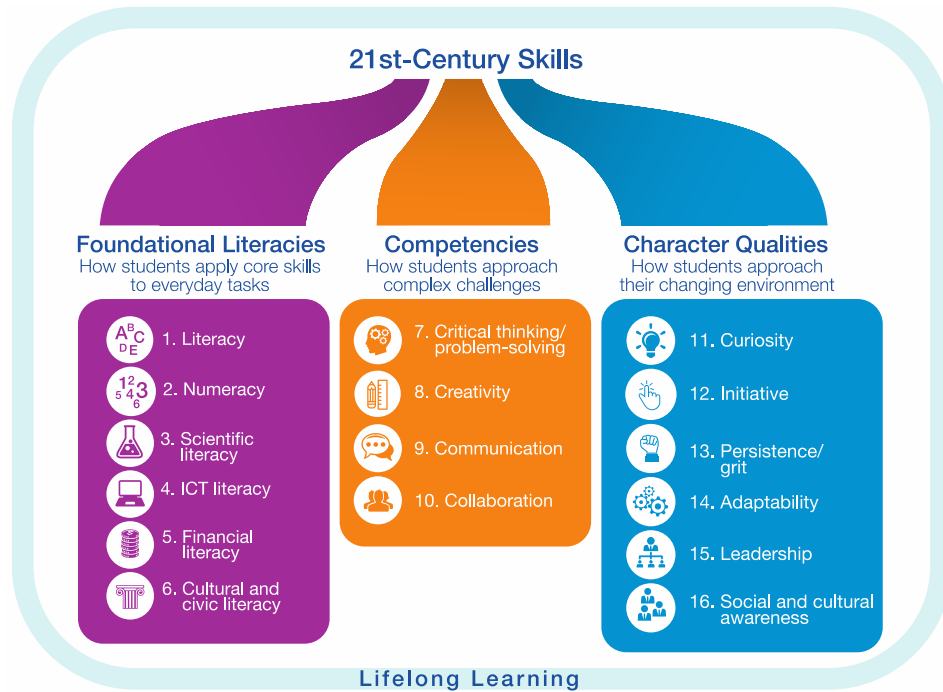
At the same time, not all of MRDH's citizenry is well prepared. As the City of Rotterdam has recently documented: 43% of Rotterdam pupils in primary education have low educated parents, three times the national average; 22% of Rotterdam pupils need extra care, twice the national average; 22% of Rotterdam pupils (up to 18) are from poor families, more than three times the national average; and, 12% of Rotterdam pupils are in highest secondary education (VWO), almost half the national average.

These educational deficits are exacerbated by a highly disruptive and ever-evolving digital Third Industrial Revolution business environment that requires a continuous upgrading of talents and skills across the workforce and over the lifetime of every worker. Traditional education to prepare students for the beginning of their work life is therefore no longer adequate to provide a set of skills and knowledge that can accompany a worker over his or her lifetime. Learning is not just acquiring a set of skills in school, but also lifelong learning to constantly adapt and improve one's skills. The conventional idea of high quality knowledge garnered by specialized education within a specific profession will, to some extent, make way for the ability to permanently learn new skills in different contexts.

In the old world, the education and the labor market were separate: children went to school until a certain age and then went to work, but never saw the inside of a classroom again. Today, people continue learning until they retire. The ambition should be to engage the MRDH workforce in life-long learning, enabling professionals and skilled workers to keep up with the technological and social changes that will be continually transforming their professions.

With accelerating economic changes looming on the horizon due to the convergences and synergisms of the GAIN technologies (Genetics, Auto-robotics, Informatics and Nano-engineering) and the ubiquitous diffusion of the Internet of Things, education will have to adopt and adaptively manage a strategic vision based on reimagining, redesigning, reorienting, reinventing, and reinvesting for a society and environment in need of retraining, regenerating, restoring, renewing, and recycling its human, civic and social capital, natural capital, and intellectual and financial capital.

²³² See: http://www3.weforum.org/docs/WEF_Global_IT_Report_2015.pdf



Source: WEF (2015) New Vision for Education, Unlocking the Potential of Technology, World Economic Forum, in collaboration with the Boston Consulting Group.

Preparing students for the opportunities and challenges that accompany the transition into a Smart Netherlands and a Third Industrial Revolution economy requires a fundamental rethinking of the nature of education. The First and Second Industrial Revolutions enshrined a model of teaching designed to prepare students to be skilled industrial workers. The classroom was transformed into a microcosm of the factory. Students were thought of as analogous to machines. They were conditioned to follow commands, learn by repetition, and perform efficiently. The teacher was akin to a factory foreman, handing out standardized assignments that required set answers in a given time frame. Learning was compartmentalized into isolated silos. Education was supposed to be useful and pragmatic. The “why” of things was less discussed than the “how” of things. The goal was to turn out productive employees.

The Third Industrial Revolution is altering the pedagogy of the classroom. The authoritarian, top-down model of instruction is beginning to give way to a more collaborative learning experience. Teachers are shifting from lecturers to facilitators. Imparting knowledge is becoming less important than creating critical-learning skills. Students are encouraged to think more holistically. A premium is placed on inquiry over memorization.

In the traditional industrial classroom, questioning the authority of the teacher is strictly forbidden and sharing information and ideas among students is labeled cheating. Children quickly learn that knowledge is power, and a valuable resource one acquires to secure an advantage over others upon graduation in a fiercely competitive marketplace.

In the Digital Age, students will come to think of knowledge as a shared experience among a community of peers. Students learn together as a cohort in a shared knowledge community. The teacher acts as a guide, setting up inquiries and allowing students to work in small-group environments. The goal is to stimulate collaborative creativity, the kind young people experience when engaged in many of the social spaces of the Internet. The shift from hierarchical power, lodged in the hands of the teacher, to lateral power, established across a learning community, is tantamount to a revolution in pedagogy.



Apps for Spurring Solar and Efficiency Techknowledge



<http://www.critigen.com/solution/solar-map-standard-edition>

While the conventional classroom treated knowledge as objective, isolated facts, in the collaborative classroom, knowledge is equally regarded as the collective meanings we attach to our experiences. Students are encouraged to tear down the walls that separate academic disciplines and to think in a more integrated fashion. Interdisciplinary and multicultural studies prepare students to become comfortable entertaining different perspectives and more adept at searching out synergies between phenomena.

The idea of learning as an autonomous private experience and the notion of knowledge as an acquisition to be treated as a form of exclusive property made sense in the First and Second Industrial Revolution environment. In the Collaborative Age, learning is regarded as a crowdsourcing process and knowledge is often treated as a publically shared good, available to all, mirroring the emerging definition of human behavior as deeply social and interactive in nature. The shift from a more authoritarian style of learning to a more lateral learning environment better prepares today's students to work, live, and flourish in tomorrow's collaborative economy in the Metropolitan Region of Rotterdam and The Hague.

COIN ASSET- EXAMPLES OF APPLIED ACTION!

Growing ASSETS Building by Building, Campus by Campus, City by City



Apps for Spurring Solar & Efficiency Tech-knowledge

The new collaborative pedagogy is being applied and practiced in schools and communities around the world. The educational models in the emerging digital era are designed to free students from the private space of the traditional enclosed classroom and allow them to learn in multiple open Commons, in virtual space, the public square, and in the biosphere. Rethinking primary, secondary, and university education in the region to prepare current and future generations for employment in both the automated capitalist marketplace and the emerging Sharing Economy will be an urgent and major priority.

ASSET – EXTERIOR BUILDINGS!

SOLAR POWER TOOLS

Geo-Spatial Visual Mapping Solar-capable Surfaces
integrated with long-term financing option apps

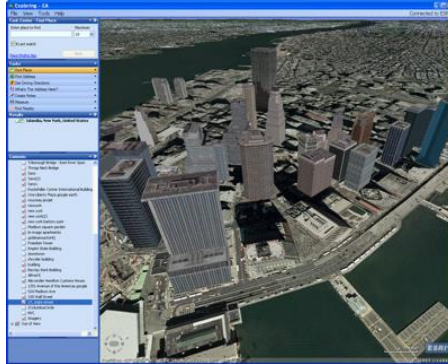


Apps rapidly evolving and speciating

The MRDH educational system will want to explore a range of best practices emerging in school systems around the world, including extending the learning environment into the community with service learning and clinical engagement, virtual learning via Skype and FaceTime in shared global classrooms, and online learning with MOOCs.

The alternative, staying entrenched in the sunset of the Second Industrial Revolution, with fewer economic opportunities, a slowing of GDP, diminishing productivity, rising unemployment, and an ever-more polluted environment is unthinkable, and would set the Metropolitan Region of Rotterdam and The Hague on a long-term course of economic contraction and decline in the quality of life of its citizenry.

ASSET – INTERIOR BUILDINGS AS LEARNING LAB!



RMI Deep-Dive 10xE Learning Tools & Experience



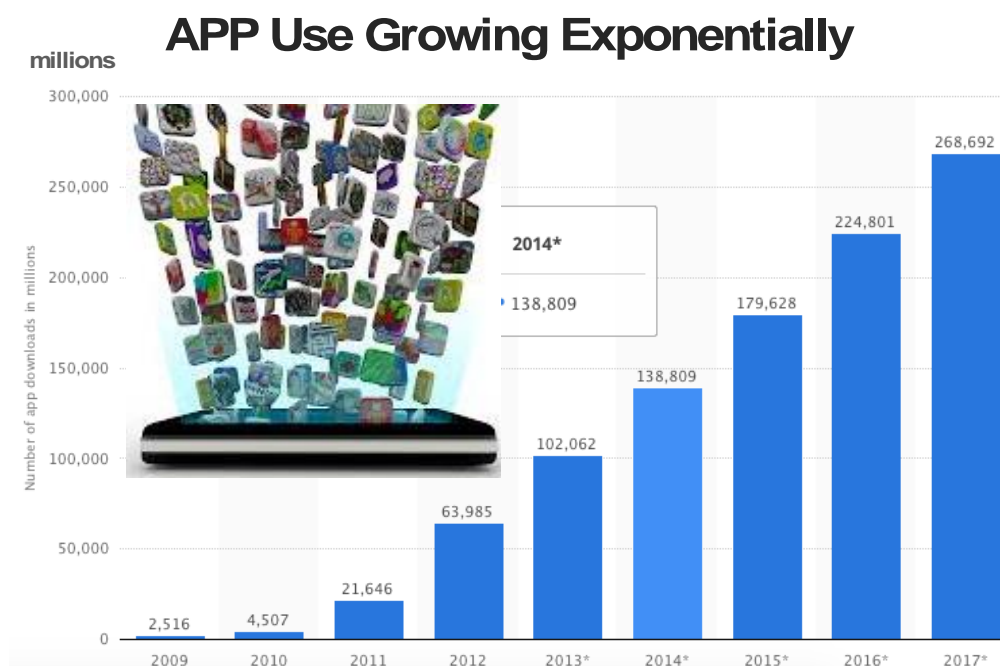
Using web COIN to Scale real-world big-gain results

5.0 NEW BUSINESS MODELS AND VALUE CHAINS

5.0.1 Catalyze at least 10 successful scale-ups, boosting jobs growth and new investment in the region, and catalyze at least 20 successful cross-over projects with other sectors.

Prize competitions offer one venue to motivate innovation and pursuit of solutions to mission-based problems. These contests can focus on technical, scientific, or creative challenges. Software and apps challenges have emerged as a major source of competitive prizes. Coders and designers are posed specific technical issues requiring software development or coding solutions; these can take the form of creating websites, coding algorithms, or developing mobile apps. Organizations may pose contest challenges for the public at large, seeking

software or app creations that employ specific open and available data sets, or require a defined set of functionalities specified by the organization for tackling an unresolved software issue. Many contests and challenges take a two-part approach, with the first part addressing proposals and ideas, and the second part focused on creating prototypes, coding solutions, and apps. Numerous contests and challenges have participatory designs to actively engage citizens and the public-at-large; this can take various forms of feedback such as selection of favorites, voting on finalists, and providing comments about the contest.



5.0.2 Foster development and innovation in the use of the North Sea as a “production site” - A growing worldwide demand for food and quality ingredients challenges us to explore new modes of production. Offshore cultivation of seaweed in the North Sea offers a number of sustainable business opportunities. Seaweed cultivation contributes to local employment, sustainable food, and biomass production. Feedstock for PolyLactic Acids (PLA) used in 3D printing, can be grown in collaboration with offshore wind farms and, of course, is a future-proof, entrepreneurial option for Scheveningen Harbor (Innoport).

5.0.3 Propose setting up an Impact Fund, targeting (fuzzy front end) innovations developed by local Small Enterprises which address Societal challenges - The objective is to boost radical innovations with financial means, focusing on R&D investments that will facilitate small enterprises to scale up to medium enterprises.

Third Industrial Revolution Consulting Group

5.0.4 Cross-inseminate and cross-pollinate, with all the other pillars, clusters and sectors - The prosumer, sharing, and impact economies arise from and interact with both traditional and pioneering firms, as well as the myriad of societal institutions (academia, non-profits, government agencies). Overcoming conventional silos and nurturing connections and ongoing interactions is key to sustaining and growing next economy innovation opportunities.

5.0.5 Project the increase in employment across the various sectors of the economy engaged in the transition to a Third Industrial Revolution paradigm. The IoT-based TIR economy greatly expands global interconnectedness by collapsing distances and time differences, as well as geographical boundaries. In addition to local and regional employment, there is expanding virtual employment, and virtual teams working together while spanning the globe. As a region, MRDH has the potential to grow exports based on the experience and learning curves gained locally in implementing the Roadmap Next Economy. For example, the global market for energy efficiency improvements over the next three decades is in the tens of trillions of dollars, while the global market for solar and wind power systems constitute many tens of trillions of dollars over the same time frame. The portfolio of skills to pursue these vast markets turns on the educational learning, training, and accumulated experience gained in MRDH.

5.0.6 Undertake economic modeling of new types of employment required for the build out and scale up of a digital economy. Economic modeling (and other tools like scenario analysis and participatory backcasting), can provide insights useful for preparing for future conditions. For example, shifting from a fossil fueled to a renewable powered economy leads to different employment needs and skills. Similarly, the shift from combustion-engine vehicles to battery-electric mobility leads to changes in manufacturing, maintenance and repair businesses and infrastructure. Renovating the building stock with deep retrofits and incorporating wireless smart sensor networks and big data building analytics for creating grid-connected smart buildings, represents large pools of needed skills and talents. And the overall shift from an extractive resource-intensive linear economy to an IoT-based Knowledge-as-a-Service, sharing and circular economy portends massive changes in the portfolio of skills required.

5.1 TECHNICAL

5.1.1 Establish a quadruple knowledge network engaged through an open access platform that focuses on the cross-cutting issues associated with the growing Sharing Economy. A number of technical questions and challenges have arisen as the Sharing Economy expands. For example, there are questions of insurance coverage of risks specific to various sharing

economy business models. In other cases there are technical legal issues that need addressing, pertaining to existing laws and regulatory practices that may impede the growth of the sharing economy, and new laws, policies and regulations that can help catalyze growth. Technical issues around economic and financial business models are worthy of ongoing examination and analysis, given the spectrum of Sharing Economy models from 100% profit-maximizing in the marketplace to 100% non-profit in the civil society.

5.2 REGULATORY

5.2.1 Establish a new Commissioner on Security and Resilience.

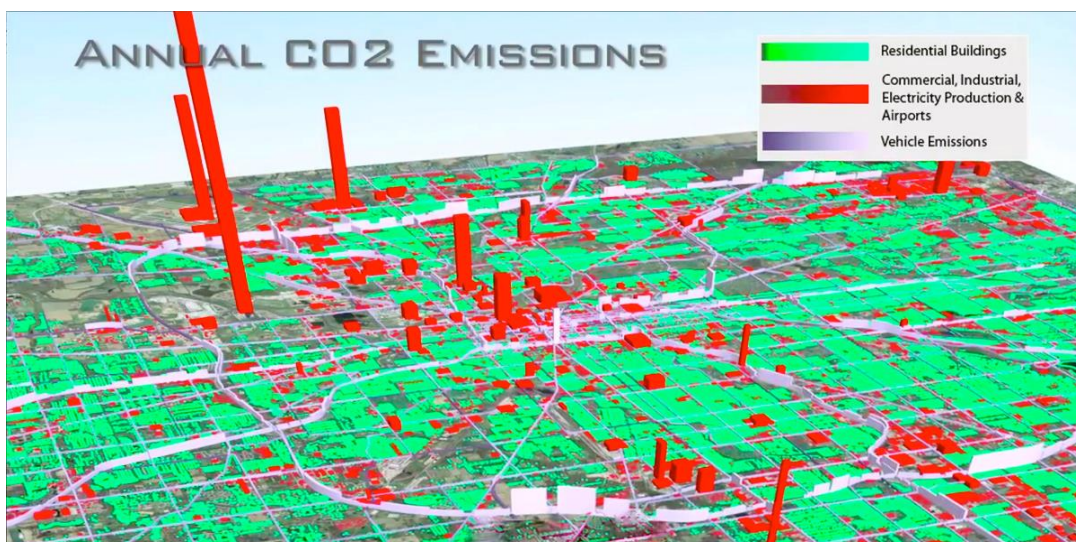
[See description at 1.1.2.1 above]

5.2.2 Prepare new regulatory policies tailored to new business practices in the Prosumer and Sharing Economy. A big challenge will be to anticipate and recommend regulations that remain pertinent in a rapidly changing environment. Selected aspects would be i.e. to assure, via regulatory action, a level playing field between the market economy and the Sharing Economy, in order to avoid unfair competition.

ASSET – CITYSCAPE SCALE!

APP-Aggregating Assemblages of Buildings
 Priority-Ranking Biggest Opportunities
 Incorporating Financing Algorithms

COINs for learning, skills, training, practice, verification, adaptation, time saving



Arizona State University researchers have developed a new software system capable of estimating GHG emissions across entire urban landscapes, all the way down to roads and individual buildings. Until now, scientists quantified CO2 emissions at a much broader level. Dubbed "Hestia" after the Greek goddess of the hearth and home, the system combines extensive public database "data-mining" with traffic simulation and building-by-building energy-consumption modeling. Its high-resolution maps clearly identify CO2 emission sources in a way that policy-makers can utilize and the public can understand. Hestia provides a complete, three-dimensional picture of where, when, and how carbon dioxide emissions are occurring. Credit: Kevin Gurney, Bedrich Benes, Michel Abdul-Massih, Suzanna Remec, Jim Hurst

5.3 POLICY

5.3.1 Establish a new Commissioner of Prosumer/Sharing Economy. A sharing city requires city authorities to play a leadership role in scaling up *public commitment to the vision*, backed up by the appropriate government regulations and sufficient startup capital. A new Commissioner of the Prosumer/Sharing economy will take a leading role in marshaling locally supported initiatives designed to create sharing activities available for all the citizenry. Features include build-out of the infrastructure essential for physical and digital sharing, providing Sharing Economy start-up and scale-up enterprises with incubation and support centers, and harnessing unused and underused public resources. The Commissioner will be

tasked with the mission of developing appropriate regulations and indicators for the development and expansion of the Sharing Economy in MRDH. At the same time, issues raised by citizens about the prosumer/sharing economy need to be addressed. Big Data is one major issue that will become more important over time, and opportunities and risks must be broached. These include property rights on generated data, data protection, privacy and surveillance. Another aspect should be the possible concentration of data in the hands of a few big operators, and what consequences could result out of this situation.

CHANGE READINESS MATRIX



Image source: www.ascd.org/publications/books/109019/chapters/The-Organizational-Change-Readiness-Assessment.aspx

5.3.2 Create a systematic map of the assets owned by MRDH to identify those that could be shared. Community engagement in the Sharing Economy can be encouraged through an open

access collaborative platform established by government agencies. The platform should include a comprehensive mapping of the assets owned by the cities and MRDH, including an inventory maintained by each agency in regards to their needs, goals, operations and policies. The agencies should also examine and identify local share-ability criteria to include when issuing procurement bids and contracts. This will allow citizens to participate and respond to these numerous opportunities. A core feature of the TIR is to position cities and regions as sharing economies.

5.3.3 Mobility sharing requires developing forward-thinking frameworks and policies by transportation policymakers. Cities will be tasked with creating a more open, free-flowing landscape of options that includes bicycles, bikeshare, ridesharing/ride-hailing, walking, and multiple car-sharing services – all of which must coexist and complement each other.

5.3.4 Establish social entrepreneurial parks and sharing hubs. Promote Sharing Economy innovative business models through crowdsourcing and crowdfunding entrepreneurial ideas. This can be facilitated by setting up an online platform designed to be self-organizing and maintained with open access to databases and directories, while promoting interaction and activities among the participating entrepreneurs and citizens. This can be further promoted by integrating the online platform with onsite sharing hubs. Ensure access to affordable high-speed Internet for all citizens, including mobile access.

5.3.5 Set up a civic innovation lab to drive innovation in collaborative technologies. The build-out of an IoT platform for a TIR, connecting Europe and its partnership regions in a single integrated economic space, will allow business enterprises and prosumers to produce and distribute their own virtual goods and their own renewable energy, use driverless electric and fuel-cell vehicles in automated car sharing services, and manufacture an array of 3D printed products at low marginal cost in the conventional marketplace, or at near zero marginal cost in the Sharing Economy, with vast economic benefits for society.

5.4 EDUCATION

5.4.1 Cultivate next economy skills and tactics (tinkering, lifelong learning, personal entrepreneurship, glocalization skills etc). People need to be resilient, autonomous and effectively experimental. Current educational practices prepare employees for set boundaries, as if both the economy and the city are static entities. MRDH should experiment with new approaches to education and promote knowledge and experience sharing. MRDH should evaluate the future-proof and e-skills that are prerequisites to ensure that the future workforce fits the labor market's demand.

5.4.2 Redesign pedagogy and curricula to be compatible with the interconnected, distributed, open, and collaborative platform of the digital economy and the new business models that accompany it. The education system developed during the Second Industrial Revolution was modeled after the assembly line. The read-write-arithmetic curricula (product) was broken down into chunks and fed to students along a predetermined linear schedule of sequences. Students were tested for rote retention and compliance, getting stamps of approval (grades), allowing movement to the next level. In order to complete the curricula on schedule, there was little time allotted for imaginative questioning and exploring any particular chunk in deeper or broader detail. In many school systems if students repeatedly failed to assemble the chunks of learning in the allotted time, they were rejected, had to repeat the grade level, and often dropped out of school. With the advent of Internet platforms populated by ecosystems of apps, accessible by smart phones and tablets, knowledge and multi-media resources can now be communicated, distributed, retrieved, shared, co-created, and peer-produced, anywhere, anytime, with anyone else (person or machine). New forms and combinations of learning are now possible and available, ranging from self-initiated to distributed learning clusters, from MOOCs to self-organized groups of geographically dispersed, self-motivated individuals focused on achieving a goal or mission. The Internet has become an endlessly expanding library repository of open source, open access resources, courses, and tools. A new pedagogy is needed to harness these increasing knowledge assets both for students throughout their educational schooling, and for retraining and up-skilling teachers and workers in the new professional endeavors spawned by the emerging Third Industrial Revolution.

5.4.3 Introduce prosumer and sharing economy concepts, values and operating principles in secondary schools and university curricula. Educational institutions already have access to an immense pool of open source courses on every topic taught in school, which are freely shared worldwide, and used in classes structured around collaborative learning groups. Educational professionals such as Dr. Teemu Leinonen, Professor of New Media Design and Learning at the Aalto University School of Arts, Design and Architecture in Helsinki, Finland, likens the collaborative learning process to playing in a jazz band. “The natural place, the stage, for collaborative learning and knowledge work is online. A teacher and supervisor should act as the leader of a collaborative group of learners. She should participate to the playing, lead the work but also step back when someone is ready to play a solo. Multifaceted communication is a key. In a collaborative learning group the participants should learn to play their instruments: computers and software needed to create new knowledge. The instruments can be various. They can be tools for searching information, tools to evaluate and validate the information found, tools to conceptualize things in written or visual forms, tools for programming, tools to

design models and simulations, tools for collecting data, tools to measure things, tools to create audio and video. There are many and all groups don't need them all. Important is to learn to be a master of some of them and to be able to play a bit with the other instruments, too. At least for fun. Collaborative learning and knowledge work doesn't end when the school day is over. It continues in different times and spaces. Learners should be encouraged to use the skills they have learned. To start their own group. To learn and to work for fun. To make most out of the skills and knowledge learned in another project.”²³³

5.4.4 Make a conceptual shift from the notion that “knowledge is power,” to the new emphasis of “knowledge as a shared social experience.” Traditionally, knowledge was coveted, kept secret, and controlled, to strengthen one's position in the market and society. The growth of the Internet and ubiquitous access via smartphones (pocket supercomputers), tablets and computers, now puts a premium on sharing knowledge. As mentioned earlier, Wikipedia is an exemplary model.

5.4.5 Foster reverse-mentoring opportunities. Young people have been the early adopters of ICT gadgetry, such as electronic games, smart phones, social media, and an endless stream of apps. They rapidly master programs, applications, and the newest technologies from their peers. Young people also comprise the bulk of Internet start-ups. Their elders, including parents, teachers, and school administrators, are more apprehensive in adopting and becoming adept with the digital devices. Enabling students to share their mastery through reverse mentoring is enriching for the student and older learner, as well as providing opportunities for cultivating emotional and social skills which are becoming essential attributes for the evolving jobs in the Next Economy.

5.4.6 Enlarge the domain of available learning tools and technologies. Just as the slide rule has been superseded by handheld calculators, computer spreadsheets, and smartphones, tablets and PCs have displaced pencil, paper and 3-ring binders. New digital design tools and Internet technologies, in turn, have emerged for learning purposes. These include highly inventive apps, a myriad of virtual reality technologies (e.g., immersion through head-mounted displays, augmented reality, telepresence) wearable devices, smart algorithms, Big Data analytics, machine learning and artificial intelligence (AI), as well as smart sensors and affective computing. These technologies allow for a variety of new learning modes, including the observational, experimental, analytical, mental and cognitive, emotional, social, and physical.

²³³ See: <https://teemuleinonen.fi/2015/09/28/computers-are-the-instruments-of-collaborative-learning-and-knowledge-work/>

	Traditionalist	Boomer	Gen X	Gen Y
Training	The hard way	Too much and I'll leave	Required to keep me	Continuous and expected
Learning Style	Classroom	Facilitated	Independent	Collaborative & networked
Communication Style	Top down	Guarded	Hub & Spoke	Collaborative
Problem-Solving	Hierarchical	Horizontal	Independent	Collaborative
Decision-Making	Seeks approval	Team informed	Team included	Team decided
Leadership Style	Command & Control	Get out of the way	Coach	Partner
Feedback	No news is good news	Once per year	Weekly/Daily	On demand
Technology Use	Uncomfortable	Unsure	Unable to work without it	Unfathomable if not provided
Job Changing	Unwise	Sets me back	Necessary	Part of my daily routine

Image source: Reverse Mentoring, <http://blog.gpstrategies.com/coaching/reverse-mentoring/>

5.4.7 Engage students in field experiments and applied scientific research. Experiential learning that engages the whole self, mind and body, can accelerate learning in ways not as yet achievable in classroom instruction. With smart phones outfitted with a portfolio of advanced apps, student teams are capable of gathering diverse forms of data (numerical, visual, aural), conducting scientific experiments, performing tests and analyses, assembling multi-media presentations of findings, and establishing a repository of resources to share with other students (anywhere) wishing to build upon the experiments. Through the process, students absorb the mind-set and cultivate the skill sets of researchers implementing real-world rigorous science standards and procedures. The range of experiments is limitless: use the school, home, and community as a living laboratory, monitoring energy, material, and waste patterns; perform analyses on how the school can transition to becoming a zero emission, positive energy campus; do the same for other buildings in the neighborhood; compile data and findings (numerical, textual, visual, web mapping) on a platform for future students to augment; or inventory the surrounding streams, vegetation, soils, and air quality and perform a range of experiments and data gathering for assessing the health of local ecosystems.

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5.4.8 Provide each student with a square meter plot of soil to grow their own biological textbook throughout their educational years until graduation. The creative exercise of nurturing an assemblage of seeds and seedlings into a prospering garden includes an intrinsic feedback process. Peer sharing of outcomes gleans insights as to the effects of over or under watering, depleted or nutrient-rich soil, optimal plant selection, too much sun or shade, as well as opening up the worlds of horticulture, pollination, botany, entomology, plant sciences, and hands-on skills of composting, mulching, grafting, seed saving, as well as many STEM (science, technology, engineering, math) competences. By graduation, students will have become master horticulturalists, with a lifetime recreation or avocation, and certainly well-informed citizens on agro-food-flower related issues.

5.4.9 Provide opportunities for youngsters to experience and engage with business and work environments. Experience can be gained through innovative apprentice initiatives, professional mentoring programs, or by school club-initiated projects collaborating with local businesses, non-profit groups, cooperatives, and public agencies on enterprising tasks.

5.4.10 Set up the opportunity for primary school students to run a micro-enterprise for a short period of time, initiated with a modest incentive of five+ euros. The experimental enterprises may create and instill a sustained enthusiasm to explore the emerging prosumer and Sharing Economy. Such mini-entrepreneurial adventures could be as simple as setting up a Sharing Economy operation based on the food and flowers produced from a pupil's biological textbook.

5.4.11 Establish a network of business and entrepreneur volunteers who serve as advisors interacting with pupils. Business professionals can share Aesop-like tales - "Let me tell you a story" - that illuminate lessons learned, enthusiasms experienced, innovations achieved (or failed), and other narratives of the business world. This is one way of encouraging schools and local businesses to work more closely together.

5.4.12 Include core aspects of business and entrepreneurial knowhow for teachers as part of their ongoing professional development. Provide a training venue designed to engage teachers in understanding the requisite skills and perspectives (proficiencies and competences) needed to flourish in the business world and market place.

5.4.13 Include professional and vocational callings that encompass self-employment and entrepreneurship. The rise of the sharing and prosumer economy requires new skill sets and additional competences that are not generally included in school instruction.

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5.4.14 Young people need to be made aware of all the different work opportunities and possible routes to success. This includes engaging business professionals to provide insights and advice. It also involves making young people aware of how other young people are actually creating enterprises at an early age. Primary school children now routinely learn how to program and produce their own apps and web sites; other students are using data visualization apps and software to design gardens, or map the suitable rooftops and growth spots for solar PV systems, as well as performing the economic and financial calculations of electricity generation. The examples are legion, and the Internet enables peer-to-peer sharing and learning about the diversity of innovative applications.

5.4.15 Rethink, redefine and redesign the curriculum from one focused on skill sets to one focused on problem solving. Encourage different kinds of learning, shifting from memorizing facts to engaging in problem solving in collaboration with others. Instead of skill-oriented instruction, consider the innovative “phenomenon” methodology being implemented in Finland that prioritizes the “four Cs: communication, creativity, critical thinking, and collaboration.”²³⁴ These are skills that are key to working in teams, and more in alignment with and conducive to leveraging the planetary interconnected society we live in.

5.4.16 Advance work-based learning within the Dutch Vocational and Education Training (VET) system. The Netherlands has a vibrant VET system encompassing a significant percentage of students pursuing vocational studies. The VET system is widely supported and well-funded through public and private financial resources. The private sector is actively involved in the VET system, making available well-received short courses, and advanced degree programs. To remain vital, vibrant, and meaningful requires incorporation of learning resources germane to professions demanding digital skills and competences.

5.4.17 Encourage the engagement of industry practitioners in teaching new workplace skills. Good teachers are the predominant determinant in successful student learning. Teachers’ skills and competences require periodic updating. However, it is uncommon for industry professionals to teach in VET schools, given the regulatory requirement of a teaching certificate. Yet, it is in times of swift changes in the kinds of competences and skill required for work that industry professionals are most valuable to share such needed skills.

5.4.18 Help adults transitioning into new careers with “how to” research and learning how to open source tools available through the Internet. Learners of all ages have at their fingertips (tapping a smartphone) a virtually endless supply of open access learning resources. These

²³⁴ See: <http://www.nea.org/assets/docs/A-Guide-to-Four-Cs.pdf>

resources can be retrieved in diverse formats: text, video, visual, audio, spreadsheets, numerical, analytical, interactive, in-depth discussions, animations, educational courses from hundreds of top universities, apps, tools, peer-to-peer projects, collaborative networks, etc. Many adults need guidance and assistance on how to find these free resources, and use them most effectively. Compared to the cost of pursuing another college degree, motivated adults can save time and financial resources tapping into the Internet's knowledge assets.

5.5 FINANCIAL

5.5.1 Hold an ongoing series of app contests with monetary awards to winners who address issues related to the Sharing Economy. For example, issues of trust are one of the main concerns that prevent Sharing Economy services being more widely adopted. Trust issues can arise between businesses and the users of their services, and between the users themselves. This challenge is looking for ways in which digital solutions or services can be used to help overcome trust issues in the Sharing Economy. To cite just one example, the Sharing Economy has already begun to have an impact on retail and the home improvement market, with customers sharing inspiration, knowhow, skills and even tools for projects through online services. Retailers need to engage with these services and include aspects of sharing into their own business offerings. A third example relates to opening city data to citizens. Cities can play a key role in developing the Sharing Economy, both through the services they provide and by facilitating the development of other services. Cities have huge amounts of data, ranging from health and housing to the environment and the economy. This data could be used in the sharing economy, but it is difficult for cities to know how to make best use of it.

5.6 R&D

5.6.1 Establish civic labs networks for citizen engagement – City Governments can engage citizens in collaborative innovation networks by establishing civic innovation labs. Cities are becoming the crucibles of experimentation, determining through ongoing exploration and gathering evidence as to what kind of model fits best with their local conditions and citizenry. The Boston Mayor's Office of New Urban Mechanics (MONUM) and the Seoul Innovation Bureau are examples of best practices on operationalizing civic innovation labs. National governments should also establish a national civic labs network, to encourage knowledge sharing among local labs.

5.6.2 Use open data and open platforms to mobilize collective knowledge – In launching pilots as part of a Smart City development, attention should be focused on establishing open platforms rather than proprietary ones. Open platforms are designed to naturally facilitate interaction among citizens and local companies, harnessing their collective intelligence. The non-profit OpenPlans and their Shareabout platform for gathering public feedback is a good illustration of the open source collaborative common tools available to any city, eliminating the need for depending upon proprietary tools. Moreover, the open source tools evolve and improve as more cities adopt them and implement refinements.

5.6.3 Open up problem solving to citizens, using online tools. Enable citizens to discuss and debate ideas, and participate in the decision process prior to implementation. *Better Reykjavik* is a good case study of best practices.

5.6.4 Open up data to the public to help generate innovative solutions to urban challenges. Taxpayers have been funding Big Data accumulation by government agencies for decades. Opening this data to citizens, civic groups, academics and companies can result in discovering new, productive applications with the data. The Open Data Challenge series, sponsored by the Open Data Institute, co-founded by the inventor of the World Wide Web, Sir Tim Berners-Lee, is designed to catalyze innovative ways of applying city data through harnessing the collective intelligence of citizens, civic entities, companies, and public agencies.

5.6.5 Involve smaller companies and civil society organizations in smart city pilots. Small and medium sized businesses, cooperatives, and civic organizations are rich sources of innovation and inventiveness, increasingly around novel digital and internet applications. In undertaking smart city pilots, research initiatives, and development projects, include the opportunity for these smaller entities to participate. One example is the focus of the UK's Small Business Research Initiative (SBRI) which is reaching out to innovative start-ups and small businesses for participation in smart city pilots and other public R&D programs.

5.6.6 Launch an IoT starter's kit, based on Raspberry Pi Zero. This inexpensive, credit card-sized single board computer has been used over the past decade to encourage the teaching and learning of basic computer science for students and professionals alike.

5.6.7 Experiment with blockchain technology on public issues. Blockchain, called a secure, distributed ledger, has been defined as "a system that's secure without a higher authority, distributed across many strangers' computers, yet tamper-proof, and promises a mechanism

for trust mediated directly between individuals."²³⁵ It is currently being used worldwide by hundreds of banks, financial institutions, insurance companies, and large businesses tracking supply chain inventories. Many more applications are emerging as innovatively applied to a range of transaction-like activities and processes. The following visual illustrates some of the possible applications.



Source: Amit (2015) Public and Private Blockchain Concepts and Examples, Let's Talk Payments (LTP), August 10, 2015, <https://letstalkpayments.com/public-and-private-blockchain-concepts-and-examples/>.

5.6.8 Develop the first experimental "accelerator" for street level entrepreneurship - See Sidewalk Labs (<http://www.sidewalklabs.com/>), how Google is turning cities into R&D labs.

²³⁵ See: <http://www.bbc.co.uk/programmes/b066wfp4>

THE FINANCIAL UNDERPINNINGS OF A MORE PRODUCTIVE MRDH ECONOMY

The Roadmap Next Economy is taking hold. Indeed, there are many intriguing ideas for large-scale productivity projects that are now being proposed and discussed. Yet, if the Metropolitan Region of Rotterdam and The Hague is to elevate its level of economic performance, it will need both *purposeful effort* and a *different pattern of investments*.

John Byrne (Foundation for Renewable Energy and Environment), Job Taminiau (Foundation for Renewable Energy and Environment), Michael Casey (AGENTIC), Rik Willard (AGENTIC) and John "Skip" Laitner (Economic and Human Dimensions Research Associates), TIR Consulting Group LLC

Purposeful effort means the set of new skills, smart policies and programs that enable the development and deployment of energy efficiency upgrades, renewable energy technologies, and, more broadly speaking, the substantial upgrade of its existing infrastructure. The latter includes more productive buildings, industrial operations, transportation and telecommunication services, power and water supplies, and the like. A different pattern of investment refers to a higher level of annual outlays in the technologies and infrastructure upgrades that move away from the current generation of Second Industrial Revolution tools and machines to those which underpin a more integrated and productive Third Industrial Revolution economic foundation— the digital Communications Internet, the digital Renewable Energy Internet, and the digital GPS automated and soon driverless Transportation and Logistics Internet which link buildings and other structures into a more optimal flow of goods and services in ways that also reduce overall costs for the region.

A high priority should be placed on the creation of an MRDH Sustainable Infrastructure Finance Platform (SIFP). This is a proposal that complements three key ideas from the TIR Consulting Group LLC: 1) the need to build up a more productive capacity within the MRDH economy through the more efficient use of energy and other resources;²³⁶ 2) the creation or use of an authority capable of launching a proposed Sustainable Energy Finance (SEF) strategy to provide

²³⁶ Laitner, John A. "Skip", Exploring the Economic Benefits of the RNE Innovation Scenarios (24 August 2016); see also Robert Wilhite, Kathleen Gaffney, Tiffany Chow, and Rowan Watson, Navigant Consulting, Inc., The Third Industrial Revolution for Energy - Metropoolregio Rotterdam Den Haag (MRDH) (16 June 2016).

the phased-in capital that is required to kick-start the investment pool;²³⁷ and 3) the new set of blockchain technologies and their equivalent which can provide a new generation of investment capabilities to continue the steady march toward a higher level of economic performance.²³⁸ While the details are discussed more fully in these several respective working documents, this section provides an overview of the key concepts to better characterize their more vital context. In addition, it adds two other elements. First, it promotes an extension of existing public authorities or cooperatives to embrace both an aggregation of the financial opportunities on the demand-side, but also the aggregation of energy and other materials to ensure low-cost access to key resources, all in a timely fashion. Second, it highlights the opportunity for MRDH to build on its current expertise and financial capacity to promote the ideas embedded here at the highest levels within both the Netherlands and the other 27 Member States of the European Union.

The Financial Framework for Catalyzing a Smart Transition of the MRDH Economy

As of 2014, MRDH is a €98.9 billion economy as measured by its Gross Domestic Product, or GDP (NEO 2016).²³⁹ While a smaller region of 2.3 million within the Netherlands, with about 14% of the nation's total inhabitants, it has a per capita GDP that is about 8% higher than the nation as a whole. Both MRDH and the Netherlands enjoy a slightly more prosperous economy with a GDP per inhabitant that is more than 20% higher than developed economies as a whole. Like all regions, however, MRDH must confront the social and economic reality of both climate change²⁴⁰ and an economy that is less robust than in the past. Climate change and a weakening economy share a common denominator: the highly inefficient use of energy and other resources that results in the pumping of large quantities of greenhouse gas emissions into the atmosphere. Were both the Netherlands and the global economy twice as energy-efficient as

²³⁷ Byrne, John and Job Taminiau, Foundation for Renewable Energy and Environment (FREE), Assessment and Application of Sustainable Energy Financing as Infrastructure Investment in Metropolitan Region of Rotterdam and The Hague: A "Sustainable Energy Finance" (SEF) Strategy (15 June 2016).

²³⁸ Willard, Rik and Michael Casey, The Agentic Group, Comments on Blockchain Technology for MRDH (13 June 2016).

²³⁹ MRDH Economic Data from Netherlands Economic Observatory, January 2016.

²⁴⁰ Perhaps as a timely reminder of the growing problem of climate change, a former EPA colleague and now weather editor for the Washington Post, Jason Samenow who writes in a 16 May 2016 news story that the average temperature of the planet was 1.11 degrees Celsius above the long-term average in April, shattering the old record from 2010 by 0.24 degrees Celsius. He notes further that "2016's average global temperature is so far out in front of any preceding year that climate scientists say there's basically no way it won't become the warmest ever recorded." See, [Earth's relentless streak of record-warm months expands to seven](#).

they are today, only half of the energy-related greenhouse gas emissions would be forced into the upper atmosphere.²⁴¹

At the same time, the very reason that the climate is burdened by an excess of greenhouse gas emissions is the same reason the economy is constrained by an array of costs which robs it of its overall vitality—that is, the wholly inefficient use of energy and other resources. Hence, there is the very real need to solve both the climate and the economic problems together, through a much greater emphasis on the productive use of assets and resources. This is where MRDH has a critical asset – its immediate focus on the development of major projects that can initiate an investment upheaval of its infrastructure and technology base toward a more productive transformation of the regional economy.

