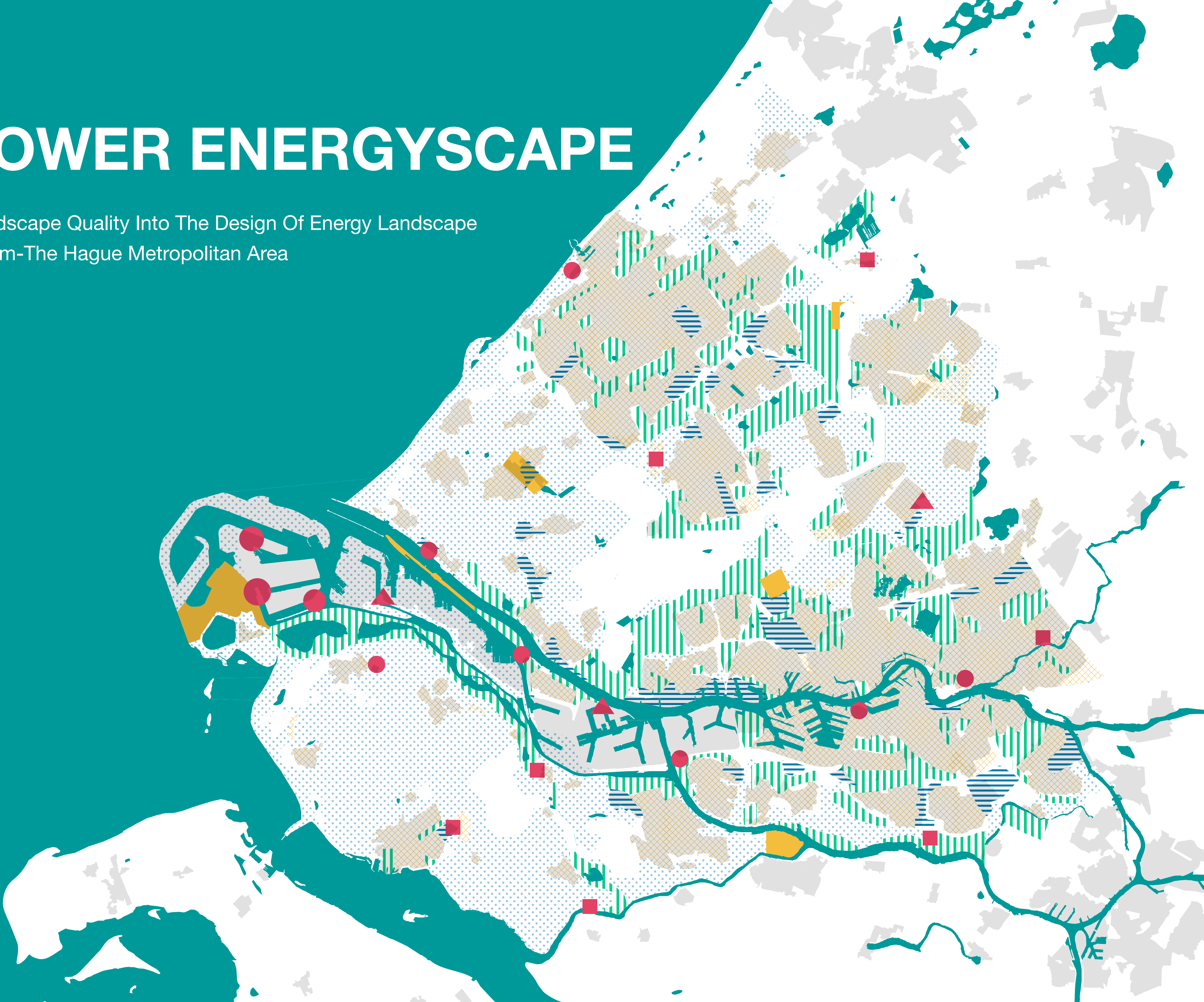
EMPOWER ENERGYSCAPE

Integrating Landscape Quality Into The Design Of Energy Landscape
In The Rotterdam-The Hague Metropolitan Area



Tianyue Ma
June, 2019

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P5 report

Deflt University of Technology | Faculty of Architecture and the Built Environment | Msc Urbanism

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Msc Thesis - P5 Report
Empower Energyscape
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Preface photo by author

Motivation

Frankly speaking, sustainable and resilient development has always drawn my interest. It is widely acknowledged that sustainability is becoming an inevitable trend as the whole world is under the great pressure of environmental issues and resource depletion.

During my bachelor in China, I did my graduation project related to urban ecology, which has considered urban development as a part of nature and focused on making a regional plan that preserves and brings different landscapes into a functional system. Since then, I started to be interested in urban landscape planning and design. In the first year here at TU Delft (MSc2 Q3), I began to have an initial understanding and review on urban metabolism by working on developing a sustainable energy system in AMA, during which I found myself really interested in the quantitative approach, statistical analysis, flow analysis, regional research and vision-proposal approach. On the other hand, the relation between energy production and landscape has been re-attached when it comes to the third generation of energy landscape: renewable energy landscape, which provides the opportunity to combine these two conceptual domains together.

As a matter of fact, it comes to my mind if it is possible to facilitate sustainable energy approach from a landscape perspective. Through literature review and phenomenon observation, I realize that there is a practical gap between energy planning and landscape quality which slows the energy transition. This has also become my initial motivation to do my graduation project. Moreover, as global climate change and fossil fuel resource depletion become more evident, this project will also give an insight on how to design energy landscape in any other regions and countries.

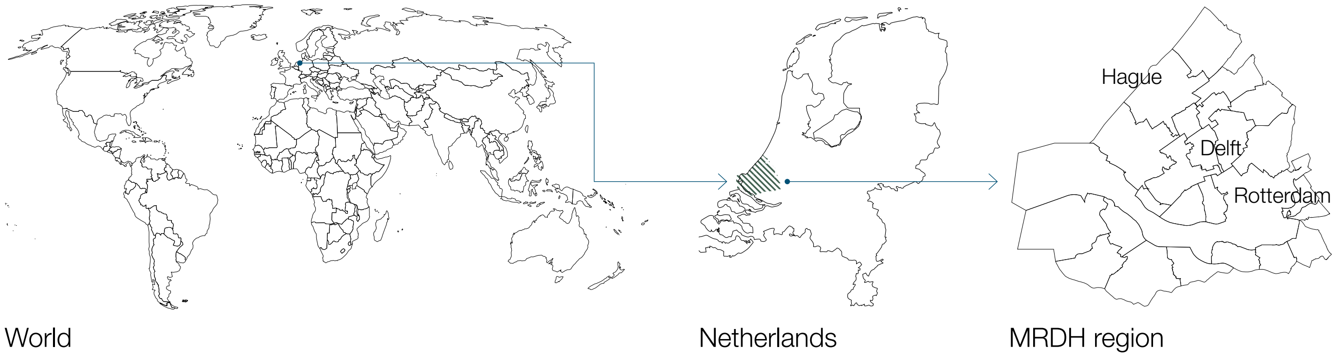
CONTENT

01 INTRODUCTION

Image 1. Bridge of Rotterdam
Source: www.prologis.com

1.1 What Is MRDH?

Located in the large urban area named Randstad, the Rotterdam-The Hague metropolitan area (MRDH) was founded in 2014, encompassing the cities of Rotterdam and The Hague as well as 21 other municipalities (MRDH Atlas, 2014). Rotterdam is a modern city since it was rebuilt after WW2, while The Hague still has a historic center. Also, with TU Delft and Erasmus University Rotterdam, the region is considered an important part of the knowledge belt of the Netherlands.



Map 1. location of the MRDH region

Image 2. Modern city Rotterdam

Image 3. Historic center The Hague

Image 4. Greenhouse in Westland

Source: all from public domain

1.2 Impressions Of MRDH

Visualization 1. First impression of the MRDH

1.3 Energy Intensive MRDH

With the largest European port and the majority of Dutch greenhouse sector residing within its borders, this region has become not only one of the most important but also the most energy intensive areas of the Netherlands, even the West Europe.

However, the MRDH is almost impoverished in terms of energy resources, except a small amount of natural gas and sustainable energy resource (Smart Energy Delta, 2016). With most of the used energy of natural gas, crude oil and coal imported in the port of Rotterdam, the region plays an essential role in a reliable and abundant energy supply for Northwest Europe.

The MRDH is confronted with many challenges in the energy transition approach, as it is currently energy intensive and highly dependent on fossil fuels (Smart Energy Delta, 2016). The challenges come from both side of global climate change and fossil fuel depletion, which will be further discussed in the following chapters.

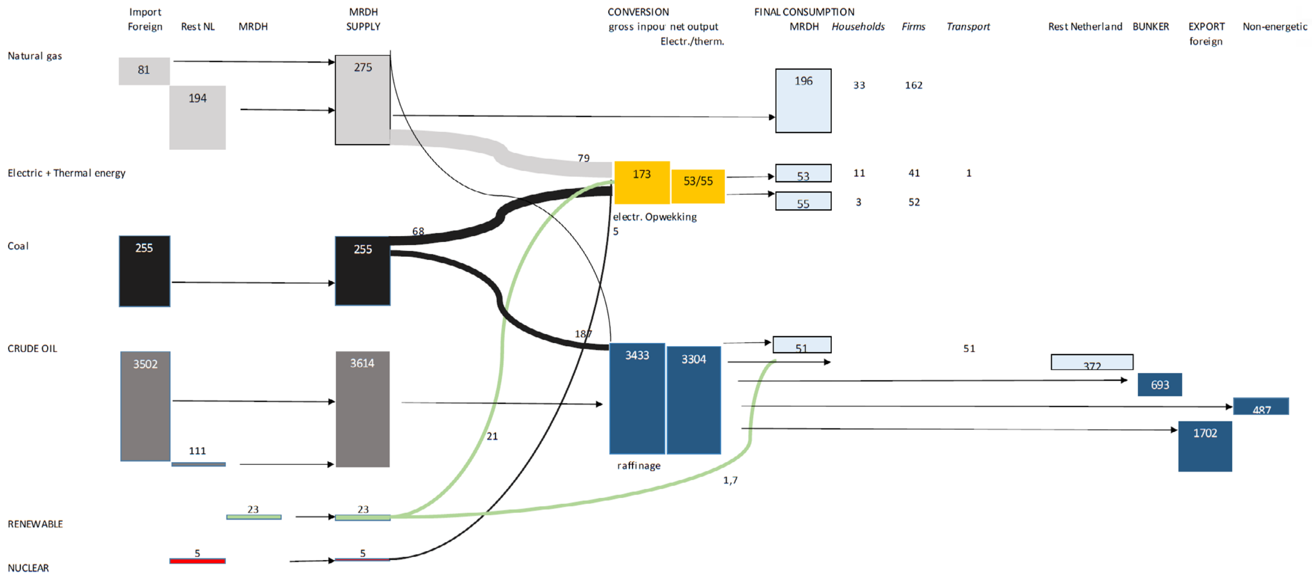
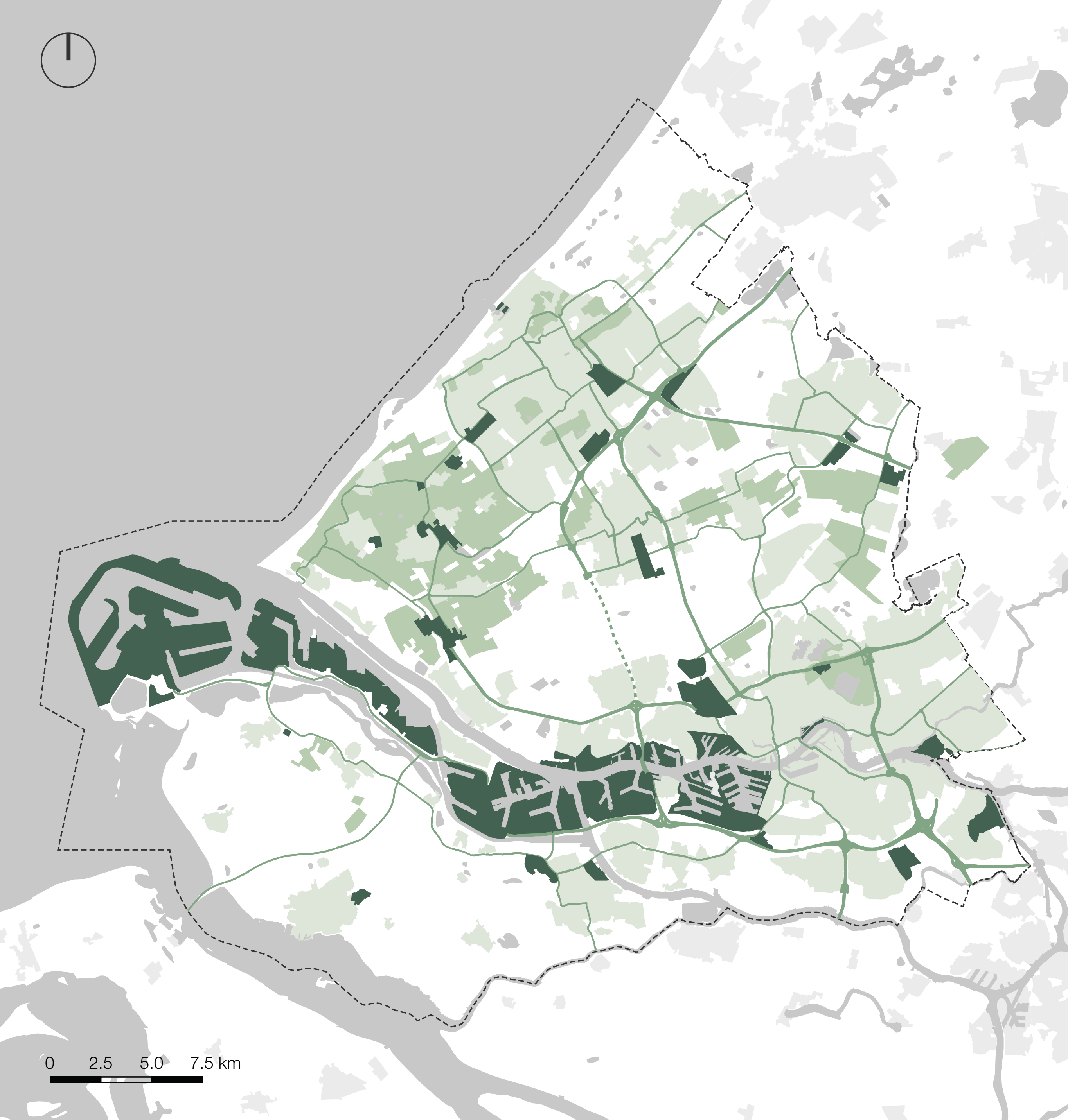


Figure 1. energy flows in Petajoules equivalents for the MRDH.
Source: Smart Energy Delta, 2016

Image 5. Harbor industrial landscape

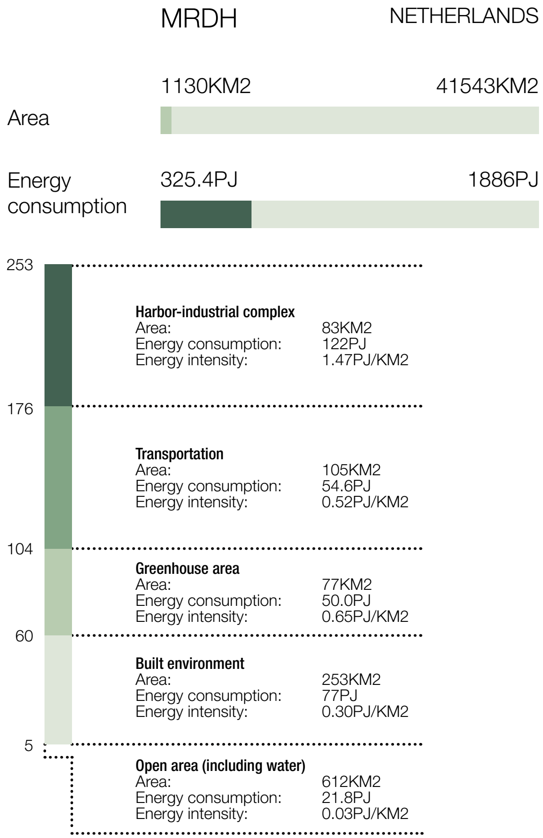
Image 6. Greenhouse landscape

Source: all from public domain



1.4 Energy Consumption

Because of the harbor-industrial complex and greenhouse area, accounted for only 2.7% of the area in the Netherlands, the MRDH consumes 17.3% of the total energy use, making the region quite energy intensive.