Like all economies, MRDH maintains a large infrastructure that underpins its overall economic performance. Working estimates indicate an existing €300 to €350 billion outlay in the region’s existing capital stock (buildings, roads, bridges, and related infrastructure) that must be substantially upgraded if the regional economy is to improve its overall performance. In effect, a more productive infrastructure can increase both productivity and provide a greater level of resilience for inhabitants and businesses within the region. At normal rates of replacement, however, one can imagine that it may require 50 years or more to fully modernize the economy from a Second Industrial Revolution performance to meet expectations of the Roadmap Next Economy. Consequently, there is a need to quickly aggregate both the supply of and the demand for resources and energy, and to accelerate the redirection of capital away from the old and into the new. This brings us then to the central ideas behind the MRDH Sustainable Infrastructure Finance Platform (SIFP), as complemented by the Sustainable Energy Finance model and the development and deployment of the Blockchain technology.

The proposals described in this section of the report, therefore, represent an integrated strategy capable of providing, maintaining, and managing a key driving force behind a TIR transition: the organized supply and demand of low-cost capital for sustainable technologies at an infrastructure-scale. This strategy is illustrated in Figure 1. Within the strategy, the MRDH

²⁴¹ By way of comparison, the TIR Master Plan for Nord-Pas de Calais suggested an eventual efficiency improvement that could reduce total energy use by about one-half with renewable energy technologies meeting all remaining energy needs by 2050. This would effectively bring that region’s energy-related carbon emissions down to zero. See, [Nord-Pas de Calais Third Industrial Revolution Master Plan – 2013](#), Jeremy Rifkin, Benoit Prunel, Solenne Bastie, Francis Hinterman, John Laitner and Shawn Moorhead. Bethesda, MD: TIR Consulting Group LLC. 2013. For yet a different approach that relies more heavily on renewable energy technologies throughout the world’s economies, see Jacobson, Mark and Mark Delucchi et al., [100% Clean and Renewable Wind, Water, and Sunlight \(WWS\) All- Sector Energy Roadmaps for 139 Countries of the World](#), August 9, 2015.

SIFP represents a central interface platform between the supply and demand of capital. The platform interacts with many different agents of capital supply (e.g., investors, asset managers) and with actors that have projects looking for funding (e.g. residential, commercial, public, etc.). The financial mechanism, called here the Sustainable Energy Finance (SEF) strategy, represents coordinated interaction along innovative program mechanics that unlock guaranteed monetary returns for infrastructure-scale sustainable energy (e.g., energy efficiency, rooftop solar, mobility improvements, etc.) at low cost. An aggregation function is included in the strategy to focus on large-scale capital provision (e.g., institutional investors but also pooled individuals through for instance crowdfunding efforts) to lower costs and to join together many end-users of energy services and create economies of scale.

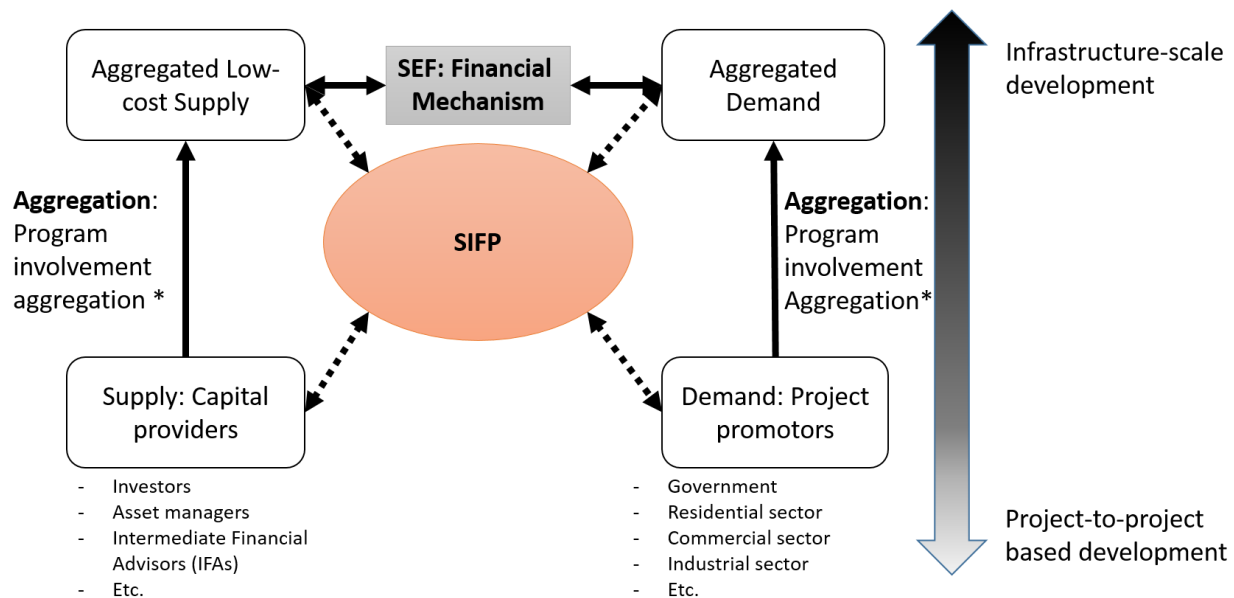


Figure 1. Summary overview of the integrated strategy that combines the SEF financial mechanism with an aggregation function, a communication function, and a management function. The integrated strategy is consistent with green finance principles.

** Aggregation can include community choice aggregation (CCA) and crowdfunding efforts. The SEF strategy, relying on pooled financing, standardized contracts, and guaranteed savings also fulfills much of the aggregation function.*

MRDH Sustainable Infrastructure Finance Platform/Sustainable Energy Finance Model

The MRDH Sustainable Infrastructure Finance Platform (SIFP) can be positioned as a central interface platform that catalyzes and supports the financing of major projects that lead toward greater social, economic, and environmental sustainability. These might include RNE-related and other necessary projects, as well as their active promotion throughout the region and among potential investors and project organizers. In tandem with the establishment of a Sustainable Infrastructure Finance Platform, MRDH should consider adopting a Sustainable Energy Finance (SEF) strategy as the key financial mechanism of the infrastructure-scale transactions between pooled finance and aggregated demand for capital. The SEF strategy represents an integrated sustainable development finance structure that facilitates the interaction between providers and recipients of sustainable energy services and capital, aggregates both supply and demand to a new infrastructure-scale level, and provides a financing pathway towards implementation of such large-scale efforts. The overall positioning and functioning of the approach can be visually captured (see Figure 1 above).

Market-tested in the United States with favorable results, the SEF strategy turns costs (e.g., energy, water, materials) into valuable investment-grade assets at a scale and a rate of return that is attractive to individuals and institutional investors alike. Furthermore, the strategy avoids up-front expenditures or other costs by local government, due to the self-financing nature of the assets. Essentially, the SEF tool is a capitalization strategy which involves the creation of a public authority (or the use of an existing authority) that can raise the required capital through loans or bond issuance. The strength of the SEF investment strategy lies in its program mechanics in which the investment and associated costs are repaid entirely through guaranteed Euro, energy, water, and material savings in standardized contracts.

Other capabilities of the SEF investment model include:

- The creation of a public authority (or the use of an existing authority) that aggregates MRDH's need for a more productive and sustainable energy resources into actionable and financeable projects that can attract low-cost capital, and do so at a scale and rate of return that is attractive to investors;
- Standardized transactions that rely on a common, standardized documents platform that accelerates supply and demand of sustainable energy finance and keeps transaction costs low;

- Guaranteed energy and Euro savings for investors and program participants alike that match or exceed all financing and capital costs; and
- The enabling of the market and its varied stakeholders—including Energy Service Companies (ESCOs), energy and other community cooperatives, civil society organizations, investors, relevant public law bodies, and intermediate financial advisors—to prepare for and participate in the RNE transition. In contrast to previous project-to-project business models, the structured approach trains stakeholders to operate at a new infrastructure-scale where sustainable energy and other RNE technologies can replace second industrial revolution infrastructure.

The SEF investment strategy enables the aggregation of demand for conventional energy services, and then transforms them into sustainable energy services. While clearly a form of green financing, it is much more than that. It also includes much greater levels of energy and resource efficiencies which help the Metropolitan Region achieve a balanced set of social, economic, and environmental objectives together.²⁴²

A Resource Aggregation Authority

While the Sustainable Energy Finance model provides a useful aggregation of demand-side projects (whether energy-efficiency upgrades or rooftop photovoltaic systems), there is an array of other complementary institutional arrangements that MRDH may want to harness to drive greater investments in renewable energy and energy efficiency upgrades at an equivalent regional-scale. One such approach is the Community Choice Aggregation (CCA) that is a variation of energy cooperatives.²⁴³ The CCA model is a vehicle that enables community governments to aggregate or pool energy customers to purchase and develop energy resources, as well as to administer energy programs, on behalf of their residents and businesses. This institutional arrangement allows the local community to shape the CCA program to prioritize desired benefits, including increased investment in renewable energy

²⁴² In many ways what we now call green or climate aware financing might be equally called Economic Performance Financing (EPF) through Economic Performance Bonds (EPB). In other words, and as already suggested, we absolutely need to engage in both a higher level of performance and climate change mitigation and adaption practices. If we don't achieve that multiple objective, we may (or may not) achieve some environmental goals, but we may short-change the social and economic goals.

²⁴³ As one example of a local energy cooperative, De Windvogel (Wind Bird) is a 25-year old MRDH-based cooperative consisting of 3,300 members with a number of wind turbines generating a total of 7,600 MWh per year.

sources and energy efficiency, economic development, carbon reduction strategies, and workforce development efforts.²⁴⁴

Not unlike some energy cooperatives, CCAs have the authority to buy and/or develop energy resources on behalf of the residential, commercial, and government energy customers within its jurisdiction. Whether heat or electricity, the energy continues to be distributed and delivered over existing pipelines, electricity lines, and other infrastructure that is owned by a private company or investor-owned utility.

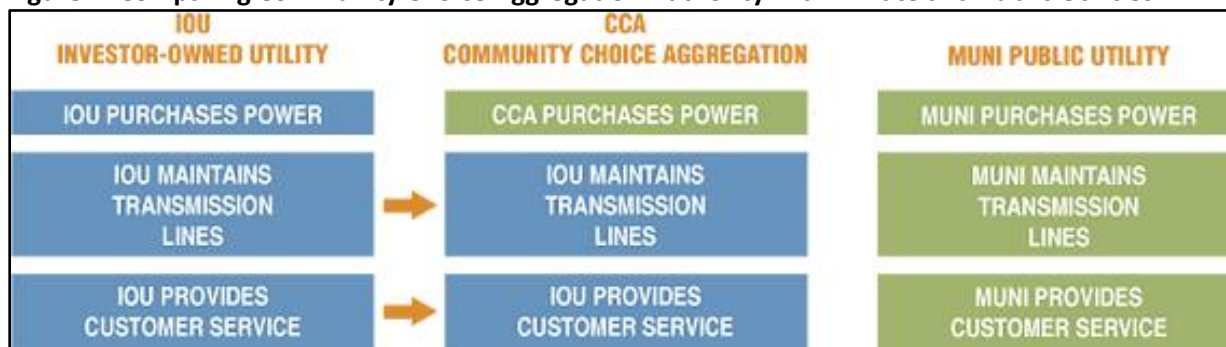
By establishing a CCA program, cities and municipal authorities can assume increased ownership and control over their electricity generation and consumption. CCA provides a platform for managing the community's energy resources through the administration of energy efficiency programs, as well as through the development of local renewables. Some local communities have been motivated to form community choice programs as a means to achieve greater levels of renewable energy generation, encourage local investment in energy resource development, reduce greenhouse gas emissions, amplify the community's level of energy efficiency, and catalyze electricity grid modernizations efforts.²⁴⁵ These investments in a cleaner and more efficient mix of energy resources tend to stimulate more immediate job creation while also reducing the cost of energy services for all customers. For example, current aggregation contracts in the Midwestern part of the United States are yielding up to 25% rate savings while rate savings on the East coast are averaging a savings of 10 to 14% (as of September 2013).²⁴⁶

²⁴⁴ With origins in the State of California, CCA is statutorily enabled in California, Illinois, Ohio, Massachusetts, New Jersey, New York, and Rhode Island with a handful of other states considering legislation. For more background on the idea of a Community Choice Aggregation model as it might be applied in the Netherlands or the region, see the resources of Local Energy Aggregation Network (LEAN Energy US) at <http://www.leanenergyus.org/>. For a quick review of energy cooperatives in Europe, see the Navigant report cited in footnote 11 of this overview.

²⁴⁵ Gordon, M. (2014). CCA and Microgrids: Community Driven, Private Enterprise Models for Smart Grid Innovation.

²⁴⁶ The data are from footnote 3 in the explanation offered at: <http://www.leanenergyus.org/what-is-cca/>.

Figure 2. Comparing Community Choice Aggregation Authority with Private and Public Utilities²⁴⁷



Source: <http://www.leanenergyus.org/what-is-cca/>

As explained by LEAN Energy US, an energy aggregation authority can be used on an opt-in or opt-out basis (depending how the CCA or public authority is constituted). But, as they note: “the most common and successful programs are opt-out. This means that consumers are automatically enrolled after a successful public referendum at the local level, as was done in Illinois and Ohio; or, enrolled when their local elected representatives (city council or county board) voted to form or join a CCA program, as happened in California. The opt-in approach is voluntary but participation rates are traditionally very low which reduces the value of group purchasing and makes it harder for local programs to achieve economic viability. Opt-out aggregation achieves the necessary market scale for effective group purchasing, but allows a customer to switch back to utility service or other energy providers at any time. Either way, customers always have the choice to stay or go.”²⁴⁸

LEAN Energy US, further explains: “Because CCA is a revenue-based system—not government subsidized—such programs are self-supporting from an existing revenue stream.” The energy costs that consumers pay to a retail energy supplier or an investor-owned utility “are bundled and redirected to support the group purchase of energy through a local CCA program.” As shown in Figure 1 above, there is a clear separation between energy production and the actual distribution of the different energy resources. As envisioned here, the partnership with an existing energy supplier as the primary distributor is one that is negotiated and established within the existing market structure. In California, for example, the local utility has entered into a partnership with the CCA authority. The retail energy provider benefits from the group

²⁴⁷ While this example draws on the business model of the electric utility, it could also be extended to include the development, bulk purchase and distribution of transportation fuels, industrial chemicals, water resources, and more.

²⁴⁸ See: <http://www.leanenergyus.org/what-is-cca/>

purchasing power through lower costs. As LEAN Energy US notes, the utilities or other energy supplies are “made whole” through cost recovery surcharges (or exit fees), also covering reasonable profits, as they lose energy sales. At the same time, the energy supplier retains its ownership and management of “the distribution infrastructure, and all final energy deliveries, repairs, billing, and customer service functions.”²⁴⁹

How might such an authority be administered? In the State of California, there are currently three management options. The “most common approach is through an inter-jurisdictional joint powers agency (JPA) that serves as a public, non-profit agency on behalf of the municipalities that choose to participate in the CCA program. This is the model under which Marin Clean Energy and Sonoma Clean Power operate, for example. A second option is a single city or county that might structure a CCA through an Enterprise Fund; this is the model under which Lancaster Energy Choice in California operates. In this option, the CCA is managed “in house” as a separate program/fund within existing municipal or government operations. Still a third option involves a commercial, or third party management where the CCA’s operations are delegated by contract to a private firm. This model is new in California so its risks and benefits are yet to be fully vetted or realized.”²⁵⁰ What specific approach makes the most sense for the metropolitan region? That remains open as it will also depend on how the SIFP/SEF might complement the operations and purposes of the CCA.

Yet, this authority provides the means to further increase and organize the flow of energy resources in ways that enhance SIFP/SEF. In fact, new tools are now in play as blockchains are giving more power to individual consumers to negotiate without a single authority and match energy resources with specific energy demands.²⁵¹

²⁴⁹ Ibid.

²⁵⁰ Ibid.

²⁵¹ Aviva Rutkin, [Blockchain-based microgrid gives power to consumers in New York](#). 2 March 2016. In this case, while solar panels on the roofs of terraced houses in New York City soak up sunshine, a pair of computers connected to the panels quietly crunch numbers, counting how many electrons are being generated so that they can be bought and sold as needed to neighbors rather than go through a central authority or utility. This project, run by a startup called Transactive Grid, is the first version of a new kind of energy market, operated by consumers, which may very well change the way we generate and consume electricity. Although not referenced here, these arrangements can also include much more than heat and power, but transportation fuels, water resources, and the flow of other materials, goods and services within MRDH.

A Sustainable Energy Finance (SEF) Strategy: Implementation and Deployment

The deployment of the Internet of Things will require low-cost financing at scale. A Sustainable Energy Finance (SEF) strategy²⁵² provides the financial mechanism for unlocking and directing infrastructure-scale and low-cost capital to facilitate the TIR transition. The SEF strategy is discussed in detail in the following sections and is then illustratively applied to MRDH.²⁵³ SEF is suitably positioned to contribute to the advancement of the mission statement of the MRDH:

“De Metropoolregio Rotterdam Den Haag is in 2025 internationaal marktleider in het ontwerpen, ontwikkelen, maken en vermarkten van oplossingen op het gebied van duurzaam leven in een sterk verstedelijkte deltaregio. In de regio worden samenhangende oplossingen bedacht, getest en geproduceerd voor mondiale logistieke, energie-, voedsel- en veiligheidsvraagstukken.”²⁵⁴

The SEF strategy enables the Third Industrial Revolution transition as the investment model turns costs (e.g., energy, water, materials) into valuable assets at a scale and rate of return that is attractive to investors. Furthermore, the model avoids up-front expenditures or other costs by local government due to the self-financing nature of the assets. Other capabilities included in the SEF strategy:

- Aggregates MRDH’s community demand for sustainable energy into actionable and financeable projects that can attract low-cost capital at scale;

²⁵² The SEF investment model was conceived by the leadership of the Foundation for Renewable Energy & Environment (FREE). FREE operates multiple SEF investment programs in and beyond the United States. The SEF investment model represents an evolutionary step forward from the Delaware Sustainable Energy Bond market example provided in this briefing paper. Dr. John Byrne spearheaded the Delaware Sustainable Energy Utility (SEU) task force and was intimately involved in the design and launch of both the Delaware SEU and its Sustainable Energy Bond program. For more information, please see www.freefutures.org. Byrne; et al. (2007). [The Sustainable Energy Utility: A Delaware First](#) (PDF). Sustainable Energy Utility Task Force; Byrne, John; Martinez, Cecilia; Ruggero, Colin (2009). "Relocating Energy in the Social Commons: Ideas for a Sustainable Energy Utility". Bulletin of Science, Technology and Society 2: 81–94. [doi:10.1177/0270467609332315](https://doi.org/10.1177/0270467609332315).

²⁵³ The exploration in terms of the application of the SEF investment model within an MRDH context as presented in this briefing paper should be seen in a light of evolutionary progression: the findings and estimates offered here serve an illustrative function and additional research is required to advance possible implementation of the SEF strategy in the MRDH.

²⁵⁴ See Metropoolregio Rotterdam and Den Haag, 2014. Agenda Economisch Vestigingsklimaat. Document available at: <http://mrdh.nl/over-mrdh>, page 4

- Offers standardized transactions relying on a common, standardized documents platform that accelerates supply and demand of sustainable energy finance and keeps transaction costs low;
- Guarantees energy and Euro savings for investors and program participants alike that match or exceed all financing and capital costs; and
- Enables the market and stakeholders (including, for instance, Energy Service Companies (ESCOs), civil society organizations, investors, relevant public law bodies, and intermediate financial advisors) to prepare for and participate in the TIR transition. In other words, in contrast to project-to-project business models, the strategic approach trains stakeholders to operate at a new scale where sustainable energy and other TIR technologies replace second industrial revolution infrastructure.

The agglomeration economy of MRDH presents characteristics that are especially suitable for the SEF strategy²⁵⁵:

- a) The Metropolitan Region encapsulates 23 municipalities (about 2.25 million people). This level of scale provides substantial investment opportunities to drive transformational change;
- b) The Metropolitan Region has outlined an ambitious vision to become a European powerhouse in terms of the green economy;
- c) Historically strong interconnections between the various municipalities creates an enabling environment for transformation; and
- d) The eight focal points of the Metropolitan Region's economic development strategy – particularly energy, sustainability, and financing – align closely with the SEF's capabilities.

SEF application in the MRDH context is estimated to unlock significant benefits. Calculations performed yield a €12.6 billion self-financing investment potential for energy efficiency in the built environment and rooftop solar. A summary of key contributions is provided in Table 1.

²⁵⁵ See for instance: a) Atlas Metropoolregio Rotterdam and Den Haag, 2014. Document available at: [http://mrdh.nl/sites/mrdh.nl/files/files/Metropool Atlas editie2 compleet\(1\).pdf](http://mrdh.nl/sites/mrdh.nl/files/files/Metropool%20Atlas%20editie2%20compleet(1).pdf); and b) Metropoolregio Rotterdam and Den Haag, 2014. Agenda Economisch Vestigingsklimaat. Document available at: <http://mrdh.nl/over-mrdh>.

Table 1. Overview of several economic, environmental, and social contributions resulting from a combined deployment of rooftop solar PV and energy efficiency in the built environment. Euro amounts in millions.

	Energy Productivity		Solar PV		Total	
	Phase 1	Full Potential	Phase 1	Full Potential	Phase 1	Full Potential
Investment Potential	€1.300	€6.600	€1.200	€6.000	€2.500	€12.600
LCOE	8.3		17 / 12*		NA	NA
Financed term (years)	12		20		NA	NA
Job creation	16.000 – 20.000	80.000 – 100.000	9.000 – 18.000	46.000 – 88.000	25.000 – 38.000	126.000 – 188.000
CO₂ reduction	TBD	TBD	TBD	TBD	TBD	TBD

Collaborative governance strategies deployed by MRDH capture agglomeration benefits usually limited to provincial and state-level administration while retaining municipality-scale capacity to adequately address local socio-economic challenges. For instance, Rotterdam and The Hague, due to their size and position in the Dutch economy, could serve as anchor participants in a strategic financing plan to promote greater inward integration while simultaneously driving the national and international profile of the region.²⁵⁶ Such anchor participation opens up opportunities for the smaller municipalities to gain access to technology options previously outside of the price range of their scale of procurement. Further, the agglomeration economy of MRDH can benefit from first mover advantages and act as a driver of a replication process throughout the Netherlands and, subsequently, the European Union.

The SEF strategy is market tested as it has been successfully applied in the United States.²⁵⁷ The market test is illustrated by a brief case outline of the strategy's application in the U.S. state of Delaware under the heading of the Sustainable Energy Utility (SEU). Of course, the U.S. case is meant to illustrate feasibility and not to be treated as a blueprint. Any investment at scale must reflect and adapt to its context. Indeed, recognition of the strategy's capability to be flexibly adapted to different contexts motivated several high-level endorsements (Table 2).

²⁵⁶ OECD, 2016. OECD Territorial Reviews – The Metropolitan Region of Rotterdam-The Hague, Netherlands. Doi: 10.1787/9789264249387-en.

²⁵⁷ See [Citi Post Pricing Commentary on the Delaware Sustainable Energy Utility](#).

Table 2. The SEF strategy, operationalized in the U.S. under the heading of the Sustainable Energy Utility (SEU), has been featured in several high-profile communications.

Source	Quote	Date
International Energy Agency (IEA) Energy Technology Perspectives 2016	<i>The Sustainable Energy Utility (SEU) has demonstrated its capacity “to address many barriers to tapping into the local sustainable energy potential”</i>	2016
The White House	<i>“the Sustainable Energy Utility (SEU) [is] a one-stop shop for [...] energy efficiency solutions”</i>	December 02, 2011
Asian Development Bank Communiqué	<i>As part of the priority to facilitate the scale-up of energy efficiency and renewable energy, the Communiqué recommends policy-makers consider “establishing a Sustainable Energy Utility (SEU). [...] to fund energy efficiency and renewable energy as infrastructure investments”</i>	June 24, 2011

The case for a MRDH deployment of the SEF strategy is discussed by following the structure of the rest of the report:

- **New business model and value chain:** The section includes an outline of the conceptual functioning of the SEF strategy, including core characteristics. An example of its application in the United States, under the heading of the State of Delaware’s SEU, ²⁵⁸ is included as well to illustrate the market test of the concept.
- **Technical:** The section discusses the program mechanics of the SEF investment model.
- **Regulatory:** An evaluation of the MRDH regulatory and market context.
- **Policy:** The section describes elements of the MRDH context that could facilitate or hamper deployment of the investment model as part of the overall TIR strategy.
- **Education:** A brief section on the education-related elements of the strategy.
- **Financial:** A section on the financial characteristics of the SEF model. A case study example is also described to illustrate SEF potential in MRDH. The case study example outlines investment potential for both energy efficiency and solar photovoltaic (PV)

²⁵⁸ This model was first applied in the U.S. state of Delaware and has since found application in Washington, DC, Pennsylvania, and California. The SEU model is positioned as an energy governance model unlike conventional energy utilities as described by Byrne and Taminiau (2016): Byrne, J., Taminiau, J. (2016). A review of sustainable energy utility and energy service utility concepts and applications: realizing ecological and social sustainability with a community utility. Wiley Interdisciplinary Reviews: Energy and Environment, 5: 136-154. Doi: 10.1002/wene.171.

technology implementation in MRDH. The case study example illustrates both a long-term total technical potential and a short-term implementation option.

- *R&D*: A preliminary discussion on the projected application of the SEF model for other technology options, including energy storage, transportation, or digital monitoring and verification (M&V).
- A brief outline of strategic steps and an evaluation of the value of SEF in the context of MRDH.

New Business Model and Value Chain: The Sustainable Energy Financing (SEF) Investment Model

The significant investment potential for TIR energy technology options and the value of a comprehensive sustainable energy financing strategy is consistently confirmed in studies of technical, economic, and feasible deployment of energy efficiency and renewable energy. For example, for the Netherlands as whole, energy efficiency strategies could drive 50% to 80% CO₂ emission reductions in the built environment by 2050.²⁵⁹ Similarly, a recent study by the Planbureau voor de Leefomgeving (PBL) found a total rooftop PV potential of 66 GWp (~50 TWh), equivalent to the electricity consumption of the Dutch building stock.²⁶⁰ A host of other studies corroborates the finding of significant investment potential.²⁶¹ Such findings motivated the European Commission's assessment of energy savings as the EU's "biggest energy resource"²⁶² or Europe's "first fuel" by the Energy Efficiency Financial Institutions Group (EEFIG) (an expert group compiled by the European Commission and United Nations Environment Programme Finance Initiative).²⁶³ For the case of the Netherlands, the potential has been described as "limitless."²⁶⁴

²⁵⁹ PBL (2014a). Op weg naar een klimaatneutrale woningvoorraad in 2050. Policy Analysis Report. The Hague: PBL.; PBL (2014b). Op weg naar een klimaatneutrale woningvoorraad in 2050. Achtergronden en uitgebreide resultaten. The Hague: PBL.;

²⁶⁰ PBL (2014). PV potentieelstudie: het potentieel van zonnestroom in de gebouwde omgeving van Nederland. The Hague: PBL.

²⁶¹ Van Sark, W. (2014). Opbrengst van zonnestroomsystemen in Nederland. Utrecht: University Utrecht.; Vreugdenhil, C. (2014). Een studie naar het potentieel van PV in Nederland. Wageningen: WUR.; Tuominen et al. (2012). Energy savings potential in buildings and overcoming market barriers in member states of the European Union. *Energy and Buildings* 51: 48-55. Doi: 10.1016/j.enbuild.2012.04.015

²⁶² COM (2011) 0109 final

²⁶³ EEFIG (2015). Energy Efficiency - The first fuel for the EU economy.

²⁶⁴ Blok, K., de Visser, E. (2005). Energiebesparing : de onbegrensde mogelijkheden. Paper gepresenteerd op het MNP symposium 'Hoeveel energiebesparing is nodig?', Nieuwspoor, Den Haag, 28 Oktober 2005.

According to the EEFIG, the way forward is to gain access to available capital and benefit from existing interest and enthusiasm in the capital markets. Such access is currently limited: energy and sustainability ‘funding gaps’ are repeatedly enumerated. For example, to meet EU targets by 2020, EU member states face a funding gap of €500–700 billion in the energy supply sector (electricity and heat), a €200 billion gap for transmission networks and storage, and another €400 billion funding gap for distribution and smart grid improvements.²⁶⁵ Current investment levels are too low to close the gap.²⁶⁶ The EEFIG report, for instance, finds investment level shortfalls of 50% (by 2020) to 80% (by 2050) to meet European energy efficiency targets.²⁶⁷

Attracting low-cost financing at scale is, therefore, a critical component of a transformative approach such as the TIR. This challenge requires explicit consideration of the energy efficiency and renewable energy investment decision process and, in particular, the barriers that limit both supply and demand of low-cost capital.²⁶⁸ Barriers to sustainable energy finance have been well documented and include:

- i. Sustainable energy technology options such as renewable energy and energy efficiency require substantial up-front investments to be recouped over long lifetimes;
- ii. High transaction costs due to, for instance, a lack of standardization;
- iii. A lack of familiarity with the programs, key players and financial concepts;
- iv. Fragmented landscape of energy efficiency potential across many locations and users. As a study by McKinsey Global Energy and Materials put it: “[t]his dispersion ensures that efficiency is the highest priority for virtually no one.”²⁶⁹
- v. Measurement and verification of energy savings is difficult and performance uncertainties can stifle investment decisions.

²⁶⁵ Jacobsson, R., Jacobsson, S. (2012). The emerging funding gap for the European energy sector – will the financial sector deliver? *Environmental Innovation and Societal Transitions* 5: 49-59. Doi: 10.1016/j.eist.2012.10.002.

²⁶⁶ De Jager et al. (2011). Financing renewable energy in the European Energy Market. Ecofys: Fraunhofer ISI: TU Vienna: Ernst & Young, Project number: PECPNL084659.

²⁶⁷ This estimate was determined for the buildings sector in the European Union. The building sector represents the greatest potential to save energy as 75% of the building stock was constructed during periods with no or minimal energy-related building codes. In addition, buildings are long-term assets that experience low levels of turnover making retrofitting and investment in the existing building stock attractive energy saving options.

²⁶⁸ Parker, M., & Guthrie, P. (2016). Crossing the energy efficiency chasm: an assessment of the barriers to institutional investment at scale, a U.K. perspective. *Journal of Sustainable Finance & Investment*, 6(1), 15-37. doi: 10.1080/20430795.2016.1159650

²⁶⁹ Granade, H., Creyts, J., Derkach, A., Farese, P., Nyquist, S., & Ostrowski, K. (2009). Unlocking energy efficiency in the U.S. economy. McKinsey Global Energy and Materials, p. 9.

The investment decision-making process is complex (see Figure 3). An investment model that can fuel the MRDH transition pathways needs to systematically overcome market, institutional, economic, and financial barriers that currently hamper investment. In particular, as seen in the illustration, infrastructure-scale investment is constrained by a broad set of elements, including the drivers for the demand and supply of sustainable energy capital. The drivers are ranked based on importance.

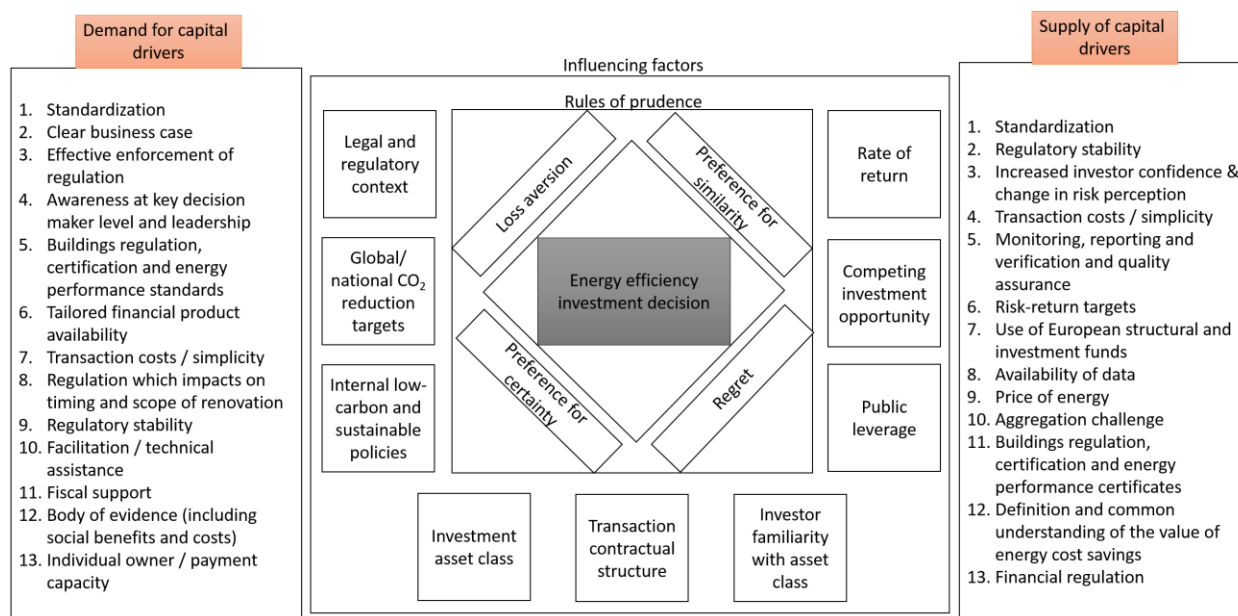


Figure 3. Overview of the decision-making process for infrastructure-scale energy efficiency investment, including the key drivers for both demand and supply of the necessary capital. ²⁷⁰

The SEF investment model is designed to comprehensively address the broad sustainable energy decision-making landscape depicted in Figure 1. To improve both investor confidence and generate a clear business case for the participants in the model, it helps to first discuss several of the core characteristics of the model:

- **Self-financing:** SEF economics do not require regulated price increases to cover renovation costs nor rely on taxes to capitalize renovation.

²⁷⁰ Sources: Parker, M., & Guthrie, P. (2016). Crossing the energy efficiency chasm: an assessment of the barriers to institutional investment at scale, a U.K. perspective. *Journal of Sustainable Finance & Investment*, 6(1), 15-37. doi: 10.1080/20430795.2016.1159650; EFIG (2015). *Energy Efficiency - The first fuel for the EU economy*.

- **Market-tested:** The SEF strategy draws from a \$72.5 million market-tested application that was rated AA+ by Standard & Poor's rating service. Other programs have since been implemented in California, Washington DC, and Pennsylvania.
- **Capable of unlocking a suite of technologies:** The mechanism can be applied to a wide range of different technologies. We provide a brief example of the use of the strategy for rooftop solar.
- **Flexible:** Different jurisdictions present different legal, policy and other conditions that require the financial mechanism to be adaptable to local circumstances.
- **Capable of offering a broad range of benefits.**

Self-Financing as a Basis for Capitalization

The SEF investment model has successfully overcome key barriers and delivered infrastructure-level scale investment at low cost. Conceived, designed, and launched by the leadership of the Foundation for Renewable Energy & Environment (FREE), the SEF investment model represents a best practice model recently highlighted by the International Energy Agency (IEA) Energy Technology Perspectives 2016.²⁷¹ Fundamentally, the SEF model is anchored by an economic perspective that builds on a basic principle of conservation: monetizing savings (whether energy, water, or materials) which cost less than paying the retail price as the source of its capital investments. Figure 4 illustrates this dynamic for a selection of U.S. states²⁷² and MRDH²⁷³: the gap between the cost to buy energy and the cost to save energy forms the basis for capital investment.

For example, a study of the institutional building stock in the Netherlands found retrofit costs of 2.9 – 3.3 €cents/KWh for lighting.²⁷⁴ In contrast, the 2015 cost of electricity was 19.7 €cents/KWh for households and 8.4 €cents/KWh for industry.²⁷⁵ Commercial and institutional buildings can expect retail prices of about 14.8 €cents/KWh.²⁷⁶ For lighting options, and for

²⁷¹ IEA (2016). Energy Technology Perspectives – toward sustainable urban energy systems. Paris: OECD Publishing

²⁷² Hoffmann et al. (2015). Total cost of saving electricity through utility customer-funded energy efficiency programs: price data Energy Information Administration (EIA) Monthly Energy Review.

²⁷³ For the MRDH region, cost to save energy is estimated in the illustrative case study example covered in this briefing paper. The cost to buy energy is derived from EuroStat electricity price statistics.

²⁷⁴ Sipma, J.M. (2014). Verbetering referentiebeeld utiliteitssector. Energy Center of the Netherlands (ECN). Cost to save energy calculated over 20-year lifetime (same as in original study) and 2% financing cost.

²⁷⁵ See http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

²⁷⁶ Ministerie van Economische Zaken (2014). Prijsvergelijk electriciteit. The Hague, Netherlands: Ministerie van Economische Zaken & PWC. Document available at:

many other technologies, the cost to save energy is considerably below the cost to use energy. This is particularly the case when a package of energy savings options are deployed at a large scale: economies of scale reduce procurement costs while expensive technology options are balanced out by technology options with short-term payback periods. For instance, PBL uses a 10%-25% cost reduction for portfolio deployment of energy saving options (in contrast to single project deployment).²⁷⁷

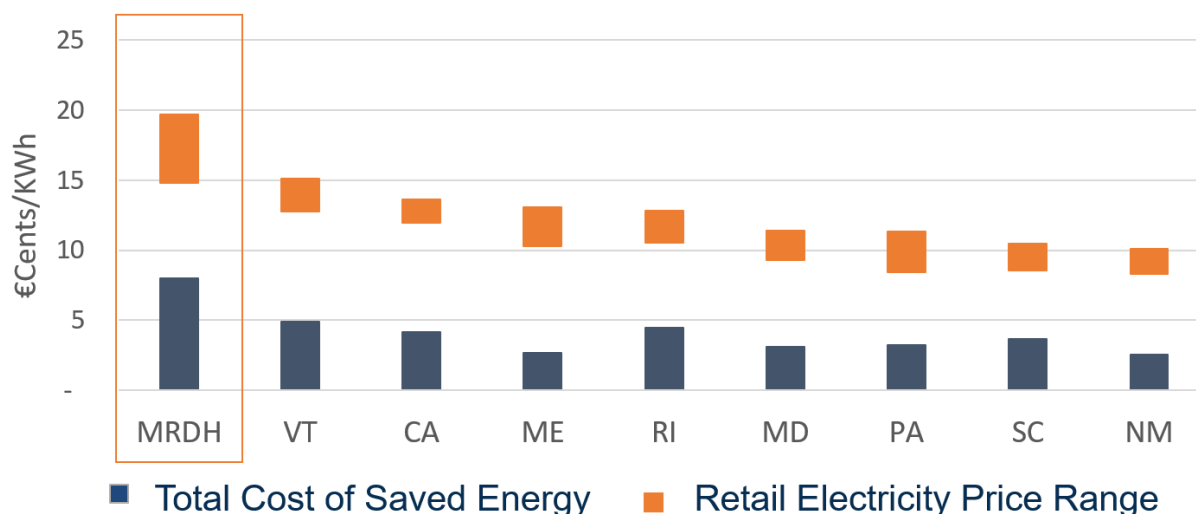


Figure 4. Simple representation of SEF economics. The gap between the cost to buy energy and the cost to save energy forms the basis for capital investment.

The capital investments are used to procure energy, water, and material conservation measures and on-site renewable energy options to lower SEF program participants' costs (SEF economics can be extended to include other technology groups such as energy storage, mobility, etc.). Measures are implemented up to the maximum point of savings that can be covered without raising the original energy costs of the program participant. This is conceptually illustrated in Figure 5.

<https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2014/06/01/prijsvergelijk-elektriciteit/prijsvergelijk-elektriciteit.pdf>

²⁷⁷ PBL (2014). Vesta; ruimtelijk energiemodel voor de gebouwde omgeving: data en methoden.

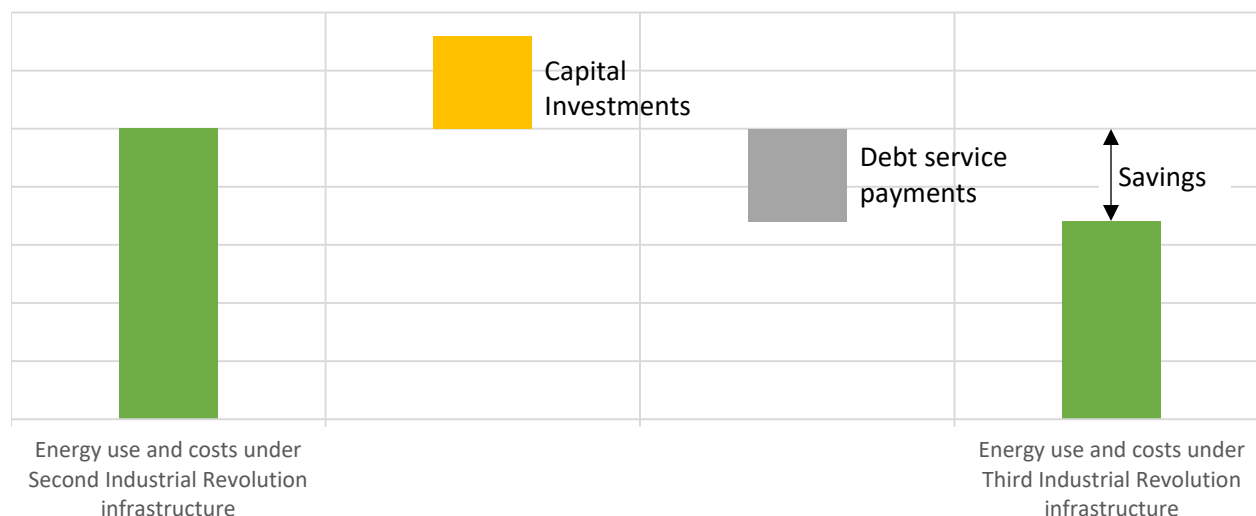


Figure 5. Conceptual overview of reduction of energy use and costs for program participants under SEF programming.