Map 2. Energy consumption map
Data source: De gemiddelde energiegebruiksdichtheid in Zuid-Holland uitgesplitst per realm

1.5 Fossil Fuel Import and Extraction

Coal and oil are still being used in the MRDH but by far the largest part is import, except a small amount of oil from regional fields. With the further extraction of local natural gas and oil reserves, the region will be more and more import-dependent in energy.

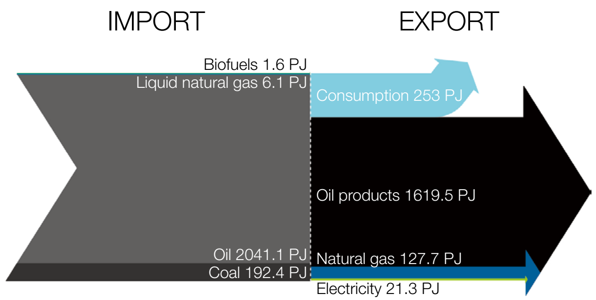
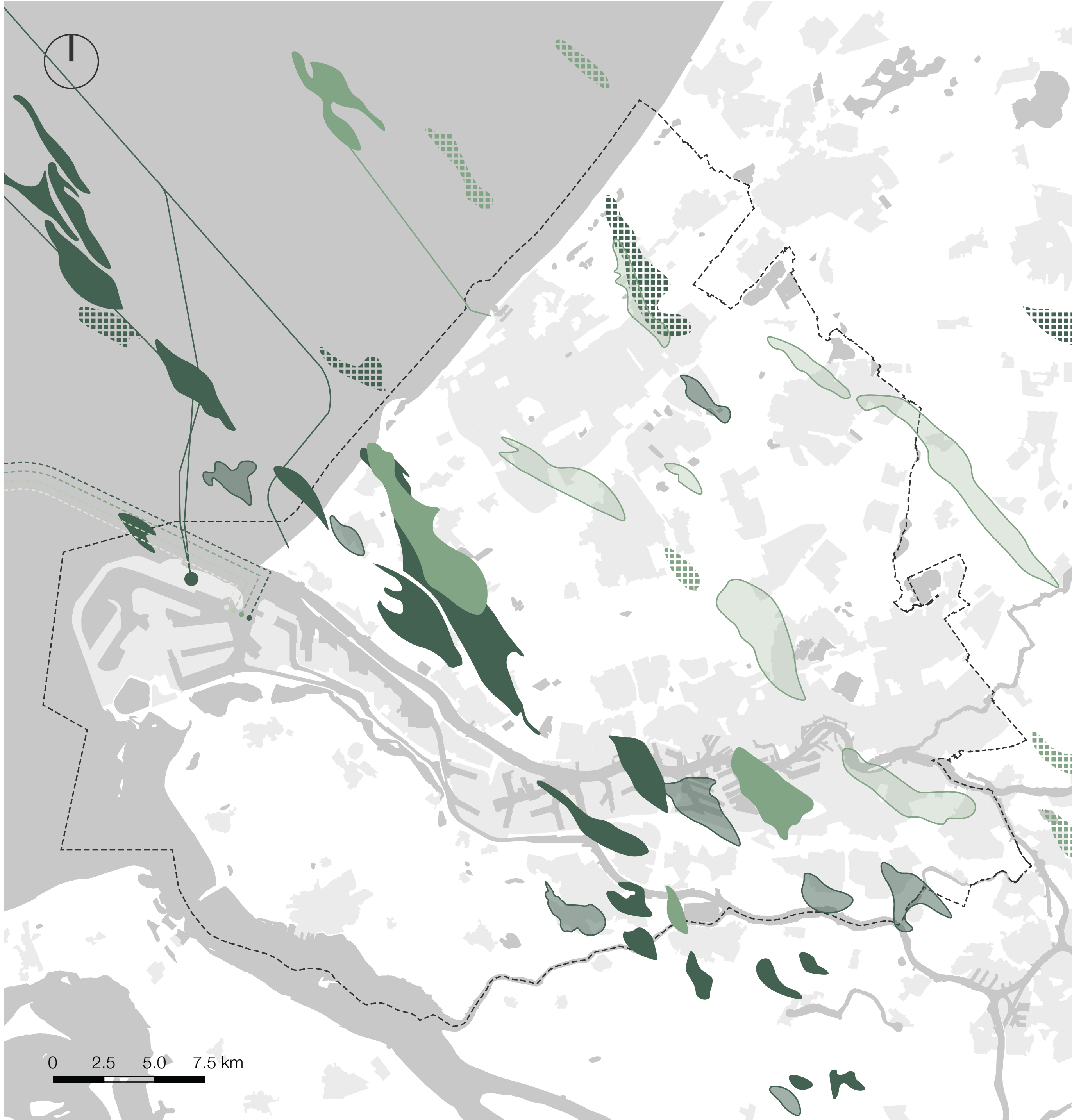


Figure 2. Import and export of energy in the Rotterdam harbour
Source: Quintel Energy Transition Model



Map 3. Import and extraction of fossil fuel energy
Data source: www.nlog.nl/en/map-fields, drawn by author

02
PROBLEM FIELD

Image 7. Flooding Delft
Source: www.tudelft.nl/2014/tu-delft/tu-delft-aan-de-slag-met-ruimtelijke-adaptatie

2.1 Global Climate Change

"Scientific evidence for warming of the climate system is unequivocal."

- Intergovernmental Panel on Climate Change

It is revealed in the mid-19th century that carbon dioxide and other gases such as NO2 can trap heat in the atmosphere (NASA, 2018). There is no doubt that human expansion of the 'greenhouse effect' should be responsible for the current global warming problem (NASA, 2018).

Although the amount of atmospheric CO2 has changed in fluctuation throughout history, for more than 4 million of years it had never been above 300 parts per million, which means the global climate had also been changing in an acceptable and moderate cycle. Just in the last 650,000 years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about 7,000 years ago marking the beginning of the modern climate era - and of human civilization (NASA, 2018).

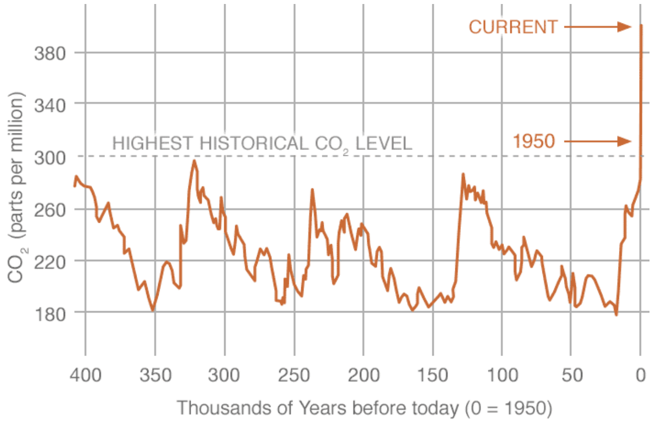


Figure 3. Atmospheric CO2 content
This graph provides evidence that atmospheric CO2 has increased since the Industrial Revolution.
Source: NASA

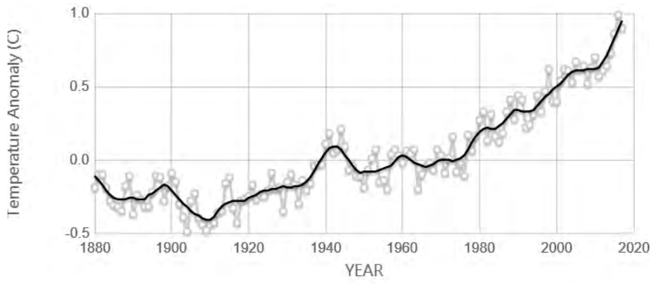


Figure 4. Global surface temperature (average)
This graph shows that seventeen of the 18 warmest years in the 136-year record all have occurred since 2001, with the exception of 1998.
Source: NASA/GISS

Then the balance of this environmental stability started to deteriorate rapidly. Since the second industrial revolution, the significant development of fossil fuel based industry has also contribute to a significant rise of CO2 in the global atmosphere. In 1950, it has already reached the highest historical CO2 level and has been increasing without any stagnation ever since.

Therefore, the planet's average surface temperature has risen about 0.9 degrees Celsius since the late 19th century. The past 35 years have seen most of the warming phenomenons, and the five warmest years are recorded since 2010 (NASA, 2016).

What' worse, according to The Intergovernmental Panel on Climate Change, there will be a continuous temperatures rise of 1.39 to 5.56 degrees Celsius over the next century (IPCC, 2016). This prediction warns that all the environmental threats caused by global warming will keep lasting or even deteriorating for the following decades.

2.2 Environmental Threats and Social Issues

It is widely acknowledged that global climate change is not only a matter of the continuous increase of the tempreture. Also, the negative effects on the environment has already been observed all around the world (Picture 3~5).

Despite all the explicit environmental threats, there has also been a variety of hidden social issues. Climate change has potential impacts on global water and food security in terms of availability, stability, utilization, and access (Schmidhuber and Tubiello, 2007), which directly results in severe starvation and healthy issues in some developing countries. Due to global climate change, there has shown an increase in the global burden of disease which is responsible for more than 150,000 deaths worldwide in 2000 (Sheffield and Landrigan, 2011). Children, the elderly and the poor, as vulnerable people, will be more affected. (Sheffield and Landrigan, 2011).

Therefore, human security is increasingly undermined because of the injustice caused by climate change. There has been a significant rise in the risk of violent conflicts since the access to and the quality of natural resources that are essential to livelihoods is reduced (Barnett and Adger, 2007).

Image 8. Droughts and heat

Image 9. Stronger hurricanes

Image 10. Air pollution

Image 11. Hunger

Image 12. Healthy issue

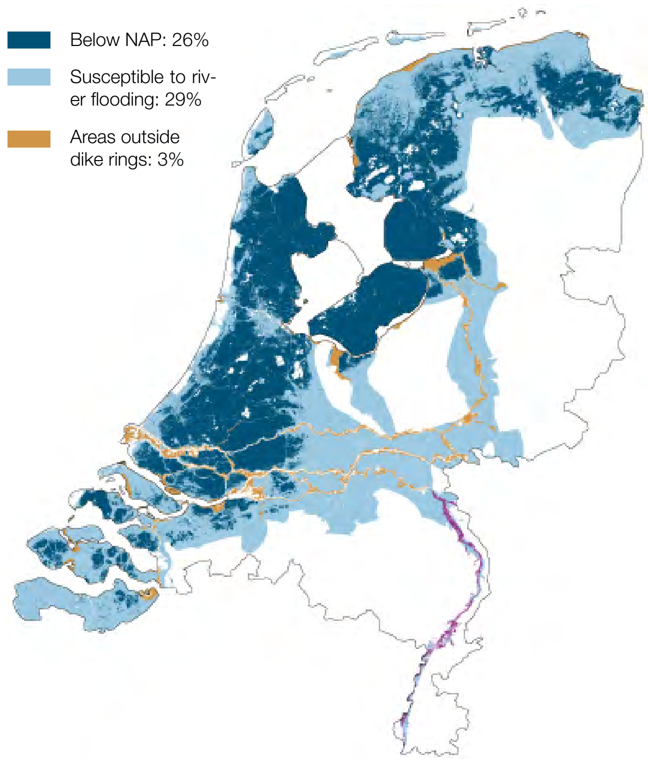
Image 13. Violence and crimes

Source: all from public domain

2.2.1 Rising Sea Level in Netherlands

The threat of flooding issue is becoming more serious due to the rising sea level caused by global climate change especially in island nations and lowlying delta regions (Bindoff et al. 2007), of which Netherlands is the most representative victim.

As 26% of its land is below the sea level (including almost the whole region of MRDH) and 29% is susceptible to river flooding (NEAA, 2007), Netherlands is confronting a great problem of the rising sea level, primarily caused by the added water from melting ice sheets and glaciers and the expansion of seawater as it warms (NASA,2018). And in the near future, there will be a continuous rise in the sea level because oceans usually need a long time to respond to the warmer situation at the Earth's surface (NASA,2018), which puts the barrier dunes and dikes under the great pressure of keeping the water out of the land.



Map 4. Flood risks of the Netherlands.
This map shows that 26 percent of the country is below sea level, and 29 percent is susceptible to river flooding.
Source: Netherlands environmental assessment agency, www.pbl.nl/en/dossiers/Climatechange/content/correction-wording-flood-risks

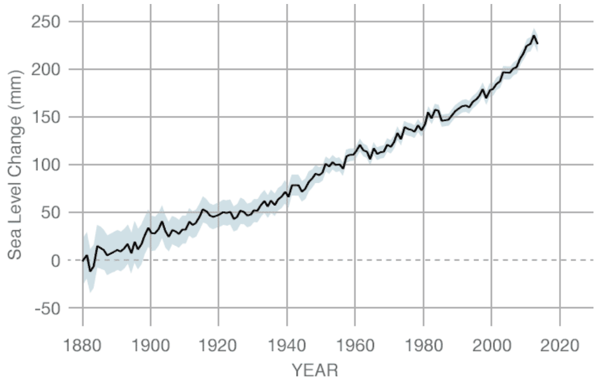


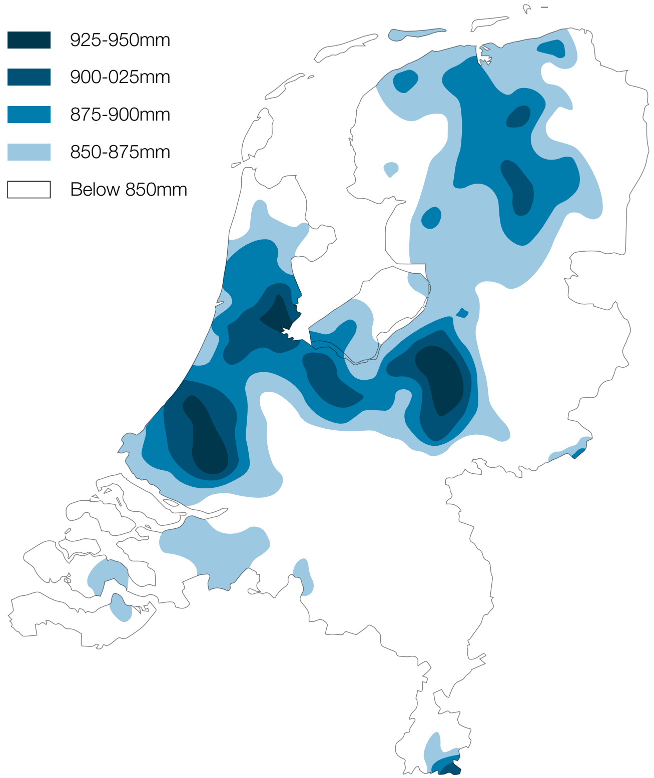
Figure 5: Global sea level change
This graph, derived from coastal tide gauge data, shows how much sea level changed from about 1870 to 2000
Source: NASA/GISS

2.2.2 Extremes of Precipitation in Netherlands

The pattern of precipitation has also changed due to global warming. Warmer air can hold more water vapor (CCES, 2017). It is estimated that there will be a 7% increase in the air's capacity for water vapor when the temperature rises for 1 degree (CCES, 2017). The atmosphere which contains more moisture is the reason why more intensive precipitation events have been observed worldwide.

In Netherlands, the higher temperatures will cause more evaporation from the North Sea and this moisture will be carried westwards with the air circulation and fall as rain in the Netherlands (PBL, 2013). The extreme precipitation in summer is therefore projected to increase more in the coastal regions (including the MRDH) of the country than further inland (KNMI 2009b).

Also, many agricultural, economic, and environmental regimes will be impacted as disruptive, potentially damaging storms become more frequent and more intense (GLISA, 2010). On 28 July 2014, a short-term precipitation event happened in the Netherlands. Precipitation totals in excess of 130 mm fell in just a few hours leading to localized flooding, €10 m property damage and widespread traffic disruption (Eden et al., 2018).



Map 5. Average annual rainfall from 1981-2010
This map shows that Amterdam Metropolitan Area, Rotterdam-The Hague Metropolitan Area and Arnhem region rank top 3 in terms of the amount of precipitation.
Data source: www.elektro-rama.nl/weather/Klimaatatlas/Klimaatatlas-Neerslag.html, drawn by author

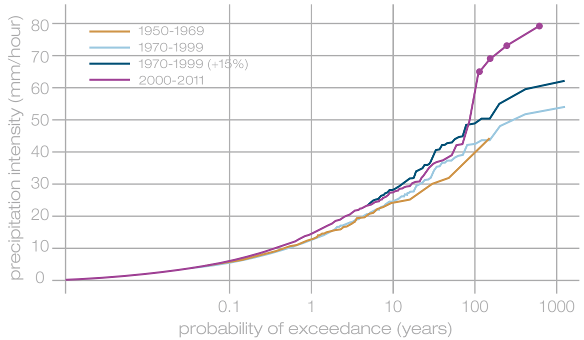


Figure 6. Precipitation intensity in the Netherlands
This graph shows that four highest measurements are indicated by the small purple dots; all of them occurred after the year 2000.
Data source: projects.knmi.nl, drawn by author

2.3 Depletion of Fossil Fuel Resources

"Fossil fuels are an incredibly dense form of energy, and they took millions of years to become so. And when they're gone, they're gone pretty much forever."

- From ecotricity.net

Oil, natural gas and coal are three types of fossil fuels on the earth. It's only a matter of time before the depletion of reserves because none of them are renewable, and the depletion rate is increasing rapidly due to the significant rise in global population and the living standard in parts of the world.

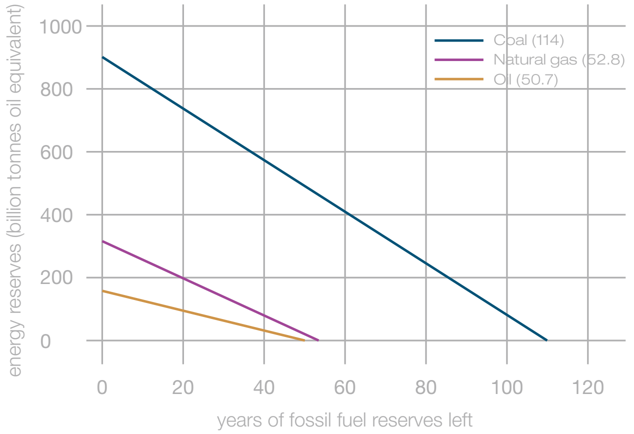


Figure 7. Years of fossil fuel reserves left
The number of this figure is based on known reserves and annual production levels in 2015.
Data source: www.ecotricity.co.uk/our-green-energy/energy-independence/the-end-of-fossil-fuels, drawn by author

Globally, crude oil reserves are vanishing at the rate of 4 billion tonnes a year. If this rate keeps static without any increase for our growing population or aspirations, the current oil deposits will last until 2065. After the oil runs out, the energy gap needs to be filled by the increased production of natural gas. However, the reserves of natural gas will only extend to additional three years, taking the world to 2068.

Therefore the coal will become the only fossil fuel resource. Although the deposits of coal will still last for more than 100 years, it is not feasible to use coal to fill all the energy gaps left by the depletion of oil and natural gas because of the incredible amount of CO_2 emissions from burning all that coal.

2.3.1 Natural Gas Depletion in Netherlands

Netherlands is the largest producer of natural gas in the European Union (NLOG, 2016). Since many of these accumulations are developed and are currently on production, only part of the initially producible volume of gas remains (NLOG, 2016).

What's worse, amongst the 10 largest gas fields in the world, the Groningen field is severely restricted on its production due to the continuing discission on gas extraction and associated induced seismicity above the field (NLOG, 2016). It is estimated that after 2040, the expected supply from natural gas reserves will be practically negligible.

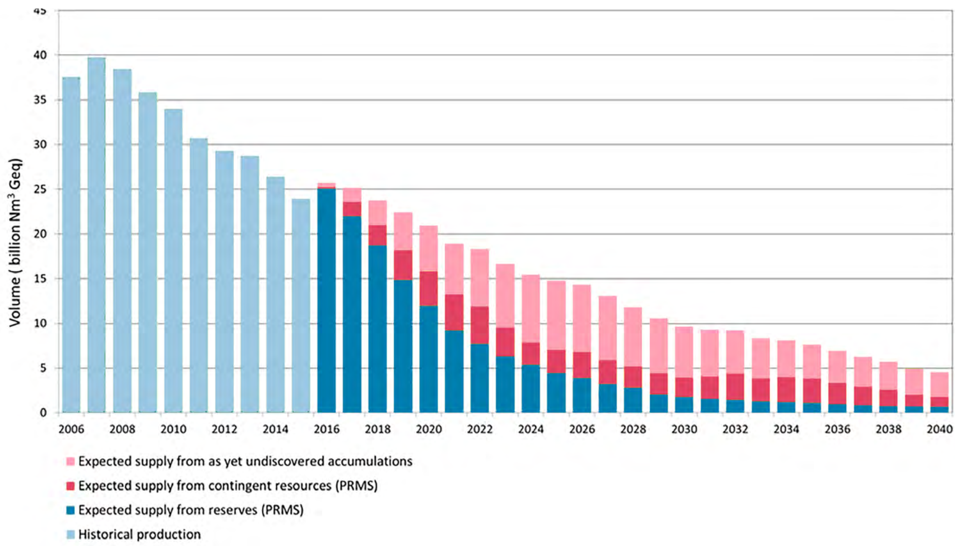


Figure 8. Expected trend in the supply of Dutch natural gas
Data source: www.nlog.nl/en/oil-and-gas-fields-overview

2.3.2 Oil Depletion in Netherlands

As at 1st January 2013, there are 48 proven natural oil accumulations in the Netherlands. At present, 12 of these accumulations are producing (NLOG, 2016). Similar to natural gas, there will also be an evident decline in the production of domestic oil since 2018. In 2040, the expected supply will decrease 85% compared with the production in 2018.

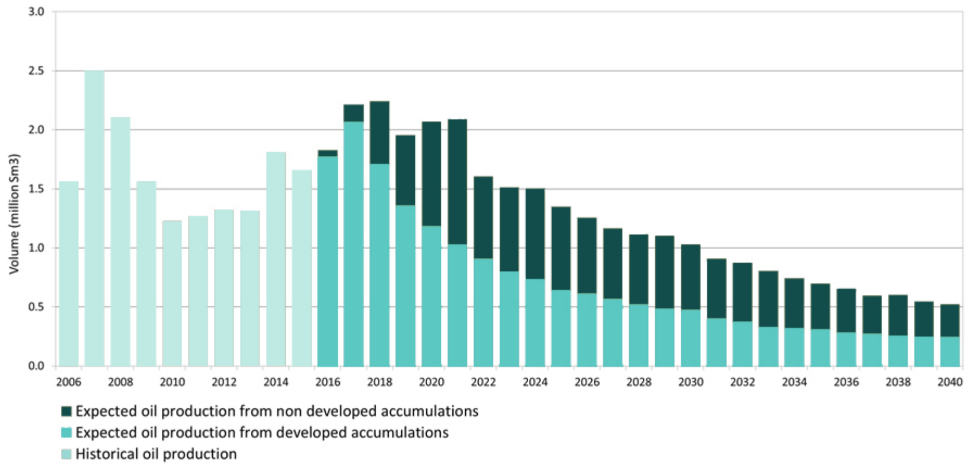


Figure 9. Expected trend in the supply of Dutch Oil
Data source: www.nlog.nl/en/oil-and-gas-fields-overview

2.4 Import-dependent Energy System

The energy dependence of the Netherlands measured by the amount of net energy import of total energy use, has changed throughout history. From the line chart showed beside, there used to be an incredible decline in the energy dependence from 1965 to 1975. This is because in 1959, the Groningen gas field was discovered and has accounted for 50% of the natural gas production in the Netherlands (Whaley, 2009). After 1975, the energy dependence has been rising in fluctuation due to the increasing demand of fossil fuel energy for industrial development and human aspiration.

The tipping point was in 2014. when the Dutch government decided to reduce production to 42.5 bcm from the Groningen gas field after demonstrations against exploitation because of the increase in induced earthquakes (Reuters, 2014). Later in 2016, the Dutch Prime Minister confirmed that gas extraction from the northern Groningen gas field will be reduced even further to 24 bcm per year for the coming five years (Reuters, 2016). Therefore, the amount of net energy import has grown significantly since 2014 in order to meet the domestic demand. As a result, around 40% of total energy use in Netherlands is imported, which makes the nation highly import-dependent and unresilient in energy system.

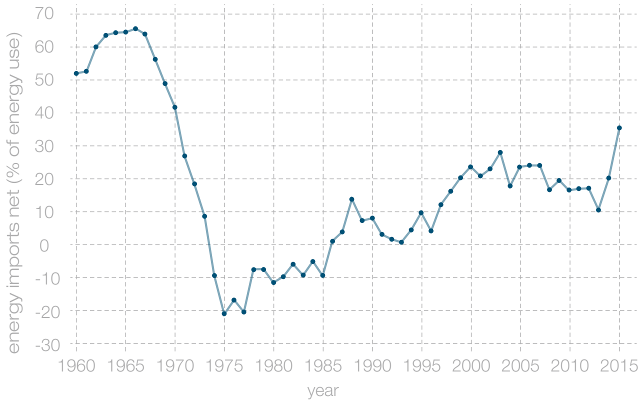


Figure 10. Energy dependence of the Netherlands
This graphic illustrate energy dependence through the measurement of net energy import of total energy use. There is a significant rise after year 2013.
Data source: data.worldbank.org/indicator/EG.IMP.CONS.ZS?locations=NL, drawn by author

This import-dependent energy system can be easily affected by the change of global situation such as geopolics and political relations. As Netherlands is dependent on the oil and gas resources in the Persian Gulf, Russia and the Caspian Sea region (BP, 2004), the supply of imported energy relies on the ability and willingness of OPEC and Saudi Arabia to meet demand at a reasonable price and on the predictable use of available spare capacity to adjust supply to any temporary production losses, or sudden surges in demand (Correlje and Linde, 2006). Any negative change in the geopolitics of those exporting regions or in the political relations will put the Netherlands in certain degrees of passive condition, of which the worst is the national energy break down.

2.5 Problem Focus: Sustainable Energy Transition

In conclusion, confronted with all the threats and challenges discussed above, the MRDH is really standing at the tipping point of transforming the traditional energy landscape (fossil fuel based energy generator and excavation site) towards sustainable energy landscape, including renewable energy sources such as solar energy, wind energy, bioenergy, tidal power, geothermal energy, etc.

This energy transition is quite essential to the future development of the region. First of all, in contrast to fossil fuel energy, there will be almost no greenhouse gas emissions by renewable energy sources. Even when including “life cycle” emissions of clean energy (the emissions from each stage of a technology’s life—manufacturing, installation, operation, decommissioning), the global warming emissions associated with renewable energy are minimal (Sathaye et al., 2011).

Secondly, as mentioned before, the air and water pollution emitted by coal and natural gas plants is linked to many healthy problems, while renewable energy technologies almost don't produce the pollution. Usually wind, solar and hydroelectric system produce energy without polluted air emissions (UCS, 2017). And although geothermal and biomass systems emit some air pollutants, the total



Image 14, 15, 16. Traditional energy landscape



Image 17, 18, 19. Sustainable energy landscape

Source: all from public domain

polluted air emissions are much lower than fossil fuel based power plants. Furthermore, while water is highly demand in traditional energy production, wind and solar energy don't consume water, which avoids water pollution or limited supplies by competing with agriculture, and drinking water (UCS, 2017).