A Market-Tested Model: The Case of the Delaware Sustainable Energy Bond Series

The SEF investment model was first applied in the United States. Operationalized through the Delaware Sustainable Energy Utility (SEU)²⁷⁸ in the U.S. state of Delaware, on behalf of six state agencies and two institutions of higher learning, the Sustainable Energy Bond Series was issued in 2011. The issuance of the state-wide, tax-exempt bond issue raised \$72.5 million in sustainable energy capital from the private market, sufficient to invest in energy saving measures that deliver a guaranteed \$148 million in aggregate energy savings.²⁷⁹ All-in program costs, including capitalized interest over the serialized maturity of the financing, were \$110 million thus generating a \$37 million premium benefit for the program participants (Figure 6).

²⁸⁰

²⁷⁸ The SEU concept is the result of 20 years of research conducted by Dr. John Byrne and his colleagues at the Center for Energy & Environmental Policy (CEEP) at the University of Delaware. Additional information on the model can be found at <http://freefutures.org/seu-initiative/>.

²⁷⁹ Original planned issuance of the bonds stood at \$67.4 million. However, average coverage of orders and allotments by maturity of the DE SEU bond offering was 1.2x. In addition, the \$67.4 million par value Sustainable Energy Bond was oversold within two hours of its offering. The serial bond issue generated premiums in excess of \$5 million and sold at the low arbitrage yield of 3.67% over its 20 year debt service period.

²⁸⁰ The Delaware SEU example offers a guide to how what we call here the Sustainable Energy Finance (SEF) strategy can unlock significant energy savings when applied in a comprehensive strategy: a national application of the model in the U.S. along the same lines as described in this chapter would present a \$25 billion energy

Analysis of first year savings of the program finds that ESCO verified cost savings of all completed projects exceeds the 25% GESA guaranteed cost savings by 3%.²⁸¹ Importantly, utility bill savings analysis also found that performance year cost savings of the completed state projects are higher than the guaranteed cost savings by 3%. Annual energy savings for the DE SEU projects delivers an annual emission reduction of 46.8 million pounds of CO₂. Finally, research contrasting the Delaware SEF with conventional energy utilities in the United States finds considerable SEF outperformance in terms of realizing energy savings.²⁸²

The serialized maturity schedule of the DE SEU bond offering provides the opportunity of combining short-term and long-term retrofits: benefits from short-term retrofits help retire early debt service obligations and remaining future savings of these measures help accelerate long-term retrofit payback. As a result, the bond series was able to unlock deep retrofit opportunities: the average simple payback of the bond offering is 14 years with maturities as long as 20 years. Serialization in this manner also establishes cash flow optimization as the mixing of short-term and long-term maturities can engage lower overall interest rates. For example, the maturity schedule includes 1-year bond maturities at 0.65% borrowing rate all the way up to 20-year maturities (rate = 4.37%) for a 3.67% effective borrowing rate. Noting the strong general credit quality of the State of Delaware, the contractual guarantee provisions which include an absolute and unconditional payment provision upon annual appropriation,²⁸³ and annual payments that are date certain and not subject to acceptance, Standard & Poor's rated the sustainable energy bond at AA+.

investment market in the public sector alone (i.e. applying the model in municipalities, universities, schools, and hospitals). When applied at this level, approximately 300,000 additional green jobs and 225 million metric tons of greenhouse gas emission reduction could be realized. Source: calculations by authors.

²⁸¹ Chu, C., Bruner, A., Byrne, J. (2015). DESEU energy efficiency revenue bond series 2011: Project savings analysis. Newark, DE: Center for Energy and Environmental Policy. Report prepared for the Delaware Sustainable Energy Utility.

²⁸² Byrne, J., Taminiau, J. (2016). A review of sustainable energy utility and energy service utility concepts and applications: realizing ecological and social sustainability with a community utility. *Wiley Interdisciplinary Reviews: Energy and Environment*, 5: 136-154. Doi: 10.1002/wene.171.

²⁸³ Please note that "absolute and unconditional" is not the same as a general obligation: "[...] neither the state nor any political subdivision thereof shall be obligated to make payments on the bonds. Neither the faith and credit nor the taxing power of the state or of any political subdivision thereof is pledged to the payment of the principal or of the interest on bonds. The issuance of the bonds shall not directly or indirectly or contingently obligate the state or any political subdivision thereof to levy or to pledge any form of taxation whatever therefor, or to make any appropriation for their payment." (source: [Citi Post Pricing Commentary on the Delaware Sustainable Energy Utility](#).)

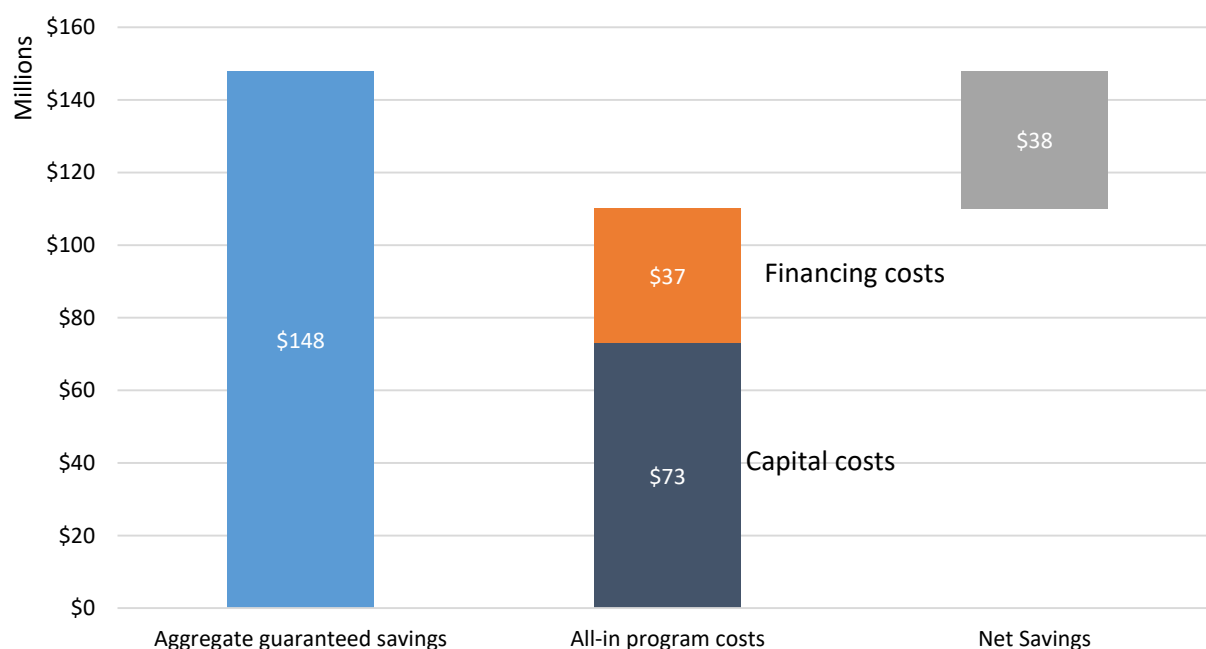


Figure 6. *Guaranteed savings exceed the all-in program costs, allowing a premium benefit to the program participants and Delaware. Numbers are for lifetime of the program.*²⁸⁴

Including other TIR Technologies: The SEF Model and Renewable Energy

Broadening the SEF strategy, FREE has developed a peer-reviewed framework that applies the investment model to renewable energy at scale. In particular, FREE has conceptualized a strategy for urban jurisdictions to implement decentralized solar PV at large-scale. Captured under the concept of ‘solar cities,’ an initial investigation and application of this framework has focused on the city-wide deployment of solar energy in large urban contexts.²⁸⁵ Positioned as a commitment to infrastructure-scale deployment, a solar city strategy essentially constructs an urban renewable energy power plant by utilizing the vast rooftop ‘real estate’ available in all cities.

Using a SEF financing strategy, analysis of the practical application of such a solar city strategy was conducted for three European cities (Amsterdam, Munich, and London) in addition to three

²⁸⁴ [Citi Post Pricing Commentary on the Delaware Sustainable Energy Utility.](#)

²⁸⁵ Byrne, J., Taminiau, J., Kurdgelashvili, L., & Kim, K. (2015). A review of the solar city concept and methods to assess rooftop solar electric potential, with an illustrative application to the city of Seoul. *Renewable and Sustainable Energy Reviews*, 41, 830-844. Doi: 10.1016/j.rser.2014.08.023

mega-cities (New York City, Seoul, and Tokyo). The study found *technical* potential for about 10.6 GWp and *economic* potential for about 3.2 GWp of PV in the six cities combined (economic potential is equivalent to about a \$10 billion investment opportunity).²⁸⁶

Preliminary calculation of the monetary benefits that an *economically feasible* deployment would yield suggest project lifetime benefits outstrip costs by about 4:1 when only the value of generated electricity and policy support is incorporated and a 6:1 ratio when system-wide benefits (e.g., peak shaving, grid decongestion) are considered.²⁸⁷

The analysis of the six cities shows that solar city application is a feasible strategy. In particular, high retail electricity prices and resulting grid parity conditions, existing policy support systems, a well-developed PV market, dense urban development, and high credit ratings benefit the viability of the approach. The analysis, for instance, showed for Munich that a 180 MW solar city deployment could cover debt repayments over a 12-year financing schedule without relying on policy support (Figure 7).

²⁸⁶ Byrne, J., Taminiau, J., Kim, K., Seo, J., & Lee, J. (2016). A solar city strategy applied to six municipalities: integrating market, finance, and policy factors for infrastructure-scale development in Amsterdam, London, Munich, New York, Seoul, and Tokyo. *WIREs Energy and Environment* 5, 1: 68-88. Doi: 10.1002/wene.182

²⁸⁷ Byrne, J., Taminiau, J., Kim, K., Seo, J., & Lee, J. (2016). A solar city strategy applied to six municipalities: integrating market, finance, and policy factors for infrastructure-scale development in Amsterdam, London, Munich, New York, Seoul, and Tokyo. *WIREs Energy and Environment* 5, 1: 68-88. Doi: 10.1002/wene.182

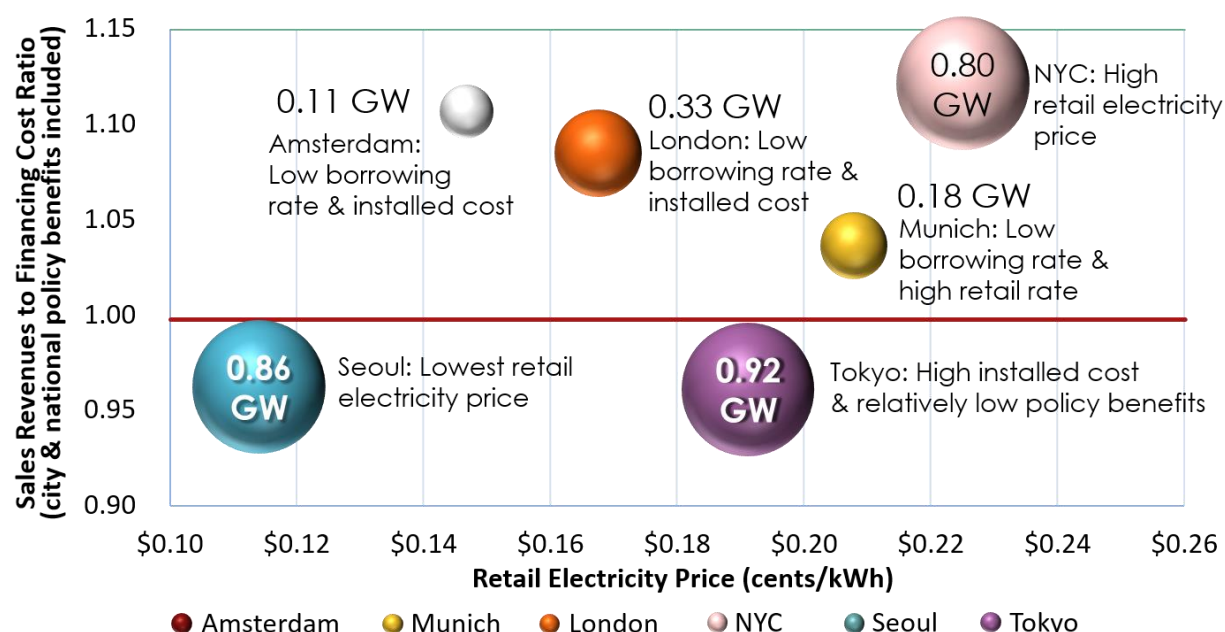


Figure 7. Overview of potential solar city application in six cities around the world under 12 year financing conditions.

An Investment Model that can be replicated to fit context-specific requirements: Diffusion of the Strategy

The SEF investment model has received endorsements from the White House²⁸⁸ and the Asian Development Bank.²⁸⁹ The SEF investment model – and the public authority model that forms the foundation of the investment model, i.e. the Sustainable Energy Utility – have received recent highlighting by the International Energy Agency (IEA) as being a model capable of driving urban energy transformation.²⁹⁰

In terms of its application to other contexts, the SEF investment model and the SEU authority model have diffused across the United States and globally.²⁹¹ SEF models are now active in

²⁸⁸ See: <https://www.whitehouse.gov/the-press-office/2011/12/02/we-cant-wait-president-obama-announces-nearly-4-billion-investment-energy>

²⁸⁹ See: <http://www.adb.org/sites/default/files/publication/29817/second-asia-pacific-dialogue-clean-energy.pdf>

²⁹⁰ IEA (2016). Energy Technology Perspectives – toward sustainable urban energy systems. Paris: OECD Publishing

²⁹¹ International investigation is, among others, documented in a 2009 special issue of the Bulletin of Science, Technology, and Society (Bulletin of Science, Technology & Society. Special issue: Sustainable Energy Utilities: new

Washington, D.C., Pennsylvania, and California. Seoul Metropolitan Government is actively considering implementation of the application.

An example of SEF diffusion and context-specific application is the Pennsylvania Sustainable Energy Finance Program (PennSEF, operated by FREE and partners).²⁹² PennSEF provides technical and legal assistance, as well as low-cost capital, for energy improvement projects by municipalities (including counties and governmental agencies), universities, schools and hospitals. For instance, the Regional Streetlight Procurement Program (RSLPP) (a program element of PennSEF), assembles the resources to design, procure and finance the transition to LED street lighting tailored to the specific needs of 40 municipalities in eastern Pennsylvania. These 40 municipalities together represent over 700,000 citizens. Technology cost reductions of up to 37% are available to the municipalities and more expensive technology options, such as internet connected street lighting for detailed monitoring, verification, and data analysis become available due to the pooled financing.

Additional Benefits of the Approach

- **Extra savings for program participants:** Under SEF program mechanics, ESCOs are incentivized to underestimate savings in order to meet, guarantee and avoid shortfall penalties. Typical underestimate guarantees 96% of estimated savings and savings continue to accrue beyond term of debt service to the benefit of program participants.²⁹³
- **Non-energy benefits accrue to participants:** Non-energy benefits (e.g., operational savings or deferred maintenance) can be as much as 40% or more of the total economic savings generated by such projects.²⁹⁴
- **Avoidance of interest cost penalties for small program participants:** Through pooled financing, the program avoids possible interest cost penalties for small jurisdictions.²⁹⁵

energy strategy for the new climate. Volume 29, No. 2). This special issue contains articles on SEU/SEF investigations in, inter alia, South Korean, Indian, and African development contexts.

²⁹² The Pennsylvania Treasury Department has partnered with the Foundation for Renewable Energy and Environment (FREE), with financial support from the West Penn Power Sustainable Energy Fund, to develop a prudent, market-based investment vehicle that promotes energy and water efficiency, clean energy generation, economic development and environmental improvement.

²⁹³ Shonder, J. (2013). Beyond guaranteed savings: additional cost savings associated with ESPC projects. Oak Ridge National Laboratory, ORNL/TM-2013/108.

²⁹⁴ Larsen, P.H., Stuart, E., Goldman, C.A. (2014). Current policies and practices related to the incorporation of non-energy benefits in energy saving performance contract projects. American Council for an Energy Efficient Economy Summer Study 2014.

- **Overcomes geographic segmentation:** Overcoming issuer size segmentation can also overcome geographic segmentation as pooled financing opens access to national/international markets to attract capital.²⁹⁶
- **Economies of scale opens technology options:** Pooled financing realizes economies of scale in the procurement of energy conservation and renewable energy technology. Opens up technology choices unavailable to individual participants.
- **Unlocks deep retrofits:** Energy conservation measures with short paybacks ('low hanging fruit') can be used to unlock 'deep' retrofit options. 'Deep' retrofit options (i.e., measures with long payback periods) provide significant savings potential – case study analysis by Rocky Mountain Institute of 'deep' retrofit success stories found an average 58% energy use reduction.²⁹⁷
- **Technology portfolio approach:** Programs can include a wide array of energy, water, and material conservation measures (electrical and thermal), combined heat and power (CHP), distributed generation (e.g., solar PV), microgrids, smart energy management, and transportation infrastructure.
- **Ease of participation:** The SEF public authority, through its financial advisors, bond counsel, and co-chairs provides technical and financial assistance to participants from the initial project scope to financial close.
- **Trains the market for transformative change:** Finally, the structured approach outlined in the SEF strategy primes the market, including ESCOs, issuers, bondholders, and program participants, for future deployment of follow-up bond issuances. In other words, the approach trains ESCOs to operate at a scale previously inaccessible to their project-to-project business model, educates bondholders about the benefits and potential of the program, and brings in future program participants. In effect, the program creates and nurtures an energy conservation and on-site renewable energy market that positions these energy resources as infrastructure-scale options and trains all involved to reconsider these energy choices in this manner.

²⁹⁵ Empirical evidence for the interest cost penalty for smaller jurisdictions is provided by: a) Simonsen, B., Robbins, M., & Helgersen, L. (2002). The Influence of Jurisdiction Size and Sale Type on Municipal Bond Interest Rates: An Empirical Analysis. *Public Administration Review*, 61(6), 709-717. doi:10.1111/0033-3352.00141; and, more recently, b) Bastida, F., Guillamó, M.-D., Benito, B. (2014). Explaining interest rates in local government borrowing. *International Public Management Journal*, 17:1, 45-73. Doi: 10.1080/10967494.2014.874257

²⁹⁶ Bastida, F., Guillamó, M.-D., Benito, B. (2014). Explaining interest rates in local government borrowing. *International Public Management Journal*, 17:1, 45-73. Doi: 10.1080/10967494.2014.874257

²⁹⁷ Rocky Mountain Institute (RMI) (2015). Deep energy retrofits using energy savings performance contracts: success stories. Rocky Mountain Institute, Boulder, CO.

The Technical Workings of the SEF Investment Model

A critical component of the SEF tool is its capitalization strategy which involves the creation of a public authority or the use of an existing authority that can raise required capital. Such capital raises can be in a variety of forms (e.g., loans or bonds). The Delaware example above used the issuance of sustainable energy bonds, backed by appropriation, as a key pathway towards capitalization of the energy conservation measures and renewable energy installations.

However, the primary strength of the SEF investment model lies in its program mechanics and the provisions of the agreements therein. To accommodate demand for sustainable energy financing, FREE has developed two variants of the SEF investment model: a) a guaranteed energy savings variant; and b) sustainable energy services variant. As described below, the two variants of the model operate in a similar fashion. The key difference between the two variants is the structuring of energy savings and billing. In particular, debt raised under the guaranteed savings variant is placed on the books of the program participants. Such debt obligations are typically less attractive to the private sector and, indeed, this variant of the model has been successfully applied in a public sector context. The guaranteed energy savings model does allow for more aggressive energy savings and unlocks longer investment options with longer payback periods.

The second variant, the sustainable energy services option, bills the cost of energy savings on a per kWh basis to the program participant. This bill can be an add-on to existing municipal billing (e.g., waste, sewer, etc.). Program participants, under this variant of the model, do not carry the debt on their books – they have only an obligation to provide payment for delivered services. Paying off investments through monthly or bi-monthly billing cycles (much like a power purchase agreement but now for savings), the approach is typically more attractive to the private sector. However, overall, the second variant is less capable of unlocking very aggressive savings opportunities.

The Guaranteed Energy Savings Option

The guaranteed energy savings variant has been market-tested in the Delaware example (outlined above). Figure 8 provides a schematic of the program mechanics associated with the variant and outlines the relationships between program participants, energy service companies (ESCOs), the sustainable energy bond issuer, and the bondholders or loan providers. These relationships are as follows:

- 1) A public (or public-private) authority aggregates demand for sustainable energy services from the public (e.g., local governments, non-profit organizations) and private sector.
- 2) The participants enter into Guaranteed Sustainable Energy Savings Agreements (GESAs) with ESCOs. GESAs describe conservation services and onsite clean energy generation services and defines service performance guarantee(s). Guarantees are expressed in monetary amounts.
- 3) Participating organizations, ESCOs, and the Issuer enter into multi-year, performance-based Program Agreements outlining data reporting, criteria for measurement of services, job creation, etc.
- 4) Issuer (i.e. the public authority or an existing authority partnering with the public authority) enters into Instalment Payment Agreements with participating organizations. Participating organizations agree to make payments for installation of on-site clean energy and energy efficiency upgrades.
- 5) Issuer issues (tax-exempt) by-appropriation bonds secured by payments under the Instalment Payment Agreement. Alternatively, the issuer engages with loan providers to raise the level of capital required.

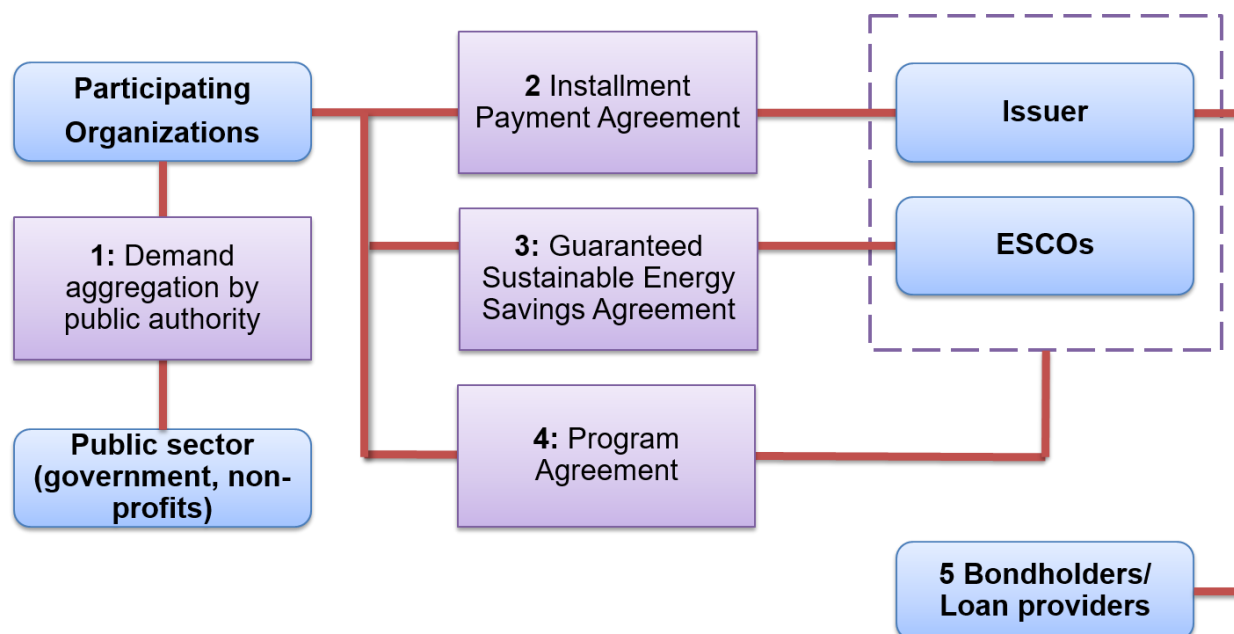


Figure 8. Simplified program mechanics of the SEF approach targeting the public sector. Agreements / relationships are numbered and provided in the body text of this briefing paper.

The SEF Sustainable Energy Services Variant

The second variant of the SEF investment model incorporates components and lessons learned from tested financial frameworks such as on-bill financing, property assessed clean energy (PACE), and power purchase agreements. As mentioned, this approach is typically seen as more attractive to the private sector due to its handling of the debt. The program mechanics of this variant are described in Figure 9. This variant operates in much the same way as the first variant:

1. A public authority aggregates demand from the private (e.g., residential, commercial, and industrial) and public sectors.
2. The issuer enters into Sustainable Energy Services Agreements with these participating organizations. Participants agree to pay issuer for the sustainable energy services (including conservation and onsite clean energy generation) delivered during the term of the agreement.

3. Issuer (i.e. the public authority) enters into Service Performance Agreements with ESCOs. Agreements describe conservation measures and onsite clean energy generation, and define performance guarantee(s).
4. Participating organizations, ESCOs, and issuer enter into multi-year, performance-based Program Agreement outlining data reporting, criteria for measurement of services and job creation.
5. Issuer will issue (tax-exempt) bonds secured by payments under the Sustainable Energy Services Agreement.

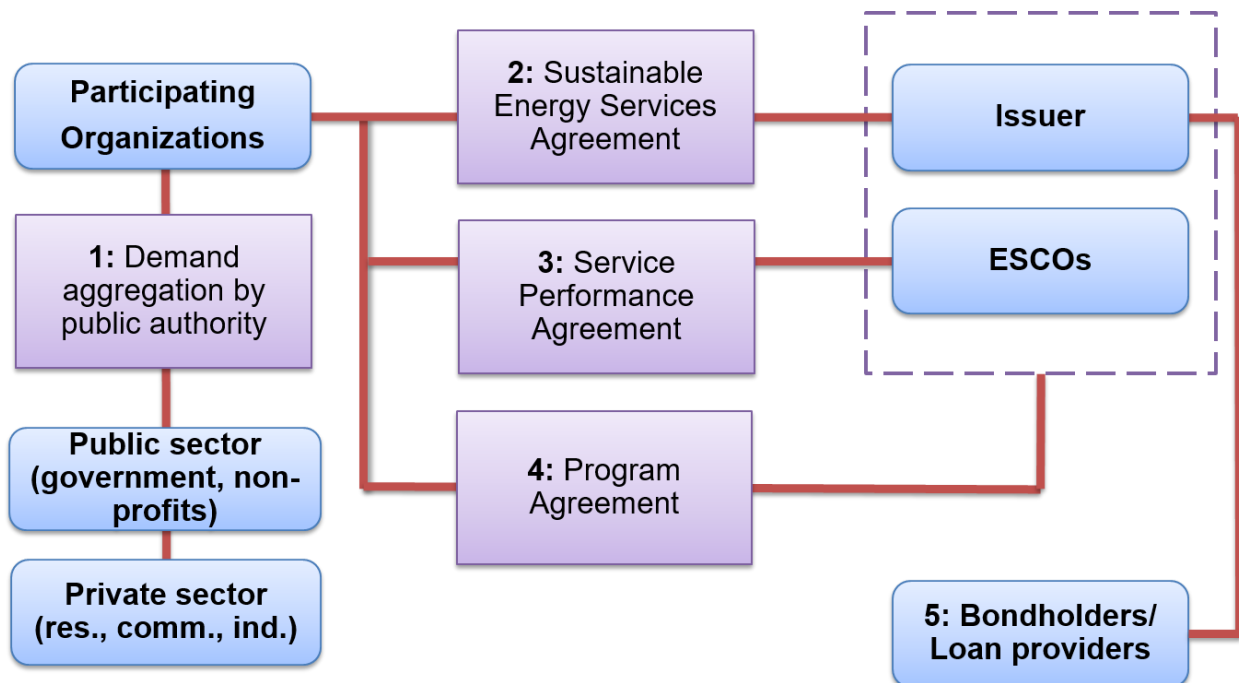


Figure 9. Simplified program mechanics of the SEF approach targeting the private sector. Agreements / relationships are numbered and provided in the body text of this briefing paper.

The SEF Model Overcomes Pervasive and Challenging Barriers

A critical first benefit of the SEF investment model, regardless of which variant is deployed, is that the strategy avoids the practice of many governmental and regulatory programs currently in use which assess end users for funds that conventional utilities operate to meet sustainability goals. As such, SEF economics do not require regulated utility price increases to cover

renovation costs. SEF economics similarly does not rely on taxes to capitalize renovation but reaps social advantages such as benefiting low-income households.

A critical second benefit of the investment model is that it is market-tested (see above). Investors, credit risk managers, program participants, and other parties involved have favourably evaluated the investment model. For instance, Standard & Poor's rating agency rated the Delaware sustainable energy bond at AA+ and investors oversubscribed the bond issuance in under two hours (yielding a \$5 million premium). Further testament to the favourable evaluation of the SEF investment model:

- a) Delaware plans to introduce a second \$75 million bond to the market in 2016;
- b) The White House recognized the strategy in its Better Buildings Challenge; and
- c) The International Energy Agency (IEA) recently highlighted the value of the approach, particularly for driving urban energy transformation.²⁹⁸

The SEF investment model provides sufficient flexibility to adapt it to new contexts. The model, and its public authority backing in the form of the SEU, has been successfully applied in different jurisdictions with different characteristics. Investigation of the model is ongoing in a variety of jurisdictions as well. Finally, the investment model can be widened to include a broad range of other technology options. FREE has been actively investigating the use of the investment model for, particularly, solar photovoltaic (PV) technology in urban contexts.

In terms of the challenges and barriers outlined in Figure 3, the SEF investment model answers many of the challenges and barriers outlined (Table 3).

Table 3. Overview of the benefits provided by the SEF approach in relation to the challenges raised in Figure 3.

	CHALLENGE	SEF APPROACH
SUPPLY & DEMAND	<i>Standardization</i>	<i>Uses a common, standardized documents platform.</i>
	<i>Transaction costs / simplicity</i>	<i>Project pooling yields document and rating cost economies of scale.</i>
SUPPLY	<i>Increased investor confidence & change in risk perception</i>	<i>Guaranteed Energy Savings Agreement provides guaranteed Euro savings that exceed financing costs.</i>
	<i>Definition and common</i>	

²⁹⁸ IEA (2016). Energy Technology Perspectives – toward sustainable urban energy systems. Paris: OECD Publishing

	<i>understanding of the value of energy cost savings</i>	
	<i>MRV and quality assurance</i>	<i>In accordance with the GESA, ESCOs performance use internationally recognized M&V protocols. If it appears that Euro savings are falling short, the ESCO is committed to use its best efforts to remedy the performance failure. Failing that, the ESCO must pay for the shortfall.</i>
	<i>Price of energy</i>	<i>Lowers costs due to lower cost to save energy than to use energy. Fixed escalation of energy, water, or materials rates determined by the program.</i>
	<i>Aggregation challenge</i>	<i>SEF public authority aggregates participant demand.</i>
	<i>Lender's approach to risk assessment</i>	<i>No cross collateralization or risk associated with involvement of participants with lower credit ratings.</i>
DEMAND	<i>Tailored financial product availability</i>	
	<i>Appropriate timing for energy efficiency measures within the traditional building cycle</i>	<i>Customized and serialized financing optimization.</i>
	<i>Facilitation / technical assistance</i>	<i>The SEF public authority acts as one-stop-destination for program participants and has access to a trusted advisor.</i>
	<i>Fiscal support</i>	
	<i>Individual owner / payment capacity</i>	<i>All program costs are paid within the bond issue. Participants face no upfront costs.</i>
	<i>Aggregation challenge</i>	<i>SEF allows cities, counties, and other jurisdictions to aggregate their buying power in order to procure sustainable energy supplies. The SEF strategy, as such, follows a community choice aggregation pathway.</i>

Regulatory, Policy, and Market Considerations Associated with the SEF Investment Model in the MRDH Context

Under the SEF approach envisioned for the MRDH, a public authority is established that aggregates sustainable energy demand and raises required capital to fund the identified energy saving and renewable energy opportunities. Alternatively, the approach could use an existing public authority to raise the funds (e.g., Bank Nederlandse Gemeenten) or a public-private

partnership could be established to perform this function. For instance, in the case of the Pennsylvania Sustainable Energy Finance Program (PennSEF, operated by FREE and partners²⁹⁹) an existing authority – the Pennsylvania Economic Development Finance Authority – is used to issue the bonds. This illustrates the flexibility of the model as it can both rely on the creation of new authorities with bond issuing authority (i.e. the Delaware example) or can rely on existing authorities (the PennSEF example).

In terms of community demand aggregation, the approach could also rely on existing networks, private agencies, and public authorities. The investment model, as a whole, is flexible and can be adapted to the context in which it is applied. Overall, the function of the model is to:

- a. overcome fragmented decision-making by relying on an authority dedicated to sustainable energy problem-solving 24/7 (either newly established or already existing);
- b. pool project investments into cost-efficient financing scales; and
- c. bring such financing portfolios to bond holders or loan providers;

The SEF model relies on a separate organization that acts as a trusted advisor that can provide technical, legal, policy, and financial assistance. In addition, the trusted advisor offers independent, objective monitoring and verification of investment performance and identifies actions needed to comply with the savings guarantee.³⁰⁰

The Metropolitan region of Rotterdam and The Hague offers an excellent test bed jurisdiction for a SEF strategy. MRDH can also serve as a springboard that allows for later replication of the approach to other cities/regions in the Netherlands and abroad.

Relevant Market Conditions

The Energy Service Company (ESCO) market in MRDH – indeed, across the Netherlands – is in its early stages. Rotterdam, however, stands out, according to the World ESCO Outlook, as it was the first major property owner to enhance the sustainability of its building stock through

²⁹⁹ The Pennsylvania Treasury Department has partnered with the Foundation for Renewable Energy and Environment (FREE), with financial support from the West Penn Power Sustainable Energy Fund, to develop a prudent, market-based investment vehicle that promotes energy and water efficiency, clean energy generation, economic development and environmental improvement.

³⁰⁰ FREE has performed the role of trusted advisor in its programs in the U.S. and Asia.

the use of ESCOs.³⁰¹ The nascent ESCO market faces competing market factors such as the implementation of grants, voluntary agreements, and comparable services provided by government agencies.³⁰²

While data on energy saving efforts and agencies is scarce, the market potential is significant. For instance, an investigation into the energy savings potential of the Dutch institutional building stock found technical savings potentials of 37% and 64% for gas and electricity use, respectively. Similarly, a study for the residential building stock found a 39% reduction potential for both gas and electricity use.³⁰³ Achievable through ‘deep’ retrofits, such 30%-40% energy savings throughout the building stock of the country represent multi-billion Euro investment opportunities.

The SEF investment model operates at an infrastructure-level scale that requires strong partners. For example, the Sustainable Energy Bond Series issued in Delaware were underwritten by Citi. Similarly, the bond offering relied on the strong AAA credit profile of the state of Delaware. In terms of ESCOs, similarly strong partnerships will be required. As such, as part of the overall strategy, MRDH could advance the ESCO market, certify proper training and performance, guarantee early adoption with the transformation of all government and public buildings into Internet of Things nodes, and provide government-supported training for thousands of semi-skilled, skilled, and professional workers that will be needed to transform the MRDH building and other asset stock.

MRDH Renewable Energy and Energy Efficiency Policy Context

In terms of the built environment, a key policy in the Netherlands that seeks to drive energy efficiency is the continuous strengthening of the standards for new construction.³⁰⁴ The result is that new construction, as a whole, is on track to meet required energy saving targets and

³⁰¹ Also see Hufen, H., de Bruijn, H. (2016). Getting the incentives right: energy performance contracts as a tool for property management by local government. *Journal of Cleaner Production*, 112(4): 2717-2729. Doi: 10.1016/j.jclepro.2015.10.036

³⁰² Bertoldi, P., Boza-Kiss, B., Panev, S., & Labanca, N. (2014). *European ESCO Market Report 2013*. Joint Research Centre Science and Policy Reports. Publication by the European Commission.

³⁰³ Tigchelaar, C., Leidelmeijer, K. (2013). *Energiebesparing – een samenspel van woning en bewoner*. Energy Center of the Netherlands (ECN).

³⁰⁴ ECN, 2015. *Energy efficiency trends and policies in the Netherlands*.

policies.³⁰⁵ However, in terms of the existing residential and non-residential building stock, PBL notes that efforts are lagging behind established targets.

A key policy tool in the MRDH built environment context is energy labelling of existing and new construction buildings. Energy labels provide homeowners, renters, social housing agencies and others with information regarding the building's energy performance. However, the baseline ('nul-meting')³⁰⁶ established in a recent MRDH report notes:

- a) The limited application of the policy tool: on average, only 31.9% of the building stock in MRDH has received a label; and, more importantly,
- b) The low performance of the building stock that has received an energy label: scores reported by the baseline analysis do not perform better than a "C" score, many are labelled "D" and even one is considered an "E" score (energy labels range from "A++", the best performance evaluation, to "G", the worst performance level).

The baseline analysis shows much room for improvement in the built environment. While respondents to a periodical survey performed by Energy Centre Netherlands (ECN) indicate willingness to invest in energy saving measures, particularly to capture cost savings and improve comfort, they simultaneously indicate that a) lack of financial resources and b) lack of knowledge of who best to contract with to perform energy saving measures, are key barriers limiting investment.³⁰⁷ However, evaluation of policy tools that provide such knowledge, particularly energy audits, but do not extend beyond that have been found to have limited effect.³⁰⁸ Additional elements that limit the effectiveness of such policy tools are the time and transaction costs borne by the homeowner, for instance in finding and applying for financial incentives, and the idiosyncratic nature of energy audits (the quality of energy audits can differ substantially from one auditor to the next).³⁰⁹

³⁰⁵ PBL, 2014. Energie besparen gaat niet vanzelf – evaluatie energiebesparingsbeleid voor de gebouwde omgeving. Den Haag: Planbureau voor de leefomgeving.; ECN & Rigo (2013). Energiebesparing: een samenspel van woning en bewoner – Analyse van de module Energie WoON 2012.

³⁰⁶ Van Lente, R. (2015). Inventarisatie duurzaamheidsbeleid metropoolregio en Provincie Zuid-Holland. Den Haag.

³⁰⁷ ECN & Rigo (2013). Energiebesparing: een samenspel van woning en bewoner – Analyse van de module Energie WoON 2012.

³⁰⁸ Murphy, L. (2014). The influence of energy audits on the energy efficiency investments of private owner-occupied households in the Netherlands. *Energy Policy* 65, pp. 398-407. Doi: 10.1016/j.enpol.2013.10.016

³⁰⁹ Palmer, K., Walls, M., O'Keeffe, L. (2015). Putting information into action: what explains follow-up on home energy audits? Washington, DC: Resources for the Future.

A similar perspective emerges when evaluating the Dutch renewable energy market and policy context. The 2013 Netherlands' Energy Agreement sets the Dutch ambition to realize 14% of renewable energy in the energy mix by 2020 and uses the Sustainable Incentive Scheme (SDE+) as the key driver to meet this target. The SDE+ is a market-sensitive FIT with a technology neutral budget. Least-cost renewable energy technology options have been particularly able to take advantage of the support mechanism. Rotterdam and The Hague make up 12.8% and 13.2% of the installed PV capacity in MRDH, putting both cities in the top 20 in the Netherlands. However, at a combined 54.9 MWp,³¹⁰ MRDH still has significant potential to expand its reliance on solar PV for energy supply.

In order to accelerate energy savings in MRDH, therefore, a comprehensive strategy, such as found in the SEF investment model, is required that delivers guaranteed savings, carries most of the time and transaction costs (which are rolled into the bond offering), and prequalifies auditors and installers. In addition, the SEF investment model relies on a trusted advisor that performs detailed monitoring and verification of energy savings to diagnose performance and, where needed, obligate energy saving companies (ESCOs) to make up for the shortfall.

Education

The SEF investment model raises implementation of sustainable energy and other technologies to a level of infrastructure-scale change. By operating a series of such capitalization rounds, the model trains all market participants to reconsider project-to-project level change as large-scale, infrastructure-level programming and respond accordingly. FREE has found that public and private program participants, ESCOs, investors, installers, etc. benefit from education days where the program is clearly articulated and outlined. Such education days cover all elements of the SEF financing model but in a tailored format suitable to the target audience. Education days can be preceded by a series of online material that is made available to program participants.

Financial Estimate of SEF Application in the MRDH Context

The Netherlands is AAA rated, establishing solid context for the strategy outlined in this briefing paper. The robust rating could, as was done in the case of Delaware, provide credit risk

³¹⁰ Van Lente, R. (2015). Inventarisatie duurzaamheidsbeleid metropoolregio en Provincie Zuid-Holland. Den Haag.

mitigation services through, for instance, partly aligning credit risk with the national or provincial counterparts to MRDH.

Existing funding channels could be tapped to help set up and, perhaps, operate the SEF platform. Examples of such funding channels are:

- European Energy Efficiency Fund: this €265 million fund provides debt and equity instruments to local, regional and (if justified) national public authorities or public or private entities acting on their behalf.
- European Investment Bank: In 2007, the European Investment Bank (EIB) pioneered the green bond option and, to date, the EIB is the largest green bond issuer with €10 billion issued. Of particular interest in the context of a MRDH SEF approach is the EIB's repositioning of its role in the green bond market: green bond issuance is now an "autonomous strategic goal" of the EIB's Corporate Operational Plan 2015-2017. The EIB's Climate Awareness Bond (CABs) series is a solid example of this new objective: the EIB is building a benchmark yield curve and has, so far, issued five CABs in EUR to raise the profile of the market. The current CAB yield curve sports three benchmarks: a) one €400 million issuance at 11/2019 (4 years) maturity and 1.34% interest; b) two 11/2023 (8 years) issuances, one €400 million and the other €600 million, both at 0.5% interest; and c) two 11/2026 (11 years) issuances at €250 million each and both at 1.25% interest. The EIB is, therefore, well positioned to support the SEF approach.³¹¹
- Project Development Assistance: the European Commission has set up different facilities to support the development and launch of ambitious and replicable energy efficiency projects such as ELENA (grants to local and regional authorities to develop and launch large-scale sustainable energy investments) and PDA (helps public and private project promoters develop sustainable energy investment projects).

Possible Setup of a MRDH SEF Platform: Opening Two Financing Windows

Under the setup outlined here, the MRDH SEF platform acts as a one-stop-destination for financial contributors and project promoters alike. The flexibility of the model allows for various organizational setups whether they rely on existing agencies and partnerships or the creation of a new authority. The chosen organizational construct should be sensitive to the Dutch and

³¹¹ The roll-out of further green bonds is supported by the market's increasing attention to environmental and financial integrity through the Green Bond Principles. However, to use the green bonds as a part of a larger collective action strategy, the market will be reliant on further efforts to maintain current standards. Support policies could be formulated at the EU level to advance the market.