What's more, renewable energy can contribute to stabilizing energy price in the future (UCS, 2017). While the stability of fossil fuel energy in the Netherlands can be easily affected by geopolics and political relations, domestic renewable energy production can keep stable for decades or even centuries. The investment to install renewable facilities is high upfront, however, they are cheap to operate and maintain (UCS, 2017). With the development of renewable technologies, the cost has been declining steadily and are projected to drop evern more.

Last but not least, normally, fossil fuel technologies are automatic and capital intensive. However, the renewable energy industry is more labor intensive (UCS, 2017). For example, both solar panel installment and wind turbine maintainance need human forces, which provides more job opportunities to the society.

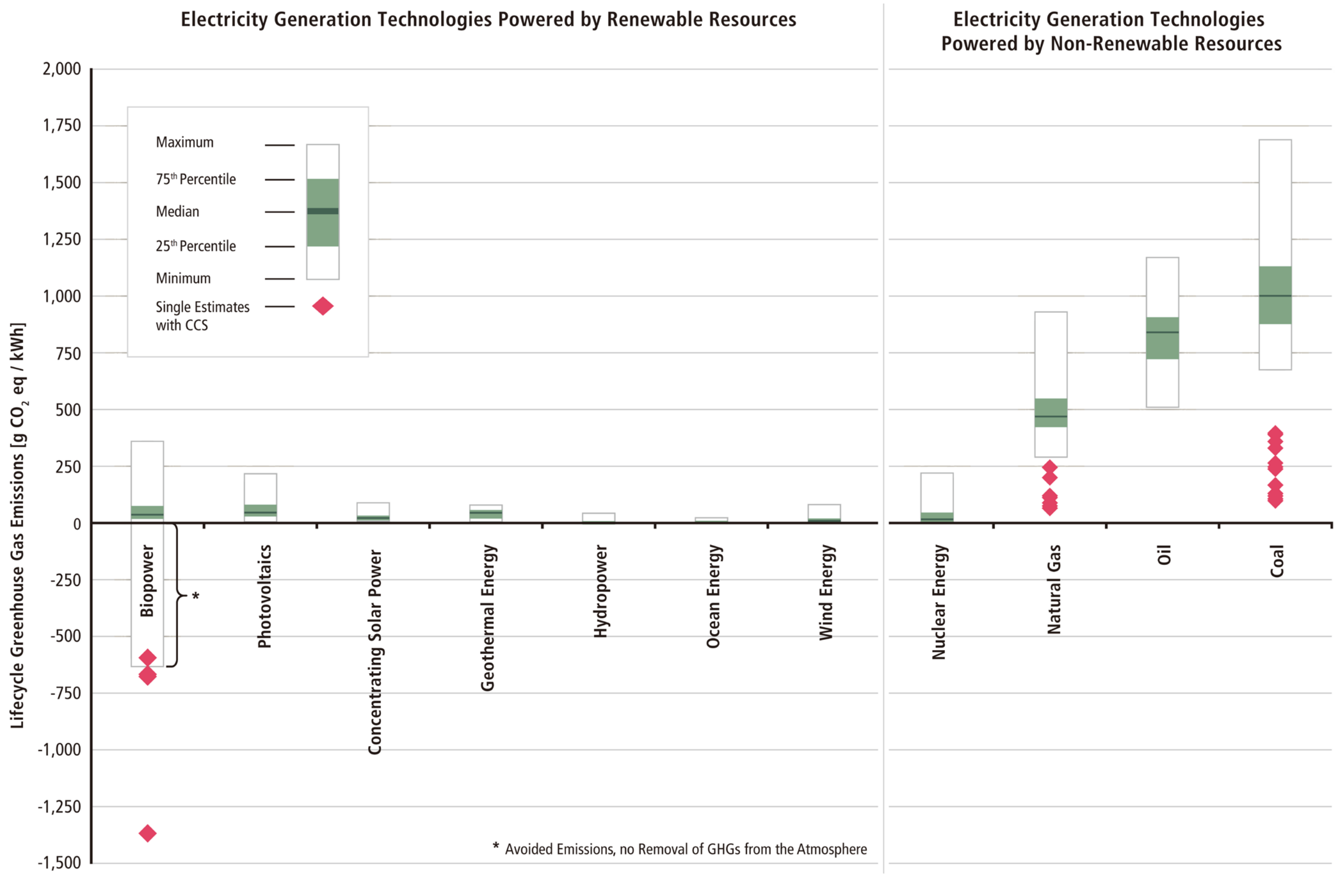


Figure 11. Different sources of energy produce different amounts of greenhouse gases.
This graphic illustrates that renewable energies tend to have much lower emissions than other sources, such as natural gas or coal.
Source: IPCC, 2011 Special Report on Renewable Energy Sources and Climate Change Mitigation (Chapter 9)

03
PROBLEM ANALYSIS

Image 20. Maasvlakte Rotterdam
Source: www.portofrotterdam.com/nl

3.1 Policies and Visions

Paris Agreement

At COP 21 in Paris, on 12 December 2015, Parties to the UNFCCC reached a breakthrough agreement to deal with climate change and to facilitate and intensify the necessary actions and investments towards a sustainable low carbon future.

According to the Paris Agreement, the EU as a whole would need to achieve a 50% reduction of greenhouse gas emissions below 1990 levels by 2030. By 2050, the EU would need to reduce greenhouse gas emissions by about 90%, which is within the 80-95% reduction range already adopted (UNFCCC, 2015).

Therefore, renewable energy sources are expected to replace fossil fuel based power plants in the short term.

National vision and policy

Participated in Paris Agreement, the Netherlands is taking part in a global effort to develop a low CO2 energy economy that is safe, reliable and affordable. Supported by industries,

Image 21. Paris Agreement
Source: www.time.com/4723481/donald-trump-paris-agreement-withdraw/

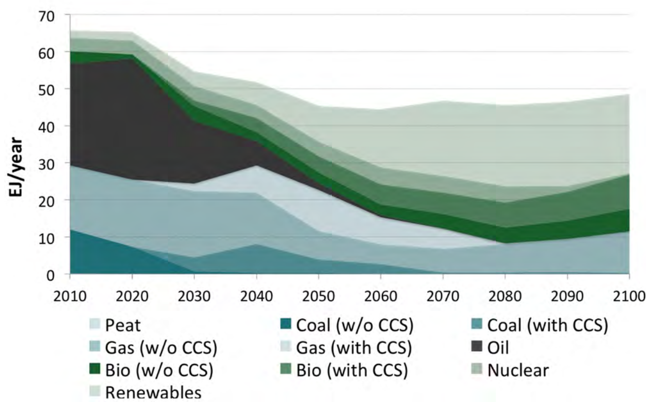


Figure 12. The EU's primary energy mix developments in line with Paris Agreement
Source: Bill Hare, 2016

NGOs and governments, the society-wide Energy Agreement for Sustainable Growth includes goals for energy efficiency savings to 1.5% of total energy use and for an increased share of renewable energy: 14% by 2020 and 16% by 2023 (Ministry of Economic Affairs, 2016).

In national energy policy, three main principles are brought out: 1) reduce CO2 emission; 2) make the most of the economic opportunities that the energy transition offers; 3) integrate energy in spatial planning policy (Ministry of Economic Affairs, 2016).

Regional vision and policy

The MRDH has put forward an energy vision named 'Smart Energy Delra', of which the ultimate goal is in 2050, the region will have a clean energy supply (Roadmap Next Economy, 2016).This means energy saving, efficient use of energy and residual heat, more use of clean energy sources like sun, wind and tidal energy and clean fuels like green power and hydrogen (Roadmap Next Economy, 2016).

3.2 Current Approach

Unfortunately, although there are many visions, policies and regulation brought forward to accelerate the sustainable energy transition, the current approach in Netherlands is still far too slow. According to the statistics service Eurostat, it is illustrated that the Netherlands is near the bottom of a new table on renewable energy use in Europe. Compared with more than 30% in Sweden, Finland, Latvia, Austria and Denmark, only 6% of the energy used in the Netherlands comes from renewable sources in 2016, which has risen from just 2% in 2004.

Among the 28 EU Member States, with 8.2 percentage points from reaching its national 2020 objective, the Netherlands is also the furthest away from its target. One of the reasons that can explain the slow approach in sustainable energy transition is the low public acceptance. When social or public acceptance is widely identified as a positive attitude towards a technology or measure, it leads to supporting behavior and the counteracting of resistance by others if it's necessary (Hofman, 2015).

Even if technologies are suitable in a certain context technically and economically, it still may not be integrated successfully because of public resistance, lack of awareness of the technology

Image 22. Public resistance of sustainable energy
Source: Public domain

and so on (Hofman, 2015). In fact, there have been protests all over Europe against wind farms, geothermal facilities and other green initiatives (Dröge and Messer, 2012), which evidently delays the energy transition.

With the ongoing trend of decentralization, clashes with local communities are also increasing due to the installation of renewable energy facilities in many areas (Hofman, 2015). The public acceptance for these technologies is vary low because of the visual impacts on landscape and ecosystem, noise, shadow flicker and high investment paid by taxes.

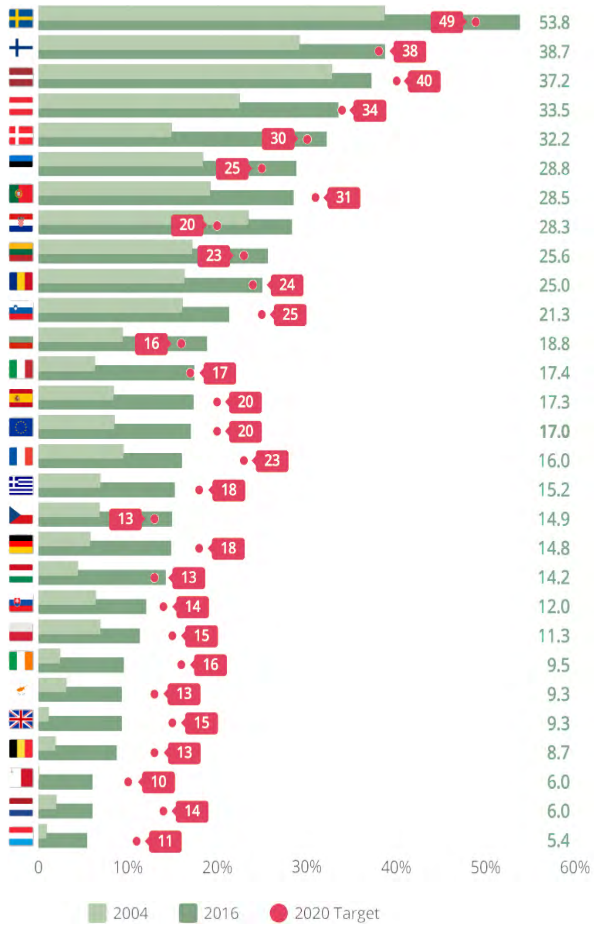
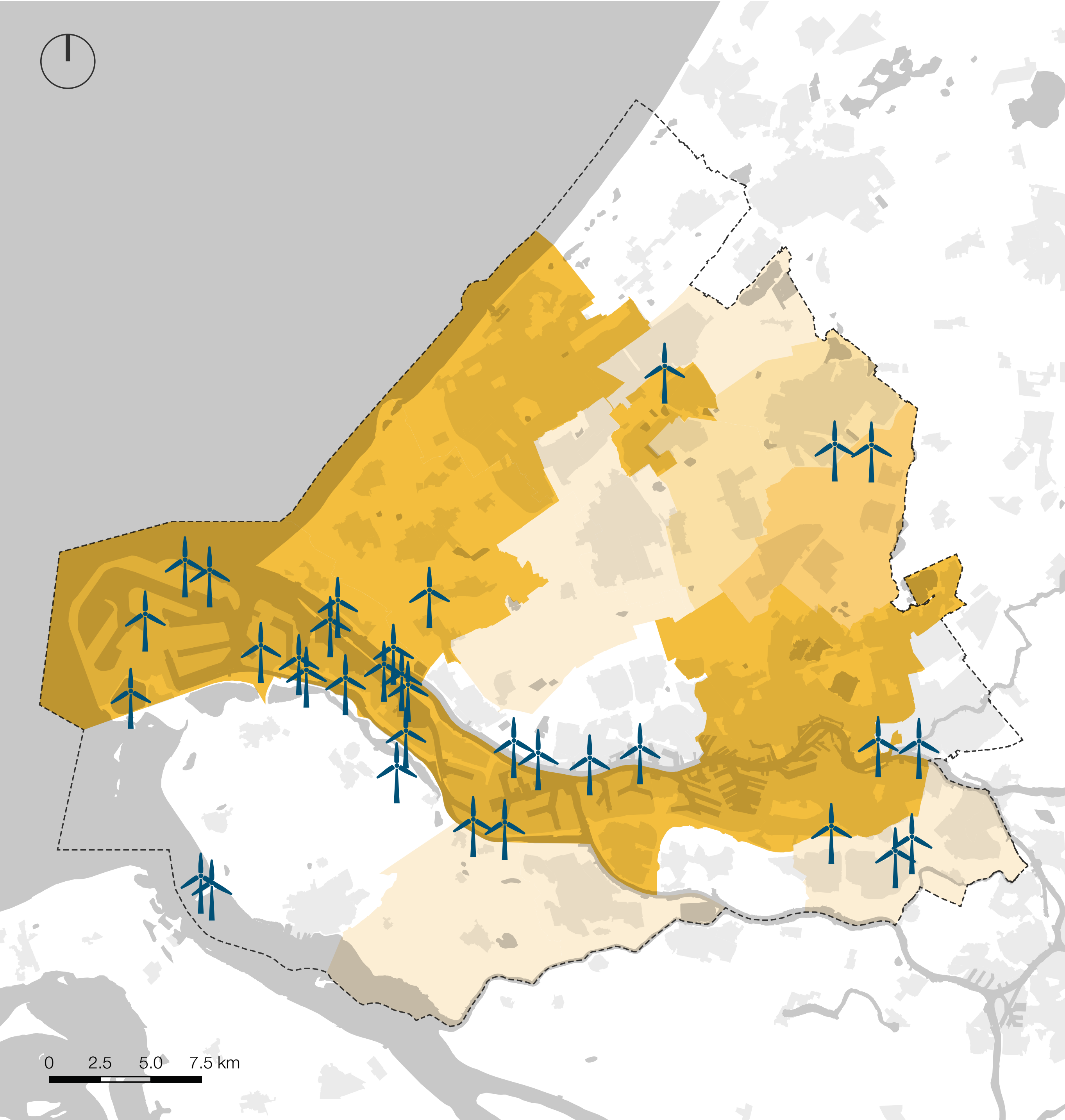


Figure 13. Share of energy from renewable sources and 2020 target (in %)
Source: Eurosta, 2016. www.statista.com/chart/12715/whos-winning-europes-renewable-energy-race/



Current Renewable Energy

By 2016, the total renewable energy production of the MRDH region is 8.88 PJ, only 2.7% of total energy consumption. The majority of the renewable energy technologies applied in the region are wind turbines and biomass digester.