MRDH context. The resulting authority delivers energy efficiency, load reduction services, clean energy supply, material savings, transportation investment, digitalized monitoring and verification and a range of other TIR technologies and options.

One possible setup is to establish a public authority that resembles the Sustainable Energy Utility (SEU) model as implemented in the United States. Structured as a not-for-profit public authority (or public-private partnership), such a setup would be seen to:

- Serve a public mission, providing sustainable financing for sustainable development at infrastructure-scale;
- Justify public seed funding and other forms of state-backing for risk financial mitigation and technical assistance due to its public mission statement;
- Tailor access to context-specific financing to project promoters (e.g., national and local government, civil society, private sector, public-private partnerships) and enable access to investable projects for financial contributors (e.g., pension funds, impact investors, insurance companies, etc.) as it serves as an interface between these two groups.

The setup could employ the two variants as developed by FREE by opening two financing windows (Figure 10). These financing windows could advance sustainable energy implementation in the residential, commercial, industrial, and public sectors while tailoring flexibility to program participants. Overall, the program mechanics would be similar as outlined above.

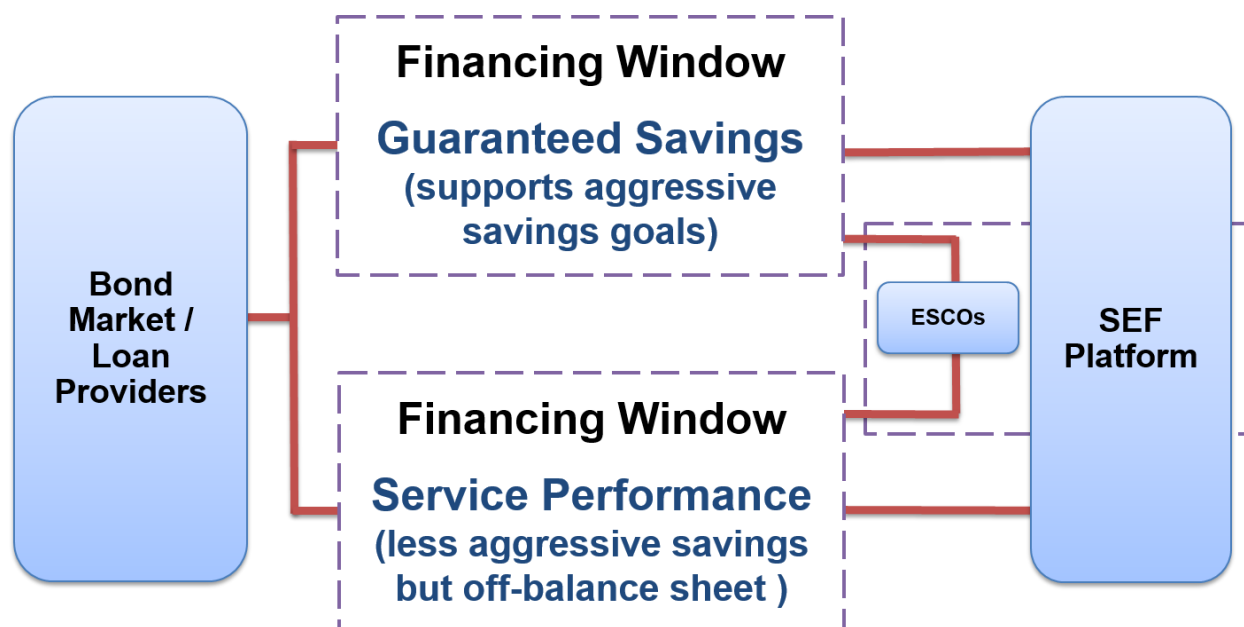


Figure 10. Overview of the program mechanics of a MRDH SEF approach. Investment offerings are made to both the public sector and the private sector. Connections illustrate relationships between participating organizations, ESCOs, bondholders/ loan providers and the SEF platform.

Evaluating SEF Application in MRDH: Case Study Analysis of Solar PV and Energy Productivity

A case study analysis was conducted to illustrate the SEF approach for the context of MRDH. The case study analysis covers energy efficiency improvement potential and on-site renewable energy opportunity. Results provided in this section serve illustrative purposes: further research is required to develop detailed market estimates and financial overviews.

The case study analysis proceeds through several steps:

- First, the analysis seeks to determine the market potential for both energy productivity in the built environment and rooftop solar PV;
- Second, using a peer-reviewed assessment framework developed by FREE, the section outlines a phased strategy for energy productivity investment and a similar strategy for solar PV.
- Finally, key findings are summarized.

Estimating Built Environment Electricity Efficiency Market Potential

The existing built environment is a key focal point of an energy use reduction strategy. As discussed, targeted policy efforts have been successful in upgrading new construction standards and ensuring new construction meets consistently more stringent energy specifications. As indicated in a policy analysis by the Dutch Planbureau voor de Leefomgeving (PBL), new policy efforts so far have only partially accelerated retrofitting of existing buildings.

³¹² At current retrofit rates, stated policy targets are difficult to meet. Current retrofit rates are tripled in some of the scenarios developed by PBL.

The residential building stock data in MRDH compares to a little over 1 million buildings. Of this, about 420,000 qualify as single-family homes while the rest are multi-family housing. The residential building stock is relatively old: about 48% of the residential building stock was constructed prior to 1970, 39% between 1970 and 2000, and the rest since 2000.

Data from LISA was used to add about 118,000 non-residential buildings to the analysis.³¹³ Non-residential building stock could not be disaggregated by construction year. The residential building stock can be disaggregated by construction year and type (single family or multi-family):

- The database of residential buildings consists primarily of multi-family buildings (roughly 627,000 buildings) instead of single-family housing (roughly 424,000 buildings);
- The building stock is relatively old: 42% of single-family and 53% of multi-family buildings has been constructed before 1970. This is particularly true for the Rotterdam and The Hague building stock;

Using PBL data, annual electricity consumption of MRDH residential buildings was estimated at 3.75 TWh. Using estimates for heating, water, and cooling services (i.e. primarily natural gas use), the additional annual energy consumption of the residential sector was estimated at 4.9 TWh/year for single-family housing and 3 TWh/year for multi-family housing. This puts the total for the residential sector at 11.7 TWh/year. In terms of non-residential energy consumption (not including industry) an estimate of 8.6 TWh/year was calculated.

Estimating Rooftop Renewable Energy Potential

³¹² Vringer, K., van Middelkoop, M., Hoogervorst, N. (2014). Energie besparen gaat niet vanzelf – evaluatie energiebesparingsbeleid voor de gebouwde omgeving. PBL: Den Haag.

³¹³ LISA-bestand (<https://www.lisa.nl>).

Application of the solar city concept is explored here for MRDH. Several studies have explored the rooftop potential at the national level for the Netherlands.³¹⁴ A 2014 Planbureau voor de Leefomgeving study estimates a total rooftop space of about 600 square kilometres, of which 400 square kilometres could be available for solar PV installation.³¹⁵ Under their assumptions, this space is equivalent to a technical potential of about 66 GWp (50 TWh of electricity). For comparison, the 2014 installed capacity level in the entire country was 0.7 GWp. Indeed, overall, electricity production would be higher than national consumption (effectively establishing the Netherlands as a whole as a net production country). The technical potential would, according to the 2014 PBL study, overwhelm the capacity of the Dutch electricity grid due to regional and local imbalances between production and consumption. As such, they estimate that anything above 20 GWp would require grid modifications or generation caps during peak moments. The application of smart grid technologies could extend the feasible potential by another 8 GWp.

To determine the suitable rooftop space, the 2014 PBL study relies on numbers from Vreugdenhil (2014). The same numbers were used in the determination of the technical potential for MRDH. The overall method applied to calculate the market potential is derived from a study conducted by FREE researchers.³¹⁶ Using the same building stock data as reported under the energy productivity market potential estimate, a total 14.9 million square meters of single-family housing rooftops and 10.6 million square meters of multi-family housing rooftops is suitable for PV installation in the MRDH. Similarly, after considering the number of floors per building (a so-called ‘stapelfactor’), an additional 7.5 million square meters of non-residential rooftop space is considered PV suitable. These numbers account for obstacles and rooftop angles but do not yet incorporate factors such as shading effects (either architectural shading consequences or panel-to-panel obstructions) and PV system service requirements. Accounting

³¹⁴ Van Sark, W. (2014). Opbrengst van zonnestroomsystemen in Nederland. Utrecht: University Utrecht.; Vreugdenhil, C. (2014). Een studie naar het potentieel van PV in Nederland. Wageningen: WUR.; Tuominen et al. (2012). Energy savings potential in buildings and overcoming market barriers in member states of the European Union. *Energy and Buildings* 51: 48-55. Doi: 10.1016/j.enbuild.2012.04.015

³¹⁵ PBL (2014). PV potentieelstudie: het potentieel van zonnestroom in de gebouwde omgeving van Nederland. The Hague: PBL.

³¹⁶ Byrne, J., Taminiau, J., Kurdgelashvili, L., & Kim, K. (2015). A review of the solar city concept and methods to assess rooftop solar electric potential, with an illustrative application to the city of Seoul. *Renewable and Sustainable Energy Reviews*, 41, 830-844. Doi: 10.1016/j.rser.2014.08.023; Byrne, J., Taminiau, J., Kim, K., Seo, J., & Lee, J. (2016). A solar city strategy applied to six municipalities: integrating market, finance, and policy factors for infrastructure-scale development in Amsterdam, London, Munich, New York, Seoul, and Tokyo. *WIREs Energy and Environment* 5, 1: 68-88. Doi: 10.1002/wene.182

for these factors puts total (residential and non-residential) rooftop space available for PV deployment at a suitable tilt angle at 14 million square meters.

Self-Financed Energy Productivity in MRDH: a Full Potential and Phase 1 Scenario

The market potential analysis provided above can be translated into a savings potential by relying on empirical evidence of performance of energy saving measures. The analysis incorporates the following elements:

- The analysis includes the notion that older buildings can drive larger levels of energy savings due to their typically lower levels of current performance;
- The analysis excludes 50% of the pre-1970 residential building stock to account for restrictions surrounding historic or architecturally significant buildings; and
- The analysis excludes savings potential in relatively newly constructed buildings as the literature review presented above indicates that new construction typically aligns with well-established energy performance labels. As such, residential buildings since 2000 have been excluded from the energy savings potential analysis.

The analysis calculates a *Full Potential* scenario and a *Phase 1* scenario. The Full Potential scenario presents the results if all residential and non-residential buildings are available for retrofitting (but retaining the three exceptions listed above). To illustrate a more practical first step, the Phase 1 scenario outlines the results if 20% of the Full Potential result can be strategically applied in a SEF investment model. The results for these analysis are provided in Figure 11. A Full Potential deployment of energy saving measures would yield about a 25% reduction in MRDH energy use (about 4.3 TWh per year). Savings estimates per building type and construction year vary from 25%-45%. This is consistent in relation to case study analysis of deep retrofit performance where 40%-60% energy use reductions have been observed.³¹⁷

³¹⁷ Rocky Mountain Institute (RMI) (2015). Deep energy retrofits using energy savings performance contracts: success stories. Rocky Mountain Institute, Boulder, CO.

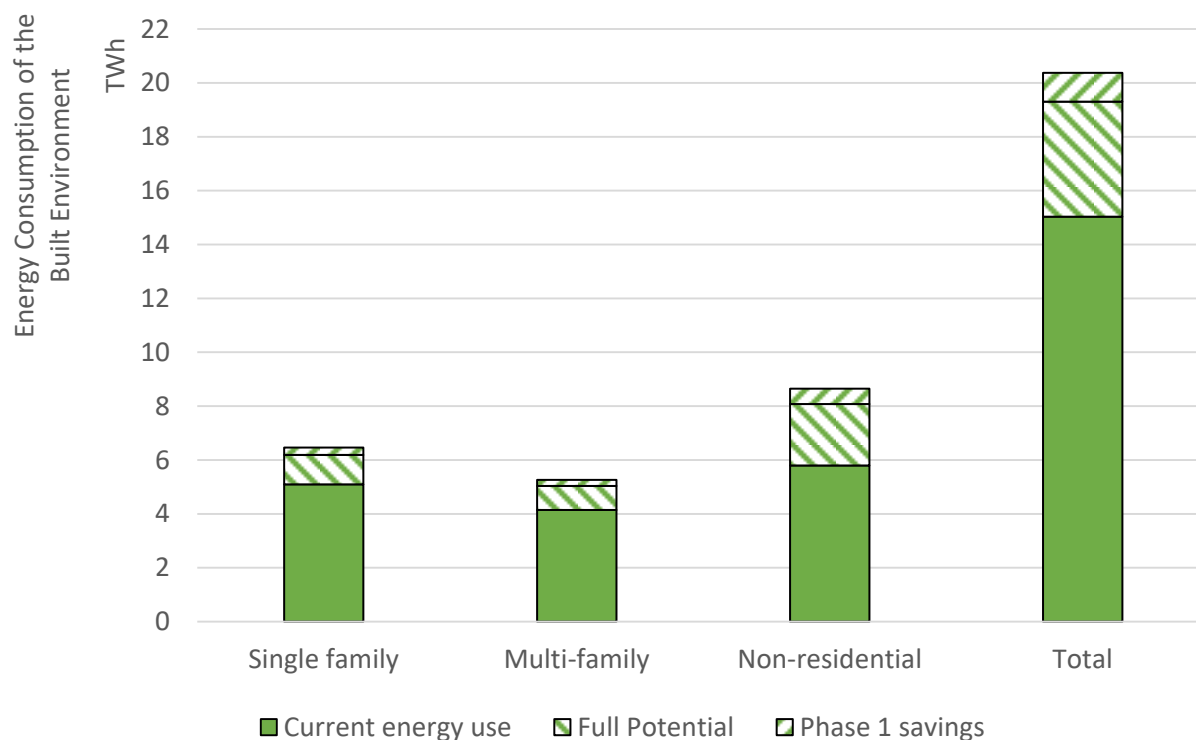


Figure 11. Overview of Phase 1 and Full Potential savings potential in the MRDH built environment.

In terms of estimating the cost of retrofitting the building stock, the analysis incorporates that older buildings are likely more expensive to retrofit than newer buildings. However, cost estimates are also adjusted to account for the programmatic nature of the proposed program: a SEF investment round would include a large number of buildings, would absorb many of the time and transaction costs into the financing, would likely substantially reduce ESCO costs (e.g., search costs to maintain ESCO pipelines are significantly reduced), and could spread costs out over a larger timeframe than typically accepted by private actors. Accounting for these factors yields a total investment potential of about €6.6 billion in the Full Potential analysis and €1.3 billion in Phase 1. Importantly, such an investment potential relates to self-financing energy saving measures where the avoided cost is equal or greater than the debt service to repay the bond/loan.

Self-Financed Solar PV in MRDH: Transforming the Urban Environment to a Solar PV Power Plant

The rooftop area suitable for PV installation can be translated to an overall potential to deploy PV. Here, too, we constructed both a *Full Potential* and a *Phase 1* scenario to illustrate the possibilities for MRDH. Using the FREE peer-reviewed assessment framework, installation potential can be estimated: A Full Potential deployment corresponds to about 2.82 GWp of solar PV (about 2.62 TWh/year) while a Phase 1 deployment is equal to 0.56 GWp (0.52 TWh/year). These results are illustrated in Figure 12. The results shown for Amsterdam, Rotterdam, and The Hague are for the residential building stock only (non-residential building stock was not available in the LISA source at this level of government). The results for MRDH can be compared to the findings for the Metropolitan Region of Amsterdam (MRA).

In terms of an investment opportunity, the estimated Full Potential represents a €6.0 billion investment while the Phase 1 scenario presents about a €1.2 billion option.

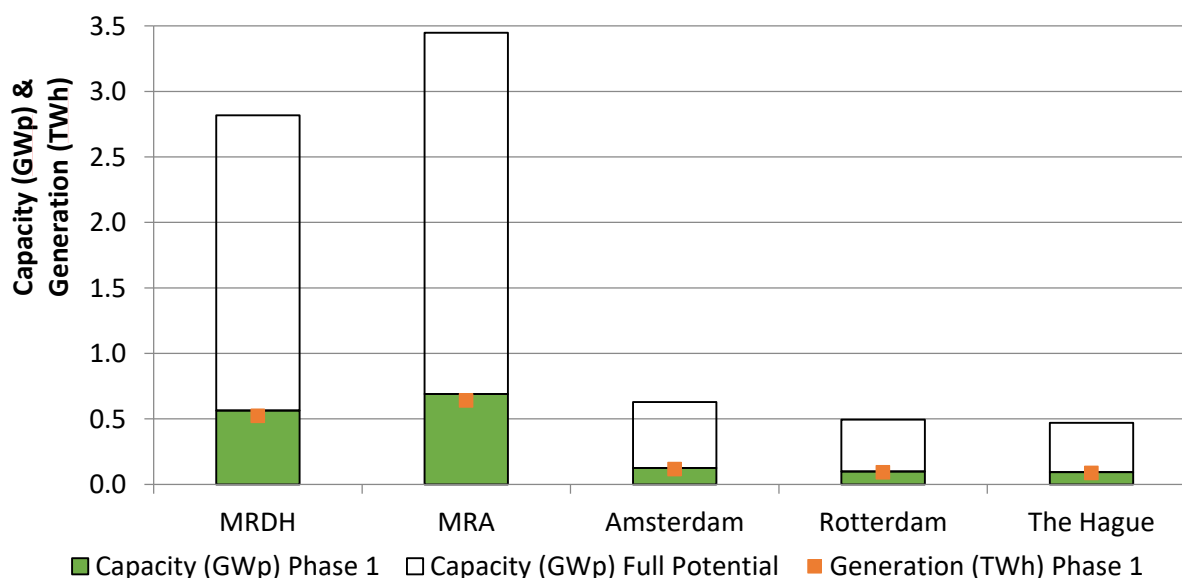


Figure 12 Overview of the MRDH solar PV potential (Phase 1 and Full Potential). For illustrative purposes, the calculations for the Metropolitan Region of Amsterdam is also provided. The contribution to total solar PV provided by Rotterdam, The Hague, and Amsterdam are for residential building stock only. The MRDH and MRA results are for both residential and non-residential building stock. The analysis used 20% module efficiency and a 25 degree tilt for solar system installation.

TIR – FREE Initial Estimate of Energy-related Investment and Impact

Deploying the combined energy productivity and solar PV contribution estimated above presents a significant self-financing opportunity. Insight into this opportunity can be gained by plotting the contribution of energy productivity improvements and solar PV installations on the electricity use of MRDH (Figure 13). Electricity consumption data are obtained from Tennet Netherlands. National data are adjusted to MRDH on a per GDP basis. Clearly, the combined effect of these two technology options can substantially affect the MRDH energy profile. Combining the contribution of these two technologies with other TIR technologies (e.g., energy storage, digitalized monitoring and verification, etc.) could further transform the energy profile.

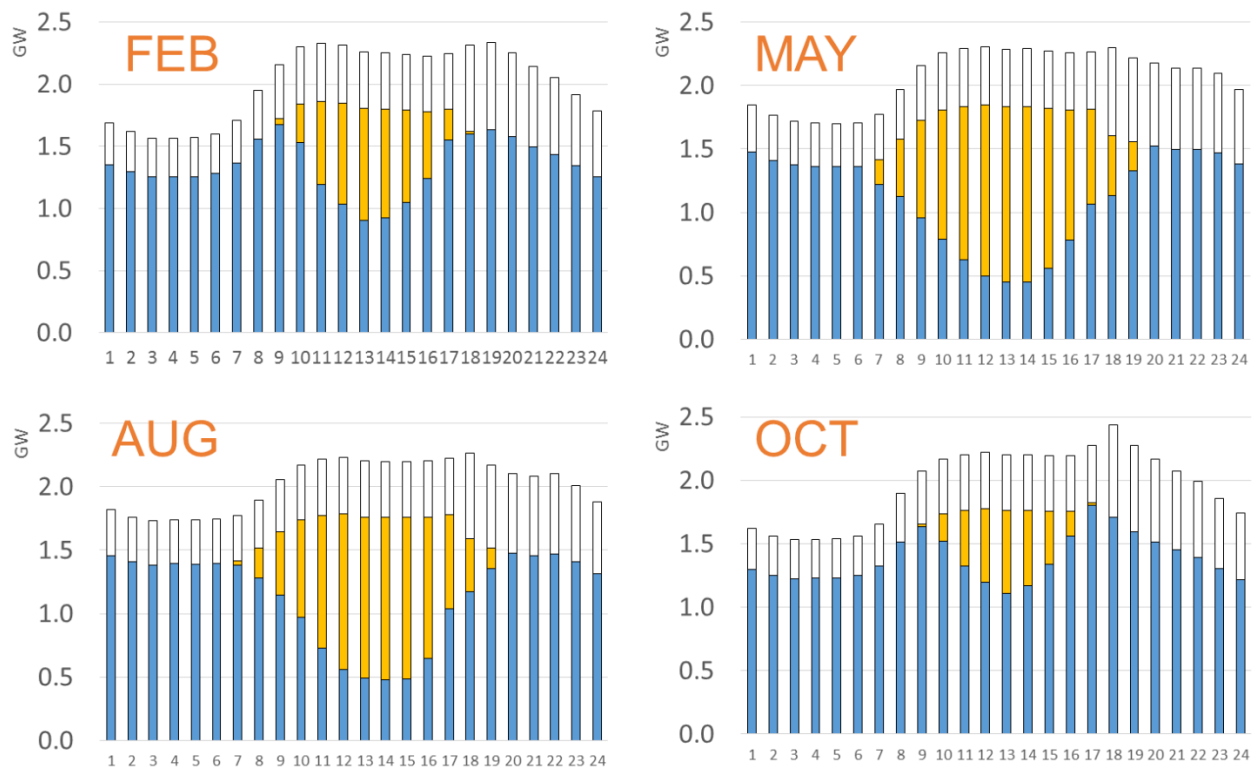


Figure 13. Load curve contribution of a combined energy productivity and solar PV strategy using the SEF investment model. The white bars are the contribution of energy efficiency (lowering energy consumption across the day) while the yellow bars illustrate the contribution of solar PV. Solar systems show stronger performance in summer months than in winter months. The contribution of energy efficiency improvements is here illustrated to be stronger in evening hours than it is during the day, largely due to the inclusion of a large number of residential buildings. Energy efficiency improvements are

estimated to lower consumption in evening hours by 30% while 20% during the other hours of the day. PV peak shaving calculated for a 2.82 GWp at a 25 degree tilt.

Research and Development (R&D) Considerations Associated with the SEF Investment Model in the MRDH Context

The case study example outlined in this briefing paper focuses on energy productivity improvements and rooftop solar PV. Of course, many additional TIR technologies are available that can be funded through the SEF investment model (e.g., on- and off-shore wind, energy storage, mobility improvements, etc.). New technologies (e.g., microfinancing, blockchain, crowdfunding, digitalization of infrastructure, transport, etc.) offer opportunities that can be connected to the SEF investment model. Intelligent linking of the various technologies can accrue knock-on benefits that accelerate the TIR transition.

For example, SEF financing could benefit from technologies that allow for real-time, digitalized measurement and verification (M&V) to pin-point peak shaving opportunities, harvest additional energy saving, ensure investor confidence due to enhanced data analytics, and diagnose any potential energy saving shortfalls.³¹⁸ Automated M&V refers to using customer-facing energy information systems (EIS; also called energy and management information systems or EMIS) that not only enable savings – through pre-measure detection of savings potential, for instance – but also automate the quantification of whole-building energy savings relative to a baseline period.³¹⁹ A big part of the promise of the new approach is its power in scale and precision: while it remains unlikely that measurements of energy savings will ever match precision levels for measuring energy consumption, a portfolio of energy conservation measures, supported by automated M&V, could achieve a very high degree of certainty. An approach that uses automated, software-based systems to determine energy savings stands in sharp contrast with conventional M&V options: what can be called a “widget-based” approach where accounting of savings is done for each additional piece of machinery or technology (e.g.,

³¹⁸ Rogers, E., Carley, E., Deo, S., & Grossberg, F. (2015). How Information and Communications Technologies Will Change the Evaluation, Measurement, and Verification of Energy Efficiency Programs. Washington, DC: American Council for an Energy Efficient Economy (ACEEE).

³¹⁹ Granderson, J., Price, P., Jump, D., Addy, N., & Sohn, M. (2015). Automated measurement and verification: performance of public domain whole-building electric baseline models. *Applied Energy*, 144, 106-113. doi:10.1016/j.apenergy.2015.01.026

higher efficiency lighting) through engineering estimates.³²⁰ Streamlining and automation of M&V efforts could reduce costs compared to traditional processes which typically rely on building engineering expertise and have limited scalability. In addition, the combined deployment of such technologies could advance investor confidence.

Proposal for Application of SEF Model in the MRDH

MRDH can substantially advance its mission statement by deploying TIR technologies at an infrastructure-scale, and the SEF investment model presents a suitable and fitting approach to implement such change. The approach envisioned for MRDH can be initiated by following a series of steps and processes.

First, the SEF investment model relies on an authority that has the capability of borrowing low-cost capital from either the capital markets or a loan provider. As discussed in the briefing paper, the SEF investment model is flexible as to the organizational setup of this authority: it can be a newly established public authority specifically designed for this purpose or it can function as part of an existing authority. For example, the Delaware SEU represents an example of a public authority specifically designed to advance sustainable energy in Delaware while the PennSEF program relies on an existing authority. In any case, the authority needs to have the capability or access to an existing public and/or private network to organize and structure finance, aggregate demand, and establish project portfolios at infrastructure scale.

Second, the authority will need to rely on a team of technical, legal, financial, and policy experts that, among others, a) assists in the formulation of standardized contractual arrangements (as provided in the program mechanics above) that represent all parties involved; b) that performs a diagnostic monitoring and verification (M&V) function to ensure any potential shortfall in performance is made whole by the ESCOs; c) is not profit oriented and represents program participants; and d) navigates the complex landscape of technical developments, legal complications, financial aspects, and policy change.

Third, the SEF platform prequalifies ESCOs based on their capacity to fulfil program operations. Relevant qualifications of ESCOs are elements such as their market size, pricing, experience with large-scale projects, etc. In doing so, the SEF platform provides a strong market signal to the ESCO market to develop in the direction of providing infrastructure-scale services for

³²⁰ Kramer, H., Russell, J., Crowe, E., & Effinger, J. (2013). Inventory of Commercial Energy Management and Information Systems (EMIS) for M&V applications. Portland, Oregon: Northwest Energy Efficiency Alliance / Portland Energy Conservation, Inc.

decentralized users. This step of prequalification addresses some of the time and transaction costs currently limiting individuals to engage in energy efficiency improvements.

Fourth, the authority engages community participants (residential, commercial, industrial, and public) to inform them of the two open financing windows and their benefits. Importantly, the authority here will rely on a 'boots on the ground' team that can maintain close relationships with the community participants.

Fifth, interested and eligible community participants sign a non-binding letter of interest (LOI) and discuss their specific goals, timeline, energy patterns, etc. with the SEF team. The interested parties are informed about the prequalified ESCOs.

Sixth, the authority brings together pre-selected ESCOs and interested program participants. ESCOs perform a no-cost, pre-contract audit and present initial energy savings potential.³²¹ Participants sign guaranteed energy savings agreement with their selected ESCO. Guaranteed energy savings agreement includes an investment grade audit, a construction proposal, a savings guarantee, and a proposal for measuring and reporting savings each quarter.

Seventh, the authority brings the bond offering to market to fund the capital expenditures of the selected energy conservation measures and on-site renewable energy options (and any other TIR technologies included in the portfolio). No upfront costs are required from any of the program participants. Guaranteed savings cover all program costs. Transaction costs, such as origination fees, are covered by the bond offering.

Eighth, the SEF investment strategy, can be extended to the rest of the Netherlands. With its first mover advantage, MRDH can play an important leadership role in this diffusion process. MRDH can, for instance, recommend regions and other member states to establish similar kinds of public authorities, specialized to the context of those communities.

Evaluating the Proposal in Two Dimensions

When considering the implementation of a SEF investment strategy to support the MRDH Roadmap Next Economy, it is helpful to visualize the proposal along two key dimensions: potential value and ease of implementation. As provided in the illustration below, the SEF investment strategy can be considered a "flagship proposal" (i.e. a proposal that MRDH can proceed to fund, design, build, and implement as a highest priority). A scoring methodology

³²¹ FREE has developed specific model approaches for government participants that need to meet procurement guidelines.

relying on a set of value and implementation factors was used to arrive at the illustration. The SEF investment strategy for the MRDH achieves 93/100 points under the scoring method.

The scoring breakdown is provided below:

Proposal “1”: A Sustainable Development Finance Strategy:

Value Factors

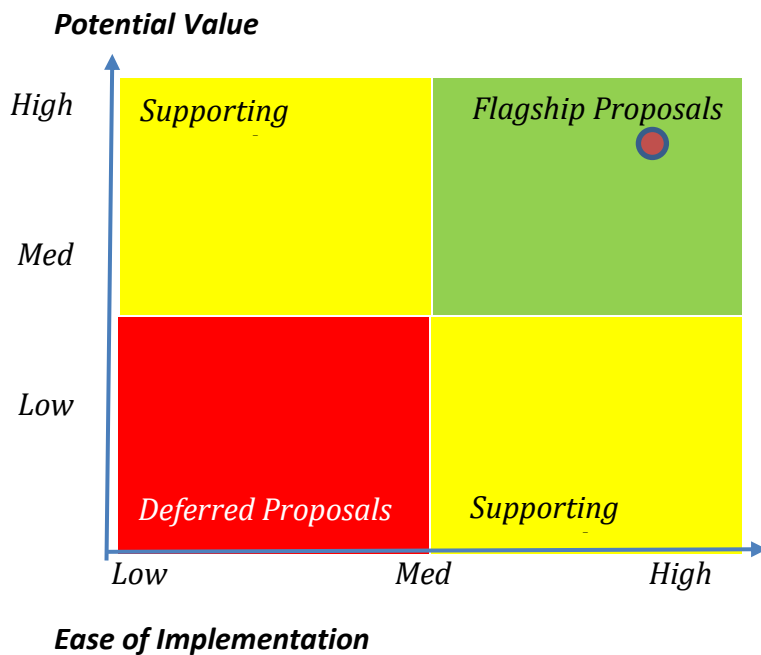
- Reduces final energy consumption: Assigned score is High (5), Weighting is 2, total score is **10**
- Reduces CO₂ emissions: Assigned score is High (5), Weighting is 3, total score is **15**
- Increases % of renewable energy: Assigned score is High (5), Weighting is 2, total score is **10**
- Provides knowledge in subsequent projects: Assigned score is High (5), Weighting is 1, total score is **5**
- Supports multiple TIR pillars: Assigned score is High (5), Weighting is 1, total score is **5**
- Strengthens MRDH assets: Assigned score is Med (3), Weighting is 1, total score is **3**

Total Value Score = **47** points (y-axis).

Implementation Factors

- Technology commercially available: Assigned score is High (5), Weighting is 1, total score is **5**
- Requires specialized skills or partners: Assigned score is Med (3), Weighting is 1, total score is **3**
- Provides an upscalable platform: Assigned score is High (5), Weighting is 2, total score is **10**
- Requires minimal decommissioning: Assigned score is Med (3), Weighting is 1, total score is **3**
- Can be self-funded: Assigned score is High (5), Weighting is 3, total score is **15**
- Requires little start-up time: Assigned score is High (5), Weighting is 2, total score is **10**

Total Implementation Score = **46** points (x-axis).



Flagship Proposals – Proceed to fund, design, build, and implement as a highest priority. Ex: Proposal “A”

Supporting Proposals – Secondary focus, but should be included as potential value-add, but only after Flagship Proposals move forward. Ex: Proposal “B”

Deferred Proposals – Not ready for implementation, but should be documented and periodically reviewed. Ex: Proposal “C”

Blockchains: Conception and Execution

There are many challenges to overcome before this distributed super-structure can be constructed, but perhaps the biggest is the foundation of a new trust protocol. The centralized legacy systems of the Second Industrial Revolution inherently imbued trust in the institutions and people that dominated the economy – the public utilities, the large banking systems, and the top-down organizations that controlled society’s businesses, government agencies, and educational institutions. But in breaking up that system, there will need to be a different social architecture. Without some standard by which to assure ourselves that contractual obligations will be met, that the electronic devices executing those obligations are properly identified and authorized to do so, or that the digital information produced and shared by these transacting machines is accurate, we cannot build this new, distributed economy.

While the Sustainable Infrastructure Finance Platform (SIFP), the Resource Aggregation Authority, and the Sustainable Energy Finance (SEF) Strategy provide a framework for organizing and financing the transition to a Third Industrial Revolution Roadmap Next Economy, a new technology – the Blockchain – will be critical to establishing the public trust to invest significant funds in the build out and scale up of a Third Industrial Revolution infrastructure.

The Blockchain, the distributed ledger technology that underpins Bitcoin and other digital currencies by creating a transparent, immutable record of changes in valuable information, introduces new thinking and applications that go far beyond finance, and far beyond Bitcoin itself. Blockchains (“capital-b” for the Bitcoin Blockchain and “small-b” for other blockchains) should be thought of as general-purpose platform technologies, creating a distributed trust protocol that allows a distributed or semi-distributed economy to flourish. It represents an indispensable base-level infrastructure for social and process governance that can unlock the collaborative innovation that drive gains in aggregate efficiency and economic growth in the Third Industrial Revolution. This is why the information that follows can be applied to more or less all the verticals and transitional pathways that Rotterdam and The Hague are looking to transform – again, including but not limited to, finance.

Over the past year, mainstream interest in blockchain technology has surged internationally. Google searches for the word “blockchain” show a hockey-stick-like exponential surge. The world’s biggest banks, largest consulting firms, most influential non-government organizations and, recently, leading national and regional governments and central banks are all investing in and exploring blockchain technology’s potential. There is widespread belief that it will usher in sweeping new efficiencies globally by cutting out waste and middlemen and empowering end-

users and startup innovators. Blockchain solutions are now being applied to everything from the real-time settlement of stocks and bonds to the copyrighting of digital music.

In this way, the Blockchain breakthrough heralds the Internet's next evolutionary phase and provides the best existing technology case for effectively realizing the Third Industrial Revolution. The first phase, led by the development of the World Wide Web in the 1990s, vastly distributed and opened access to information. However, that left in place an uneven playing field dominated by rent-extracting gatekeepers, ensuring that inefficiencies and a lack of interoperability persisted, simply because the Internet could not solve society's dependence on a centralized system of trust. While Internet technology pressed forward, it was ironically locked into an aging trust paradigm unsuited to the nature of its very self. Hence, like many processes before it, inefficiencies and rent-seekers were all it *could* know.

In this second, blockchain-led phase, developers are building the so-called "Internet of Value," a system of peer-to-peer information exchange founded on a distributed trust network with distributed governance. Based on a core, decentralizing algorithm, the blockchain is generating new paradigms of trust and accountability and evolving into a borderless, ownerless architecture upon which myriad new applications will be based. Just as Silicon Valley and other regions that led the Internet's first phase of infrastructure building were assured of developing the explosive array of business applications that were later built up on it, so too will the pioneers in this Internet of Value phase be rewarded with rich new opportunities.

In this next phase of network infrastructure building, the emphasis will be on integrating it into the physical world. The present phase is about how to mediate, collate, measure and analyze the valuable data being generated by the billions, possibly trillions, of gadgets and sensors that comprise the Internet of Things and how to assure that their inputs and outputs can be reasonably trusted, for it is trust in the system that generates and unlocks value. Moreover, it offers a chance for regions that have long been involved the manufacture and, most importantly, trade and exchange of things, to lead this new development.

The global goods trade is, of course, the Netherlands' historical forte; more to the point, it's Rotterdam's *raison d'être*. And because the port city and The Hague have already invested in the modernization of that trading infrastructure, they present ideal lead locations for integrating this new trust protocol.

There is significant work to be done testing and perfecting blockchain technology. Already, there is an intense debate brewing over what kind of ownership and control structure should be hard-written into its core software. However, the world is not sitting back and waiting for

that to be resolved by itself. No one cluster of companies, no educational institution, and no government has yet claimed the mantle for driving what is ultimately an open-source, global process of discovery. This means that regions that spearhead development and adoption of the blockchain will not only gain an upper hand in global competition but will also set the agenda as to how it develops and is regulated. They will profit most from the ability to export the knowledge and expertise they accumulate.

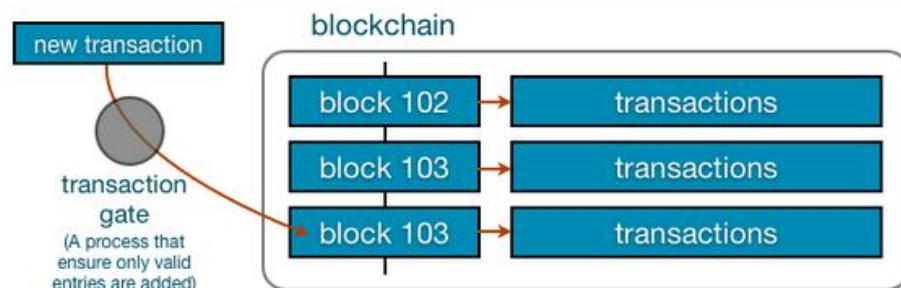
This is a first-adopter's moment; and the Metropolitan Region of Rotterdam and The Hague can seize it.

Blockchain Explained

As enthusiasm for this technology has grown, the word "blockchain" has been attached to a wide array of distributed ledger technologies. Indeed we must differentiate the "capital-B" Blockchain which underpins the Bitcoin digital currency, from "small-b" blockchains which are developed for other uses.

How blockchain works

A blockchain is a database shared by every participant in a given system. The blockchain stores the complete transaction history of a cryptocurrency or other record keeping system.



Transactions aren't recognized until they are added to the blockchain. Tampering is immediately evident, and the blockchain is safe as record because everyone has a copy. The source of discrepancies is also immediately obvious.

Image Source: <http://www.zdnet.com/article/how-blockchain-is-likely-to-change-it-and-business-forever/>

Many blockchains differ quite significantly from bitcoin's unique design, which were aimed at removing the need for a centralized third-party in peer-to-peer transactions, as laid out in Satoshi Nakamoto's White Paper.³²² That has spurred debate about whether these newer models deserve the "blockchain" label. MRDH officials will need to weigh the pros and cons of each model, but to understand the true, transformative and disruptive possibility of these technologies, it is important to review the fundamentals of the original (Bitcoin) version. To that end, we look here at the four pre-existing technologies that come together to form bitcoin as a novel whole.

Peer-to-peer file sharing. Distributed file-sharing networks, such as Bittorrent, allow an authenticated file or series of files to be distributed among multiple nodes that communicate equally with one another across a flat network architecture over which no entity has control. Bitcoin uses that idea and extends it. Its case, the file – constituted as a token of value or digital currency evolves over time, with ownership transferred in a distributed way.

Public Key Infrastructure: The exchange of public keys and their management via associated private keys is the foundation of secure identity on the Internet. Bitcoin was the first implementation of PKI that made no attempt to integrate with the legacy forms of identity. In the Blockchain, which was set up as an append-only ledger that's publicly broadcast to all nodes on the network, the "identity" of users engaged in a transaction is established as the outcome of a relationship between certificates. The parties to a transaction alone identify the devices/certificates that will participate in the exchange. This was the first form of secure digital identity without participants having to trust in the centralized and human-administered Certificate Authority framework.

Hashcash (commonly referred to as Proof of Work): Invented by Adam Back, Hashcash, which was originally developed as a spam-reducing measure for email, requires a computer that is sending a message to do a certain amount of computationally intensive work that can be easily verified by the receiving computer - a trivial problem for sending a single email but a prohibitively expensive one for a spammer sending millions. Bitcoin adapted Hashcash as a proof-of-work algorithm to prevent any of the many computerized "miners," which voluntarily join the network to validate transactions on the Blockchain, from deploying an unlimited number of nodes and corrupting the consensus system that secures the ledger's integrity.

³²² Nakamoto, S., "Bitcoin: A Peer-to-Peer Electronic Cash System," released October 31, 2008.
<https://bitcoin.org/bitcoin.pdf>

Virtual currencies and Meta-Assets (Bitcoin, et al): To incentivize miners to gather up the authorized transactions initiated via the Blockchain's public key infrastructure and populate them as an update to the public ledger, the bitcoin algorithm provides rewards. These are defined as a certain amount of algorithmically created virtual currency + transaction fees, awarded to the first miner to resolve the proof-of-work computing puzzle in each roughly 10-minute "block" period. The random distribution of the puzzle results means rewards are meted out much like a lottery: a miner can increase their chances of winning by adding computational capacity but that strategy becomes prohibitively expensive at a scale necessary to assure more wins than losses. Since Bitcoin's beginning in 2009, this incentive/disincentive system has prevented any one miner from taking charge of the ledger, ensuring -- in a distributed manner - the ongoing integrity of a record that now runs to 120 million transactions and a market capitalization of more than \$10 billion.

In combining these elements, the elusive Satoshi Nakamoto created the first truly censorship-resistant, or tamper-proof, ledger: the Blockchain. This was a centuries-in-the-making breakthrough in finance, since people could now transact directly with each other without the intermediation of a "trusted" third party to confirm their respective balances. In parallel, it was a process that could only be born of the Internet.

Bitcoin as a currency for peer-to-peer payments was the first use case for the Blockchain. It soon became apparent that other forms of property and stores of valuable information could be converted into digital assets in this system and transferred directly between peers in a verifiable way. There has been an explosion of ideas around this concept, especially in finance.

Since Bitcoin's launch, other blockchain designs have been developed with different approaches to solving the consensus mechanism. Some of these blockchain spinoffs use a Bitcoin-like "permissionless" system in which anyone is free to participate as a miner. These include the Ethereum Foundation, a new, distributed governance platform for parties to conduct "smart contracts" and exchange digitally issued assets. Ethereum also uses a distributed, virtual-currency-reward system but is scheduled to migrate from an initial proof-of-work consensus algorithm to a less resource-taxing "proof of stake" model. That new model is yet to be proven in the real world as being robust enough to ensure tamper-proof ledger, open to rogue actors.