2016 RENEWABLE ENERGY PRODUCTION

Unit: PJ	ELECTRICITY	HEAT NETWORK	BIOGAS
WIND	1.44	—	—
SOLAR	0.42	—	—
BIOMASS	1.41	4.50	0.96
GEOTHERMAL	—	0.16	—
TOTAL	8.88 (2.7% of total energy consumption)		

Table 1. Current renewable energy production
Data source: klimaatmonitor.databank.nl/

PV panels productivity, unit: kW-peak/municipality

- > 14000
- 10500<14000
- 7500<10500
- 3500<7500
- <3500
- Wind turbines

Map 6. Current renewable energy
Data source: www.windenergie-nieuws.nl, drawn by author

3.3 Gap in Practice

In order to deal with the public resistance of sustainable energy especially in terms of implementing renewable energy infrastructures, the knowledge gap within energy landscape which separates sustainable energy transition and spatial quality apart needs to be addressed.

Energy transition and spatial quality have, to date, been treated as two separate conceptual domains. While mainly focusing on the productivity, economic profit, potential and future demand of sustainable energy, the energy industry has paid only minor attention to social-spatial impacts in modeling possible future energy systems and solutions (Blaschke et al, 2013). On the other hand, the planning and design approach of embedding spatial quality is mainly concentrated on buildings, public spaces, open green spaces, etc., rather than deal explicitly with 'energy landscape' in most European countries.

This practical gap between energy production and landscape quality has evoked the public resistance of sustainable energy transition because people are more aware and concerned about the quality of living environment which they can feel, experience and evaluate during everyday life.

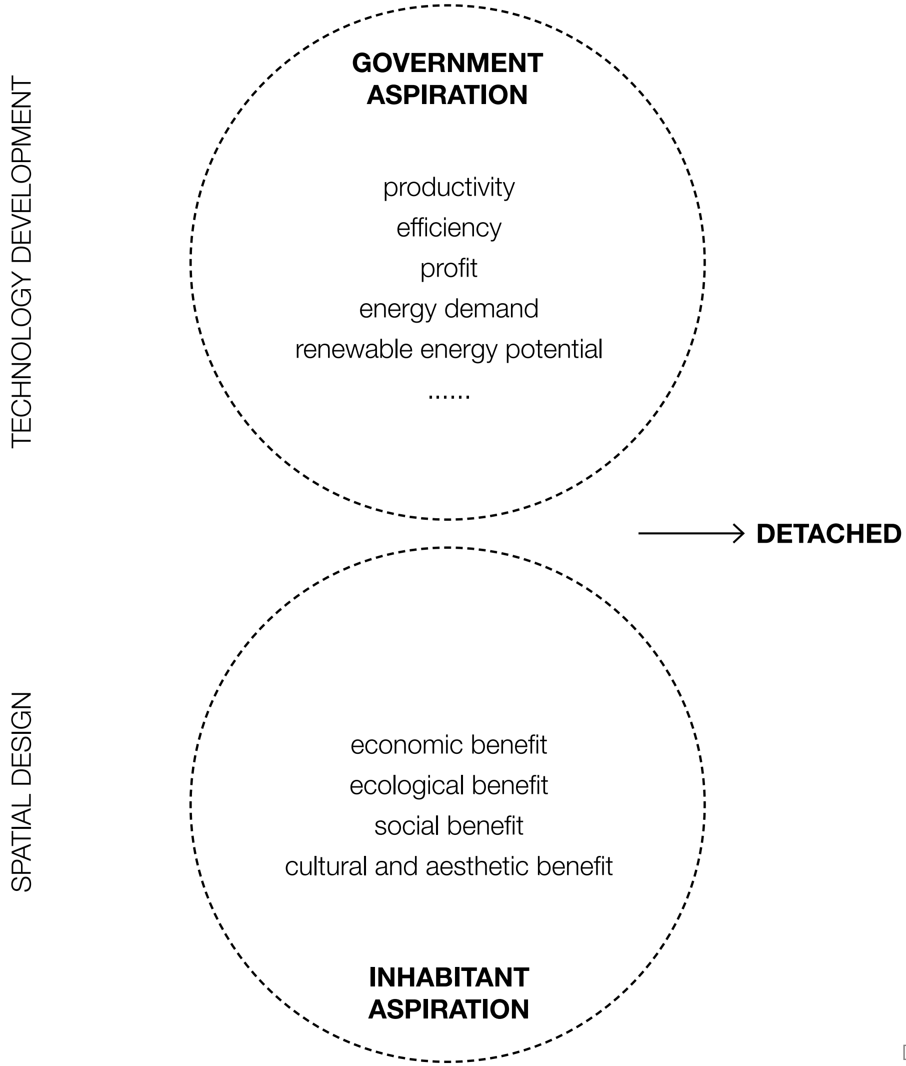


Diagram 1. Practical gap

3.4 Hypothesis

Based on the existing knowledge gap, a hypothesis is brought out that embedding spatial quality in sustainable energy landscape will reduce the public resistance, thus to facilitate the ongoing trend of sustainable energy transition.

3.5 Problem Statement

With the largest European port and many energy infrastructures residing within its borders, the Rotterdam-The Hague metropolitan Area (MRDH) has served as one of most energy intensive regions which constituents 17.3% of the total domestic energy consumption and plays an essential role in a reliable and abundant energy supply for Northwest Europe. However, this energy intensive development model has also brought challenges from both climate change and fossil fuel depletion, resulting in multiple ecological, environmental, economic and social issues, which will obstruct the further growth of the region. Therefore, there has been an urgency in transforming traditional energy landscape to sustainable energy landscape in or-

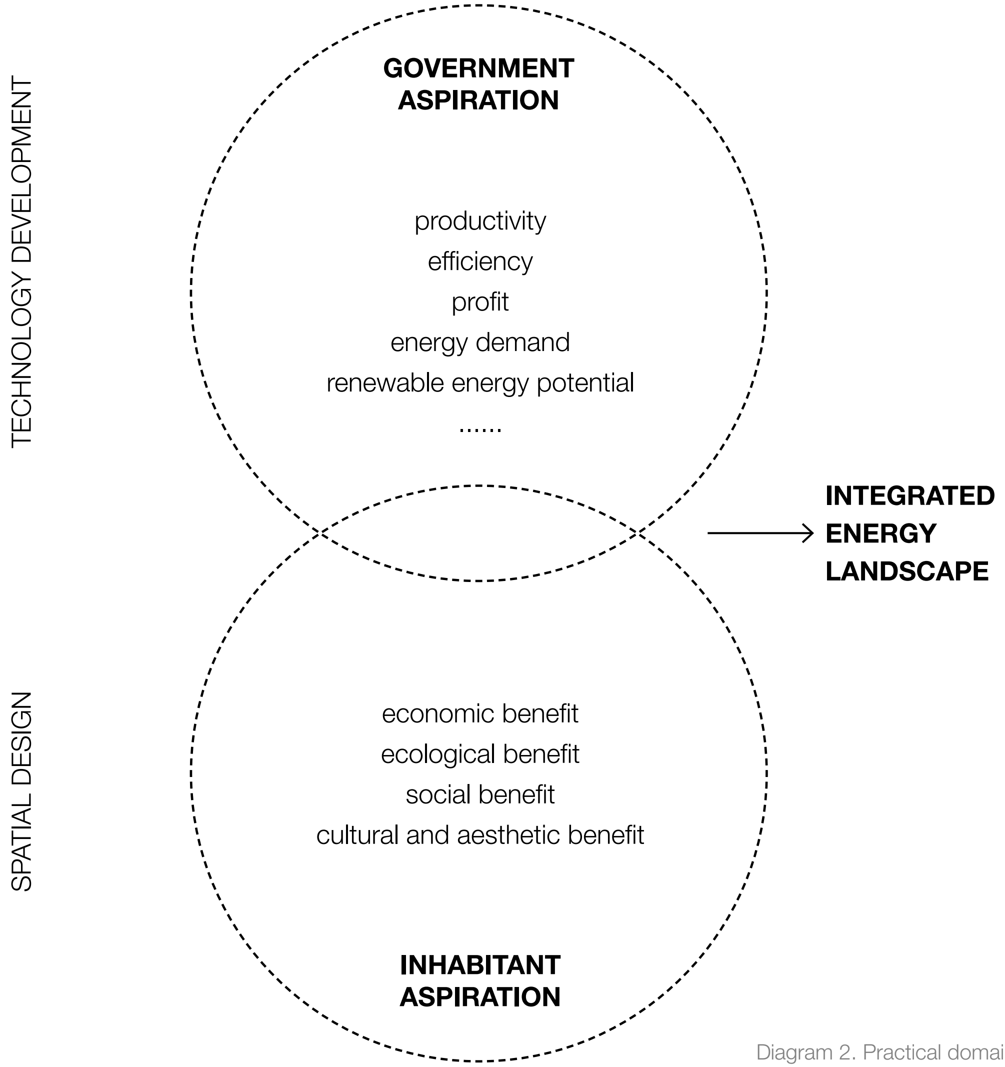


Diagram 2. Practical domain overlapping

der to combat the problems caused by fossil fuel based energy structure.

Although the Netherlands has released many policies and regulations on sustainable energy, the current approach is still far too slow. Only 6% of the energy used in the Netherlands comes from renewable sources in 2016, which has risen from just 2% in 2004. One of the reasons that can explain the slow approach is that the renewable energy technologies are facing public resistance. People keep holding protests because of the visual impacts on landscape, noise, shadow flicker and impacts on ecosystem.

Thus, the practical gap within energy landscape which separates sustainable energy transition and landscape quality apart needs to be addressed. Energy transition and landscape quality have, to date, been treated as two separate conceptual domains. The deficiency in spatial planning and design has evoked the public resistance because people are more aware and concerned about the quality of living environment.

With the focus on sustainable energy landscape and landscape quality, this project gives a new insight on how spatial planning and design can improve the landscape quality of energy landscape, in order to increase the public acceptance which helps to accelerate the energy transition.

3.6 Conceptual Framework

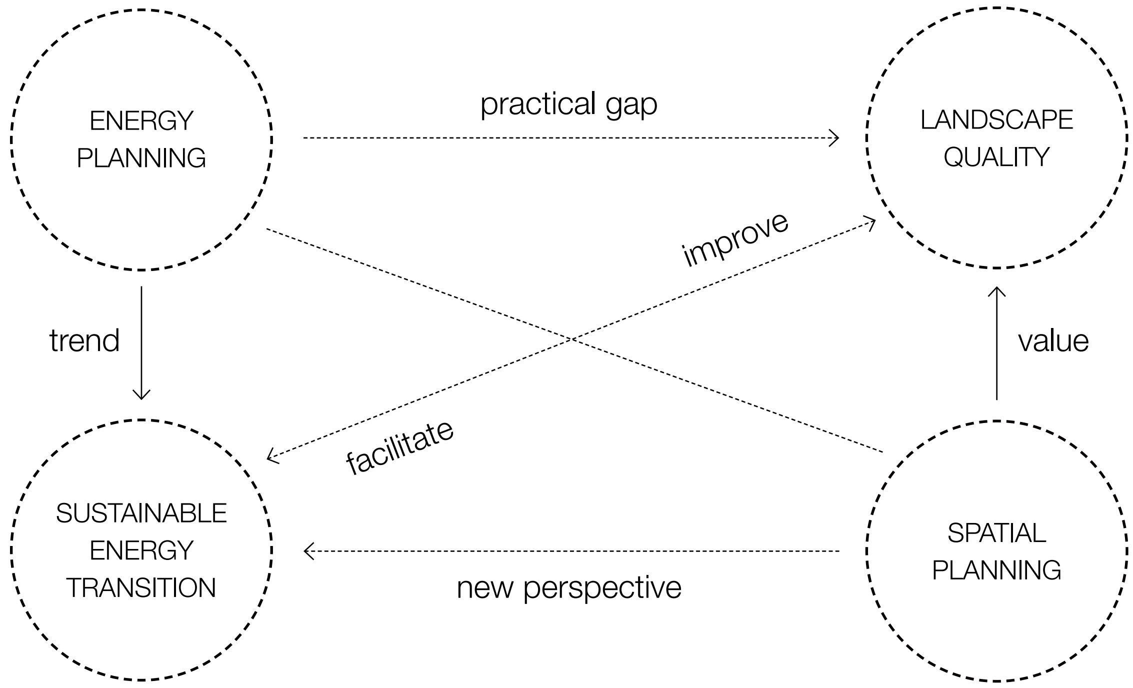


Diagram 3. Conceptual framework

3.7 Research Aim

The aim of the research is to facilitate the ongoing trend towards sustainable energy. By integrating landscape quality into the design of energy landscape, the public will be more concerned and supportive about sustainable energy transition, thus to contribute to creating a more sustainable, livable and resilient MRDH.

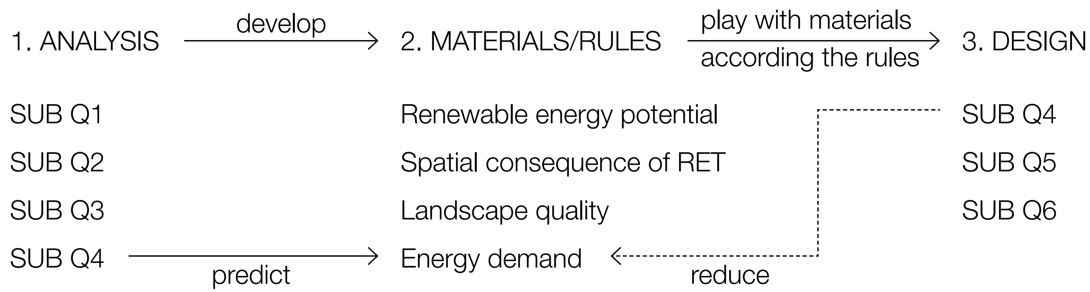
3.8 Research Question

How to integrate landscape quality in the energy landscape which facilitates sustainable energy transition of the Metropolitan Area Rotterdam-The Hague (MRDH) through spatial planning and design?

To answer this main research question, the following sub-questions need to be developed:

Descriptive questions:
1. How to map the potential of renewable energy in the region?
2. What are the general spatial implications of renewable energy technologies?
3. What's the current landscape quality?