"Permissioned" blockchains, by contrast, rely on some authorizing entity to determine who can participate as validators of the ledger. Often they are designed to harness the benefits of a shared ledger state amongst a small group of already friendly institutions. They may or may not

include a native digital token or currency. (Unlike permissionless ledgers, this is not a prerequisite for their security model, which instead revolves around participants' trust in the authorizing body). This structure is more flexible, since changes to the software can be directly ordered and do not require consensus among a disparate body of unidentified participants, as in Bitcoin's case. It is also arguably more readily applied to existing legal frameworks. But there is legitimate concern among cryptocurrency experts that the permissioned structure falls short of the secure, distributed ideals established by the Bitcoin protocol. Without a truly open-source, permissionless platform, the technology is not subjected to constant peer review and "white hacker" attacks, which means it not being constantly upgraded and so inevitably remains vulnerable. These closed-loop systems also lack the "crowd-sourced" innovative power that's brought to bear on the most open of open-source software programs. Hence, the boundaries of invention seem limited.

So-called "Federated" blockchains seek to have the best of both worlds, with both a central point of control and a robust "outer layer" of permissionless players.

Serious stress tests are required of all these models that help define the degree to which any system is censorship-resistant, for example, which may depend on the legal structure of the blockchain consortium and whether there is any capacity, or incentive, for the validators to collude. Deciding which model to adopt or promote will likely involve tradeoffs between security/open innovation (permissionless) and efficiency/consistency with existing laws (permissioned). We see permissioned ledgers as potentially useful implementations in specific use cases, but advise that the ultimate goal should be to strive for as much decentralization as possible. One option may be for "small-b" blockchains to be "anchored" into the Blockchain (Discussed below).

Core Blockchain Concepts for MRDH to Consider

The Blockchain gives rise to a number of core innovation concepts with which to build a more versatile and robust economic governance system. We will explore four in particular -- the device identity model, anchoring, tokenization and smart contracts -- and highlight their application to potential projects that the government can pursue.



Identity and the Blockchain.

Most people in the Netherlands own a variety of devices capable of cryptographic authentication, such as smartphones, tablets, and desktop or laptop computers. Increasingly, computing devices are embedded into machine-to-machine networks within the Internet of Things. As the locus of authentication shifts to the user's devices, the would-be attacker's target also shifts. Rather than fraudulently presenting themselves as any of the users of a service to break into its database (or simply downloading a copy of the hacked database online) the attacker confronting the device identity model must compromise the actual device in the user's possession. The result is much less "value" per attack, which creates a financial disincentive for the hacker.

Important applications like Facebook and ApplePay already rely on Device Identity to protect their systems, but the Blockchain was the first to exclusively rely on it. Additionally, because the ledger is distributed across a wide array of computers and is constantly validated by that network, the security around the information generated by those devices is also profoundly more secure than anything held on a centralized database. As online services increasingly leverage the device identity model, expect identity fraud to more intensely concentrate on older systems that still rely on shared secrets such as passwords and Government ID numbers.

This concept is vital to the development of the Third Industrial Revolution in the Metropolitan Region of Rotterdam and The Hague. The economy of the future will be built upon the bedrock of a robust, secure form of digital identity.

That identity concept should be defined and constructed – both technically and legally – to protect citizens' privacy, give them control over their data, and foster the confidence to forge a multi-dimensional array of relationships between each other and with their machines. Securely identifying the digital actors, be they human, corporate or device, will be essential for any expansion of smart contracts, micropayments, programmable money and machine-to-machine transactions. These are the kinds of interactions that will facilitate smart electricity grids, smart transportation systems and the other infrastructure components of an Internet of Things ecosystem in the Metropolitan Region of Rotterdam and The Hague. Obviously these interactions must be secure, and a blockchain-based model will be a vital part of that.

Amid the shift to the device identity model, users will demand a mix of multi-factor authentication, likely including encrypted biometrics, to secure their exclusive access to each device. The information and protocols pertaining to those factors cannot reside on the device itself, but neither can it be stored in centralized database, which would recreate a vulnerable attack vector for the most sensitive of all personal information. Instead, blockchains can be used to mediate permissions via each actor's unique private key access, keeping sensitive data outside of hackers' reach.

Anchoring/Auditability

A key reason why the Blockchain is described as being essentially immutable or tamper-proof is because proof-of-work mining is *cumulative*. In order to persuade the network to change an old transaction on the Blockchain, a rogue actor would need to present more computational work than the ledger has benefitted from *since the current transaction*.

The current computing power of the Bitcoin Blockchain's network is about 15 million petaFLOPS, or 15 zettaFLOPS. The current market price of computing power is \$0.08 per gigaflop. If we take this estimate, it would take roughly \$1.2 Trillion (\$1,200,000,000,000) worth of computing power to be completely dedicated to the task of attacking the Blockchain in order to even have a chance at changing recent records. This is not a static situation, of course. Hardware costs will fall and new modes of computation such as quantum computing may one day arise. But the underlying, open-source technology underpinning the Blockchain is also evolving, becoming increasingly robust as thousands of developers worldwide are constantly

improving it. And while computing power costs fall, the constant addition of computing power to the network will continue to build its defenses.

Importantly, the older a record is, the more computing power it requires to make changes. This is a level of records integrity never before possible for digital systems -- quite probably for anything ever produced in the analog or paper worlds, either. What's more -- and importantly for MRDH purposes -- it can be harnessed by those same legacy systems. Every critical existing database can be given this level of security in its past records by having administrators periodically create a SHA256 hash of their past state, and embedding that into the Blockchain. This process, which allows anyone to later compare the original set of data to this reduced hash format and prove a match to ascertain its integrity, is called *anchoring*. Whenever a past record doesn't reconcile with the anchor, it constitutes overwhelming evidence of tampering. This creates an audit trail in real-time, one that constitutes a considerably more superior tool for verification than any of the human-dependent, backward-looking audit tools that the big accounting firms use.

We strongly suggest that government agencies in Rotterdam and The Hague pursue anchoring solutions to improve the integrity of all financial and government record-keeping systems.

Currently, transaction fees on the Blockchain are around \$0.07 per transaction. For the cost of \$0.07 per day, the records of a firm or agency could be made completely immutable during the daily close. This has significant implications for financial accounting as it almost eliminates the prospect of bookkeeping fraud and makes the task of auditors far more comprehensive, efficient and less expensive. With government transparency increasingly in demand, here is an opportunity to set an example and distinguish the administration from others in Europe, helping to attract investors and maintain sound ratings from EU officials. The Port of Rotterdam in particular could use this anchoring technique, when dealing with shipping and logistics data, to set a higher bar for port management that the rest of the world must follow.

Tokenization

It is possible to issue a token on the blockchain that represents a real world security like a stock, bond, title, deed, or even a certificate of authenticity and which can be moved between accounts in that setting. In capital markets, its promise lies in real-time, seamless post-trade clearing and settlement, as well as in migrating custodial services from an expensive process of physical asset security to one of automated, software-backed security. The costs of maintaining the current, intermediary-dominated system are significant, not only in the fees paid to these institutions or the long, multi-day delays in concluding transactions but more importantly in the

hundreds of billions of dollars tied up in collateral, withheld capital, and stranded assets. Unlocking those funds will speed up transactions and release liquidity into markets that have been starved for it since the financial crisis. Meanwhile, if property titles are validated and transferred through this means, the provenance can be proven in real-time, with a clear, immutable record of ownership, liens and other attachments. This can greatly lower the friction and costs in real estate transactions, potentially doing away with title insurance and other intermediary services.

When combined with the secure, remote, automated execution of legal claims that are facilitated by *smart contracts* (see below) as well as blockchain-based auditability of source data, the significant reduction in transaction costs that tokenization allows could also foster entire new asset classes, making it cost-effective to securitize income receivables that would otherwise be ineligible for traditional financial engineering. Examples of this smart, blockchain-proven securitization include the sale of claims on revenue earned by household solar panel installations or income earned from temporary housing rentals, and trade financing.

Governments have a unique opportunity to experiment with these kinds of securities, create test markets around them, thus taking a leading role in establishing a new asset class. In the United States, the State of Delaware is playing its role in the U.S., approving the creation of special “distributed ledger securities” that would insert certification and title metadata into the record so that, eventually, this information can be automatically updated to official shareholder or bondholder registry once the transaction is executed. Meanwhile, the Monetary Authority of Singapore, which is responsible for issuing all Singapore Government Securities (SGS), is piloting a program to issue those bonds over the blockchain. (In this case, Singapore is using a private blockchain, not by tokenizing into the Bitcoin Blockchain.)³²³

However, the municipal bond market is yet to be tested, presenting some unique innovation opportunities for MRDH. Local government agencies such as the Port of Rotterdam Authority could issue blockchain-ready revenue bonds that use smart contracts to automatically and securely deliver interest payments drawn from the specified secured revenue stream. The pricing for such instruments could be quite generous, given the confidence that the structure promises investors. MRDH’s strong credit rating makes it an ideal jurisdiction to run such tests. It would align with other areas of Rotterdam’s financial innovation leadership, including with its foray into social impact bonds, for which smart contract technology offers a potentially useful way to automatically administer investor payouts when key social objective thresholds are met.

³²³ Based on interviews at Monetary Authority of Singapore offices in Singapore, April 19, 2016

The Economic Chain of a Blockchain-based Circular Economy Marketplace



Image Copyright: William Mougayar, 2016

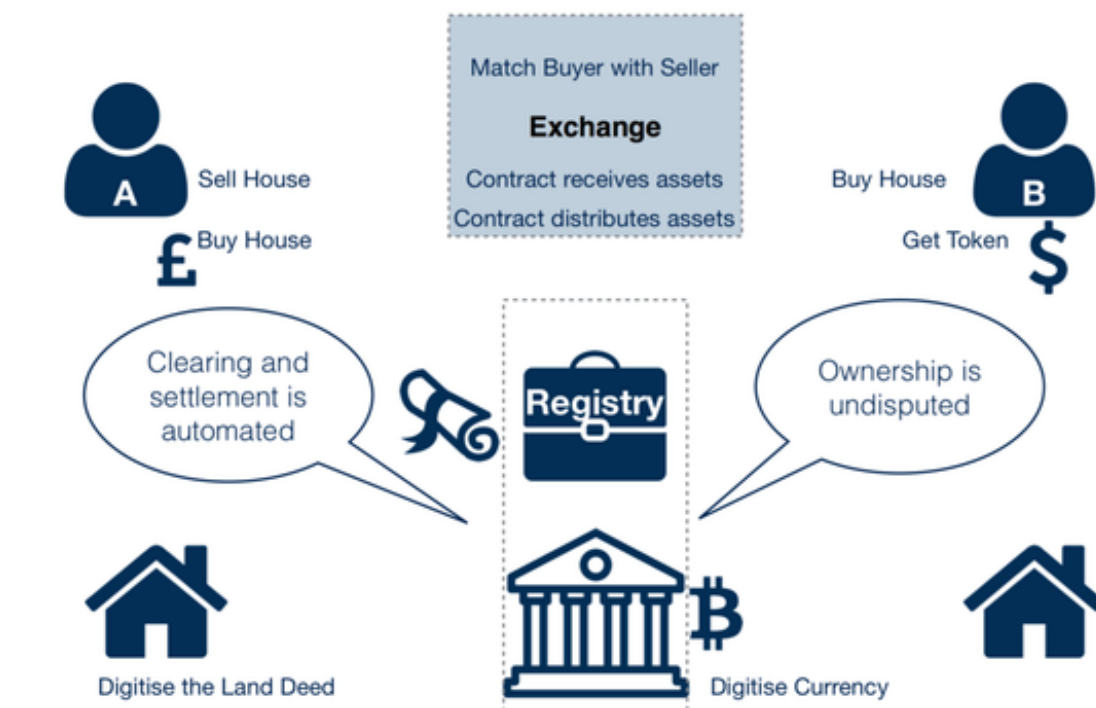
Tokenization also raises the prospect of sovereign currency itself being embedded into the blockchain. This is being investigated by many countries, including some in the EU. Once euro-backed IOUs are issued into a blockchain, payments can be transferred across this system in fiat. That could allow smaller and medium-sized financial institutions to transfer funds across borders without paying expensive fees and collateral costs to correspondent banks. Similarly, local exchange trading systems (LETS), substituting currency systems aimed at encouraging localized and policy-targeted spending in parallel with the national legal tender economy, could also be administered in this manner. The transition pathways associated with developing the entrepreneurial region, next society and circular economy could all be served by these local currency initiatives. When placed into a blockchain environment, where smart contracts can give money a programmability that it cannot have in the cash or banking systems, local currencies can be designed with incentives to encourage certain types of spending. The algorithm behind them could be set so that these local tokens are earned for performing some civic duty, for example, and can ensure that they are only negotiable for certain services that benefit the citizenry in some collective way, such as for public transport or for wellness and fitness services.

Smart contracts

A smart contract refers to a piece of software describing a complex process involving tokens and participants, such as escrow, delivery vs. payment, and other common contractual arrangements. An interesting aspect of smart contracts is that many can be *enforced by The Blockchain itself*, instead of by a third-party institution. Smart contracts and tokenization promise to obviate entire layers of market infrastructure by having the rules that govern the relationships between issuers, owners and traders built directly into the covenants governing a blockchain. Additionally, the payments-layer is embedded in parallel. This combination of rules, traders and payments in one algorithmic flow forms a quasi-legal and automated execution layer to usher in an era of *programmable money* and opens a wealth of powerful new applications to give investors greater confidence in the execution of their claims and interests.

In particular, smart-contract capability will be important to transactions within the Internet of Things. As the Metropolitan Region of Rotterdam and The Hague explore sensor-driven “smart city” solutions to mobility and congestion, for example, it will need these distributed smart contract structures to regulate the transfer of funds and information between vehicles and traffic management systems. For shipping and logistics under the rubric of the Port of Rotterdam, smart contracts promise to revolutionize trade finance and inventory management as they could permit automatic payments, the release of collateral and the execution of other obligations in a secure, provable manner. *One simple illustration: ships needing to hasten their movement into or out of the port could have the ability to almost instantly negotiate with both port authorities and neighboring ships for the right to move ahead in queue. This would be accomplished by the payment of port tokens between ships at the press of a button, and verified or denied by the mediation of the port itself.*

How Smart Contracts Work



In the sometimes conflicting worlds of finance and public interest, smart contracts can also be a powerful tool to optimize the use of funds for policy objectives. In this way, they can augment the work that Rotterdam is already doing on social impact bonds, by establishing inviolable rules for how target objectives are measured and for how payments to investors can be made when they are met (for example, once the carbon footprint of a certain project reaches X level, renewable energy generated, dividends will start automatically flowing to investors). The same structure could be used to regulate government subsidies, where needed, such that they automatically cut out when the cost of production falls to a certain level of once a project becomes profitable. On the equity, rather than bond, side, smart contracts could help to regulate the administration of a "B-corp" of social impact investors. The ever-growing pool of social impact investing funds are often geared toward novel technological solutions, so such an approach could find a ready market of buyers.

The industry that will likely be most disrupted by smart contracts is law. Yet it is clear that lawyers will be needed in droves to help write the software that drives these contracts. The recent collapse of an Ethereum-based smart contract-driven venture-capital fund known as The

DAO, illustrates the opportunities for well-trained, software-savvy lawyers. An unidentified attacker exploited an unforeseen feature of The DAO's code to drain the fund of \$50 million. The event demonstrated that, notwithstanding its promises, smart contract technology still needs significant development work to align automated execution with legal principles and to ensure that users fully understand how the software will handle their contractual rights and obligations. MRDH should work with The Hague-based Netherlands Bar Association to formulate strategies for educating lawyers about the blockchain and coding techniques.

Direct Blockchain Applications for a Digital MRDH

TRANSITION PATHWAY: DIGITAL GATEWAY TO EUROPE

The Communications Internet

Blockchain Technology: Security by Design

The TIR objectives for a cutting-edge communications system that serves as a foundation for growth and value creation focus on the need for security and for protecting privacy while also opening up data and encouraging collaboration and creativity. Under existing approaches to network management, those goals can seem contradictory – regulatory and other measures to protect data tend to close off access, hindering its use in collaboration. We believe that MRDH, in pursuing these goals, needs to consider how a distributed trust architecture like the blockchain can help resolve that challenge.

Whereas existing cybersecurity measures concentrate on preventing attackers from gaining access to big, vulnerable siloes of information, building firewalls within the institutions that control our sensitive information, the blockchain has security built into its very design. The most vulnerable data is stored under the device identity model, which makes for a disincentive for hackers as it offers a much less cost-effective attack vector than one where many clients have their data stored in one place. Whatever data is shared publicly is done so in a hashed form, mapping the original source information to a single alphanumeric string with an algorithm that is, for all intents and purposes, mathematically impossible to undo. Yet that same hashing function can easily be used to prove the veracity of any person's claim to have access to the original source data without them having to reveal it. This structure means that actors can have vital identifying information hidden and yet still transact and share data with each other, with those exchanges stored on a ledger that is distributed across thousands of autonomous nodes. Whatever information is made public – the exchanges of hashed data that are recorded in

unbroken, immutable chain of transactions – is then secured by the fact that it would take a prohibitively high cost of computing power to compromise the integrity of that ledger. Together, these different elements mean that the blockchain incorporates “security by design.”



Balancing Privacy and Open Data

With this secure framework in place, a unique combination of transparency and privacy is possible. Meanwhile, researchers are developing new tools that can be applied to strengthen each of these aspects. Big Data analysis methods are discovering that blockchain transactions can deliver powerful pools of information to identify trends and behavior within the kind of

complex systems that digital societies are creating. At the same time, sophisticated new encryption tools such as *homomorphic* information sharing and zero knowledge proofs, will allow users and institutions that design blockchain solutions for that information sharing to bring in new layers of protection. MRDH should put itself at the forefront of developing these new approaches to the development of this core communications architecture. That means incorporating blockchain research into the kind of innovation-promoting proposals laid out in the TIR plan, such as the creation of knowledge/ideational centers within educational institutions and the use of public contests to encourage research.

IP as Digital Asset

One major transformational prospect that the blockchain can unleash is the empowerment of owners of intellectual property and creative works. This promises to have a major impact for, on the one hand, the strengthening of innovators’ commercial rights but, on the other, more flexibility in terms of how their work is shared. The concept of a “digital asset,” in which the rights and ability to use a piece of intellectual property can be directly programmed into a transaction associated with that IP opens the door to innovative usage models.

When incorporated with some of the ideas encapsulated by the Creative Commons and the many open-source collaborative projects that the Internet allows, a more open system that’s befitting of the dynamic, digital economy of the future is conceivable. If it seeks to become a

digital gateway to Europe, MRDH should insert itself into that discussion and take the lead on designing such models.

Ubiquitous Computing

The blockchain will also be important in the ongoing process by which computing power and storage are increasingly pushed off desktops and into “the network.” As of now, this concept is defined as “the cloud,” where both data and computational activity are increasingly outsourced to services that run off servers housed in big data centers. The problem with this model is that it is extremely energy inefficient. McKinsey, commissioned for a New York Times article in 2012³²⁴, found that on average, data centers were “using only 6% to 12% of the electricity powering their servers to perform computations. The rest was essentially used to keep servers idling and ready in case of a surge in activity that could slow or crash their operations.” That imposes enormous hidden costs on the vital consumer and business IT infrastructure of the economy and compounds the inefficiencies of a centralized energy system that is already beset with extensive transmission and distribution losses.

The answer lies in the development of powerful “embedded” chips that can perform general-purpose computing functions without depending on a large motherboard circuit. “The cloud” will eventually reside not in high-cost, energy-gobbling server farms but in the vast array of everyday electrical devices that surround us – air conditioners, televisions, refrigerators. When combined with distributed, local energy grids, which place renewable power generation close to end-user devices and employ smart energy recycling methods and IoT-based data management to boost “exergy” outcomes, this “ubiquitous computing” model promises profound efficiency gains. In fact, if societies are to sustainably tap the promise of the data-driven, smart digital economy, it is vital that this be implemented.

For similar reasons as those described above regarding communications security, distributed trust protocols like the blockchain will be needed to make ubiquitous computing viable. Such a system cannot be managed by a centralized entity such as a cloud computing service company, because the model’s distributed structure makes it impossible to invest trust in one attack-vulnerable institution.

³²⁴ Glanz, J, “Power, Pollution and the Internet,” *The New York Times*, September 22, 2012
http://www.nytimes.com/2012/09/23/technology/data-centers-waste-vast-amounts-of-energy-belying-industry-image.html?_r=0



Already, innovative blockchain-based distributed data storage systems are being developed by startups such as Storj and Maidsafe, which reward people with cryptocurrency for providing hard-drive space to a giant pool of shared computer memory. These systems use a combination of high-tech encryption, blockchain-based proof-of-storage analysis, Bittorrent-like algorithmic optimization of packet data sharing, and crypto-tokens incentives to organically manage a self-regulating, seamless market around this vital resource.

Beyond data storage, the same is being done for computing itself. The smart contract solutions being developed on top of blockchain networks will mediate transactions between devices and software providers, while both will outsource the computing work to the same amorphous network of embedded chips. Those owners of these networked mini computing devices will be compensated with various digital currencies ("tokens"). This is the secure, distributed future that's envisioned in the bitcoin-inspired movement surrounding "embedded mining" and software-as-a-service (SAAS), but it need not involve Bitcoin itself. Again, MRHD has both an

opportunity and a direct interest in steering and promoting innovation and education in this field.

The Renewable Energy Internet

Blockchain-based, distributed microgrids

Decentralization and smart grids – inherently based on renewable energy sources such as solar -- are key to electricity efficiency. They cut out transmission loss, permit the recycling of heat output for local uses and, when combined with complex dynamic system modeling, can optimize energy distribution among consumers, producers, prosumers and their devices. Properly modeled, market signals in these systems will encourage ongoing investment and development of increasingly efficient generation techniques. When coupled with interconnectivity between different distributed nodes, with smart, multi-directional flows of power and transactions, these systems create a security buffer against the risk of system-wide downtime or the threat of cyberattacks that centralized utilities must endure.

However, because decentralization massively increases the trust challenges, we cannot achieve this goal without the blockchain. Who or what is to regulate the vast multitude of transactions between actors that will shift between being consumers and producers – or their hybrid, *prosumers* – and their multitude of interconnected devices, as well as with the legacy generators and utility managers? Once established, the blockchain permits these otherwise mistrusting different entities to engage in transactions with each other. By tapping smart meters as “oracles” – or sources of trusted data input -- we can use a blockchain ledger to build and keep a precise, immutable record of the ever-shifting distribution of excess energy production, usage and storage. On that foundation, smart contracts can be written that automate transfers of electrons and funds based on the variable price signals given off by demand for valuable crypto-tokens, which function as the native medium of exchange for users of the system (this doesn’t have to be bitcoin; there are various blockchain technologies coming online that will peg such tokens to fiat currencies).

The more that power generation is moved to the edges of the system, the more complex the measurement of the flows and value exchanges is going to become. So, as we start to integrate the legacy public systems with smart homes and smart localized solar panels or wind farms, blockchain-based data is going to be essential. Enforcing transparency with smart meters is only one aspect of meeting this challenge. The blockchain is the other piece. This is why major power companies such as RWE, NRG and others, as well as startups such as Vienna-based Grid

Singularity and New York-based LO3 Energy are investing in blockchain-managed grid management.³²⁵

Reliable community governance

Communities can organize their common solar panel or windfarm assets into smart microgrids with a cooperative governance structure that ensures that the dividends from cheaper and more efficient power are reinvested back into the community. To ensure that those co-ops cannot be monopolized by one player, their governance can be organized into an incorruptible distributed autonomous organization (DAO) based on a blockchain.

Under this arrangement, the distribution of funds is automated through a set of smart contracts that are validated by a blockchain network. The bylaws that dictate this distribution can only be changed under certain, democratic voting preconditions that are written into the software. This is also a means for the coop to give confidence to social-impact investors that may wish to help finance their operations under a benefits corporation (B-corp) arrangement.

Social impact bonds or ESCO financing instruments that are tied to sustainable energy outcomes could attach themselves to such structures, boosting transparency and confidence in the long-term management of the process.

Financing

The steps needed to achieve the goal of a “zero carbon metropolitan region” for MRDH and stakeholder partners such as the Province Zuid-Holland will need to be accompanied by innovative financing strategies. Investors who are committed to backing initiatives that have energy savings as their core objective need to have confidence in the data used to measure progress toward those goals. That’s where the blockchain’s qualities as an immutable record and distributed trust platform for fairly executing contractual rights are extremely valuable.

One area is the issuance of green bonds. Data based on reliable sources can be anchored in the blockchain, where the distributed ledger gives its strong, real-time auditability. That data can then be used as the core pricing driver for bonds that a public authority from Rotterdam or The

³²⁵ See: <http://www.greentechmedia.com/articles/read/the-energy-blockchain-could-bitcoin-be-a-catalyst-for-the-distributed-grid>

Hague could issue and pay for the work to be done by an Energy Service Company (ESCO) to achieve the carbon emission reduction goals. Whether it's work done to clean up brownfield sites or to retrofit buildings to turn them into Net Zero Energy Buildings (NZEBS), recording and anchoring into the blockchain provides an invaluable service to the financing effort. With that data now in accurate, trustworthy and more easily comparable form, investors can more efficiently go through the price discovery process in comparing different projects to one another. Overall, this helps remove information risk from the green finance asset class and so lowers the costs to project managers.

Given Europe's commitment to a continent-wide conversion to renewable energy and to slashing carbon emissions, we expect green finance instruments to quickly evolve into a very large, liquid asset class. By incorporating trusted blockchain data into that industry, the markets will become democratic and thus more sought-after, particularly for investors looking to trade them in cap-and-trade and other carbon offset markets. The MRDH has an opportunity to take a leading role in this area, accruing great financial benefits from this first-mover status.

As the recent revelations about abuses at U.S. fintech firm Lending Club show, it won't be enough to cut out middlemen in crowdfunding and other "peer-to-peer" lending platforms; these big public markets for this vital new infrastructure need the kind of distributed exchange systems enabled by blockchains and the device identity model. In effect, to accommodate all these new actors and asset categories, the securities industry will move toward distributed equity and bonds markets in which settlement and clearing occur in real-time, peer-to-peer over a blockchain.

Securitized Solar Assets

One area in particular that shows great innovative promise is the idea of blockchain-based solar energy securitization markets, which have the potential to unlock large amounts of top-level finance and direct it to what are otherwise small, local projects. Modeled on the idea of mortgage-backed securities (MBS), we foresee the creation of PVBS (photovoltaic-backed securities). PVBS would be directly collateralized against solar microgrid assets that are incorporated into structures such as the coop-run systems described above. The assets would be bundled with kill-switch chip technology and registered as immutable property title in the blockchain. The data derived from the system's smart meter-monitored output and from each prosumer's income generation and payment flows would be automatically input into the same immutable ledger and used as the foundation for the execution of contractual obligations. If

loan repayments or dividends aren't paid according to preset rules, a smart contract-administered limit on power access can be administered, remotely executing a de facto, if temporary property seizure.

In this way, PVBS would arguably be even less risky than asset bundles comprised of real estate loans. The latter's underlying assets are far less uniform, aren't subject to the precision of a data-rich asset source, and do not have the same capacity for software-mediated automated execution of both borrowers' and lenders' rights. PVBS would represent a unique new form of crypto-security, a precisely demarcated claim on the generating capacity or on the tokenized revenue-earning power of set groups of PV cells. They could be packaged as debt or equity securities that could, in turn, be sold in the carbon cap-and-trade markets. Here too, the MRDH has an opportunity to seize a first-mover advantage by taking the lead in this innovation field.

TRANSITION PATHWAY: ENTREPRENEURIAL REGION

Port of Rotterdam

Trade Finance

Building on the supply chain and e-marketplace software concept, blockchain technology also creates an opportunity to incorporate a payments and trade finance component. The current system of trade finance, largely based on letters of credit, tends to exclude small and medium-sized enterprises as they are unable to convince banks to guarantee funds on their behalf. New services are working to use the blockchain to change that.

Standard Chartered and DBS have made a first foray into this arena by developing a system that would record the invoices that exporters provide in return for finance on a blockchain ledger. Not only should that significantly increase the accuracy and reliability of the data compared with the current paper-based system, thus lowering risks to banks and in turn the cost of finance, it should also mean that the invoices are effectively converted into digital assets. They can be traded, in other words, bringing liquidity to the system, which further reduces risks and costs.

Smart contract escrow arrangements might also be developed to get around trade finance restrictions. Exporters and importers could enter into blockchain-based contracts that automatically unlocked frozen payments as soon as the goods are provably delivered. Banks could float that escrow amount for a fee, knowing that they will automatically be repaid when

their client's goods are delivered. Under this structure, smart contracts add even more assurances to the participants, widening access to finance in the process.

The Port of Rotterdam could play a catalytic role in encouraging these kinds of services. It could partner with Netherlands-based banks to develop these kinds of services, in tandem with supply chain management services. Again, its role as trustworthy authenticator could be leveraged across these platforms, steering shipping business its way.

Smart Agro-Food-Flowers

Blockchain-Based Organic Farming Certifications

The biggest challenge in developing organic food and farming methods, which are critical to sustainability and the long-term health of the population, is that these inherently distributed farming methods struggle to compete with the economies-of-scale of large agribusinesses. The solution has been for organic farmers to collectivize their marketing and sales efforts to try to boost their bargaining power. However there is a fundamental problem in that large-scale buyers can't be assured that the produce coming from multiple producers is of uniform quality and truly produced under organic conditions. The blockchain offers a potential solution as it can be used to keep track of authenticated credentials of producers as well as the quality and provenance of seeds, organic fertilizers, and final produce as they are used and extracted along the agricultural supply chain. This way, consumers can be assured assuring that their food is organic, and that their producers from which they are buying their food are following sustainable farming practices. In a blockchain, a farmer is unable to alter the record inserted by whatever body is employed to periodically verify that he or she is meeting required standards. As bio-sensory technology advances, this authentication process can be increasingly automated and, therefore, will become increasingly trustworthy.

Once an agreed-upon trusted standard can be established in this manner, distributed organic food production can be sold more like a uniform commodity. Here, the blockchain is also useful: smart contracts, transparent data and the very low transactions costs that digital money affords would allow the creation of commodity derivatives based on pools of organic food. The "low friction" efficiencies that this technology brings to finance means that derivatives markets could in theory trade with smaller contracts than are typically traded in the big commodity markets in Chicago and elsewhere. The end result is a more cost-effective and more liquid source of financing for the organic food sector.

MRHD can lead the way in this approach. It should encourage designated organic produce certifiers to incorporate their accreditation process into a blockchain ledger. The record-keeping processes of warehouses and freight companies that store and move that produce should also interface with the blockchain, creating a transparent supply chain that would strengthen the financial commoditization process. Here's another opportunity for Rotterdam to lead the way in setting pricing models for trade in organic, sustainably farmed food, encouraging them through cheaper finance to develop a new exportable product to flow through its port

Smart Life Sciences & Health Technologies

The TIR vision of a vast open array of digitalized health data in which patients have control an ability to spur research and solutions is another that will be aided by the introduction of the blockchain. The Netherlands is far ahead of many other countries in terms of digitizing its records. And with the engagement of private insurers in the provision of fixed-price, mandated universal health care, there is greater scope for central coordination of data sharing than in, say the fragmented healthcare system of the United States. Nevertheless, privacy around medical records is an inherent problem everywhere, because it clashes with the broader goal of making as much data available as possible for the sake of both public health administration and medical research. It's a problem that the blockchain's alternative approach to both privacy and transparency/accessibility can address.

Even with the Netherlands' mandated digital records system, medical data remains fragmented and distributed – a function of all the operators in the system. Hospitals, doctors, insurers, labs, pharmaceutical companies, academic researchers, governments, patients, and now those patients' wearable devices, are all sitting on their own highly valuable, but highly sensitive pools of data. But for problems of compliance, interoperability and process inefficiencies, it can be very difficult to bring these disparate entities to share data with each other in ways that are effective and protective of patient rights.

Various fixes to this problem are now being developed with blockchain technology, with the U.S. Department of Health and Human Services now offering funding awards to encourage pilot studies in this field.³²⁶ The solution is not to incorporate all the data in one database or even to create standardized information; it lies in a blockchain-based permissions system. Private keys can be used to grant access to controlled parcels of data to pre-approved entities. Smart

³²⁶ Higgins, S, "US Government Issues Call for Blockchain Healthcare Research," Coindesk, July 6, 2016. <http://www.coindesk.com/health-human-service-department-seeks-blockchain-papers/>

contracts can be used to control the degree to which that data, once stored, can be shared. What's more, other cryptographic tools such as secret sharing protocols and zero-knowledge proofs can be built on top of the blockchain to obscure whatever elements of the data need to be hidden from view. That means that someone – such as a researcher – needing access to the aggregate information can use it but without seeing any of the personal information.

We can also embed the concept of a digital asset into this overarching concept of personal control, and work in tandem to incentivize information sharing. Medical and genetic information, once irrevocably assigned to the patients to whom it belongs, can be treated as an asset, a form of intellectual property over which the individual has control. Who else should own a person's genetic sequence than the individual, for example? Once that data is embedded in a blockchain environment over which a person has unique control, it can be treated like the asset that is – shared, restricted, sold, traded, whatever the owner of the IP so desires. Given the liabilities and regulation that currently constrain health organizations from sharing their siloed pools of data at anything less than great cost, it's unlikely that this personal ownership model would result in less information being shared. However, this needs to be tested rigorously, not least because of the high sensitivity of this vital personal data. Here's an opportunity for MRDH health and research organizations such as hospitals and genomic sequencing labs to do some exploratory pilots. It could potentially unlock a great deal of data and thrust the region into a biotech leadership role.

TRANSITION PATHWAY: NEXT SOCIETY

The Sharing Economy

Startup Opportunities

The TIR proposals include suggestions for encouraging startups that are focused on building platforms and products that integrate with the sharing economy and build out the Digital Netherlands for the Third Industrial Revolution. Where the blockchain can help here is by unlocking creative new financing vehicles to bring capital into the startup ecosystem. Europe lacks of an established, Silicon Valley-style venture capital infrastructure and that poses significant challenges to creating a startup hub. A new approach is needed.

If regulators can give more leeway on securities issuance and investor participation rules – which they've already done in the U.S., the U.K. and elsewhere to boost jobs – while embracing the blockchain as a tool to keep issuers honest, then the issuance of crypto-securities and

company currency-tokens offers a way to bypass the (frankly, somewhat antiquated) VC model and instead raise finance from a broader investing public. Various startup blockchain companies have raised funds in this way – notably Ethereum – though there needs to be clearer controls (again, regulated and enforced within the blockchain itself) dictating the use and redemption of those funds. In essence, the blockchain functions as an automated book-runner in these crypto-crowdfunding exercises, turning the financing exercise into a de facto IPO without having to rely on an expensive and overly regulated investment bank as underwriter.

This scenario necessarily opens new conversations about the public's stake in such projects. In an alternative sense, and perhaps as a hedge against regulatory angst, these digital tokens can also be used by the public as "localized currency" (rather than stocks or cash), unlocking access to a range of public- and private-sector services. As new, corporate and other interest group-based value tokens and cryptocurrencies are issued over the blockchain, a broader definition of what constitutes a token/share/currency of value will be needed. We are moving into a world in which value can be generated, exchanged and stored in many more innovative ways than what we are used to. MRDH should encourage and embrace these new value creation models so that its citizens can learn from them and set the pace for the rest of Europe.

Smart Regulation

Governments that want to encourage innovation among financial startups using blockchain technology should themselves take an innovative approach to how they regulate them. Some of the issues that typically get raised by applicants for banking licenses and money transmitter licenses simply need not be addressed if aspects of blockchain software are used properly to meet compliance standards. Maintenance of reserves can be verified by placing the transactions around those reserves into a transparent blockchain environment, for example. That might obviate the need for costly quarterly audits. Similarly, strict rules on firms acting as custodians of their customers' assets are arguably redundant when applied to accounts holding digital currency that are managed via "multi-sig" password arrangements. In this particular form of blockchain-based smart contract, transactions can only be executed when a combination of two or more private keys are applied to it, typically by different parties. They can be designed such that it's provably impossible for the custodian to lose or steal a client's funds. Again, that may negate the need for strict rules such as capital adequacy to protect customers' interests. If regulators can be creative in their approach to such matters, it could greatly lower the burden that startups face and remove some of the barriers to entry that have

kept the financial sector's expensive, inefficient incumbents from facing the kind of disruptive pressure that other industries have come under in the Internet era.

These are the kinds of ideas behind the U.K. Financial Conduct Authority's innovative "sandbox" approach toward promoting financial innovation. The MRDH should take a leading lobbyist in role in encouraging similarly innovative approaches to regulation at the national level in the Netherlands and in the EU.

Economic Inclusion

The cultivation of the Next Society, one in which citizens and residents engage in digital value creation via the Sharing Economy, distributed infrastructure and collaborative education necessarily requires a radical rethink of what constitutes "identity." We have already discussed how the creation of a robust digital identity is vital to the implementation of blockchain solutions in the digital economy and how the blockchain itself can play a role in that. Here we will add a few more points about how this technology could be used to tackle identity in new ways and so reshape and strengthen what it means to be a citizen or just a valuable participant in such an economy.

For all of the Netherlands' advances and its exceptionally high education levels, there are still too many people living on the margins – perhaps more so in Rotterdam than other parts of the country. The Rotterdam City data on education, for example, shows that 43% of schools in the primary school system have low-educated students, three times the national average, and 22% come from poor families, also three times the national average. Those family members are inherently people who are more excluded from access to the services that better-off people take for granted. And even if they have official government ID, their less-than-stellar academic and economic records mean they inevitably face a harder battle in proving their reliability as a potential economic counterpart – in establishing their creditworthiness to a lender, for example. This exclusion becomes a vicious circle – even in well-to-do Holland. Yet if the net of inclusion in a digital, networked society can be widened such that the creation of ideas and value are best formed in a crowdsourced manner, we will all be better off.

Now, a combination of Big Data and blockchain technology may have an alternative solution for the economic inclusion to such people: the concept of a web of trust. Sophisticated pattern analysis of the traceable and verifiable transactions and activity that a person – or, even just an anonymous node – makes over the blockchain or with their online or mobile activity can create

high levels of confidence around their behavior. If the traced links to other, trusted nodes are strong enough, a reputation token defined by this web of trust can be attached to the person or entity. Based on that token, service providers can then choose or not to have confidence that the prospective client is trustworthy. Compliance models can be built around this.

Aside from this web of trust model, the blockchain can create an environment in which people can verify attributes from their identity rather than having to disclose every detail about who they are when entering into transactions. The classic example is that by accessing a file that only they can access via a password stored on the blockchain, a person entering a bar can prove to a bouncer that they are of age without divulging their name, address or even their actual age. Similar tools could be used to protect sensitive information about a passport or a driver's license so that a holder of such an ID can prove they are the holder even if they do not have the document in hand. All of this points to new ways to gain access to services and to participate as a citizen of a new, digital society.

EXPLORING THE POTENTIAL ECONOMIC BENEFITS OF THE TIR ROADMAP NEXT ECONOMY INNOVATION SCENARIOS

OVERVIEW

On any given day, a helmsman will steer a large container ship into and out of the Port of Rotterdam, or a software engineer in The Hague might “telecommute” from home rather than travel to the office. At the same time, a greenhouse technician

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Human Dimensions Research Associates),
TIR Consulting Group LLC*

may power up various equipment to harvest, label, and transport trees, shrubs, flowers, and other plants to provide numerous products to consumers while a truck driver may be on the way to deliver a replacement part that will allow a manufacturer to resume production. These separate work events all share three critical elements.

The first element is that someone undertakes an activity to get the job done. This is typically referred to as the labor component of economic activity, or perhaps skilled employment. The second is the use of machinery or some type of equipment that facilitates the production of goods and services. This item is the result of annual investments made each and every year in that equipment, or perhaps in the supporting infrastructure that enables all other equipment to be used. Buildings, roads, bridges, pipelines, power plants, and new installations of renewable energy technologies are all examples of supporting infrastructure.

The combined investments in all of the appliances, equipment, and infrastructure together, as they accumulate over time, are often referred to as capital. The third element in the production process is the high-quality flow of energy – electricity, natural gas, diesel fuel or gasoline, whether they are provided by conventional energy supplies or by renewable energy resources. It is energy in the form of food that animates labor and energy in the form of electricity or natural gas that enables capital to carry out the desired set of tasks. Depending on the mix and the productive uses of all resources that are put to work, the Dutch economy is able to deliver an assortment of goods and services to meet the needs of not only regional businesses and the local residents, but also many other nations throughout the world. This so-called work is typically measured as personal income or gross domestic product (GDP).

In most economic development assessments, labor and capital are often thought to be the main elements that drive economic activity. Yet, it is energy—the third, and the most often overlooked component of the economic process—that may prove to be the more critical driver of economic and social well-being. To extend our example above, a software engineer cannot develop code without electricity to power the computer. The helmsman cannot effectively steer a ship without electricity to power navigation tools or diesel fuel to propel the ship. When optimally sourced and efficiently used, energy can amplify local economic development and foster a more robust and resilient economy. But equally true, the wrong mix of those resources, and especially the inefficient use of those resources, can appreciably constrain the larger vitality of a local or national economy.

In 2014, the Metropolitan Region of Rotterdam and The Hague, whether its workers, consumers, and businesses, or a variety of government operations at work in the region, together spent an estimated €6 billion to meet their combined energy needs. The many payments made each day or each month enable them to cool and light their homes, drive to work, listen to music or watch TV, and power the region's many commercial enterprises. Electricity purchases enable access to the Internet, as well as the filtration and purification of the water that is delivered to local homes, schools, and businesses every day.