Prescriptive questions:
4. How much renewable energy production is required in order to realize energy neutrality?
5. What are the expected scenarios of landscape quality for different urban realm?
6. How to integrate energy production and landscape quality in spatial interventions?



04 THEORETICAL BACKGROUND

Image 23. Transport bridge
Source: britishlistedbuildings.co.uk/

4.1 Concept Clarification

RENEWABLE ENERGY

The concept 'renewable energy' has mostly been related to energy production process, which refers to energy generated from renewable sources that are continually replenished by nature on a human timescale (Ellabban et al., 2014). Categorized by where they are derived from, renewable sources can be divided into different types.

1. Directly from sun: such as thermal, photo-chemical and photo-electric;
2. Indirectly from sun: wind, hydro-power, and photosynthetic energy stored in biomass;
3. From other natural movements and mechanisms of the environment: geothermal and tidal energy.

In this graduation thesis, regarding the natural conditions of the MRDH, only wind, solar , biomass and geothermal energy will be taken into consideration for further research, which often provides energy in four important domains: electricity production, air and water heating/cooling, transportation, and rural (off-grid) energy services (REN21, 2010).

SUSTAINABLE ENERGY

The concept 'sustainable energy' has broader meanings than 'renewable energy'. It refers to energy that is consumed at insignificant rates compared to its supply and with manageable collateral effects, especially environmental effects. Another common definition of sustainable energy is an energy system that serves the needs of the present without compromising the ability of future generations to meet their energy needs (Lemaire, 2004). This sets sustainable energy apart from renewable energy by focusing on the whole process of energy flow.

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy. Ideally, a sustainable energy system should consists of three main aspects: (1) replacing fossil fuel energy with renewable energy production; (2) increase energy efficiency by creating a closed cycle of energy flow; (3) reduce energy demand by increasing people's awareness of energy saving; and one principle: the system should be environmentally friendly.

As elaborate further in the context of sustainable development, they become three pillars within sustainable energy system, which is ecology, economy and society respectively.

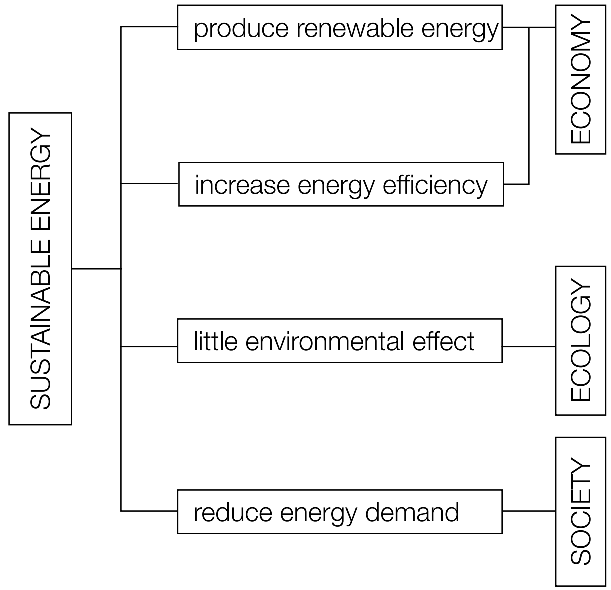


Diagram 4. Ways of achieving energy sustainability

4.2 Theory Paper

RENEWABLE ENERGY AND LANDSCAPE QUALITY

Investigations on potential implications for renewable energy technologies on landscape

AR3U023 Theories of urban planning and design
MSc Urbanism, Delft University of Technology

Tianyue Ma (4739108)

Abstract – This essay aims at discussing the relation between energy production and urban landscape, and demonstrating the potential spatial implications for renewable energy technologies on landscape quality. In order to combat with the pressure of global climate change and fossil fuel depletion, transition towards renewable energy has come to the stage and really drawn a lot of public attention. However, since energy and landscape have been treated as two separate conceptual domains during the second generation of energy landscape, the impacts on landscape quality are often neglected by the developers when deploying renewable energy technologies. Increasingly there are clashes with local communities because of the negative impacts these technologies might have on landscape quality. Therefore, it becomes essential to look into renewable energy transition from a landscape perspective. This paper firstly reveals how the relation between energy and landscape has changed throughout history. Secondly, the criteria of landscape quality are defined and discussed in four main components, which are the economic quality, ecological quality, aesthetic and cultural quality, and social quality respectively. Last but not least, possible implications of renewable energy technologies on landscape quality are explored from both positive and negative sides, giving guidelines on choosing suitable locations. As energy and landscape are highly relevant, it is important to address the spatial implications of renewable energy in the design of energy landscape.

Key words – renewable energy transition, landscape quality, renewable energy, spatial implications, energy landscape

1 Introduction

It has been more and more widely acknowledged that our current fossil fuel-based energy system is facing the great pressure from both global climate change and nonrenewable energy depletion. Many novel energy sources, especially the renewable ones, are rapidly developed and exploited in order to find plausible alternatives to fossil fuel energy. However, standing at the tipping point towards renewable energy landscape, there are still some drag forces which slows the transition. Since energy and landscape have been treated as two separate conceptual domains throughout history, the potential impacts of renewable energy technologies have on landscape quality are often neglected during practices. When deploying these technologies, governmental authorities and developers are usually more concerned about the energy sector, such as amount, efficiency, profits, etc. While on the other side of a coin, what is more important and appreciated by local inhabitants is the living quality generated by the landscape. That's why increasingly there are clashes with local residents and communities because of the widespread concern that developing renewable energy technologies might deteriorate the landscape quality.

In order to reduce the public resistance against energy transition, necessity and great values have been attached to studies that are looking from a landscape perspective. First of all, in Chapter 2, this essay reveals the changing relationship between energy and landscape throughout history, divided by the first and second generation of energy landscape. Also, the drivers for renewable energy development and the characteristics of the third generation: renewable energy landscape are discussed. The conclusion is that in this new generation, the relationship between energy and landscape is much closer than ever before, which makes the impacts on landscape quality also more obvious and perceptible. Secondly, Chapter 3 discusses the conceptualization of landscape quality, from which an assessment matrix is developed to define landscape quality by different criteria. By this matrix, same criteria will be used to analyze and access landscape quality in every case which makes the analogy or the comparison between landscapes more plausible. Finally, in Chapter 4, since the relationship between renewable energy and landscape has become very close, the possible impacts on landscape quality are discussed, giving guidelines for further study and design. Only when landscape quality is integrated in energy landscape planning, can the awareness and acceptance of local inhabitants increase.

2 The relation between energy and landscape

2.1 Historical development of energy landscapes

The investigations on renewable energy transition from a landscape-based perspective might seem novel, but the history of different energy generations reveals that there has been a hidden relation between energy and landscape since the moment when energy was conceptualized by our ancient ancestors. Indeed, energy production and distribution has played a primary role in shaping the local landscape for centuries, with the relation in between also changing back and forth from the local to the global throughout the history (Boer, 2018).

The term 'energy landscape' has obtained its meaning since the interaction between human and environment started to become intensified after agricultural and later urban settlements occurred around 10,000 years ago (Bogucki, 1996; Pasqualetti, 2012). For instance, wood was widely used for construction and particularly for fuel in the time of the Rome Empire, which resulted in widely deforestation in Europe (Tainter, 1988). It can be considered as one of the earliest types of 'energy landscape' because the landscape was highly influenced by energy-related activities (Noorman&De Roo, 2011). Thus, an energy system which depends on the local physical and socio-economic landscape has characterized the first generation of energy landscape, where energy production and consumption were located close to each other, creating dense energy landscapes (Pasqualetti, 2012; Boer, 2018). During this time period, energy was rather dependent on self-organized access to local resources managed by landlords instead of a public good guaranteed by states or local authorities.


windmill; public domain


forest for fuel; public domain

Later in the 20th century, with the radical industrial revolution and fast development in energy-related technologies, evident changes have also occurred in energy system, which resulted in so-called the second generation of energy landscape. One of the main features of the second generation of energy landscape is that a more intensive use of energy becomes dominant, especially based on the resources with a high-power density such as coal, oil and gas, which can be extracted and excavated from a large scale of underground layers far away from densely populated human settlements, and usually be processed in an industrial complex. Therefore, the impact of energy production becomes less visible in most of the regions (Boer, 2018). At the same time, since energy consumption has started to be spatially detached from energy production, facilities for long-distance energy transport such as high-voltage electricity lines and pylons are more visible, mostly affecting the aesthetic beauty of the landscape.


offshore oil well; public domain


electricity power plants; public domain

2.2 Drivers for renewable energy

As energy production plays a more and more important role in the global political games, both national governmental bodies and corporate representatives have set top-down policies and regulations to ensure the energy security. For those countries without sufficient domestic energy production, their nation states have become increasingly concerned about geopolitical uncertainty due to oil and gas dependency on foreign countries, aggravated by the fact that some Middle Eastern regions are considered relatively unstable (Correljé & Van der Linde, 2006).

Also, the wide use of fossil fuel energy is considered as a main culprit for the increasing atmospheric CO2 related to the global climate change. Organizations from both national and international level are working on the general agreement of restricting the CO2 emissions from fossil fuels. Therefore, the concern about energy security and environmental quality have become the primary driving factors towards more sustainable energy system (Boer, 2018).

2.3 Third generation: renewable energy landscape

In the early twenty-first century in Western Europe, the development and deployment of new forms of renewable energy generation dominated by solar, wind and hydropower, and energy from biomass has started to change the landscape. Similar to the relationship between energy and landscape in the first generation, renewable energy technologies not only require a considerable amount of land use, but are also highly visible in the landscape.

Grid-connected PV systems have been in use since the 1990s (Bazilian et al., 2013). Later they were first mass-produced in 2000, when a ten thousand roof program were promoted by the Eurosolar organization and German environmentalists, with the funding from government department (Wolfgang, 2013). Since the 1980s, anti-nuclear protests have provided incentives for deploying larger turbines on land, visibly affecting the landscape. During the same period, scientists and technologists have put a lot of effort to the experiments improving bio-digesters which produce gas from anaerobic digestion of residual or other biomass and organic waste streams (Laurentis, 2015). Other technologies that have been developed and deployed such as hydropower station and tidal power station are usually far away from human settlements, even though to some extent they have very close relationship with landscape, the impacts are non-perceptible to most of the people.


large wind turbines; public domain


PV panels on the roof; public domain

Another characteristic of the third generation of renewable energy landscape is decentralization. In contrast to centralized fossil fuel energy, energy from renewable sources can be generated on top of your house roof, in the neighborhood playground, and also in parks and other public spaces. It is more related to daily life and needs to be integrated into local landscapes which are perceived and sensed by people every day. The high visibility of these installations might cause conflicts with the existing landscape quality and therefore require cautious spatial planning (Boer, 2018). In the following chapters, the definition of landscape quality and how the renewable energy technologies affect local landscape will be discussed.

3 Landscape quality

3.1 The conceptualization of landscape quality

In one of his books published in 2011 'spatial quality in area development' (Dutch: Ruimtelijke Kwaliteit in Gebiedsontwikkeling) Janssen-Jansen has pointed out that landscape quality is one of the most frequently used concepts related to spatial quality. In this essay, since the term 'landscape' discussed here refers to 'urban landscape' instead of conventional 'natural landscape', landscape quality can be considered basically equivalent to spatial quality. However, Janssen-Jansen also revealed the fact that there is almost no international scientific literature on spatial quality. As a matter of fact, almost only Dutch scholars discuss about it (Franssen, 2013).

The concept of spatial quality was first introduced by Vitruvius, an architect and engineer in the old Roman Empire. He used three conjugations, that is, utility, external beauty and strength as criteria of spatial quality, which became a catalogue for the construction of Rome. His definition has been of great influence on scientists but was somehow detached from real practice (Bech-Danielsen, 2013). Later, the concept of spatial quality has changed and was considered as an important factor in the location choice in industrial countries like the Netherlands (Franssen, 2013; Assink & Groenendijk, 2009). In the industrial revolution, spatial quality was more economic oriented, which usually can be perceived in characteristics as transport costs or labour costs linked to neoclassical theories (Assink & Groenendijk, 2009). As they elaborate further, significant urbanization progress in the middle of the 20th century was another important aspect which contributed and attached values to the conceptualisation of spatial quality. Since then, accessibility of commercial areas and public service facilities plays a more important role in everyday life (Franssen, 2013). Social values such as sense of belonging, identity of place and social coherence which are generated by urban landscape has become another criterion of spatial quality. In the past two decades, with the growing awareness of both natural and living environment, the value of recreational and cultural activities, as well as governmental policies, more criteria have been attached to spatial quality (Louw et al., 2004).

Spatial quality, or in other words, landscape quality, is changing throughout the history. The contemporary world has seen different understandings of landscape quality. For instance, it can relate to the productivity of agriculture landscape where food is produced, or clean healthy environment that performs well in biodiversity. Also, visual property of the landscape is another very important factor of landscape quality. Yi-Fu Tuan, one of the most important originators of humanistic geography wrote in his book (1979): "Landscape… is not to be defined by itemising its parts. The parts are subsidiary clues to an integrated image. Landscape is such an image, a construct of the mind and of feeling." Aesthetic quality of landscape comes from two main sources which cannot be separated: from the object and from the observer (Laurie, 1975). Thus, the landscape perceived by different people also differs (Arriaza, 2004). Generally, landscape quality is constructed and valued through different interpretations from the public, instead of defined by scientific evidence. To maintain specific characteristics is important and requires a special approach (Gil et al., 2011).

3.2 The assessment matrix

As mentioned above, landscape quality is considered as the core concept in spatial planning and the main purpose of spatial policy (Assink & Groenendijk, 2009). The concept of landscape quality has been solidified since 'The Fourth Memorandum on Spatial Planning' (1988), with three main components: use value, perception value and future value. These three terms have become the point of reference in discussions on landscape quality (Assink & Groenendijk, 2009). Firstly, a high Use value occurs when space can be attached with several functions (living, education, recreation etc.). The main principle is that these different functions do not conflict with but to a certain extent can reinforce each other (Assink & Groenendijk, 2009). Perception value is more subjectively assessed and more relevant to our living environment. The modern society has seen the great value of historic awareness, cultural diversity and spatial variation presented in the landscape, which also help to creating the identity of a place and a sense of belonging. Future value includes features such as sustainability, bio-diversity, robustness and flexibility, both concerning suitability for new use forms and admissibility for new cultural and economic meanings (Assink & Groenendijk, 2009).

Although 'The Fourth Memorandum on Spatial Planning' has defined the concept of landscape quality with three components, the benefits of landscape are still missing. It was until 21st century, two Dutch planning theorists Dauvellier and Luttik (2003) elaborated on landscape quality (the original term they use is spatial quality) and developed a matrix, in which they divided the criteria in the three categories according to the positive effects they have, that is, economical quality, ecological quality, cultural and aesthetic quality and social quality. Economic quality mainly refers to the goods and services provided by landscape which can bring economic values (Heide & Heijman). Productivity of agriculture landscape is considered as one of the main economic qualities because it solidifies the base of food market. Ideally, the multi-functionality should consist of configurations that can sustain the fine-tuning outputs that society appreciates and highly values. Function adaptability is also attached to economic quality for it shows the stability. Ecological quality deals with the concepts like ecological corridor, biodiversity or environmental quality, which includes the natural environment as well as the built environment such as air and water purity or pollution, noise and

Assessment matrix of landscape quality (Dauvellier and Luttik, 2003).

	Economic Quality	Ecological Quality	Cultural/aesthetic Quality	Social Quality
Use value	Land productivity Multi functionality Reuse of vacant space	Ecological corridor		Equity and fairness
Perception value	Fine-tuning function	Transparent air Clean water Acoustic wellness	Cultural diversity Historic awareness Aesthetic quality	Space identity Sense of belonging Sense of secure
Future value	Function adaptability	Biodiversity Resilience		Social coherence

the potential effects which such characteristics may have on physical and mental health. Cultural quality is more linked to historical sites and the public events happening on site or related to that history, while Aesthetic quality is more arguably to an extent a subjective one, based on perceptions and only recognized by individuals (Leeuw, 2014). Finally, Social quality is generated from all the physical qualities mentioned above. It's more ambiguous, objective and difficult to assess as well, because it represents intimate feelings that people have on spaces.

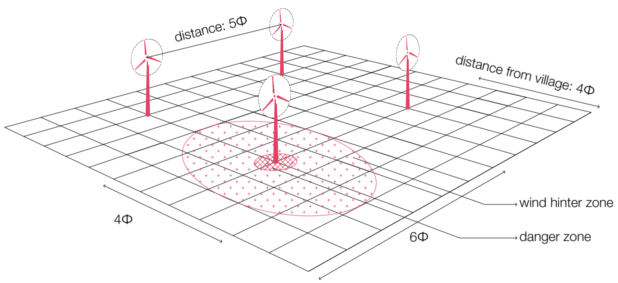
However, since there is no weight attached to each criterion, the confrontation between different values and effects does not provide sufficient handles to work with in practice (Franssen, 2013). The main concern is to define which criterion should be more addressed and highlighted than the others in a certain type of landscape. But on the other hand, using a matrix also has positive effects. By this matrix, same criteria will be used to analyze and access landscape quality in every case instead of developing and changing criteria according to different conditions, which makes the analogy or the comparison between landscapes more plausible.

4 Impacts of renewable energy technologies on landscape

Chapter 2.3 has already revealed the close relationship between the utilization of renewable energy and local landscape. While various types of renewable energy technology are widely deployed to produce clean energy in order to ease the pressure from both global climate change and fossil fuel depletion, the potential impacts that these technologies might have on the local landscape should also be taken into consideration. The most viable renewable energy technology, photovoltaics, wind turbine, biomass field and biodigester, and geothermal heat pump, their possible impacts on landscape quality will be discussed in the next chapters.

4.1 Wind turbine

With air flowing through wind turbines, mechanical power is provided to turn electric generators. It is one of the cleanest and most sustainable ways to generate electricity as an alternative to burning fossil fuels without any toxic pollution or greenhouse gas emissions (Fthenakis et al., 2009). Similar to solar energy, wind power is also abundant, inexhaustible, widely distributed, affordable and water saving, which makes it a most viable form of renewable energy.



spatial requirement of wind turbine
source: Energy landscape Flemish - POSAD

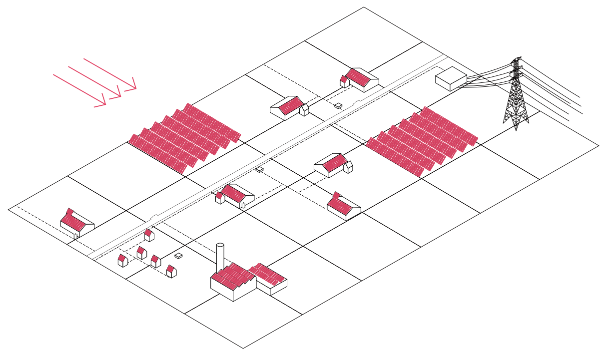
The land use impact of wind turbines varies substantially depending on the location: wind turbines placed in flat areas typically use more land than those located in hilly areas (UCS, 2018). But on the other hand, since the turbines must be placed approximately 5 to 10 rotor diameters apart, the actual land occupied by the turbines and the surrounding infrastructure (including roads and transmission lines) is only a small portion of the total area of wind facilities (UCS, 2018). Therefore, the rest of the land can be used for a variety of other productive purposes such as agriculture, livestock grazing, transportation infrastructures, and parks, which significantly reduces the concerns about land use (NREL, 2012). Alternatively, very similar to PV panels, wind turbines can also be integrated in lower-quality land or other industrial and commercial area.

Concerns on the biodiversity of wildlife become one of the main reasons why people are against the deployment of wind turbines, while the problem of noise and shadow flicker become another. Birds and bats can get killed by wind farms, especially by utility-scale wind energy facilities (Wang, 2015). However, compared to other human activities such as hunting and deforestation, the number of birds killed by wind turbines can be negligible (Saidur et al., 2011). The negative impacts on ecological quality can be minimized by proper choice of location. Sound and visual impact are the two main public health and community concerns associated with operating wind turbines (UCS, 2018). Some people near wind power facilities have complained about noise and vibration problem, but studies in Canada and Australia also found that issues won't adversely impact public health (CMOH, 2010; NHMRC,2010). However, when deploying wind turbines, it is still necessary to take the public opinion into serious consideration.

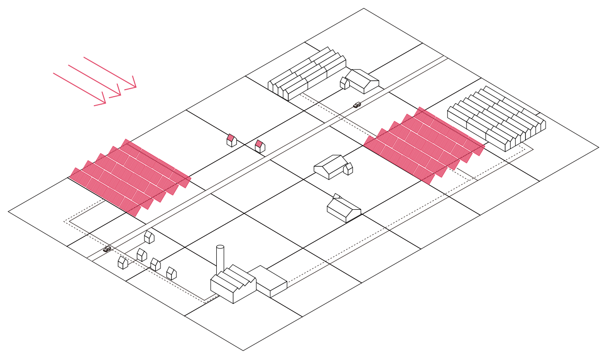
When it comes to aesthetic quality of landscape, the possible impact of wind turbines perceived by individuals also differs. To some people they are modern arts, while to others they are compromising natural landscape. And most of people hold a neutral point of view on wind turbines as long as they are not integrated in historic or cultural landscape.

4.2 Photovoltaics

Photovoltaic panels (PV) are considered to be generally of benign impact on landscape quality, which emit no gaseous, liquid pollutants and radioactive substances (Tsoutsos et al., 2005). Also, even with the related construction activities, there is little noise. When installed along the busy traffic roads and railways, it can serve as sound barriers which lowers the noise pollution from the traffic. However, besides all these benefits mentioned above, the negative impacts of PV system shouldn't be ignored.



spatial integration photovoltaic panels
source: Energy landscape Flemish - POSAD



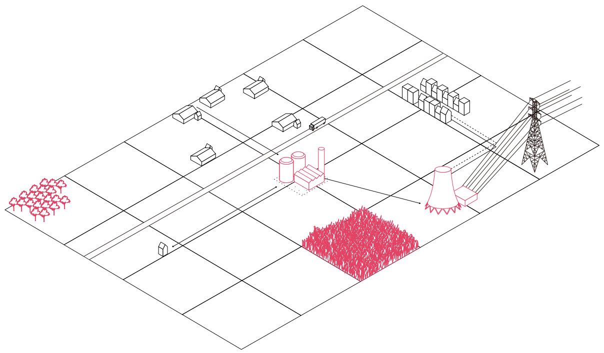
spatial integration solar collector
source: Energy landscape Flemish - POSAD

Due to the amount of land occupied by large utility-scale PV panels which cannot be shared for other uses, deployments in once-cultivable land is possible to damnify soil productive areas (Tsoutsos et al., 2005). The 'sentimental bind' of the cultivator and his cultivable land is likely to be the reason of several social disagreements and displeasure. Furthermore, it can result in land degradation and habitat loss, which heavily influences the diversity of local fauna and flora. But these impacts can be minimized by using lower-quality land such as brownfield, abandoned spaces and existing infrastructures (NREL, 2012). Smaller PV panels placed on the rooftop or integrated in building facade will also have minimal impact.

Aesthetic intrusion of PV system is highly dependent on the type of the scheme and surrounding context. It is obvious that historic site and traditional cultural spaces will be significantly influenced by PV panels, while modules integrated into the facade of modern architecture can generate aesthetic beauty. By choosing proper design for PV installations, advances in the development of multi-functionality which provide both aesthetic and practical functions such as shading and heat extraction, will add an important stimulus to architectural expression (Hestnes, 1999).

4.3 Biomass cultivation and biodigester

Biomass has a wide range of definition. It can refer to waste material from plants or animals that is not used for food or feed, such as waste from farming (like wheat stalks) or horticulture (yard waste), food processing (like corn cobs), animal farming (manure), or human waste from sewage plants (USEIA, 2018). Also, it includes crops cultivated specifically for energy production. As a promising renewable energy source, energy crops play an important role in climate mitigation, by both lowering greenhouse gas emissions and sequestering carbon in soils (Dauber et al., 2010). However, large areas of land have to be transformed to energy crop cultivation in order to reach the benchmarks of energy production, which will change major land use over relatively short time period (Dauber et al., 2010). On the one hand, converting agriculture landscape to energy crop field will reduce the original economic quality from food or horticultural sector. While on the other hand, a sudden change in land use is generally regarded as one of the major drivers for biodiversity loss (Dauber et al., 2010). It's important to develop a wide scope for land use planning including energy crops which could introduce novel agricultural landscapes of higher economic viability and environmental sustainability.



spatial integration biomass field and digester
source: Energy landscape Flemish - POSAD

Similar with fossil fuels, biomass power plants involve the combustion of a feedstock to generate electricity, which also raise concerns about air emissions and water use. However, the feedstock of biomass plants can be sustainable produced, and although the burning of biomass results in both NO2 and CO2 emissions, the carbon produced being the same quantity as what was absorbed by the plant during its lifetime, so the net carbon emission is negligible (REH, 2018). As for cultural and aesthetic quality, biomass cultivation can create a fine-tuning natural landscape by proper design.

4.4 Geothermal heat pump

Unlike wind and solar resources, which are more dependent upon weather fluctuations and climate changes, geothermal resources are available in every second. There are several geothermal technologies, including geothermal electricity and heating. This essay mainly focuses on technologies for heating purpose. Within an enhanced geothermal system, where water is initially injected and then circulates through the system, not only zero CO2 emissions are foreseen, but also none of the other problems are anticipated (GEA; CRES, 2007). Since most of the system is located underground or installed inside the buildings, it doesn't harm ecological quality or aesthetic quality of landscape.

Landscape quality influenced by renewable energy technologies. (green-positive impact; red-negative impact)

	Economic Quality	Ecological Quality	Cultural/aesthetic Quality
Use value	Land productivity (biomass cultivation, PV field) Multi functionality (combine with existing infrastructure) Reuse of vacant space (brownfield, abandoned space)	Ecological corridor (no construction)	
Perception value	Fine-tuning function (energy parks)	Transparent air (biodigester) Acoustic wellness (wind turbine, PV panel along traffic lines)	Aesthetic quality (depending on location and style)
Future value		Biodiversity (wind turbine, PV field)	

5 Conclusion

To summarize, public awareness and acceptance of renewable energy technologies can be created within the integrated energy landscape where artificial energy interventions compose a concerto together with the living environment, of which landscape quality is the key note. But moreover, the ongoing transition towards sustainable energy landscape doesn't merely require the radical deployment of enough renewable energy technologies to reach the benchmark of energy production, but also includes the synergy between energy facilities and the urban landscape. Sustainable energy is not only exploring and exploiting new forms of renewable energy, but also aiming at the reduction of energy consumption by two main measures. One is increasing the efficiency of energy use by creating synergies between different energy consumers, so that the waste energy can be recycled and reused. The other is to reduce the energy demand by evoking the public aware of energy saving. Only then can our world reach a new era of sustainable energy generation.

References

[1] Arriaza, M., Cañas-Ortega, J. F., Cañas-Madueño, J. A., & Ruiz-Aviles, P. (2004). Assessing the visual quality of rural landscapes. Landscape and Urban Planning, 69(1), 115–125. https://doi.org/10.1016/j.landurbplan.2003.10.029

[2] Assink, M., & Groenendijk, N. (2009). Spatial quality, location theory and spatial planning. Presented at the Regional Studies Association Annual Conference 2009: Understanding and Shaping Regions: Spatial, Social and Economic Futures. Retrieved from https://research.utwente.nl/en/publications/spatial-quality-location-theory-and-spatial-planning

[3] Bazilian, M., Onyeji, I., Liebreich, M., MacGill, I., Chase, J., Shah, J., … Zhengrong, S. (2013). Re-considering the economics of photovoltaic power. Renewable Energy, 53, 329–338. https://doi.org/10.1016/j.renene.2012.11.029

[4] Bech-Danielsen, C. (2013). Vitruvian Perspectives on Architectural Quality: Developing a Vitruvian discussion on green architecture – a starting point for an upcoming research project. Presented at the AESTHETICS, THE UNEASY DIMENSION IN ARCHITECTURE. Retrieved from http://vbn.aau.dk/en/publications/vitruvian-perspectives-on-architectural-quality(954fa26b-017b-4551-b639-20e2cd16501f)/export.html

[5] Biomass - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration. (n.d.). Retrieved November 27, 2018, from https://www.eia.gov/energyexplained/?page=biomass_home

[6] Boer, J. de. (2018). An area-based research approach to energy transition. University of Groningen. Retrieved from https://www.rug.nl/research/portal/en/publications/an-areabased-research-approach-to-energy-transition(0b05b909-54a5-4a21-9a35-8a97cee8bb59).html

[7] Bogucki, P. (1996). The Spread of Early Farming in Europe. American Scientist, 84(3), 242–253.

[8] Chief Medical Officer of Heath of Ontario. (2010). The potential health impact of wind turbines. Toronto, Ontario: Ontario Ministry of Health and Long-Term Care

[9] Correljé, A., & van der Linde, C. (2006). Energy supply security and geopolitics: A European perspective. Energy Policy, 34(5), 532–543. https://doi.org/10.1016/j.enpol.2005.11.008

[10] Dauber, J., Jones, M. B., & Stout, J. C. (2010). The impact of biomass crop cultivation on temperate biodiversity. GCB Bioenergy, 2(6), 289–309. https://doi.org/10.1111/j.1757-1707.2010.01058.x

[11] Drury, E.; Margolis, R.; Denholm, P.; Goodrich, A.C.; Heath, G.; Mai, T.; Tegen, S. (2012). "Solar Energy Technologies," Chapter 10. National Renewable Energy Laboratory. Renewable Electricity Futures Study, Vol. 2, Golden, CO: National Renewable Energy Laboratory; pp. 10-1 – 10-60.