Although inhabitants of MRDH derive many important benefits as they pay their energy bills, there may also be a significant opportunity to save money. As we shall see later in this section, those energy bill savings – perhaps an average of €700 million per year – will also reduce the massive amounts of greenhouse gases and other pollutants that are released into the air. By one estimate, if MRDH were to go 100 percent renewable energy by 2050, the avoided air quality health effects might be on the order of €7.5 billion per year. Moreover, the avoided 2050 global climate-change costs from converting to 100 percent renewable energy is on the order of €8.0 billion per year.³²⁷

There is no question that the production and use of energy is critical to the social and economic well-being of the Netherlands. But as the International Energy Agency (IEA) underscores, there is also a critical need for greater emphasis on the more efficient use of energy and a more

³²⁷ Mark Z. Jacobson, Mark A. Delucchi, et al. (April 2016). *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for 139 Countries of the World*. Department of Civil and Environmental Engineering, Stanford University. <https://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf>. Note that the original values reported here were originally expressed in 2013 US dollars. Those values were converted to Euros using a 2013 exchange rate of 1.328 USD per Euro. The values cited here are based on the population of MRDH compared to the results for the larger Netherlands economy.

diversified energy portfolio. The IEA further noted that the inefficient conversion of energy can create a large array of problems which can weaken or constrain the development of a more robust economy.³²⁸ German physicist Reiner Kümmel and his colleagues studied the economic process and noted that the economic weight of energy is significantly larger than its cost share.³²⁹ Research by economist Robert Ayres and his colleague Benjamin Warr documented that improvements in both the quality and efficiency of delivered energy services may be the critical factor in the growth of an economy. Indeed, they suggested that a greater level of energy efficiency is one of the primary drivers that support meaningful technological progress, and that sustained technological progress may come only with extensive upgrades in a nation's or region's overall energy and other resource efficiency. A recent study of the EU-15, with analytical results also specific to the Netherlands, amplified these insights. It concluded that the transition to a low-carbon and more robust economy should be done in a way that ensures both the higher accumulation of productive capital and the more productive use of energy.³³⁰ Both principles are wholly consistent with the pillars of the Third Industrial Revolution and the MRDH development of a Roadmap Next Economy.

For these very reasons, the MRDH economy may be at a critical intersection. According to a recent study published by the American Council for an Energy-Efficient Economy (ACEEE), the U.S. economy is only 14 percent energy-efficient. That is to say, of all the energy consumed within the economic process, 86 percent of it is wasted—released as heat, greenhouse gases and other pollutants.³³¹ While noted elsewhere in the Roadmap Next Economy, indexing data for the Netherlands suggests that the Dutch economy is more energy-efficient than the U.S. economy. Yet that comparison also indicates a less energy-efficient economy for the Metropolitan Region of

³²⁸ Nancy Campbell, Lisa Ryan, et al. (2014). *Capturing the Multiple Benefits of Energy Efficiency*. Paris, France, International Energy Agency.

http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEfficiency.pdf

³²⁹ Reiner Kümmel (2011). *The Second Law of Economics: Energy, Entropy, and the Origins of Wealth*. New York, NY, Springer. See also, R. Kümmel (2013). "Why energy's economic weight is much larger than its cost share." *Environmental Innovation and Societal Transitions*, (9): 33-37.

³³⁰ See, Vlasios Voudouris, Robert Ayres, Andre Cabrera Serrenho, and Daniil Kiose. 2015. The economic growth enigma revisited: The EU-15 since the 1970s. *Energy Policy* 86 (2015), pages 812–832.

³³¹ For more background and a deeper discussion on the critical link between the productive conversion of high quality energy and a robust economy, see Robert U. Ayres and Benjamin Warr (2009), *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*. Northampton, MA, Edward Elgar Publishing, Inc. Also see John A. "Skip" Laitner (2015), "Linking energy efficiency to economic productivity: recommendations for improving the robustness of the U.S. economy." *WIREs Energy Environ*, 4:235–252. doi: 10.1002/wene.135. For a European application of these perspectives, read Jeremy Rifkin, Benoit Lebot, J. A. S. Laitner, Solenne Bastie, Francis Hinterman and Shawn Moorhead (2013). *Third Industrial Revolution Master Plan Nord-Pas de Calais, France*. Bethesda, MD, TIR Consulting.

Rotterdam and The Hague compared to the Netherlands as a whole, and to many other developed nations. In reality, the MRDH economy appears to waste the same 86 percent of its high quality energy resources as the United States. With that magnitude of ongoing energy losses each day, and an over-reliance on fossil fuel resources more broadly, MRDH may face serious economic and competitive challenges should it continue with its current pattern of energy production and consumption.

As suggested in this assessment, systematic upgrades in the use of much more energy-efficient technologies and productive investments in renewable energy systems can provide all of the MRDH energy needs by 2050. As also indicated, it is both technically and economically feasible to encourage such a transition.³³² In summary, a significant portion of the billions of Euro already spent each year for energy consumption can be used in other ways to more productively strengthen the country's larger economy—provided local business leaders and local policy makers choose to encourage and enable those smarter and more productive investments to be made.

This contribution to the Roadmap Next Economy explores future economic development opportunities available to the Metropolitan Region of Rotterdam and The Hague. More specifically, the analysis examines the prospective economic benefits within the regional economy if households and businesses were to shift away from current investment patterns to pursue a more productive and cleaner energy future. The analysis investigates the benefits that energy efficiency and renewable energy resources can deliver to the regional economy as the basis for a revitalized economic development. It also examines the scale of investment that will be necessary to drive those improvements. Lastly, the report determines how a shift in spending toward practical clean energy resources could strengthen the region's ability to support more incomes and jobs.

With that backdrop, the next section of this assessment provides the overall framework that reinforces the analysis found in this report. A subsequent section then explores the current patterns of economic activity and energy consumption—especially as the investigation points to

³³² In an interview, San Diego Gas & Electric Senior Vice-President of Power Supply, James Avery highlighted emerging problems associated with the rapid adoption of photovoltaic energy systems. He noted: we haven't begun "to think of the technologies that will evolve" out of the digitalization of the grid. He said, the "wealth of opportunities far exceeds the programs and applications that exist today." See, <http://www.utilitydive.com/news/sdge-if-youre-not-prepared-for-the-change-its-too-late/366979/>. For MRDH, these opportunities might include both domestically-produced resources as well as cost-effective imported energy services that depend on an array of renewable energy technologies—with all resources used more efficiently.

evidence of previous inquiries and surveys that inform a productive path forward based on the idea of the Third Industrial Revolution. It also explores the scale of purposeful effort and investments that can enable both the Netherlands and MRDH to build up those future opportunities. The last major section includes an overview of the methodology used to estimate the net jobs and other economic impacts of the greater diversity in the use of energy resources and, in particular, the greater level of renewable energy and energy efficiency improvements. It then summarizes the major economic impacts of this specific inquiry and highlights the next three critical steps that can ensure a more robust, resilient, and sustainable economy within the country. The first step includes an immediate implementation of “first energy efficiency projects” to document the scale of positive outcomes that will emerge from these initial ventures. The second step is to lay out a set of useful metrics that can assist in the evaluation of the benefits which follow from these and future projects. The last effort, logically building on the two previous steps, is to develop a policy-relevant database that can both track the major projects and policy initiatives and inform the nation about all of the net positive outcomes beyond an energy-led investment strategy. In addition, a short narrative offers further details about the economic model used to complete this assessment for the MRDH economy.

FRAMEWORK OF THE ECONOMIC ASSESSMENT

The appropriate assessment of the economic impacts of different policy opportunities for MRDH—what we call in this document a Third Industrial Revolution Roadmap Next Economy Innovation Scenario—is a function of perspective, data, and logic.³³³ The perspective is an understanding of how an economy can become much more productive and robust in the use of capital, materials, and especially energy. The data reflect both the economic underpinnings of MRDH and the specific costs and benefits associated with the development and deployment of new technologies, systems, and infrastructure. The logic of any assessment is driven by knowledge of how jobs and incomes are supported by a transition to a lower-cost economy despite initial upfront costs. It still takes money to make money, and in this special case of the Roadmap Next Economy, it takes knowledge and purposeful effort, together with a new pattern

³³³ As described throughout the other parts of the Master Plan, the RNE Innovation Scenario brings together the Communication Internet, the Renewable Energy Internet, and the automated GPS-driverless road, rail, water and air Mobility Internet on top of the Internet of Things platform. It is this Third Industrial Revolution digitalized infrastructure to manage, power, and move economic activity that allows MRDH to dramatically improve its aggregate efficiency and productivity as well as reduce its ecological footprint and the larger set of marginal costs.

of investments to enable MRDH to build a more resilient and higher quality of economic activity over the next three or four decades.

Rethinking the Underpinnings of the MRDH Economy

MRDH sits at a moment in history in which doing nothing is not an option. The regional economy shows a lagging growth in performance. Over the period 1995-2008, for example, the volume of Gross Domestic Product (GDP) per inhabitant within the region—a useful proxy of economy-wide productivity—grew at a reasonable rate of 2.3 percent per year. With a population growth of about 0.4 percent, that meant the economy as a whole grew, on average, by nearly 2.7 percent per year over that 13-year period. Over the next 7-year period through 2015, however, the economy-wide activity was essentially flat, indeed a bit smaller in 2015 compared to 2008. This is also a weaker level of economic activity when compared to the collective performance of the more than 30 countries of the Organization of Economic Cooperation and Development (OECD), which taken as a whole expanded by only 1.1 percent annually over that same period.³³⁴

While many standard economic projections suggest a continuing 3.0 percent annual growth through 2050 (the last year explored in the RNE Innovation Scenario time horizon), there are other forecasts and indications which suggest the possibility of a weaker and less robust level of economic activity—perhaps lowering the Netherlands' GDP to 2.0 percent or lower. In fact, this appears to be the case for the OECD region as a whole (OECD Long-Term Projections 2014).

This last projection is consistent with other indicators, all of which point to a lagging rate in the more productive use of capital, energy, and other resources. If we also fold in the many steps that need to be taken to address climate change and other environmental concerns, failure to explore these very possible outcomes, may leave MRDH, the Netherlands, the OECD as a whole, and all developing nations at risk. In this context, the Third Industrial Revolution Roadmap Next Economy can be thought of in two different ways. First, “RNE-like thinking” can become an insurance plan which can enable MRDH to maintain a healthy economy; and second, the RNE

³³⁴ There is a tendency among many policy analysts to assume a reasonable and smooth projection of recent historical trends and assume such patterns will continue into the mid- to long-term term projections. At the same time, however, there is a worrisome trend that suggests a significant weakening of future GDP. See, for example, OECD (2016), GDP long-term forecast (indicator). doi: 10.1787/d927bc18-en (Accessed on 30 July 2016). This latest data set suggests less than 2 percent growth over the period 2015 through 2060. Such projections greatly underscore the need to encourage a more productive investment in RNE-related infrastructure as well as both social and economic capital.

Innovation Scenario can provide insights into the kind of economic platform that can safeguard both a resilient and sustainable economy over a longer period of time.

Notwithstanding some early warning signs of a weaker Second Industrial Revolution economy, MRDH has a number of promising opportunities that can point the way to the more productive use of its many resources; and to do so in ways that build a more robust, resilient, and sustainable Third Industrial Revolution economy. These many transition pathways are described elsewhere in the RNE Master Plan. But we might ask how these options generate a net positive return compared to the standard business-as-usual or reference case assumptions. The table below highlights at least seven key drivers that can support a more robust economy as a result of any given RNE Innovation Scenario and resulting Master Plan. The individual effects and each of their primary impacts are described next.

Table 1. The Seven Major Drivers of Employment and Economic Benefits

Effect	Primary Impact
Intensity Shift	Moving away from capital-intensive to labor-intensive activities
Supply Chain Build-up	Building up greater local production capacity and local services
Energy Cost Reduction	Both unit and total cost savings for efficiency and non-efficiency
Productivity Boost	Expanding non-energy benefits
Managing Volatility	Smoothing out the price shocks
Minimizing Disruption	Avoiding the inconvenient interruption of supply
Innovation Plus	Cost breakthroughs in the delivery of energy and other services

Source: As described and discussed in the text of the manuscript.

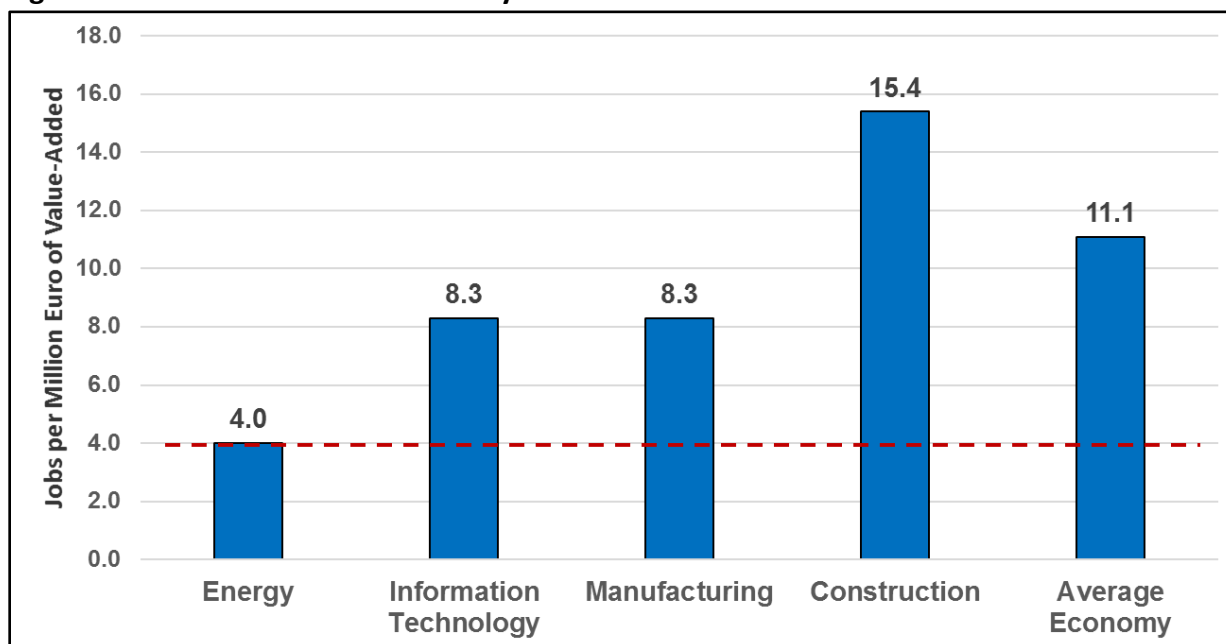
The Catalysts to a More Robust Regional Economy

The first key driver is referred to as the intensity shift. Just as some energy resources are more carbon-intensive than others—for example, natural gas produces less carbon-dioxide per megajoule of energy than does coal, while renewable energy resources produce no direct emissions compared to any form of fossil fuels—, different sectors of the MRDH economy have different income and employment intensities. In other words, different sectors support either more or fewer jobs incomes per unit of economic activity than other sectors to which they might be compared. We can follow this logic as shown in Figure 1 on the following page.

Immediate improvements in energy efficiency across all of the sectors that make up the MRDH economy will have a significant impact on new employment opportunities. Based on 2016 data

from the Netherlands Economic Observatory (which, in turn, draws on public data made available through a variety of agencies and institutions), energy services supported 4.0 jobs per million Euro of value-added, compared to 8.3 jobs in information and communication services as well as manufacturing, and 15.4 in construction and 11.1 on average throughout the economy (NEO 2016).³³⁵ Hence, for every one million Euro of value-added services generated through greater cost-effective energy efficiency improvements across the economy, MRDH will gain a net increase of 7.1 new jobs. Instead of supporting 4 jobs for energy purchases, the economy will support an average of 11.1 jobs as the energy bill savings are re-spent for other goods and services in the regional economy. This is a net gain of 7.1 jobs economy-wide for each million Euros of a cost-effective transition away from the use of conventional energy purchases.

Figure 1. MRDH Job Intensities for Key Economic Sectors



Source: Data provided by the Netherlands Economic Observatory (2016)

A second category of prospective benefits results from the build-up of regional production of goods and service. While MRDH boasts a large export market, it also imports an estimated 60 to 65 percent of its supply chain of goods and services. Moreover, it appears that MRDH only

³³⁵ This information has been generally provided on an ongoing basis in collaboration with MRDH and the Netherlands Economic Observatory over the past 9 months.

extracts 40 percent of value-added from its total economic output. By comparison, the United States pulls about 58 percent value from its total output. To the extent that the RNE master plan increases local production capacity for goods and services, this will increase both the resilience and vitality of the national economy.³³⁶

A third area of opportunity is the likely positive impacts of greater resource and energy efficiencies on both energy and non-energy costs. Even as MRDH will benefit from cost-effective reductions in energy and other resources, the remaining resource requirements will more than likely benefit from lower total costs. This is because reduced demand allows less costly resources to be deployed, and it tends to place an otherwise downward pressure on other remaining costs.

A related fourth area of benefit is the prospect of greater productivity which can expand economic opportunity—especially with the lower level of resource consumption. For example, the region's GDP in 2014 was an estimated €98.9 billion. Had the larger productivity of the nation's economy been just 0.5 percent higher over the period 2000 through 2014, the regional GDP would have been €7 billion larger. Again checking Figure 1 on the jobs per million Euro, a €7 billion gain from that higher productivity would have led to higher employment of about 77,700 jobs (all else being equal). In effect, €7 billion is 7,000 million times 11 jobs per million Euro which equals 77,700 more jobs.

A fifth and sixth set of impacts include managing the disruption in the availability of energy and other resources while also minimizing the unexpected effects of price volatilities. As the demand for goods and services is reduced in the Metropolitan Region, the EU-28 and the global market more generally, and especially as the need for imported resources is reduced, the MRDH markets will enjoy a reduced exposure and therefore a greater certainty in the availability of those resources. That is clearly a positive benefit.

Finally, the seventh major driver of greater employment and economic benefits that are likely to follow from the RNE Innovation Scenario is the continuous learning and encouragement

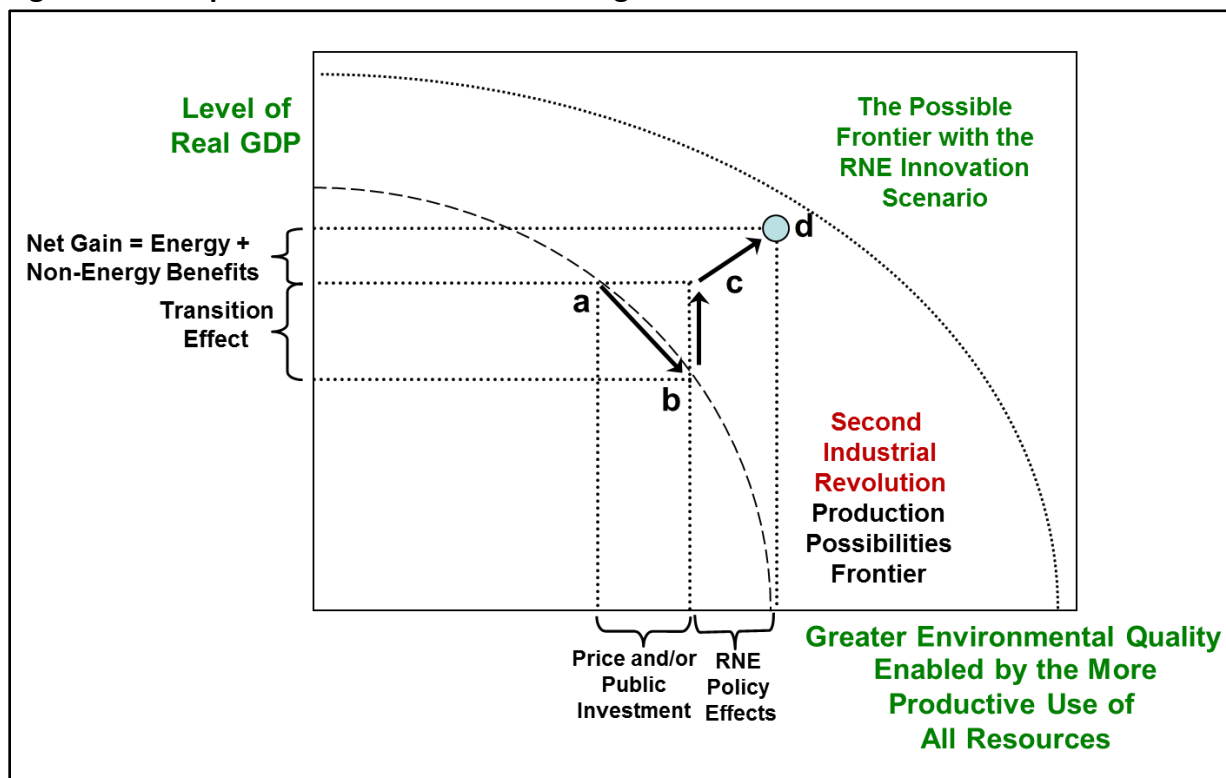
³³⁶ As a thought experiment we can imagine how building up greater local capacity and supply can increase the robustness of the MRDH economy. For example, as the region now provides an initial 35% of its resources through local purchases, we can use a multiplier formula of $[1 / (1 - 0.35)]$ to suggest a base economic multiplier of 1.54 for each dollar spent by businesses and consumers. But if the RNE master plan moves the local purchase coefficient from 35% to 45%, then the base multiplier increases to 1.82. In other words, instead of a €100 consumer purchase that might support €154, under the RNE master plan it would support more like €182, without any other additional cost to the economy.

which will catalyze greater innovations, whether the development and deployment of new general purpose technologies, or the innovative changes in business models that can satisfy social, economic, and environmental needs within the region's economy.

Figure 2, on the following page, provides a conceptual framework that helps pull the RNE Master Plan and the RNE Innovation Scenario into a useful perspective. While we cannot know at this time the scale of the eventual stimulus, the productive impact of the many positive collaborations that will be necessary, or the precise outcomes that might result from such innovations, we can offer a positive general explanation of how multiple benefits are likely to emerge through the RNE master plan.

The assumption might be made that the Dutch economy is already on what is called a production frontier at point "a" in the Figure 2 diagram above. Given the current market structures, technologies and social needs, any change to satisfy a demand for greater efficiencies, or for the reduction in greenhouse gas emissions, must likely result in a downward shift to the right on this graphic illustration. MRDH might achieve some mix of isolated productivity improvements, and there might be some reduction in greenhouse gas emissions, but it must surely come at the cost of a reduction in incomes and GDP. While the RNE Innovation Scenario envisions a set of programs, policies, and incentives that may initially shift the economy to point "b," such a shift may also create a productive transition that lifts the economy to point "c." The result is an improvement in energy efficiencies (as well as the more productive use of resources) even as the economy remains at a relatively stable level of GDP.

Figure 2. Conceptual Framework for Evaluating RNE Innovation Scenarios

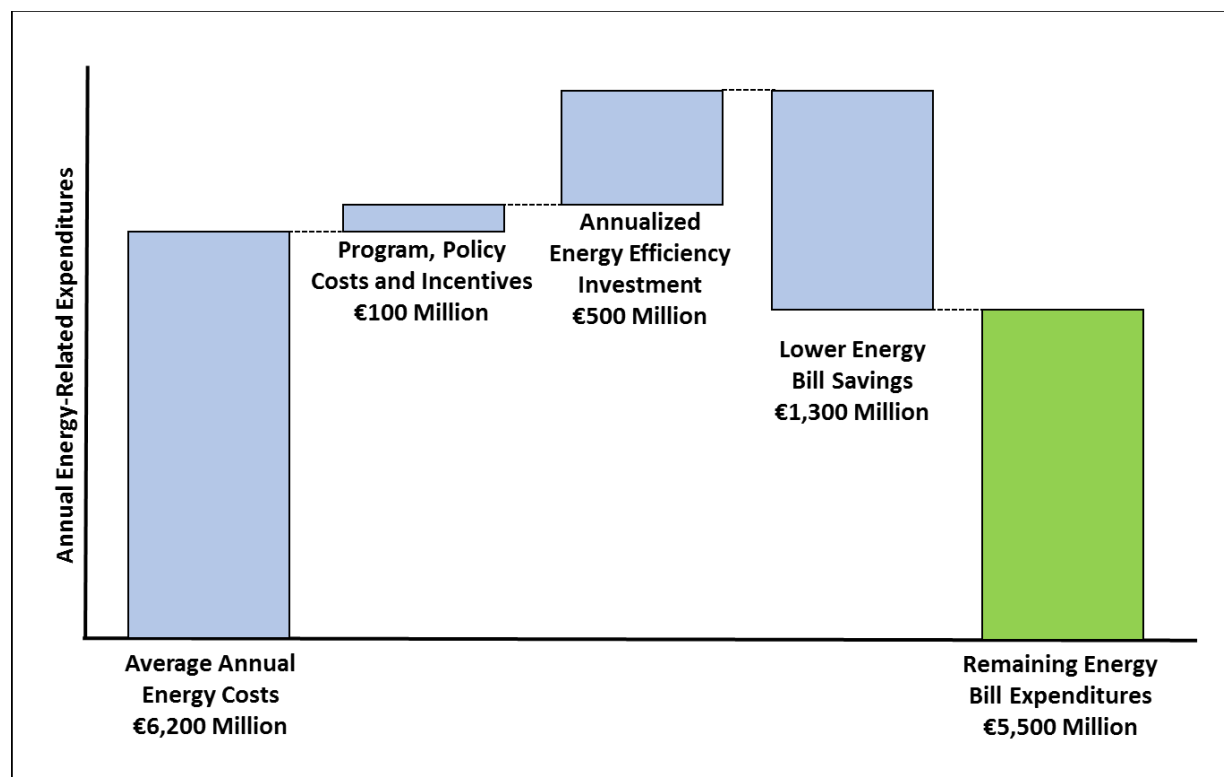


Source: John A. “Skip” Laitner (July 2016).

At some point, however, the various energy and non-energy benefits that result from an array of incentives and policy initiatives can boost the performance of the economy to a higher than expected level of performance. Although not drawn to scale in Figure 2, the migration from point “a” to the eventual point “d” might represent a 30 percent reduction in energy requirements per unit of GDP together. The net energy savings, together with a transition to a 100 percent renewable energy system might, in turn, stimulate a significant boost in net gains in jobs and GDP (as we shall see when we turn our attention to Tables 6 and 7 later in this section of the master plan). Equally critical, the RNE Innovation Scenario can become a way to catalyze the seventh benefit of such master plans—an enhanced push of the production frontier so that future technologies and markets are encouraged, developed, and implemented to the long-term benefit of the economy.³³⁷

³³⁷ It is true that a three or four percent absolute improvement over any long-term forecast may seem a very small benefit. In that regard, the roughly €4 billion net gain in GDP suggested in this assessment, compared to a reference case projection of more than €160 billion, may seem less than appealing. Yet, equally important is

Figure 3. The Average Annual Cost of Energy Services, 2014 through 2050



Source: John A. “Skip” Laitner (August 2016).

Because this idea is central to the advancements envisioned by the RNE master plans, Figure 3 above illustrates yet another of the potential economy-wide benefits which are likely to result from a lower cost of energy services. As we look forward to information provided in Table 2, MRDH appears to have an average annual energy bill of about €6,200 million (reflecting data from the annual accounts for the year 2014 looking forward to 2050). In addition, the RNE Innovation Scenario (described more fully below) can generate an initial savings of about €1,300 million per year.

understanding that the “movement to” and the “outward movement of” the production frontier can provide a sustainable basis to ensure a 3 percent growth in GDP rather than the prospect of a lagging growth rate of 2 percent growth rate. Indeed, that may be among the more important outcomes of the RNE master plan. For instance, the mere subtraction of a 1 percent from a 3 percent growth rate can mean an economy that is 30 percent smaller by 2050. The OECD is sufficiently concerned about lagging productivity worldwide, including both in the Netherlands and the United States, that it released a special study on this topic. See, *The Future of Productivity*, OECD Publishing, Paris, 2015. <http://dx.doi.org/10.1787/9789264248533-en>.

At the same time, to enable such a substantial level of savings requires MRDH to create a series of programs, policies, and incentives averaging about €100 million per year.³³⁸ It is these initiatives which, in turn, will drive the requisite large-scale of investments as they are amortized over time, much like a family might pay for a new home or building. Since the renewable technology costs are part of the average annual energy supply expenditures, it is only the energy efficiency investments that further bump up the cost to an estimated €500 million (also reflecting average annual payments for those relevant investments over time). All of this means that, although total savings might be €1,300 million each year on average, paying for the investments, programs, and policies reduces the gross savings of €1,300 million to a net savings of €700 million. The first result in exploring the costs of energy services is a lower average energy expenditure of €5,500 million per year.

As good as that outcome appears to be, it is merely the benefit from the lower total cost of energy-related resources. We can also account for other social, economic, health, and environmental costs that will impact both MRDH and the Netherlands. Recalling the country-specific impacts from the Stanford University study noted earlier,³³⁹ if MRDH were to go to a 100 percent renewable energy economy, the combined avoided air quality health effects and global climate-change might approach €16 billion in further savings by 2050. This does not include potentially sizable GDP and employment gains that are likely to accrue from the more productive pattern of infrastructure investments, energy efficiency upgrades, as well as the deployment of large-scale renewable energy systems.

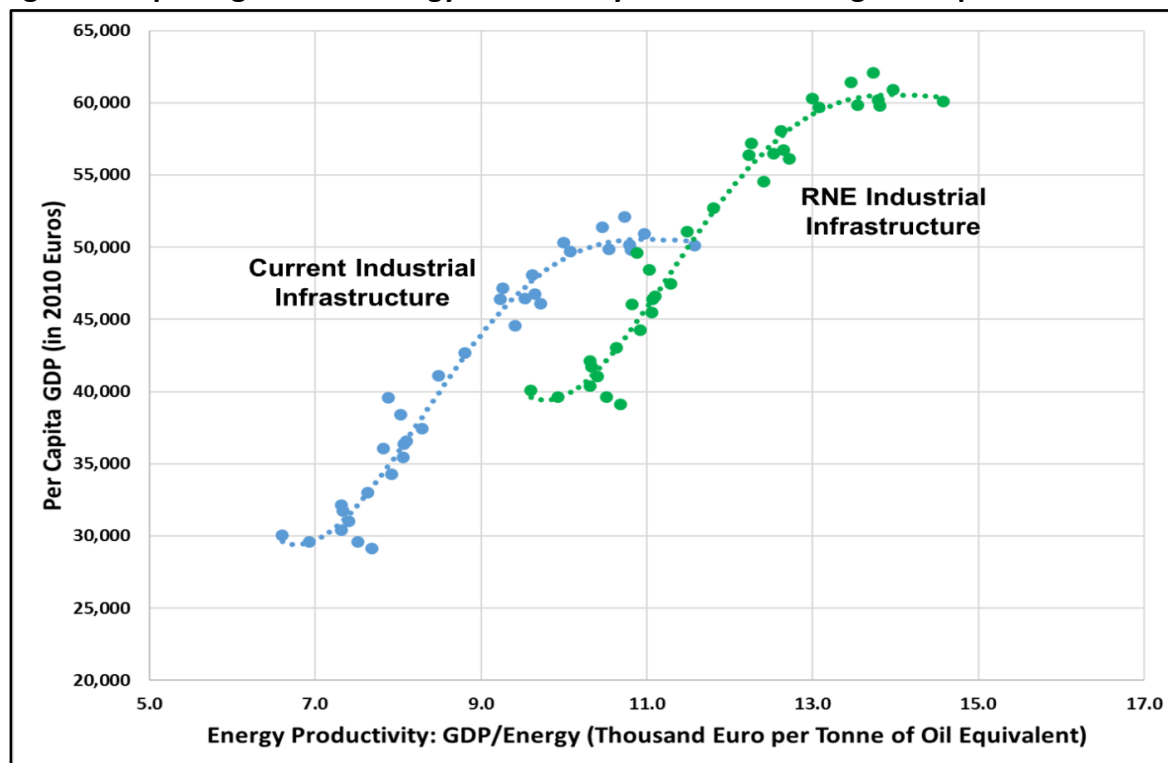
The systemic build out, scale up, and convergence of the Digital Communications Internet, Renewable Energy Internet, and Automated Transport and Logistics Internet, atop an Internet of Things platform, will position MRDH with a high-tech digital infrastructure. This digital infrastructure will enable MRDH, in turn, to achieve dramatic gains in aggregate efficiency and productivity and the equally dramatic reduction in marginal costs and ecological footprint, and will provide the new business models that accompany the RNE economy. It is this new high-tech infrastructure that affords the opportunity for more productive investments to reduce the total cost of energy services so that any remaining net costs become substantially smaller. The important element in all of this is that if MRDH is to maintain a robust economy, there will need to be a convergence of new resource efficiencies and new energy resources that reduce the

³³⁸ This figure reflects expenditures within the public, private, and non-profit sectors to educate, train, market, promote and evaluate the relevant programs and policies which will be necessary to elevate the larger performance of the MRDH economy.

³³⁹ Referencing Jacobson, Delucchi et al. (2016)

real cost of energy services in each successive year, from today through the year 2050. Figure 4 provides a further graphical illustration of such possibilities.

Figure 4. Exploring the RNE Energy Productivity Link to Increasing Per Capita GDP



Source: John A. “Skip” Laitner for the TIR RNE Core Team Using IEA Data (June 2016).

In Figure 4, the blue dots represent actual data published by the International Energy Agency (IEA) for the Netherlands over the period 1980 through 2014. The smaller set of blue dots highlight the curve of a fitted trend of the IEA data. The statistics show a reasonably tight link between energy productivity (in effect, the level of GDP supported by each metric ton, or tonne, of oil equivalent consumed within the Netherlands) as it compares to per capita GDP. In the lower left, for example, an energy productivity of €7,000 per tonne of oil consumed within the nation’s economy supported a per capita GDP of €30,000 in about 1980. In a fairly tight pattern, rising energy productivity can be seen to catalyze an increase in GDP per inhabitant. The end result is that by 2014, an energy productivity of around €11,600 supported a GDP per capita of about €50,000.

At the same time, however, an astute observer might note a flattening of the blue curve. In effect, this is the set of diminishing returns we might observe from the current Second

Industrial Revolution technologies and infrastructure. It is getting harder to generate economic and social well-being from the existing array of technologies and productivity benefits. Hence, the need to turn to what is shown in Figure 4 as the “RNE Industrial Infrastructure.” By redirecting both purposeful effort and new investments, consistent with the Third Industrial Revolution Roadmap Next Economy, we can imagine the possibility of lifting the performance of the MRDH economy to higher levels by increasing overall energy productivity and, therefore, economic productivity, as captured by the set of green dots and curves as shown in Figure 4. How might we understand this opportunity for the MRDH economy?

There have been five major published studies in the past few years by the American Council for an Energy-Efficient Economy (ACEEE), Cisco, General Electric, McKinsey, and AT Kearney, which in various ways speak to the enormous potential in terms of increased efficiencies productivity, new business models, and employment opportunities brought on by the shift to an Internet of Things smart economy. The 2014 assessment by ACEEE concluded that accelerated investments in ICT-enabled networks could lead to productivity benefits that would create a \$79 billion energy bill savings in the United States, even as the economy expanded by as much as \$600 billion.³⁴⁰ Cisco systems forecasts that by 2022, the Internet of Everything will generate \$14.4 trillion in cost savings and revenue.³⁴¹ A 2015 McKinsey report entitled, “The Internet of Things: Mapping the Value Beyond the Hype,” suggests that the build out and scale up of an Internet of Things infrastructure will have a ‘value potential’ of between \$3.9 trillion to \$11.1 trillion per year by 2025.³⁴² A General Electric study concludes that the efficiency gains and productivity advances made possible by a smart industrial Internet could resound across virtually every economic sector by 2025, impacting “approximately one half of the global economy.”³⁴³ A 2016 AT Kearney study entitled, “The Internet of Things: A New Path to European Prosperity,” says that “over the next 10 years, the market for IoT solutions will be

³⁴⁰ John A. “Skip” Laitner Matthew T. McDonnell Karen Ehrhardt-Martinez. 2012. The Energy Efficiency and Productivity Benefits of Smart Appliances and ICT-Enabled Networks: An Initial Assessment. Washington, DC: American Council for an Energy-Efficient Economy. <http://aceee.org/blog/2014/11/internet-everything-could-be-huge-boo>.

³⁴¹ Shane Mitchell, Nicola Villa, Martin Stewart-Weeks, and Anne Lange. 2013. The Internet of Everything for Cities: Connecting People, Process, Data, and Things to Improve the ‘Livability’ of Cities and Communities. Cisco. http://www.cisco.com/c/dam/en_us/solutions/industries/docs/gov/everything-for-cities.pdf

³⁴² James Manyika, Michael Chui, Peter Bisson, Jonathan Woetzel, Richard Dobbs, Jacques Bughin, and Dan Aharon. 2015. The Internet of Things: Mapping the Value Beyond the Hype. McKinsey Global Institute. <http://sensorcommtech.com/the-internet-of-things-mapping-the-value-beyond-the-hype-mckinsey-global-institute/>

³⁴³ Peter C. Evans and Marco Annunziata. 2012. Industrial Internet: Pushing the Boundaries of Minds and Machines. General Electric. https://www.ge.com/docs/chapters/Industrial_Internet.pdf

worth €80 billion, and the potential value for the EU28 economy could reach €1 trillion." The report goes on to say that the increase in productivity alone could exceed €430 billion in the EU.³⁴⁴ Based on a per capita allocation, that could mean a €2 billion boost in productivity for the MRDH economy. However, AT Kearney is quick to add that the increased capabilities brought on by the digitalization of the infrastructure will "increase exponentially when connected objects are coordinated."

What is common to all of these reports, as well as our own assessment here for MRDH, is that these "potential scenarios" can become more quantifiable when applying a new set of metrics tailored to the build-out and scale-up of the interoperable Third Industrial Revolution general purpose technology platform. As the ACEEE study commented, "the data now generally collected do not track either energy efficiency or productivity improvements driven specifically by the Internet or by smart appliances and ICT-enabled networks." Hence the importance of developing new metrics and new analytical techniques to evaluate and highlight future opportunities.

The moment the digital infrastructure evolves, real-time data, based on the metrics employed, will begin to provide a valuable dataset on the gain in aggregate efficiencies and productivity and the reduction in ecological footprint and marginal cost that can guide future investment decisions. As the infrastructure becomes increasingly interoperative, creating a multitude of cross-sector synergies—just as was the case during the First and Second Industrial Revolution—the dataset will become increasingly robust and provide increasingly accurate information from which to make future decisions on the continued build out and scale up of the digital ecosystem.

COMPARING THE REFERENCE CASE AND THE RNE INNOVATION SCENARIOS

Beginning in the late 1960s and early 1970s, Royal Dutch/Shell developed a technique known as "scenario planning." Rather than attempting to forecast a precise estimate of the global business environment, the intent was to create a series of narratives—the so-called *Rivers of Oil* scenarios—to help Shell's management anticipate the eventuality (if not the timing) of future

³⁴⁴ Thomas Kratzert, Michael Broquist, Hervé Collignon, and Julian Vincent. 2016. *The Internet of Things: A New Prosperity to European Prosperity*. AT Kearney.

<https://www.atkearney.com/documents/10192/7125406/The+Internet+of+Things-A+New+Path+to+European+Prosperity.pdf/e5ad6a65-84e5-4c92-b468-200fa4e0b7bc>

oil crises. The scenario building activity proved to be an effective tool. Armed with foresight, and with an agility and internal capacity to respond to the 1981 oil glut, Shell sold off its excess before the glut became a reality and prices collapsed.³⁴⁵

The critical question is how the RNE Innovation Scenario might compare with a typical or standard projection of the region's population and GDP, as well as anticipated energy consumption patterns. Table 2 summarizes key energy and economic variables over the period 2015 through 2050 for five benchmark years, 2014, 2020, 2030, 2040 and 2050.

Table 2. MRDH Reference Case Projection for Key Energy and Economic Variables

Economic Impact	Metric	2014	2020	2030	2040	2050
Population Growth	Million Inhabitants	2.28	2.32	2.39	2.45	2.52
GDP	Million Real Euros ₂₀₁₄	98,890	100,261	123,264	141,462	162,347
Total Energy Demand Reference Case	Petajoules	355	352	315	292	271
Reference Case Energy Expenditures	Million Real Euros ₂₀₁₄	5,796	5,820	6,188	6,446	6,715

Source: Netherlands Economic Observatory (July 2016).

According to 2016 statistics available from MRDH by the Netherlands Economic Observatory (NEO), the Metropolitan Region of Rotterdam and The Hague had an estimated 2.3 million inhabitants. Current projections show a population growth rate of 0.27 percent per year. This means that the population will reach just over 2.5 million persons by 2050. That small increase in the number of inhabitants, and especially a weak 1.1 percent increase in per capita GDP, is expected to drive total GDP further, from just under €100 billion in 2014 to a somewhat larger economy of €162 billion by 2050, an annual growth rate of 1.4 percent over that time horizon (with both values expressed in real rather than nominal terms). At the same time, building on energy consumption patterns provided by NEO, total energy consumption is estimated to be 355 petajoules (PJ) in 2014.³⁴⁶ Because of various energy policies and programs now in place, together with expected market trends,³⁴⁷ the overall energy efficiency of the MRDH economy is also expected to approach 2.1 percent per year which will offset any energy growth in economic activity. This is a significant rate of improvement, compared to the suggested 1.4

³⁴⁵ The development of the Shell scenarios was led by Pierre Wack, an economist, who was the head of the business environment division of the Royal Dutch/Shell Group planning department from 1971 to 1981. For a deeper review of these early successful efforts in scenario planning, see: Wack, Pierre. 1985. Scenarios: Uncharted Waters Ahead. Harvard Business Review. No. 85516. September-October, pages 72-89.

³⁴⁶ One petajoules is the amount of energy contained in 6.825 million gallons of diesel fuel. A total of 335 petajoules, therefore, is about 2.4 billion gallons of diesel fuel; or in the case of MRDH, about 1,050 gallons per inhabitant.

³⁴⁷ For example, see the discussion of Energy Efficiency Trends and Policies in Netherlands (September 2015), at <http://www.odyssee-mure.eu/publications/national-reports/energy-efficiency-netherlands.pdf>

percent annual rate of growth in GDP over the next 34 years. The end result is that region's total energy demands in 2050 are anticipated to be about 24 percent less, at about 271 PJ. As prices increase slightly (in real terms) through 2050, the reference case projection suggests that total energy expenditures will increase from just about €5.8 billion in 2014 to just over €6.7 billion by 2050.

There are several questions that can be raised, including: 1) how many more energy efficiency improvements are possible; 2) how much of the remaining energy demands can be met by an array of renewable energy technologies (whether wind, solar photovoltaics, solar heating, and biomass resources); and 3) how much might all of this cost? In such a case it is often helpful to begin with a thought experiment to provide a working estimate of magnitudes to place these questions in context.

Following the RNE Executive Seminar convened in Rotterdam and The Hague in June 2016, five different transition pathways were explored to enable MRDH to reach a more resilient, robust, and sustainable economy. Preliminary estimates indicated that to move MRDH into a higher level of economic performance, the region would need to invest about one year of GDP to upgrade the combination of existing energy technologies and local infrastructure between now and 2050.³⁴⁸ Other working calculations suggested that it would make economic sense to reduce overall energy demand from the projected demand of 271 PJ in 2050 (shown in Table 2) down to 207 PJ—a further one-fourth reduction compared to the 2014 base year value. As shown in Table 3, an additional energy efficiency savings of 64 PJ, with the remaining 207 PJ energy needs to be provided through some mix of renewable energy technologies. The question remains, however, how much of an investment might we imagine will be required to achieve the energy efficiency and the renewable energy targets? And will they be cost-effective?

³⁴⁸ In a presentation given by Jan Rotmans, the first working estimate was €80 billion for improvements to the infrastructure, with €30 billion that might support social and educational innovation efforts.

Table 3. Suggested Investment Scale for the RNE Innovation Scenario

	PJ Demand	Assumed Investment €/GJ	Total Investment Billion €
Starting Energy Demand 2050	271.3	-	
Suggested Efficiency Gains by 2050	64.5	200	12.9
Renewable Energy Technologies by 2050	206.9	350	72.4
Total Energy-Related Capital Costs	-	-	85.3

Source: A thought experiment drawn from various sources as described in the text.

Turning again to Table 3, there are two working estimates of investment per gigajoule (GJ) that can provide an initial calculation in this regard. The first suggests an average energy efficiency cost of €200/GJ over the 36-year time horizon from 2014 to 2050. If, for example, we assume a 3 percent interest payment over a 20-year period, that would suggest an average annual cost of 5 € cents (€ct) per kilowatt-hour (kWh). By comparison, industry paid about 8 €ct/kWh for the electricity that it used in 2014, while households paid about twice that much. On the other hand, the cost of photovoltaic energy systems—used here as a proxy for the full array of potentially available renewable energy technologies—might be about 75 percent more, or €350/GJ. Following the previous logic for energy efficiency, plus the need for additional operating and other system expenditures, the amortized cost might run about 12 €ct/kWh. These investment estimates are in general agreement with the published literature, and in consultation with members of the TIR Consulting Group.

Multiplying the two cost estimates by the benchmark energy savings or production by 2050 indicates a preliminary investment requirement on the order of €85.3 billion over the 36-year period of analysis. This is very close to the first estimate of €80 billion. The actual modelling results suggest an energy-related investment on the order of €63 billion rather than either €80 or €85.3 billion. The reason is the modelling exercise anticipates a conservative but also a reasonable improvement in technology cost and performance over time. The data and experience points to a substantially lower cost by 2050 compared to the suggested costs that might be anticipated in today's market environment.

We can now begin to compare the working example in Table 3 with published statistics made available through the Fraunhofer Institute's KomMod modelling system as shown in Table 4. This is in addition to other published estimates provided by the TIR Consulting Group.³⁴⁹

Table 4. Technology Cost Assumptions for RNE Innovation Scenario

Technology	Lifetime (Years)	Investment Cost (€2015/kW)		
		2015	2030	2050
wood boiler	20	510	533	565
solid biomass chp plant	30	1,428	1,493	1,583
biogas chp plant	12.5	421	440	466
liquid biofuels chp plant	12.5	421	440	467
rooftop photovoltaics	25	1,330	921	660
free field photovoltaics	25	1,209	837	600
solar heat	25	1,286	777	396
wind power plant	20	999	1,044	1,107
heat pump air-water	20	1,243	1,243	1,243
heat pump brine-water	20	1,492	1,492	1,492
heatpump geothermal probe	20	1,467	1,467	1,467
hydro station	60	3,300	3,452	3,505
power to heat	20	238	238	238
Li-Ion battery*	15	1,558	1,006	666
thermal storage*	20	102	106	113

Source: Fraunhofer Institute ISE (2016). Items with asterisks are costs per kWh.³⁵⁰

Table 4 highlights 15 different technologies that can be used to provide a secure and reliable energy source for a variety of home and business needs. Rooftop solar suggests a 2015 investment cost of €1,330 per kilowatt of photovoltaic capacity in 2015. With anticipated improvements in materials and design, Fraunhofer suggests costs will decline to about €600/kilowatt by 2050. This change over time may be sufficient to reduce delivered costs of electricity from about €ct 12/kWh today to perhaps €ct 7/kWh by 2050.³⁵¹ These costs also

³⁴⁹ See, for example, the extended discussion of energy resource costs in the section of the master plan entitled, Smart Energy, and also the investment costs and returns from the Sustainable Energy Finance Model, also found in this Master Plan. See also the extended discussion of energy resource costs in the Energy section of the Master Plan and also the investment costs and returns from the MRDH Sustainable Energy Finance Program, also found in this Master Plan.

³⁵⁰ While Fraunhofer references these costs in Euros per kilowatt (€/kW), these values can be converted into other units including €/GJ. Photovoltaics, for instance, has an initial capital cost of €1330/kW which would have an approximate value of €355/GJ.

³⁵¹ It is worth noting that photovoltaics, as suggested elsewhere, may already be approaching 55 US cents per watt by 2017, or about €492 per kilowatt (at current rates of currency conversion). The results reported here are, therefore, likely conservative. That is, the costs are higher than what we might expect from the future market. Hence, the net economic benefits reported here may be understated.

include annual operating and maintenance systems necessary to maintain a reliable and safe operation. How all of the changes in demand and supply add up over time, together with their associated costs to deliver the necessary energy services are summarized in Table 5.³⁵²

Drawing from the energy modeling results, Table 5 shows several key variables for two different scenarios. First, it highlights the average cost of all energy resources (€/ GJ) and the total cost of energy (€ Million per year) for what is labeled the Reference Case 2050, or the base case assumptions out to the year 2050. Table 5 then shows four primary indicator variables for what is labeled RNE 2050, or the results for Roadmap Next Economy Innovation Scenario, also in the year 2050. These last four data points are: (1) the levelized cost of energy (LCOE) in € per GJ for both energy efficiency and renewable energy; (2) the average cost of all energy supplies in € per GJ which can be compared to the Reference Case; (3); and finally, the total RNE energy cost in the year 2050 expressed in € Million per year. All costs reflect constant €₂₀₁₄ values. Again, the total scenario costs can be compared for the year 2050.

Table 5. Unit and Annual Cost Assumptions for RNE Innovation Scenario

Resource	Cost Unit	Ref Case 2050	RNE 2050
Energy Efficiency	€ ₂₀₁₄ /GJ	n/a	9.87
Renewable Energy	€ ₂₀₁₄ /GJ	n/a	24.18
Average Cost of Energy	€ ₂₀₁₄ /GJ	24.75	25.38
Total Annual Costs	€ ₂₀₁₄ Mio/year	6,715	5,251

Source: DEEPER Modeling System (2016).

Three things stand out from the information provided in Table 5. First, the average cost of energy is somewhat more expensive in the RNE 2050 Innovation Scenario compared to the Reference Case 2050 Scenario. Second, from the standpoint of the larger demand for energy services, however, this is still a positive result. The reason is that total energy costs in RNE 2050 are significantly lower compared to the Reference Case of Business-As-Usual 2050 outcomes. The fortunate result is, of course, made possible by the savings from the other investments in generating a more energy efficient economy. The total energy costs in the 2050 Reference Case are listed as €6,715 million in Table 5, so that even with the higher unit supply costs (that is, the higher € per Gigajoule), the total energy costs of the RNE Innovation Scenario are significantly less at €5,251 million.

³⁵² It is perhaps worth noting that these cost reductions are comparable to the costs characterized in the Smart Energy Delta of this master plan.

Table 6 provides a more complete “scenario context” by moving away from the assumed unit energy costs and underscoring the larger macroeconomic metrics associated with the difference between the Reference Case and the RNE Innovation Scenario. For convenience, the key reference case indicators in Table 2 are repeated while adding more of the details that underpin the RNE Innovation Scenario.

Table 6. Illustrative Financial Outcomes for the MRDH RNE Innovation Scenario

Economic Impact	Metric	2014	2020	2030	2040	2050
Population Growth	Million Inhabitants	2.28	2.32	2.39	2.45	2.52
GDP	Million Real Euros ₂₀₁₄	98,890	100,261	123,264	141,462	162,347
Total Energy Demand Reference Case	Petajoules	355	352	315	292	271
Reference Case Energy Expenditures	Million Real Euros ₂₀₁₄	5,796	5,820	6,188	6,446	6,715
RNE Innovation Scenario Energy Demand	Petajoules	355	329	282	241	207
Energy Efficiency Gain	Petajoules	0	11	33	51	64
Existing Energy Supply	Petajoules	355	319	208	100	0
Increments of New Renewable Energy Supply	Petajoules	0	10	74	141	207
RNE Innovation Investments in Clean Energy	Million Real Euros ₂₀₁₄	0	1,563	2,139	1,858	1,612
RNE Energy Innovation Energy Expenditures	Million Real Euros ₂₀₁₄	5,796	5,486	5,601	5,537	5,251

Source: Netherlands Economic Observatory (2016), OECD data / projections and DEEPER Model Simulations.

First, note the row that is labeled RNE Innovation Scenario Energy Demand, and especially note the initial energy demand of 355 Petajoules (PJ) listed in the year 2014. This is also referenced two rows down under the listing of Existing Energy Supply. Then, as both the energy efficiency investments kick in beginning in 2017 (not shown here), and the “Increments of New Renewable Energy Supply” technologies begin to penetrate the market (effectively, the array of renewable energy technologies listed in Table 4), Existing Energy Supply slowly drops to 0 GJ by 2050. The drop to zero GJ of conventional resources leads to the positive outcome of zero energy-related carbon emissions by 2050.³⁵³ This result is driven by the scaled-up set of investments in energy efficiency and renewable energy technologies, growing to an initial deployment of an estimated €2,139 million by 2030, and then declining somewhat to €1,612 million by 2050. The reason for the small reduction in total investments is because the less costly energy efficiency improvements begin to pick up more market share and penetration in

³⁵³ Although not emphasized as part of this assessment, by focusing on the economic perspective to generate significant cost-effective investments in both energy efficiency and renewable energy technologies, the economy clearly benefits from lower overall costs. At the same time, as the mix of clean energy technologies penetrates the market, the need for fossil-fuel resources slowly (and cost-effectively) declines to zero. This means that the MRDH economy will have zero energy-related carbon emissions by 2050. Hence, the more productive pattern of energy efficiency and other clean energy investments produces a significant benefit for global climate change that should exceed the anticipated target of the December 2015 Paris accord.

2030. This requires a smaller contribution from the slightly more-expensive investments in the renewable energy resources.

Also embedded in Table 6 are data that show a significant reduction in the MRDH overall cost of energy services. Rather than a suggested 2050 annual cost of €6,715 million in the Reference Case, the RNE Innovation Scenario shows a much smaller energy bill of €5,251 million—an annual savings of €1,464 million by 2050. There is one minor caution in that this represents what might be termed gross energy savings. A more useful metric (not explicitly shown) is the net energy bill savings in that year. This mirrors the costs of related programs and policies, as well as the amortized payments made for the energy efficiency upgrades which will reduce gross savings in 2050 on the order of €330 million in that year. This point is very similar to the discussion surrounding Figure 3 in which the average annual energy savings of €1,300 million over the period 2014 through 2050 is actually closer to €700 million when the added program costs together with the amortized energy efficiency upgrades are also included. At the same time, however, there are large costs of externalities that will further extend the benefits of the RNE Innovation Scenario. While referenced also as part of the Figure 3 discussion, these elements are discussed in greater detail immediately below.

REVIEWING THE ECONOMIC IMPACTS OF THE RNE INNOVATION SCENARIO

The foundation for the overall economic assessment that has been completed as part of the MRDH Roadmap Next Economy master planning process is the proprietary modeling system known as the Dynamic Energy Efficiency Policy Evaluation Routine (DEEPER). The model, developed by John A. “Skip” Laitner, is a compact 15-sector dynamic input-output model of a given regional or national economy.³⁵⁴ The model is essentially a recipe that shows how different sectors of the economy are expected to buy and sell to each other, and how they might, in turn, be affected by changed investment and spending patterns. Setting up that recipe is a first step in exploring the future job creation opportunities and other macroeconomic

³⁵⁴ There is nothing particularly special about this number of sectors. The problem is to provide sufficient detail to show key negative and positive impacts while maintaining a model of manageable size. Expanding or reducing the number of sectors will require some minor programming changes and adjustments to handle the larger matrix.

impacts as the MRDH economy shifts from the Second Industrial Revolution to the higher level of performance that is likely to be associated with the Third Industrial Revolution RNE.

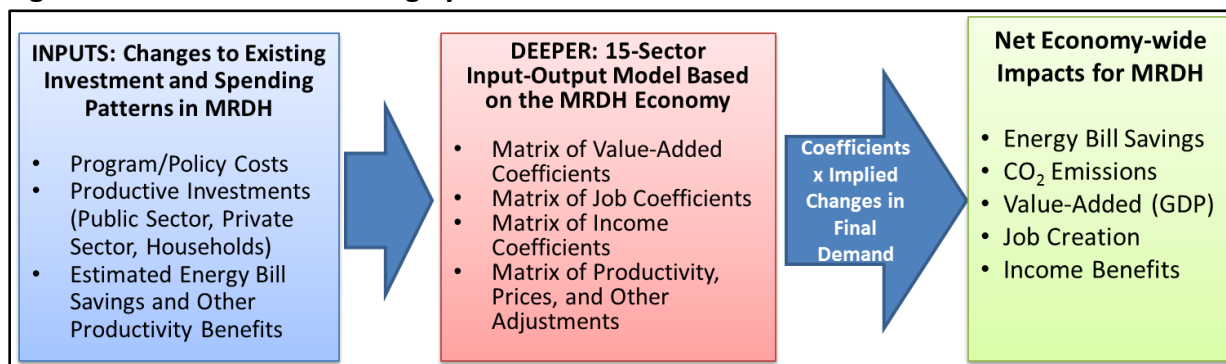
Although it has only recently been updated to reflect the economic dynamics specific to MRDH, the DEEPER model has a 26-year history of development and application. The model has been utilized to assess the net employment impacts of proposed automobile fuel economy standards within the United States.³⁵⁵ More often, it is typically employed to evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at the regional, state, and national level. As a recent illustration, it was used in 2013 to assess the potential outcomes and economic benefits of the Third Industrial Revolution in Nord-Pas de Calais, an industrial region of four million people in northern France.³⁵⁶

The timeframe of the model for evaluating energy efficiency and renewable energy technology policies and investments is 1990 through 2050. The period 1990 (or earlier as needed) through 2014 provides a useful historical perspective. The years 2014 and 2015 provide a period of calibrating the model to the regional economy while the period 2016 through 2050 provides an assessment of future trends. As it was implemented for this analysis, the model maps in the changed spending and investment patterns based on the RNE Innovation Scenario for the Master Plan over the period 2017 through 2050. It then compared that changed spending pattern to the employment and value-added impacts assumed within the 2050 Reference Case. Figure 5 below provides a diagrammatic view of the DEEPER Modeling System as it was reflected within the dynamics of the MRDH regional economy.

³⁵⁵ Gearing Up: Smart Standards Create Good Jobs Building Cleaner Cars, by Chris Busch, John Laitner, Rob McCulloch, and Ivana Stosic, Washington, DC: BlueGreen Alliance, 2012. Based on this analysis and other evidence, American President Barack Obama signed into effect the proposed 54.5 mile-per-gallon fuel economy standards in August 2012.

³⁵⁶ Nord-Pas de Calais Third Industrial Revolution Master Plan – 2013, by Jeremy Rifkin, Benoit Prunel, Solenne Bastie, Francis Hinterman, John Laitner and Shawn Moorhead. Bethesda, MD: TIR Consulting Group LLC. 2013. Note that since the release of this master plan, and the development of hundreds of projects based on that plan Nord-Pas de Calais recently merged with the region of Picardy to form a new region of some 6 million inhabitants now referred to as Hauts-de-France.

Figure 5. The DEEPER Modeling System



Although DEEPER includes a representation of both energy consumption and production as well energy-related carbon dioxide (CO₂) emissions, the analysis for MRDH focuses on the changes in larger resource productivity as well as improvements in infrastructure, information, and communication technologies, and especially greater circularity within the regional economy. These prospective changes in infrastructure and technologies are characterized elsewhere in the Master Plan with the economic assessment described here using a high level summary of these changes.³⁵⁷ The model outcomes are driven by the demands for energy services, economic goods, and alternative investment patterns as they are shaped by changes in policies and prices. As noted in the previous section, the model is built on an assumed reference case over the period 2014 through 2050 as reflected in a variety of data made available by the Netherlands Economic Observatory (NEO) in collaboration with MRDH, the European Commission, the Organization of Economic Cooperation and Development, and the International Energy Agency, among other organizations and universities.

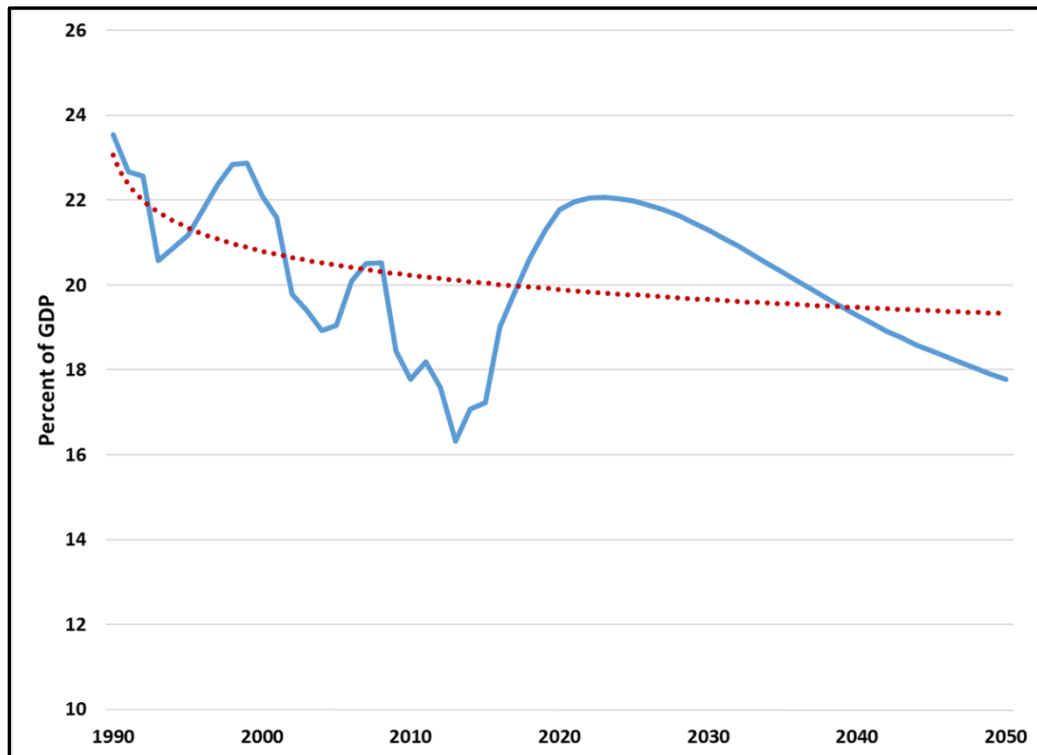
Trends that Shape the Reference Case

Using a number of these national economic projections, and with preliminary inputs from (NEO 2016), key high-level reference case data, Tables 2 and 6 (shown previously) provide a useful starting point in the assessment through the year 2050. As highlighted in Table 7 that follows, we can compare these reference case assumptions with expected results that might emerge from one or more RNE Innovation Scenarios.

³⁵⁷ See, for example, both the assumptions and scenarios described in the section on Energy. Of particular note is the set of changes referenced in Table 6 in the prior section. While that table highlights total energy consumption for the respective scenarios, it reflects each of the building, industry, and transportation energy subtotals which are described elsewhere in the master plan.

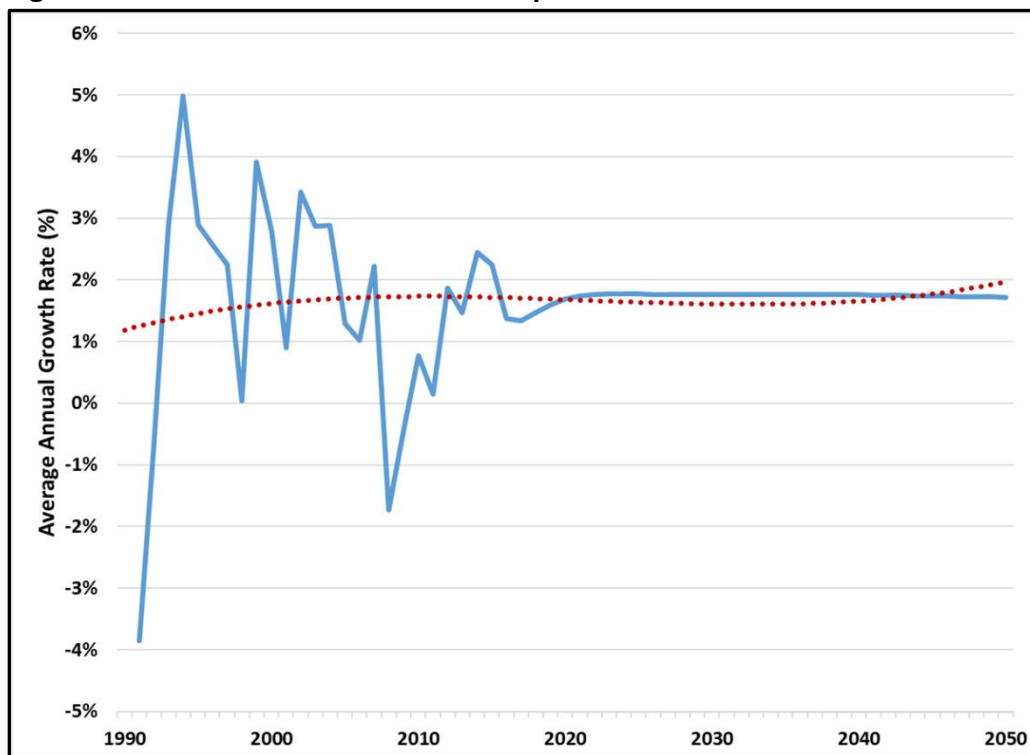
There are two key trends that have not been highlighted in the table above but underscore the positive impact of the Roadmap Next Economy. The first is the growth in economy-wide productivity as measured by GDP value per inhabitant (in million real 2014 Euros). Compared to a historical 1.2 percent annual growth rate over the years 1995 to 2014 (not shown here), recent projections for per capita GDP in the 35-year period 2015 to 2050 suggest a very similar growth in economy-wide productivity (essentially per capita GDP) of 1.1 percent annually. It is this, among other metrics, that prompted the OECD to release its 2015 report on the Future of Productivity (see footnote 10 for a further discussion and citation).

Figure 6. The Netherland's Rate of Gross Capital Formation



Source: OECD Historical and Long-term Baseline Projections (May 2016).

Figure 7. Netherland's Growth in Per Capita GDP



Source: OECD Historical and Long-term Baseline Projections (May 2016).

There is a second trend that hints at a less resilient future economy, in this case because of a declining rate of investment. Recent projections indicate that the rate of Gross Fixed Capital Formation—in effect the growth of annual investments in the Netherlands' total fixed assets—is also decreasing compared to historical performance.³⁵⁸ Data from the OECD show that, over the same 20-year period from 1990 to 2010, it averaged 20.9 percent of GDP (not shown here). As suggested in the table above, the annual rate is projected to actually decrease each year, dropping to a low of 17.8 percent by 2050. Both Figures 6 and 7 above provide a more detailed look at these key trends.

Given this backdrop, an important question to be explored within the Third Industrial Revolution planning process is whether the MRDH economy can remain both vigorous and

³⁵⁸ Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress."

sustainable as per capita GDP remains somewhat flat and the rate of Gross Capital Formation is shown to possibly decrease. The question that might be helpful to pose is what mix of purposeful effort and more productive investments might ensure the development of a more robust economy? Part of the answer has been already provided in the discussion surrounding Table 6.

A Side Note on the Job Creation Potential in MRDH

Table 1 in this section offered a useful context to understand the seven different economic and employment drivers that underpin the transition to a higher economic performance envisioned by the Roadmap Next Economy. At this point, however, it is useful to draw on other segments in the master plan to offer concrete examples of how RNE-related investments might positively impact future employment gains. For example, Germany's vast experience in retrofitting buildings provides a useful insight for the job creating potential in MRDH as it embarks on its own regional retrofitting projects. To date, as reported in the Buildings as Nodes section of the master plan, 342,000 apartments have been retrofitted, creating or saving more than 141,000 jobs in Germany.

Looking across more of the European economy, a 2011 analysis by the Buildings Performance Institute Europe (BPIE) suggested a potential energy savings in EU buildings ranging from 32 to 68 percent by 2050, depending on the scope and scale of upgrade investments. The investment cost might range from €343 to €937 billion, with a net consumer bill savings from €160 to €381 billion over the period 2012 through 2050. The combination of investments and net energy bill savings might drive a net annual employment gain of 500,000 to 1.1 million jobs.

The Stanford study by Jacobson et al., referenced elsewhere in this assessment, noted that the Netherlands could meet 100 percent of its energy needs by renewable energies alone. The investment to drive that transition would lead to roughly 199,500 net jobs to build capacity, and also to operate and maintain the entire energy system in the Netherlands. Although not specifically examined, the lower costs of energy associated with a more productive clean energy future would further drive future employment opportunities. This is consistent with Figure 1 discussion documenting the greater labor intensities associated with almost all other sectors of the economy compared to the jobs supported by conventional energy expenditures.

Understanding the RNE Innovation Scenario

A working analysis based on data published by the International Energy Agency (IEA) suggests that the Netherlands converts only 18 percent of the available energy into useful work.³⁵⁹ Within the Dutch economy, however, MRDH may be underperforming at an efficiency that is on par for the world as a whole, about 13.5 percent. This is less than for the United States (14.4 percent) and for OECD nations more broadly (16.2 percent). As already reported, that means the MRDH economy wastes more than 86 percent of the energy consumed in the economic process. The silver lining in the Table 2 data previously referenced, however, is that the energy intensity within MRDH is projected to decline at about 2.1 percent per year through 2050. The question will again be posed as to what mix of investments might accelerate the rate of energy efficiency improvements as well as the movement toward an energy production system that is anchored by an array of renewable energy technologies. If done properly, a higher level of energy efficiency, together with the development of cost-effective renewable energy systems, is likely to result in a downward pressure on the price of remaining uses of energy which would provide further net benefits to the larger economy.

Table 7 integrates the scenario cost data found in Table 6 and elsewhere. It then lays out the larger economic benefits that might be expected to emerge with the RNE Innovation Scenario, especially as interactive discussion helps shape a greater understanding of what initiatives may contribute to a more productive Master Plan.

Table 7. Energy Costs and Impacts from the RNE Innovation Scenario

Economic Impact	Metric	2016	2020	2030	2040	2050	Average 2016-2050
Efficiency Gain	Savings from Ref	0.0%	3.1%	10.6%	17.4%	23.8%	13.7%
Program Cost	Million Real Euros	5	115	137	104	78	111
Technology Investments	Million Real Euros	0	1,563	2,139	1,858	1,612	1,863
Net Energy Bill Savings	Million Real Euros	0	454	587	909	1,464	769
Energy Bill Savings Employment	Net Jobs	0	28,600	33,400	28,500	26,400	29,100
Productivity Employment	Net Jobs	0	-14,300	10,500	54,000	105,600	31,800
Total Employment Gains	Net Jobs	0	14,300	43,900	82,500	132,000	60,900
Net GDP Impacts	Million Real Euros	0	904	2,785	5,229	8,365	3,862

Source: Output from the DEEPER Modeling Systems as described in text manuscript that follows.

Two things might be noticed immediately in Table 7. First, the rate of energy efficiency accelerates to reduce consumption by 23.8 percent in the period 2016 through 2050. This is in

³⁵⁹ Here useful work refers to the use of energy to transform materials and other resources into the desired mix of goods and services within the local economy.

addition to a comparable reduction in the already energy-efficient Reference Case scenario (as shown in Table 6, moving from 355 PJ in 2014 to 271 PJ by 2050). Although not shown here or in Table 6, the presumed investment and more productive build-out of the MRDH economy will clearly increase estimates of gross capital fixed formation. Because of the greater level of cost savings in the RNE Innovation Scenario (in effect, the added 23.8 percent savings), this will stimulate both a more vigorous level of GDP per job as well as a greater number of jobs.

Consistent with the discussion surrounding Figure 2, the greater increase in energy productivity by 2050 lifts the MRDH economy to a higher level of performance so that it is about 5 percent bigger than otherwise anticipated in the Reference Case. There is also a net gain of employment—an estimated 26,400 net jobs per year by 2050 resulting from the upgrade of the nation’s energy infrastructure. These jobs are complemented by another 105,600 net jobs made possible by further non-energy and larger productivity benefits that will be stimulated by the RNE Innovation Scenario. The “average annual net gain” in jobs over the analytical time horizon is 60,900.³⁶⁰ Another way to look at these job estimates is to imagine what might happen if the MRDH scenario scaled to an equivalent success within the entirety of the European community. In that case, a five percent average increase in current employment would imply a net gain of about 9 million jobs within the EU as a whole (including the 60,900 jobs within MRDH).

While not a primary focus of this economic assessment, it is worth integrating a short overview of the complementary relationship between changes in energy consumption patterns that might also bring about an array of social, economic, health, and climate benefits. Here, we again cite two key references together with the reported results from the more conventional economic assessment of energy-related costs and benefits. The first draws on the combination of perspectives offered by Ayres and Warr (2009) and Kümmel (2011). The second highlights the findings in the assessment published earlier this year by Jacobsen et al. (2016), 100% Clean and Renewable Wind, Water, and Sunlight (WWS). With several caveats, but following the logic of net benefits that might follow from both Figure 2 and Figure 3, the table below explores this relationship.

³⁶⁰ One item of note in Table 7 is both the net positive job gains from energy-related investments and savings in the earlier years through 2020. At the same time, as the economy shifts resources from existing spending patterns into the more efficient use of energy, there is net temporary loss of jobs in other sectors. This reflects a period of adjustment that is overcome as both energy and other resource gains result in a total net positive gain for MRDH. One further note is that because of rounding to the nearest 100 jobs, it appears the productivity jobs are exactly one-half of energy-related jobs. But that result is purely coincidental as will be seen for totals in other years.

Table 8. The Array of Net Benefits (in Million Euros)

Annualized Net Benefits	Reference Case
Net Energy Savings	302
Productivity Benefits	1,032
Avoided Externalities	1,660

Source: Results as described in the text are in constant 2013 Euros.

Table 8 shows the expanded categories of three sets of benefits as they are created through productive investment, and as those benefits are then properly discounted over time and taken as an annual average over the years 2016 through 2050. With a net present value taken over those 34 years at a 5 percent discount rate, the RNE Innovation Scenario might show a net annual benefit of €302 million from reduced energy expenditures alone. That is, after borrowing funds, and paying the finance costs over time (as estimated here), a €234 million investment might return an energy savings of €302 million. This might result in a discounted benefit cost ratio of 1.29. That is a positive result, but the story doesn't necessarily end there.

Beyond energy savings, the flow of investments catalyzes a more dynamic economy so that GDP is expanded another €1,032 million net of the energy savings. This follows from Ayres and Warr (2009) and Kümmel (2011) as previously referenced, in that the reduced level of wasted energy and other resources adds a greater level of economic productivity beyond the pure energy savings alone. Finally, if we adapt the findings of Jacobsen et al. (2016), also discounted over time and averaged over the same 34-year period, we might gauge a further annual gain of €1,660 million. So what began as a pure energy savings might now be seen as a larger return from a higher level of positive energy services.³⁶¹

³⁶¹ We note an important caveat here in that the three categories of net benefits are generated from different references that may not fully compare or complement each in either scale or scope, or in a consistent methodology. At the same time, the magnitudes in Table 8 offer insights into the extended benefits that logically follow from a more productive infrastructure. The findings are consistent with the IEA report on multiple benefits of energy efficiency improvements as suggested by Campbell et al. (2014).

Immediate Next Steps

Of particular note in Tables 7 and 8, however, is that these results are only indicative of a potential RNE Innovation Scenario. At the same time, we have already highlighted three additional elements which should be brought forward into any future discussion of possible outcomes. The initial element is an immediate large-scale investment in cost-effective upgrades of the nation's building stock. The intent here is two-fold. The first is to send a signal about the imperative of a more energy-efficient and a more productive economy. Building upgrades are among the best understood of those near-term opportunities. The review of investment opportunities in the Finance section of the RNE provides a variety of self-funding options for the MRDH building stock, including both rooftop solar energy and energy efficiency upgrades. See, for example, the background discussion in the Finance section of the RNE which implies a reasonably profitable €12.6 billion investment in the regional buildings over the next ten years or so. The immediate lessons and insights from the first wave of infrastructure upgrades will help shape a second wave of activity around developing a more circular economy and a digitally-driven transportation and logistics infrastructure. The second intent of this initiative is to provide the means for collecting project data to underpin a new set of metrics. Both the data and the resulting metrics can guide next steps and aid in the assessment of how such projects might contribute to the larger social, economic, and environmental well-being of Rotterdam, The Hague, and the other municipalities within MRDH—beyond the initial energy-related investments and returns.

It is critical, then, to develop a policy database and new analytical techniques that can inform the region about the potential for more positive outcomes beyond an energy-led investment strategy. While standard economic models and policy assessment tools have generally been able to track and evaluate many of the Second Industrial Revolution economic trends, they are not equipped to fully explore the potential outcomes of RNE-like innovation scenarios.

The working groups and the TIR Consulting Group agreed that it was essential to establish a new set of metrics to allow MRDH to begin tracking real-time data at the onset of deployment of the RNE infrastructure. The data would provide the necessary information for documenting immediate project returns and for assessing future aggregate efficiencies, productivity gains, reductions in ecological footprint and marginal costs brought on by the interconnectivity of the digital platform. These are in addition to documenting the more traditional metrics including reductions in energy consumption and greenhouse gas emissions as well as positive changes in jobs, investments, total factor productivity and GDP. As MRDH tracks this data in real-time, it will be able to make critical projections on future social, economic and environmental well-

being, based on the experience and insights gained at each step of the deployment. A particular focus might be documenting the costs and benefits of an interoperational digital infrastructure.

When businesses can plug into an increasingly matured digital infrastructure comprised of the digitalized Communication Internet, digitalized Renewable Energy Internet, and digitalized Transportation and Logistics Internet, atop an Internet of Things platform, they will be able to develop and use near-zero marginal cost renewable energy in every single conversion at each stage of their value chains. This will facilitate the smart managing, powering, and moving of economic activity. The leap in aggregate efficiency and productivity and reduction in ecological footprint and marginal cost brought on by the increasing integration and interoperability of the digital Third Industrial Revolution infrastructure marks both a qualitative and quantitative leap in the economic performance of industries across MRDH.

The active tracking of Roadmap Next Economy metrics – again, including aggregate efficiency, productivity, reductions in ecological footprint, and marginal cost – will enable MRDH to make appropriate adjustments so that the goals are more likely achieved over the successive years. The value of this second step can be seen by again reviewing the macroeconomic returns highlighted in Table 7. The benefits are clearly positive but they yield on only a first indication of the larger potential gains that might accrue to the region. Among prospective changes that are not fully captured in this assessment are the very real emergence of new markets catalyzed by new fintech models, new digital technologies, new smart industries, and greater circularity. Other effects include the buildup of greater local capacity to supply more of goods and services within MRDH. A more informative assessment can be provided by continually updating the collected Big Data as the Roadmap Next Economy infrastructure is deployed and made increasingly interoperable in subsequent years.

A SHORT NARRATIVE ON THE DEEPER MODELING SYSTEM AS A POLICY ASSESSMENT TOOL

Although the DEEPER Model is not a general equilibrium model, it does provide sufficient accounting detail to match import-adjusted changes in investments and expenditures within one sector of the economy and balance them against changes in other sectors.³⁶² More to the

³⁶² When both equilibrium and dynamic input-output models use the same technology, investment, and cost assumptions, both sets of models should generate a reasonably comparable set of outcomes. For a diagnostic

point of this exercise, the model can specifically explore the energy and non-energy productivity benefits from what is now characterized as a RNE Innovation Scenario—especially as it is transformed into a pro-active Third Industrial Revolution Roadmap Next Economy.

One critical assumption that underpins the core result of the DEEPER analysis is that *any productive investment or spending—whether in energy efficiency, renewable energy, and/or a more dynamic infrastructure that pays for itself over a reasonably short period of time—will generate a net reduction in the cost of energy services (as well as a lower cost of other resources which are needed to maintain the material well-being of the MRDH regional economy). That net reduction of energy and resource expenditures can, then, be spent for the purchase of other goods and services.* We noted in the discussion surrounding Figure 1, the redirecting of €1 million in value-added spending away from energy suggests there may be roughly a net gain of about 7.1 jobs. Depending on the many sectoral interactions, as well as the complete assessment of the many effects summarized and discussed in Table 1 of this assessment, the net gain in jobs may widen or close as the changed pattern of spending works its way through the model and as shifts in labor productivity change the number of jobs needed in each sector over a period of time.³⁶³

Once the mix of positive and negative changes in spending and investments has been established for the RNE Innovation Scenarios, the net spending changes in each year of the model are converted into sector-specific changes in final demand. Then, following the pattern highlighted in the diagram of the DEEPER Modeling System, the full array of changes will drive a dynamic input-output analysis according to the following predictive model:

$$X = (I-A)^{-1} * Y$$

where:

X = total industry output by a given sector of the economy

assessment of this conclusion, see, “Tripling the Nation’s Clean Energy Technologies: A Case Study in Evaluating the Performance of Energy Policy Models,” Donald A. Hanson and John A. “Skip” Laitner, *Proceedings of the 2005 ACEEE Summer Study on Energy Efficiency in Industry*, American Council for an Energy Efficient Economy, Washington, DC, July 2005.

³⁶³ Note that unlike many policy models, DEEPER also captures trends in labor productivity. That means the number of jobs needed per million Euros of revenue will decline over time. For example, if we assume a 1.5 percent labor productivity improvement over the 36-year period from 2014 through 2050, 15.4 construction jobs supported by spending of 1 million Euros today may support only 9 jobs by the year 2050. The calculation is $16 / 1.015^{(2050-2014)} = 9$ jobs (in rounded terms).

I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)

A = the matrix of production coefficients for each row and column within the matrix (in effect, how each column buys products from other sectors and how each row sells products to all other sectors)

Y = final demand, which is a column of net changes in spending by each sector as that spending pattern is affected by the policy case assumptions (changes in energy prices, energy consumption, investments, etc.)

This set of relationships can also be interpreted as

$$\Delta X = (I-A)^{-1} * \Delta Y.$$

A change in total sector output equals the expression $(I-A)^{-1}$ times a change in final demand for each sector.³⁶⁴ Employment quantities are adjusted annually according to exogenous assumptions about labor productivity. From a more operational standpoint, the macroeconomic module of the DEEPER Model traces how each set of changes in spending will work or ripple its way through the regional economy in each year of the assessment period. The end result is a net change in jobs, income, and GDP (or value-added).

For a review of how an Input--Output framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (2009). While the DEEPER Model is not an equilibrium model, as explained previously, we borrow some key concepts of mapping technology representation for DEEPER, and use the general scheme outlined in Hanson and Laitner (2009).³⁶⁵ Among other things, this includes an economic accounting to ensure resources are sufficiently available to meet the expected consumer and other final demands reflected in different policy scenarios.

³⁶⁴ Perhaps one way to understand the notation $(I-A)^{-1}$ is to think of this as the positive or negative impact multiplier depending on whether the change in spending is positive or negative for a given sector within a given year.

³⁶⁵ "Input-Output Equations Embedded within Climate and Energy Policy Analysis Models," by Donald A. Hanson and John A. "Skip" Laitner, in Sangwon Suh, Editor, *Input-Output Economics for Industrial Ecology*. Dordrecht, Netherlands: Springer, 2009. See also, "A Pragmatic CGE Model for Assessing the Influence of Model Structure and Assumptions in Climate Change Policy Analysis," by Stephen Bernow, Alexandr Rudkevich, Michael Ruth, and Irene Peters. Boston, MA: Tellus Institute, 1998.

TIR Consulting Group LLC Biographies

In Alphabetical Order

Frits BLIEK

Frits Blik is a Principal Consultant for DNV GL, with over 10 years experience in the energy sector, preferentially active in transition projects in the area of strategy, business analysis and innovation in the energy market. His analytical skills combined with his in-depth knowledge of the energy business, processes and systems allow him to develop detailed models and perform thorough analyses. His power lies in his enthusiasm and focus on results that matter. In this way he is capable of leading multi-disciplinary highly educated teams, such as the USEF design team, in an inspiring way and delivers innovative results of high quality. Timely identification of the essential business risks and providing to-the-point insight into these risks as well as the consequences and solutions make him a valued adviser on the board level.

Yvonne BOERAKKER

Yvonne Boerakker is a Senior Consultant, Policy Advisor, and Researcher at DNV GL who has worked in the energy field for more than a decade. She specializes in renewable energy, energy efficiency, and is experienced in topics such as building standards, actual energy performance, monitoring, and implementation of renewable energy plans. She was a member of the team that generated the Kwartiermaker Green Deal Smart Energy City in 2014. Additionally, Yvonne was an initiator and collaborator of a program to support Dutch-Indonesian private sector cooperation in the Indonesian energy sector, especially in the fields of biomass, W2E, geothermal energy, and wind energy.

Yvonne holds a degree in aerospace engineering from Delft University of Technology, a master's degree in technology management from Eindhoven University of Technology, and a number of other technical certificates from renowned universities throughout the Netherlands.

John BYRNE

John Byrne is the Chairman and President of the Foundation for Renewable Energy & Environment (FREE). The Foundation was created in 2011 with a mission of promoting a better

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future based on energy, water and materials conservation, renewable energy use, environmental resilience, and sustainable livelihoods. Dr. Byrne has contributed since 1992 to Working Group III of the Intergovernmental Panel on Climate Change (IPCC). His work is published in IPCC assessments which led to greater global awareness of the problem and the award of the 2007 Nobel Peace Prize to the Panel.

He is the architect of the Sustainable Energy Utility (SEU) model and its innovative energy efficiency finance program, which received U.S. White House recognition as part of the nation's Better Buildings Challenge. The Asian Development Bank has also recommended the model to its member countries.

From 2007 to 2012, he co-chaired the Delaware Sustainable Energy Utility Oversight Board. Delaware was the first jurisdiction to create an SEU modeled on Dr. Byrne's work. He presently leads FREE's efforts to diffuse this model, with initiatives in Pennsylvania (the Pennsylvania Sustainable Energy Finance Program or PennSEF – a partnership with Pennsylvania Treasury, Drinker, Biddle, Becker Capital, and West Penn Power Sustainable Energy Fund), California (the Sonoma County Efficiency Finance Program or SCEF), South Korea (the Seoul Metropolitan Government recently signed an MOU with FREE), and others.

In addition to his role at FREE, Dr. Byrne is Distinguished Professor of Energy and Climate Policy and Director of the Center for Energy and Environmental Policy (CEEP) at the University of Delaware. CEEP's graduate program is ranked among the three best in the field. As well, he holds an appointment as Distinguished Professor of Sustainable Energy at the Daegu Gyeongbuk Institute of Science and Technology, a new university created by South Korea to lead its plan for green energy technology and policy development.

Dr. Byrne is a founding member of and serves on the board the International Solar Cities Initiative – a pioneering program to assist cities around the world in building sustainable futures. He has served on the National Council for Science and the Environment (U.S.) and advised the Interagency Working Group on Environmental Justice, coordinated by the U.S. EPA. He received a Fulbright Senior Lecturer/ Researcher Award to teach environmental policy at the Graduate School of Environmental Studies, Seoul National University, and to conduct research on a National Greenhouse Gas Abatement Strategy for the Korea Energy Economics Institute. Dr. Byrne has been recognized by the Chinese government for his expertise in energy and environmental policy and his name appears on China's foreign expert registry. He is an advisor to the Chinese Academy of Sciences and also the Chinese Academy of Social Sciences, The Energy and Resources Institute (TERI in India) and the Korea Energy Economics Institute, among

others. His work has been funded by the World Bank, UNEP, the Blue Moon Fund, the Chinese Academy of Science, the Energy Research Institute of China's National Development and Reform Commission, the Korea Energy Economics Institute, the Korea Institute of Science & Technology, the Green Technology Center–Korea, The Energy Research Institute (TERI, New Delhi, India), the National Science Foundation, U.S. Department of Energy, the National Renewable Energy Laboratory, and the U.S. EPA, among others. He has published 17 books and over 160 research articles.

Michael CASEY

Michael Casey is, among other roles, a senior advisor for blockchain opportunities at the MIT Media Lab's Digital Currency Initiative and an advisor to the Agentic Group. At MIT, he is seeking to build awareness around digital currencies and the underlying blockchain technology, helping to shape scholarship around the topic and exploring dedicated research projects that use this emerging technology to achieve social impact goals. At Agentic, he is engaged in real-world, early-stage deployments of that technology.

Before joining MIT in 2015, Michael was a senior columnist covering global finance at The Wall Street Journal. In a career spanning five continents, he covered currencies, bonds, equities and economic policy for The Journal, Dow Jones Newswires and various other media outlets. He also did a great deal of TV and radio work, hosting TV shows produced by the WSJ Live team and appearing on numerous networks as a commentator, including CNBC, CNN, Fox Business and the BBC.

After taking an interest in bitcoin and digital currencies in 2013, Michael and colleague Paul Vigna founded the Bitbeat column, a regular survey of developments in the field that's published on WSJ's Moneybeat blog. The pair went on to co-author the critically acclaimed book, *The Age of Cryptocurrency: How Bitcoin and Digital Money are Challenging the Global Economic Order* and have collaborated with documentary film makers on the topic. Michael is now a frequent public speaker, where he speaks about digital currency themes and applications for the blockchain ledger. He also advises institutions on how to understand the challenges and opportunities that are emerging from this disruptive, decentralizing technology.

Before the *Age of Cryptocurrency*, Michael had written two prior books: *The Unfair Trade: How our Broken Global Financial System Destroys the Middle Class*, an analysis the global

dimensions of the recent financial crisis, and Che's Afterlife: The Legacy of an Image, about the famous photo of Ernesto "Che" Guevara by Alberto Korda.

A native of Perth, Australia, Michael is a graduate of the University of Western in Australia. He also has higher degrees from Cornell University and Curtin University.

Elisabetta CHERCHI

Currently working as an Associate Professor at the Department of Transport, Technical University of Denmark, and has a joint appointment with the University of Cagliari in Italy.

Her main research interests are in the area of modelling consumer behaviour, microeconomic derivation of behavioural models, data collection, demand model estimation and prediction and user benefit evaluation. Her major interest is in understanding what drives sustainable transport behaviour (i.e. shift toward public transport, electric vehicles, driverless vehicles and bicycles) and how it can be promoted.

She has published 45 papers in peer-reviewed international journals (such as Transportation Research Part A, B, D, F; Transportation; Transportation Science; Transport Policy) and book chapters and presented more than 70 papers at international congresses. She is currently Area Editor of the journal Transportation, member of the Editorial Boards of three other prestigious transport journals: Transportation Research part B, Journal of Choice Modelling and Transport Policy. She has been invited to give seminars at top world universities (such as EPFL, Northwestern, Maryland, Pontificia Universidad Católica de Chile, Imperial College, ETH Zurich) and workshops on the future direction of the research at three of the most relevant conferences in the field: IATBR 2009 and 2015, ISCTSC 2014 and TRB 2012.

She is currently Vice-Chair of the International Association for Travel Behaviour Research (IATBR) where she also served for four years as Secretary and Treasurer. She has also been a member of the Ph.D. evaluation committees of 9 students and served as member of the evaluation committee to appoint an Assistant Professor and an Associate Professor in Sweden and as referee for National funds to university research in Switzerland, the Netherlands, and in Chile.

During her career she has also had a leading role in many national and international research projects, such as the Green eMotion project, a major project with more than 40 partners, funded by the European Commission, the 7th Framework program, where she was responsible

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to study consumers' preferences and attitudes to electric vehicles; the economic evaluation of projects for the regeneration of urban sites of environmental interest, funded by Italian Ministry for University Research; and the GREAT project (Green Regions with Alternative Fuels for Transport), another research project funded by the European Commission where she is currently responsible for studying the effect of dissemination/communication and awareness on the use of a new network of recharging points for alternative fuel vehicles. She has also collaborated on several international projects funded by the by the Spanish Ministry for University Research, the Department for Transport in UK; the Ministry of Transport, Spanish Government.

She is also currently a member of the Board of Directors of the Airport of Cagliari, Italy (around 4 million passengers/year).

Daniel CHRISTENSEN

Daniel currently serves as Chief of Staff at TIR Consulting Group LLC. Prior to joining TIR Consulting Group LLC, he gained on-the-ground professional experience at the European Parliament in Brussels, Belgium, and the Assembly of European Regions in Strasbourg, France.

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Giovanni CORAZZA

Giovanni Emanuele Corazza, PhD, is a Full Professor in Telecommunications at the Alma Mater Studiorum University of Bologna, the oldest academic institution of the Western World. Since 2012, he has been a Member of the University of Bologna Board of Directors, the highest governance body in the institution. He was Head of the Department of Electronics, Computer Science and Systems (DEIS) from 2009-2012 and Chairman of the School for

Telecommunications from 2000-2003. He is the President of the Scientific Council of the Fondazione Guglielmo Marconi, and a Member of the Marconi Society Board of Directors. Giovanni E. Corazza is the founder of the Marconi Institute for Creativity, a body created as a joint initiative of the Fondazione Guglielmo Marconi and the University of Bologna, to investigate and divulgate all of the most research scientific evidence on the creative thinking process in humans and in artificially intelligent machines. Since 2014 he has been Vice-Chairman of NetWorld2020, the European Technology Platform dedicated to the future evolution of communication networks, and Member of the Board of the 5G Infrastructure Association, the private side of the 5G-PPP with the European Commission. Giovanni E. Corazza was the Chairman of the Advanced Satellite Mobile Systems Task Force (ASMS TF), and Founder and Chairman of the Integral Satcom Initiative (ISI), a European Technology Platform devoted to Satellite Communications. He was a co-founder of Mavigex S.r.l., a spin-off company dedicated to the development of innovative smartphone applications. During his career he also worked for Qualcomm (California, USA) and COM DEV (Ontario, Canada). He has been the principal investigator in more than 20 European projects funded by the European Commission and by the European Space Agency. He is a Member of the Editorial Board of the Journal of Eminence and Genius. From 1997-2012, he has served as Editor for Communication Theory and Spread Spectrum for the IEEE Transactions on Communications. He is the author of two books and of more than 300 papers on diversified topics in wireless and satellite communications, mobile radio channel characterization, Internet of Things, navigation and positioning, estimation and synchronization, spread spectrum and multi-carrier transmission, scientific creative thinking. Giovanni E. Corazza received the Marconi International Fellowship Young Scientist Award in 1995, the IEEE 2009 Satellite Communications Distinguished Service Award, the 2013 Newcom# Best Paper Award, the 2002 IEEE VTS Best System Paper Award, the Best Paper Award at IEEE ISSSTA'98, at IEEE ICT2001, and at ISWCS 2005. He has been the General Chairman of the IEEE ISSSTA 2008, ASMS 2004-2012 Conferences, and of the MIC Conference 2013. He has taught several graduate and undergraduate courses on Digital Transmission, Mobile Radio Communications, Principles of Multimedia Applications and Services, Software for Telecommunications, Information Theory and Coding, Digital Receiver Design and Optimization, Creativity and Innovation. He is a Member of the Scientific Committee of the Bologna Business School, where he contributes also to the Executive Master in Technology and Innovation Management.

Kathleen GAFFNEY

Kathleen Gaffney is a Managing Director in Navigant's Global Energy practice, based in London. With more than two decades of experience in managing large-scale, multi-year engagements and overseeing the work of large interdisciplinary research teams, Kathleen plays an integral role in advising energy clients on demand-side policies, markets, and programmes. Her work centres on directing targeted market research that incorporates robust data analytics, customer segmentation, and behaviour modelling to help clients better understand evolving customer expectations and strengthen their competitive position in a rapidly changing environment. Kathleen has completed hundreds of impact assessments, process evaluations and technical research studies across a wide range of energy sector initiatives including those targeting residential, commercial, institutional and industrial sectors.

Prior to joining Navigant, Kathleen was based in London and responsible for leading DNV GL's European-focused practice on energy and climate policy and programme evaluation and, during 2013-2014, she fulfilled a similar assignment based in Sydney, Australia. Prior to 2013, Kathleen co-led a US-based evaluation practice totalling US\$ 30+ million in annual revenues. Kathleen's team focused nearly exclusively on energy policy and programme evaluation for a range of government and energy sector clients. Kathleen has more than 20 years' experience in the evaluation field and has supported skills and expertise development for more than 150 energy and climate policy and program evaluation practitioners worldwide.

Kathleen holds a BS in Economics and International Relations from The American University, Washington, DC, and an MA in Energy Management and Policy / Appropriate Technology from the University of Pennsylvania, Philadelphia, PA.

Rob van GERWEN

Rob van Gerwen is a very experienced senior technical consultant with a back ground in physics. He managed and supported many projects in the field of domestic, utility and industrial energy use. His current field of activity is smart meters and smart grids. He was involved in many (international) smart meter or smart grid projects, including smart meter cost benefit analyses for the Netherlands, Turkey, Cyprus, Belgium, Portugal and Australia. He managed and contributed to many technical due diligence and technical review projects. He developed several methodologies for assessing renewable energy projects, energy efficiency projects and smart metering/smart grid projects, both technically and financially. He worked as a smart

grid/demand response expert in a large international project for a meter manufacturer. He has additional technical experience with decentralized energy conversion technologies (micro-CHP, fuel cells, ORC-units) and is asked to perform technical due diligences in this area on a regular basis.

Luca GUALA

Luca is founder partner of MLab srl, a consulting company started in 2012 in Cagliari, Italy, which specializes in transport solutions and planning consultancy with a strong focus on sustainability and innovation. Currently, his current position within MLab is technical director. In 2015 and 2016 he taught noise assessment techniques in professional training courses.

In 2013 he worked as Chief Engineer with responsibility in Transport for the Perm City Project Bureau (Perm, Russia). From 2005 to 2011 he worked as specialist consultant first, then project director, for the transport planning Company Systematica, Milan, Italy, focusing his activity on innovative and sustainable transport solutions, urban transport plans, transport consultancy to urban planners and master-planning. Previously, he worked as a researcher at the University of Cagliari, Department of Territory and as free-lance consultant for the transport of waste and of dangerous goods and the assessment of noise and vibrations;

Luca achieved a 5 years degree (MScEng) in transport engineering at the University of Cagliari, Italy, and a PhD in transport technique and economics at the University of Palermo, Italy.

Among Luca's most relevant professional experiences of the last 10 years in the fields of urban scale transport planning, sustainable and innovative transport systems are: 2016: transport plan for the City Strategic Master Plan of Ekaterinburg, Russia (with MLA+ NL); 2015: strategic transport plan of the city of Ufa, Republic of Bashkortostan, Russian Federation (with UrbanBairam, Ufa); 2013-2014: Transport strategy for the masterplan of a large mixed-use development in Khimki, territory of Moscow, Russia (with Systematica, Italy, KCAP, NL); 2012-2016: design and implementation of the first demonstrator of the "City Mobil 2" E.C. FP7 project to test automated transit systems in a real urban environment (with CTL, University of Rome La Sapienza, Italy); 2013: planning of the automated public transport system for the women's campus of King Abdullaziz University, Jeddah, Saudi Arabia (with 2getthere, NL); 2011-12: "Green eMotion" E. C. FP7 project for sustainable micro-mobility in Rome, Italy (with CTL, University of Rome la Sapienza, Italy); 2010: mobility strategy of the Strategic Master Plan of Brussels Capital Region, Belgium (with KCAP, NL); 2009-2010: mobility strategy for the Strategic

Master-Plan and the General-Plan of the city of Perm', Russia(with CPB Perm, Russia); 2007-2009: innovative, zero-carbon mobility strategy for the Masdar City Masterplan; planning of the autonomous transport system and design of the network for the "MIST Campus" at Masdar City, UAE (with ADFEC, UAE; Fosters & Partners, UK); 2006: public transport, cycling and walking strategies of the Urban Mobility Plan of Cagliari, Italy; with Municipality of Cagliari, Italy

Hans de HEER

Hans de Heer is an experienced project manager at DNV GL, mainly in the field of business process (re)design, system development and implementation in the utilities sector. Focusing on business objectives and processes and based on his extensive technical experience, he excels at translating business needs into information architecture systems.

Over the past several years, Hans has developed specific expertise and experience in Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI); allocation, nomination and reconciliation processes, portfolio management, trade and supply, electric mobility and demand side management. Hans is a pragmatic, result driven and committed professional who easily takes responsibility. He is able to think and act on a technical, conceptual or organizational level. Hans is particularly valued when creating order and overview. In this role he consolidates the available information, defines possible actions and supervises the necessary actions leading to implementation.

Philipp KRÜGER

Philipp S. Krüger is Advisor for Cybersecurity at German Fraunhofer SIT and Co-Founder and Member of the Board at American Software Firm Scrapp Inc. Previously he was Director of the Digital Economy Project at Stiftung Neue Verantwortung in Berlin where he advised public and private stakeholders on the implementation of the new "Digital Agenda" policy initiative for Europe. Before that, Philipp advised the Free State of Saxony and the Free State of Bavaria on the creation of regional technology growth investment funds. He was the Co-founder and CEO of Explorist Inc., a U.S.-German Big Data firm which he developed while at M.I.T. Media Lab. Before that, he served as COO of Kirkwood & Sons Technology Investment, a \$700mm private equity firm, and worked as project manager at Bertelsmann and Siemens. Philipp currently holds appointments at the Tönissteiner Kreis, the Stifterverband für die Deutsche Wissenschaft,

the American Council on Germany, the Milken Institute's Young Leaders Council and the German Center for Research and Innovation. Prior to his work in technology, Philipp served the United Nations Department of Peacekeeping Operations as Field Officer during the wars in Sierra Leone and Kosovo. Philipp is a graduate of Harvard's Kennedy School of Government, M.I.T Media Lab and Augsburg-University's Law Faculty. Philipp grew up in Munich, Bavaria.

John "Skip" LAITNER

John A. "Skip" Laitner is a resource economist who leads a team of consultants, the Economic and Human Dimensions Research Associates, based in Tucson, Arizona. He also serves as the chief economist for Jeremy Rifkin's Third Industrial Revolution initiatives as well as a senior economist for the Russian Presidential Academy of National Economy and Public Administration (RANEPa). He previously worked almost 10 years as a Senior Economist for Technology Policy with the US Environmental Protection Agency (EPA). He left the federal service in June 2006 to focus his research on developing a more robust technology and behavioral characterization of energy efficiency resources for use in energy and climate policy analyses and within economic policy models.

In 1998 Skip was awarded EPA's Gold Medal for his work with a team of economists to evaluate the impact of different strategies that might assist in the implementation of smart and more productive climate policies. In 2003 the US Combined Heat and Power Association gave him an award to acknowledge his contributions to the policy development of that industry. In 2004 his paper, "How Far Energy Efficiency?" catalyzed new research into the proper characterization of efficiency as a long-term economic development resource. Author of more than 320 reports, journal articles, and book chapters, Skip has 45 years of involvement in the environmental, energy and economic policy arenas.

His expertise includes benefit-cost assessments, behavioral assessments, resource costs and constraints, and the net employment and macroeconomic impacts of energy and climate policy scenarios. His most immediate research focuses on two areas. The first area builds on the work of Robert U. Ayres and examines the links between energy inefficiency and a productive economy. In a book chapter published in 2014, Skip provides a time series dataset that suggests the United States may be only 14 percent energy-efficient, and that it is this level of inefficiency which may constrain the future development of a more robust economy. The second area explores the ways that nations, communities and the energy industry can maximize

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the economic opportunity of productivity-led investments while minimizing the risk of rising energy prices and disruptive energy supplies.

Claude LENGLET

Claude graduated as engineer from Ecole Centrale de Paris and then obtained a Master's Degree of the University of Colorado (Boulder) in 1971. He started working in prestressed concrete bridge design in a large construction company in Paris, and then moved back to the North of France where he worked in a construction design office from 1981 to 1989, working on wood construction and on new computer aided design tools.

In 1989 he decided to join an Architect team and developed his knowledge of urban planning and architectural design through numerous projects.

In 1998 he became Technical Director for Norpac (a branch office of Bouygues), leading a team of more than fifty engineers and draftsmen. From 2006 to 2009 he was responsible for R & D activities of Bouygues Construction in relation with the European Construction Technology Platform (ECTP). He then took the co-leadership of the E2B European program on buildings energy efficiency, a program that was funded at the level of one billion euros on ten years by the EC.

Starting 2009, he worked as Scientific Director of the Rabot-Dutilleul construction group. He also worked with the World Forum Lille, co-managing a think tank on CSR.

In 2013, for the Regional Chamber of Commerce and Industry and for the Regional Council in Nord-Pas de Calais, he conducted the team and the eight working groups in charge of building up the Third Industrial Revolution Master Plan as a direct interlocutor of Jeremy Rifkin's teams. The Master Plan was successfully presented in October 2013.

Zachary NAVARRO

Zachary Navarro currently holds the position of Program Manager / Executive Assistant for the TIR Consulting Group LLC. Prior to joining the TIR Consulting Group, Zachary's work focused on the development of legislation as he held various positions in the public and private sectors working as a Researcher for the House of Commons of the United Kingdom in London, a Legislative Aide for the United States House of Representatives in Washington DC, and as a

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Researcher for a management consulting firm on a contract with the Executive Branch of the United States Federal Government.

Zachary holds a Master of Science from the London School of Economics and Political Science where he studied the Politics and Government of the European Union, specializing in informal governance and the foreign policy of the EU. His MSc dissertation was entitled “Foreign Policy Convergence: The myth of the insurmountable divide between the European Union and the United States”. He also holds a Bachelor of Arts from Boston’s Northeastern University where he studied Political Science and International Affairs.

Harilaos PSARAFTIS

Harilaos N. Psaraftis is Professor at the Technical University of Denmark (DTU), Department of Transport. He has a diploma from the National Technical University of Athens (NTUA) (1974), and two M.Sc. degrees (1977) and a Ph.D. (1979) from MIT, USA. He has been Assistant and Associate Professor at MIT from 1979 to 1989 and Professor at NTUA from 1989 to 2013. He has participated in 20 or so EU projects, and has coordinated 3 of them, including project SuperGreen on European green corridors (2010-2013). He has been a member and chairman of various groups at the IMO, and has also served as CEO of the Piraeus Port Authority (1996 - 2002). He has published extensively and has received several academic and industry awards.

Andreas REUTER

Andreas Reuter has an engineering degree in aviation and space technology and completed his doctoral thesis on fatigue of wind turbines at the Technical University of Berlin. In the following years, he has worked in the wind industry for companies as aerodyn, GE Energy and Bharat Forge as project engineer, director of engineering and managing director. He was responsible for the design and the market introduction of one of the globally most successful wind turbine models. In 2010, he returned to the scientific community and now works as professor for wind energy technology at the Leibniz University of Hannover and managing director of the Fraunhofer Institute of Wind Energy and System Technology (IWES) with a total of 400 scientific employees and a well-established testing infrastructure. The main focus of his current work is the improved design process for very large wind power plants, both on- and offshore.

Jeremy RIFKIN

Jeremy Rifkin is an American economic and social theorist, author, and advisor to heads of state around the world. Mr. Rifkin is ranked 123 in the WorldPost / HuffingtonPost 2015 global survey of "The World's Most Influential Voices." Mr. Rifkin is also listed among the top 10 most influential economic thinkers in the survey.

Mr. Rifkin is the author of 20 books about the impact of scientific and technological changes on the economy, the workforce, society, and the environment that have been translated into over 35 languages.

Mr. Rifkin has been an advisor to the European Union since 2000. He has advised the past three presidents of the European Commission and their leadership teams – President Romano Prodi, President Jose-Manuel Barroso, and the current President Jean-Claude Juncker. Rifkin has also served as an advisor to the leadership of the European Parliament and numerous heads of state, including Chancellor Angela Merkel of Germany, President Nicolas Sarkozy of France, and Prime Minister Jose Luis Rodriguez Zapatero of Spain.

Mr. Rifkin is currently advising both the leadership of the European Union and the People's Republic of China. His book, *The Third Industrial Revolution*, has become their blueprint for addressing climate change and creating a smart, sustainable, digital global economy. Mr. Rifkin is a principal architect of the European Union's Third Industrial Revolution economic development plan to transform the world's largest economy into a post-carbon smart digital society. Mr. Rifkin's Third Industrial Revolution vision has also been adopted by the People's Republic of China as a centerpiece of its long-term economic development strategy.

Mr. Rifkin is the President of the TIR Consulting Group, LLC comprising many of the leading renewable energy companies, electricity transmission companies, construction companies, architectural firms, IT and electronics companies, and transport and logistics companies. His global economic development team is working with cities, regions, and national governments to develop the Internet of Things (IoT) infrastructure for a Collaborative Commons and a Third Industrial Revolution. The TIR Consulting Group LLC is currently working with the regions of Hauts-de-France (the third largest region in France), the twenty-three municipalities of the Metropolitan Region of Rotterdam and The Hague, and the Grand Duchy of Luxembourg in the conceptualization, build out, and scale up of a smart Third Industrial Revolution infrastructure to transform their economies.

Since 1994, Mr. Rifkin has been a senior lecturer at the Wharton School's Executive Education Program at the University of Pennsylvania, where he instructs CEOs and senior management on transitioning their business operations into sustainable economies.

Francesco SECHI

Francesco graduated in transport engineering at the University of Cagliari; since 1997 he has been working in the field of Transport Planning, taking part to several projects concerning private and public transport issues at national, regional, provincial and urban scale with the role of Planner, Project Manager or Scientific Supervisor.

Mainly the projects were related to the evaluation of major infrastructure projects, such as highways, underground metro, light-rail and tramway, mobility plans, traffic impact assessment, forecast of passenger and freight demand, innovative transport systems. These studies were mainly supported by predictive simulations through the use of transport simulation models. He also acquired a thorough understanding of economic and financial assessment of transport system interventions funded by the European community.

From 2002 to 2011, he has been consultant of Systematica spa firm where he has directed and coordinated the team of the local headquarters of Cagliari (with a workforce of up to 15 engineers). In 2002 he co-founded the local office in Cagliari of Systematica, of which he is a partner since 2005.

In 2012 he co-founded the company "Systematica Mobility Thinklab srl" ("Mlab" in short), an engineering firm based in Cagliari, specialized in planning and feasibility studies of transport systems, addressing both traditional and innovative systems. Currently he is chairman of the board of directors of Mlab.

He is also collaborating with the chair of "transport planning" of the faculty of engineering and with the course of "project management" of the faculty of economics of the University of Cagliari.

Gerhard STRYI-HIPP

Gerhard Stryi-Hipp, head of energy policy and coordinator "Smart Energy Cities" at Fraunhofer ISE, is a physicist and an interdisciplinary expert on technologies, market development and

policies in renewable energies and sustainable energy systems. From 1994 to 2008, he was managing director of the German Solar Industry Association BSWSolar and its predecessors. He worked on market support policy for solar thermal and solar photovoltaic in Germany and Europe, on awareness campaigns, on quality assurance measures and technical innovations of the sector. He advocates for intensified research on renewable heating and cooling and in 2005 was one of the initiators of the German and European Solar Thermal Technology Platforms. Since its foundation in 2008, he has been president of the European Technology Platform on Renewable Heating and Cooling, which developed a vision, a research agenda and a roadmap for the sector. In 2009, Gerhard moved to Fraunhofer ISE, the largest solar research institute in Europe. He conducted projects on solar thermal energy systems, e.g. on Solar-Active-Houses which are heated by more than 50% by solar thermal energy. Since 2012 he has focused his work on sustainable energy systems especially for cities and communities. He is an energy expert in the multi-disciplinary Fraunhofer project “Morgenstadt: City Insights”. With his research group “Districts and Cities” he is developing modelling tools to identify and design cost-effective sustainable energy systems for cities and regions. Based on these scenarios backwarding methods are used to derive roadmaps for the transformation of urban energy systems towards sustainability. Since 2014, he has been a member of the Seoul International Advisory Council, which gives advice to the city of Seoul for the transition of their energy system.

Job TAMINIAU

Dr. Job Taminiau oversees research that advances the mission statement of FREE (Foundation for Renewable Energy & Environment). He leads projects on ‘best practice’ energy efficiency policy, green technology investment, climate-sensitive economic development, and energy conservation awareness for public sector clients in and beyond the U.S. He completed his doctorate on climate change policy and economics at the Center for Energy and Environmental Policy (CEEP).

He has a multi-disciplinary background and his work covers subjects including energy finance, renewable energy and energy efficiency technology, (global) carbon markets, climate change policy, diffusion of innovation, transition management, and community utility development. Job manages the FREE Policy Brief Series and regularly publishes peer-reviewed papers and book chapters on a wide range of energy and environmental topics. For his work, he was rewarded with a first place climate policy thesis award from CE Delft (Netherlands), a second place in the

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MIT Climate CoLab contest, two University of Delaware Graduate Fellowships, and a FREE Minds Award. Job is always interested in engaging with other FREE Minds and is open for potential collaborations across the network.

Michael TOTTEN

Since the 1973 Arab oil embargo and price shocks, and after graduating with Honors from Yale University as a cross-disciplinary scholar, Michael P. Totten has dedicated his professional life to promoting innovative market strategies and governance policies that catalyze a solar powered economy comprised of highly energy and resource efficient buildings, industries and transportation sectors.

In the 1980s he pioneered comprehensive federal legislation, the Global Warming prevention Act (popularly known as the U.S. Productivity Enhancement and Export Competitiveness Act) which focused on accruing multi-trillion dollar savings opportunities through end-use efficiency gains. He also spearheaded the first Internet collaboration innovation network connecting state regulatory utility commissioners, for sharing methodologies focused on delivering utility services at the lowest lifecycle cost and risk via end-use efficiency gains and distributed generation.

In the 1990s Totten founded and headed the Center for Renewable Energy and Sustainable Technology (CREST), set up to harness the emerging global Internet communication and multimedia software tools for spurring best-in-play market practices and governance policies fostering zero-emission economic growth while accruing mega-scale monetary savings and biosphere benefits. CREST pioneered production and distribution of CD-based multimedia learning and decision-making software, migrated to the Internet when web tools emerged. By the late 1990s it was one of the largest Internet sites in traffic and accessible resources on energy efficiency and renewable energy. These several decades of innovative advocacy garnered Totten the Lewis Mumford Prize in 1999, given by Architects, Designers and Planners for Social Responsibility.

For the past dozen years Totten served as the Chief Advisor on Climate and Clean Tech at the global non-profit group, Conservation International. His cross-disciplinary initiatives focused on engaging scores of global corporations and national governments in getting them to adopt leadership practices and positions for achieving zero-net emissions. This was practically achieved by implementing portfolios of risk-minimizing, benefits-generating actions in

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operations and supply networks. Among his accomplishments included catalyzing Walmart's Sustainability initiative in 2004, beginning with assessing the ecological impacts, or "biosphere footprint", of their operations and supply chain.

Totten's more than 1500 presentations, articles, workshops and seminars over the past 40 years have illustrated and emphasized how Internet-based collaboration innovation networks (COINs) can leverage valuable insights from actual achievements worldwide, at far less cost and much faster speeds. In 2012 he launched the COIN initiative, ASSETs (Apps for Spurring Solar and Efficiency Tech-knowledge), to catalyze zero-net emission cities largely achieved by self-motivated citizens in their cities, companies, and campuses.

Frits VERHEIJ

Frits Verheij has been working in the renewable energy business and related areas like smart grids and energy storage, since the start of his career in 1987. Prior to joining DNV GL (then: KEMA), he held various positions at the research organisation TNO and was program manager at the Dutch Energy Agency Novem. Currently, Frits is Director Smart Green Cities for DNV GL – Energy. Additionally, he is Vice-chairman of the Board of Top consortium on Knowledge & Innovation (TKI) Urban Energy, and member of the Executive Board of USEF (Universal Smart Energy Framework).

Frits is an expert in working at the crossroads of innovation, energy policy, and strategy. He has been working for governments, utilities, industries, and other organisations in the energy sector. He knows how to work with the different interests of these stakeholders, as well as how to manage multi-client projects.

Marcel VOLKERTS

Marcel Volkerts is a Principal Consultant for DNV GL, where he focuses on smart energy systems. As a leading member of the Universal Smart Energy Framework design team and leader of the EDGaR Smart Gas Grids research project he works on creating a vision for applying smart, integrated energy systems on a large scale. In the EU-funded City-Zen project Marcel heads up the development of a multi-stakeholder serious game on the transition to zero-energy neighborhoods that provides input for roadmaps for the transition to smart green cities.

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Before joining KEMA (now DNV GL) in 2011, Marcel enjoyed an international career in IT, working for various start-ups in both the Netherlands and the USA. As the director of quality assurance and manager of the database group of Florida-based internet security firm SafeCentral (formerly Authentium), he successfully established an international quality assurance and product development organization, before stepping into a role as an internal consultant for the CTO and COO, advising on product development, competitive analysis and product certifications. Marcel holds a PhD in experimental nuclear physics, earned through research done at University of Groningen, the Netherlands.

Sophie van VOLSEM

Since 2010 Sofie is employed as a risk management consultant at DNV GL, involved in Enterprise Risk Management projects and Safety Risk projects. Her professional experience has been built up in both industry and university; she has in total over 15 years consulting, teaching and industry experience. Sofie holds a master's degree in Chemical Engineering and a PhD in Industrial Management & Operations Research from Ghent University. She is also qualified as an (internal) auditor for management systems. She has extensive cross industry experience from a range of consultancy services towards oil & gas, maritime, transportation and electricity production companies; and authorities. From a series of projects since 2012 she has acquired specific expertise related to the use of LNG and alternative fuels in shipping. Sofie has managed several projects in this domain, for authorities (EC DG MOVE, EMSA, Flemish government, port of Antwerp) as well as for maritime clients. This experience in sustainable shipping is also exercised by means of an active membership in the ESSF (EC's sustainable shipping forum) and by acting as convenor of ISO/TC67/SC9/WG1. Other areas of expertise include implementation of integrated management systems, project risk management, feasibility studies and hazard studies.

Michael Waidner

Michael Waidner is one of the pioneers of Cyber Security and Microsoft Academic Search lists him among the world's top scientific authors in the area of IT security and privacy. As a leading figure in Europe's security scene he has successfully founded new research centers and spearheaded innovative security paradigms like "Security at Large", which focusses on the security of complex real-existing systems. Waidner's broad scientific and entrepreneurial

background makes him a unique expert for applied security whose council is sought by the enterprise world and the political sphere alike.

Currently, Waidner is the Director of the Fraunhofer Institute for Secure Information Technology (Fraunhofer SIT) in Darmstadt, Germany. He holds a chair as professor for Security in Information Technology at the Technical University of Darmstadt and is also the Director of the Center for Advanced Security Research Darmstadt (CASED), Speaker of the Center for Research in Security and Privacy (CRISP), and founding Director of the Fraunhofer Project Center for Cybersecurity at the Hebrew University of Jerusalem (Fraunhofer SIT/IL@HUJI).

He started in 1986 as a researcher at the University of Karlsruhe (now Karlsruhe Institute of Technology), Karlsruhe, Germany, where he received his Diploma and Doctorate in Computer Science. In 2004 he moved to Rüschlikon in Switzerland to join IBM, where he held various technical and management positions. As a Senior Manager he was responsible for IBM Zurich's security and software research projects, and for IBM Research's global agenda in security and privacy. During that time he co-initiated the IBM Privacy Research Institute, which he led until 2006, and the Zurich Information Security Center (ZISC), a joint research center hosted by the Swiss Federal Institute of Technology (ETH). In 2006 he joined the IBM Software Group in Somers, NY, USA. Until 2010 he was an IBM Distinguished Engineer and the Chief Technology Officer for Security, responsible for the technical security strategy and architecture of the IBM Corporation.

Michael Waidner regularly participates in scientific and technical advisory boards, program committees and conferences. He is a member of the ESORICS Steering Committee, and co-initiator of the ACM Workshop on Formal Methods in Security Engineering. Up to now he has co-/authored more than 130 scientific and technical publications in the areas of security, privacy, cryptography, dependability and fault tolerance. He has co-/invented more than 20 patents.

Eicke WEBER

Born on October 28, 1949 in Münnerstadt, Germany, Eicke Weber received his doctorate in physics from the University of Cologne in 1976. After research stays at the State University of New York, Albany, USA and the University Lund, Sweden, he habilitated in 1983 also at the University of Cologne. In the same year he took a job as professor at the University of California, Berkeley in the Department of Materials Science and Engineering. In March 2004, he

was named chair of the interdisciplinary Nanoscale Science and Engineering Graduate Group.

In 1984 he received an IBM Faculty Development Award, in 1994 the Alexander von Humboldt Prize, and since 2002 he has been a fellow of the American Physical Society. In 1990 he was invited on the Tohoku University in Sendai, Japan as visiting professor, and in December 2003 he was asked to give the Zhu KheZhen talk at the Zeijang University in Hangzhou, China. Professor Weber was the first president of the Berkeley Chapter of the Alexander von Humboldt Association of America (AvHAA) serving from 2001-2003. Since 2003, he has been the founding president of the German Scholars Organization (GSO). In June 2006 he received the Order of Merit of the Federal Republic of Germany.

In July 2006, he became director of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg and simultaneously professor in the departments of mathematics and physics and of engineering at the Albert Ludwig University in Freiburg. In July 2008 he was appointed as director of the SEMI International Board of Directors. The Electrochemical Society ECS, San Francisco honored Professor Weber in June 2009 with the Electronics and Photonics Division Award. In October 2009, he was chosen to be an honorary member of the Lofte Physical-Technical Institute of the Russian Academy of Sciences, St. Petersburg. Since April 2010, Weber is a member of acatech, the German Academy of Technical Sciences, Berlin.

Robert WILHITE

In his role as a Managing Director in Navigant's Energy practice, Rob directs business strategy and regulatory advisory activities and serves as part of the Energy practice leadership team. He also supports the firm's growth with a focus on senior client relationships, engagement delivery, and industry thought leadership. Since starting his career 31 years ago, Rob has worked exclusively in the energy industry and brings a unique combination of technical knowledge and business strategy experience.

On a global basis, Rob has often advised energy clients in achieving increased efficiency in utility operations, grid automation, and technology strategy and implementation. He also supports utility strategies seeking new revenue growth and business expansion. In addition to utilities, Rob has also developed growth and market entry strategies for competitive retail energy firms, equipment suppliers, private equity firms, and industry policy groups.

Rob began his career with an 11-year stint at Florida Power & Light (FPL), where he managed State-wide energy efficiency programs and developed technical expertise in planning,

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designing, and overseeing construction of electric distribution facilities. Following FPL, Rob worked for the Electric Power Research Institute and then with Accenture. More recently, Rob applied the past 12 years of his career with KEMA (now DNV GL), where he was responsible for achieving growth, profitability, and operational performance objectives as managing director for the Americas, and as global director for all management and operations consulting. He developed KEMA's grid modernization advisory unit, overseeing expansion into one of the more successful practices within KEMA, but also positioned the firm as a respected market leader in this domain. He also co-authored KEMA's first book, *Utility of the Future: Directions for Enhancing Sustainability, Reliability and Profitability*.

Rob was recognized as one of the top 25 consultants in the U.S. by Consulting Magazine in 2009. He has also been cited as one of the Networked Grid 100 Movers and Shakers of the Smart Grid by Greentech Media in 2012, as well as participated in President Obama's Council on Jobs and Competitiveness in 2011.

Rik WILLARD

Rik Willard is the Founder and Managing Director of Agentic Group LLC, a multinational consortium of over forty (40) Blockchain, Digital Currency and related companies in the US, EU, South America and Canada, with representative offices in both London and Paris. He is recognized as a digital pioneer and serial entrepreneur, with a reputation of successfully introducing new and advanced technologies to international markets for over twenty-five years.

Prior to founding Agentic Group, in 2013, Mr. Willard was co-founder and Managing Director of MintCombine Inc. in New York City. MintCombine was the world's first think tank/startup incubator focused solely on digital currency technologies and the role of cryptocurrencies and tokenized blockchains within a wide range of business sectors. From 2010-2013, he consulted with a number of Fortune 500 companies and led a syndicate of investors interested in the convergence of social media and identity technologies.

Between 2006-2010 Mr. Willard consulted with the MGM Resorts corporation for global digital projects, including mobile and social media applications. During this time he was the lead consultant for internal and external digital signage and the lead on social media and mobile integration with signage, for application to MGM Resort properties worldwide, including their US and Asia properties. From 2001-2006, he was lead consultant to Winston & Company,

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designing display and back-end technology systems for many of the LED display projects in Times Square, New York City and working closely with major international brands such as Coca-Cola, Toshiba, LG, Anheuser Busch, Mars, and others.

In 1994 he founded Mediamerge, one of the first “dotcoms” in New York’s emerging Silicon Alley. His clients included Calvin Klein Cosmetics, Lucent Technologies, Unilever and others. He sold his interest in that company to private investors in 1999. His first company, Beam Communications, was founded in 1990 and was the first company in North America devoted to HDTV outdoor advertising technology. Beam’s clients and partners included Sony of America, Japan Broadcasting Company, Columbia Pictures, and Met Life.

Mr. Willard received his undergraduate degree from Howard University’s School of Communications. He is a Fellow of the Foreign Policy Association, an Advisor to the Field Center for Entrepreneurship at Baruch College’s Zicklin School of Business in New York City, a Board member of the Seidenberg Center for Computer Science at Pace University in New York, and a Blockchain Startup Advisor with the famous Silicon Valley incubator Plug And Play. He remains an internationally-sought speaker, featured at the Harvard Business School, the Kaufmann Institute, All Payments Spain/Australia, with numerous media engagements over the years including CNN, CNBC, and CNN International. Mr. Willard is also mentioned in Michael J. Casey and Paul Vigna’s seminal book on the origins of the cryptocurrency movement “The Age of Cryptocurrency”, as being one of the initial venture catalysts of the current digital currency movement.

This report was commissioned by the Metropolitan Region of Rotterdam and The Hague on terms that limit the liability of the TIR Consulting Group LLC for the Third Industrial Revolution Roadmap Next Economy. The analysis and conclusions presented in the report result from the exercise of our best professional judgment, informed in large part by materials and information available from a variety of sources. Use of the report by a third party, for whatever purpose, should not and does not absolve such third party from using due diligence in verifying the report's contents for its own specific purposes. Any use of the document and any reliance on or decisions based on it are the responsibility of those individuals, organizations or businesses that use it. The TIR Consulting Group LLC makes no warranty or representation as to the content or accuracy of the content of the commissioned report and does not accept any duty of care or liability of any kind whatsoever to any prospective user, and is not responsible for damages, if any, which may be incurred by that user as a result of decisions made or not made, or any actions taken or not taken, based on the report.