[12] Energielandschappen, de 3de generatie. (2011). Provincie Drenthe.

[13] Environmental impact of biomass | The Renewable Energy Hub. (n.d.). Retrieved November 28, 2018, from https://www.renewableenergyhub.us/biomass-boiler-information/environmental-impact-of-biomass-boilers.html

[14] ENVIRONMENTAL IMPACTS OF GEOTHERMAL ENERGY Based on “A Guide to Geo-

thermal Energy and the Environment” GEA and “The Environmental Impact of the Geothermal Industry” CRES. (n.d.).

[15] Environmental Impacts of Wind Power. (n.d.). Retrieved November 27, 2018, from https://www.ucsusa.org/clean-energy/renewable-energy/environmental-impacts-wind-power

[16] Franssen, G. (n.d.). Embedding Spatial Quality, 162.

[17] Fthenakis, V., & Kim, H. C. (2009). Land use and electricity generation: A life-cycle analysis. Renewable and Sustainable Energy Reviews, 13(6), 1465–1474. https://doi.org/10.1016/j.rser.2008.09.017

[18] Gil, A., Calado, H., & Bentz, J. (2011). Public participation in municipal transport planning processes – the case of the sustainable mobility plan of Ponta Delgada, Azores, Portugal. Journal of Transport Geography, 19(6), 1309–1319. https://doi.org/10.1016/j.jtrangeo.2011.06.010

[19] Heide, C. M. van der, & Heijman, W. (2013). The Economic Value of Landscapes. Routledge.

[20] Janssen-Jansen, L. B., Klijn, E. H., & Opdam, P. (2009). Ruimtelijke kwaliteit in gebiedsontwikkeling. GoudaHabiforum9789490287054. Retrieved from https://dare.uva.nl/search?identifier=d2173f61-47cb-458c-86f5-f0464f8cc371

[21] Laurentis, C. D. (2015). Innovation and Policy for Bioenergy in the UK: A Co-Evolutionary Perspective. Regional Studies, 49(7), 1111–1125. https://doi.org/10.1080/00343404.2013.834320

[22] Laurie, I. C. (1974). Aesthetic Factors in Visual Evaluation. University of Manchester, Landscape Evaluation Research Project.

[23] Leeuw, D. P. J. de. (2014, February 3). The energy transition in Dutch spatial planning: two case studies of implementing wind farms in The Netherlands [Bachelor thesis]. Retrieved October 28, 2018, from http://dspace.library.uu.nl/handle/1874/289656

[24] Louw, E., Needham, B., Olden, H., Pen, C. J., & Haag, D. (2010). ‘De toekomst van bedrijventerreinen: van uitbreiding naar herstructurering’ Gusta Renes, Anet Wetering, Hugo Gordijn Den Haag: PBL, 2009, 12.

[25] National Health and Medical Research Council (NHMRC). 2010. Wind turbines and health: A rapid review of the evidence. Canberra, Australia: National Health and Medical Research Council.

[26] Palz, W. (2013). Solar Power for the World: What You Wanted to Know about Photovoltaics. CRC Press.

[27] Pasqualetti, M. J. (2012, September 12). Reading the Changing Energy Landscape. https://doi.org/10.1201/b13037-7

[28] Saidur, R., Rahim, N. A., Islam, M. R., & Solangi, K. H. (2011). Environmental impact of wind energy. Renewable and Sustainable Energy Reviews, 15(5), 2423–2430. https://doi.org/10.1016/j.rser.2011.02.024

[29] Tainter, J. (1990). The Collapse of Complex Societies. Cambridge University Press.

Tsoutsos, T., Frantzeskaki, N., & Gekas, V. (2005). Environmental impacts from the solar energy technologies. Energy Policy, 33(3), 289–296. https://doi.org/10.1016/S0301-4215(03)00241-6

[30] Tuan, Y.-F. (1979). Thought and landscape. In: Meining, D.W. (Ed.), The interpretation of ordinary landscapes. Oxford University Press.

[31] Wang, S., & Wang, S. (2015). Impacts of wind energy on environment: A review. Renewable and Sustainable Energy Reviews, 49, 437–443. https://doi.org/10.1016/j.rser.2015.04.137

05 METHODOLOGY FRAMEWORK

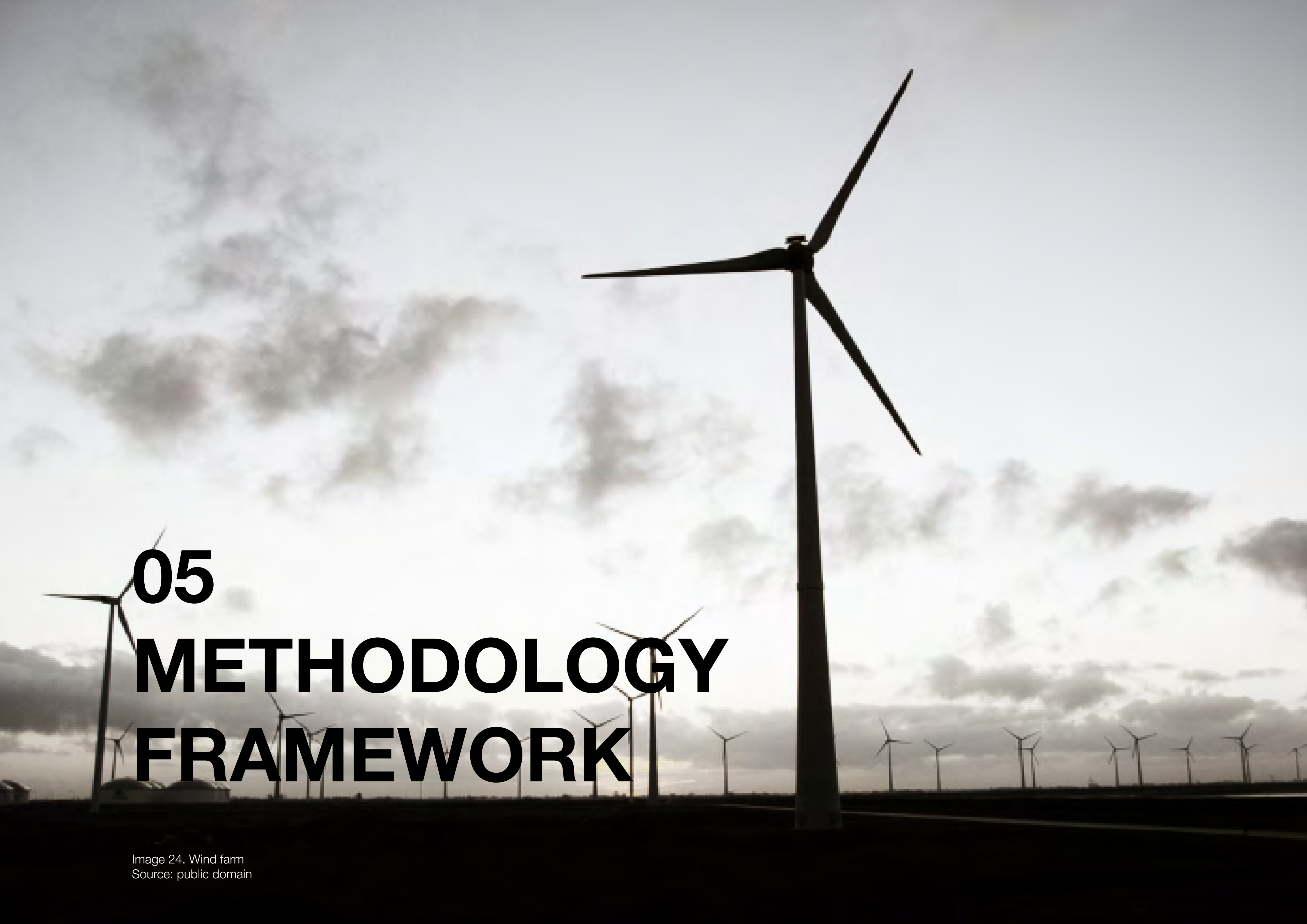


Image 24. Wind farm
Source: public domain

5.1 Introduction

With the largest European port and many industrial organizations located residing inside its border, the Metropolitan Area Rotterdam-The Hague (MRDH) is not only one of the most important energy processing and transit centers in Europe, but also the most energy intensive regions of the Netherlands. Accounted for only 2.7% of domestic land area, the MRDH constitutes 13.5% of the overall energy consumption. Evidently, the dependence on fossil fuel energy for the aspiration of development is relatively high, however, this region is almost impoverished in terms of energy reserves, except a small amount of natural gas and sustainable energy resource (Smart Energy Delta, 2016). Most of the used energy of crude oil and coal is imported in the port of Rotterdam by far, as well as natural gas from Groningen gas field, except a small amount of oil and natural gas from regional fields.

However, when it comes to future development, the MRDH will be confronted with challenges come from both side of global climate change and fossil fuel depletion, as it's currently energy intensive and highly dependent on fossil fuels. There is no question that the main cause of the current global warming trend is human expansion of the “greenhouse effect” caused by heat-trapping nature of carbon dioxide and other gases emitted by the combustion of fossil fuels (NASA, 2018). With almost the whole region lying below the sea level and susceptible to river discharge, the MRDH has become quite vulnerable to flooding issues caused by the added water from melting ice sheets and the increase of extreme precipitations (NASA,2018). On the other hand, since the MRDH is highly dependent on the fossil fuels extracted outside the area, regional energy security will be placed at risk not only because of the depletion of fossil fuel reserves, but also influenced by the changing situation of geopolics and political relations.

Therefore, many novel energy sources, especially the renewable ones, are rapidly developed and exploited in order to find plausible alternatives to fossil fuel energy. Standing at the tipping point towards renewable energy landscape, however, there are still some drag forces which slows the transition. Since energy and landscape have been treated as two separate conceptual domains throughout history, the potential impacts of renewable energy technologies have on landscape quality are often neglected during practices. That’s why increasingly there are clashes with local residents and communities because of the widespread concern that developing renewable energy technologies might deteriorate the landscape quality.

In order to reduce the public resistance and promote the transition towards sustainable energy landscape, great values have been attached to the integration of renewable energy deployment and landscape quality. Moreover, landscape quality should also be found in the synergy between different energy consumers which helps to reduce energy consumption as long as it has any spatial implication. Only when people become aware and supportive of sustainable energy, can our world reach a new generation of sustainable energy.

This chapter presents the methodological framework of this research, which aims at facilitating the ongoing transition towards sustainable energy landscape in MRDH. The main research question is '*How to integrate landscape quality in the energy landscape which facilitates sustainable energy transition of the Metropolitan Area Rotterdam-The Hague (MRDH) through spatial planning and design?*' Already started with a recapitulation of problem statement and practical gap, this chapter will demonstrate the whole structure of the research, coordinating the relation between research question, design approach and intended outcomes.

5.2 Research Design

Introduction

The research design of this thesis consists of two methodological approaches. The overall research framework is based on a four-stage methodology developed by Lucienne T. M. Blessing and Amaresh Chakrabarti (Blessing & Chakrabarti, 2009).

1. Research Clarification (R.C.)
2. Descriptive Study I (D.S.I)
3. Prescriptive Study (P.S.)
4. Descriptive Study II (D.S.II)

Within this research framework, the five-step approach (Stremke et al. ,2012) is integrated in stage D.S.I and P.S in order to develop a long-term regional design. It can form a basis from a spatial perspective and create the main research objective focused on spatial interventions and impact (Tillie, 2018).

1. Analyzing present conditions
2. Mapping near-future developments
3. Illustrating possible far futures
4. Developing integrated visions
5. Identifying spatial interventions

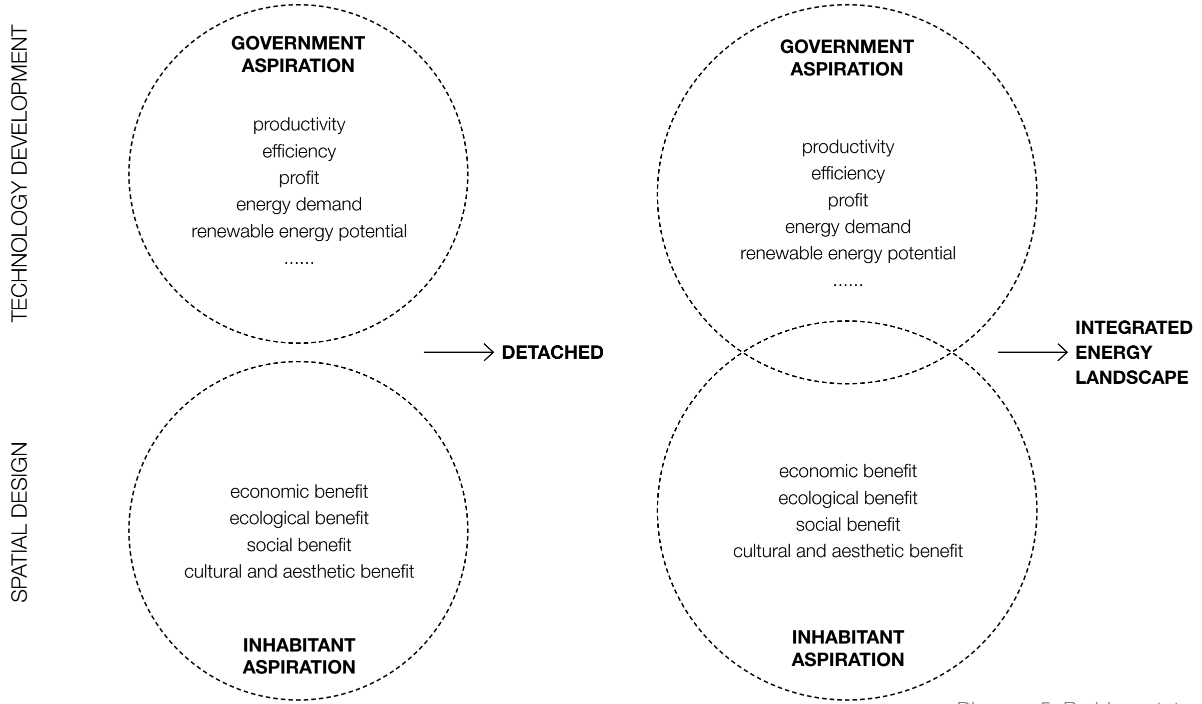


Diagram 5. Problem statement

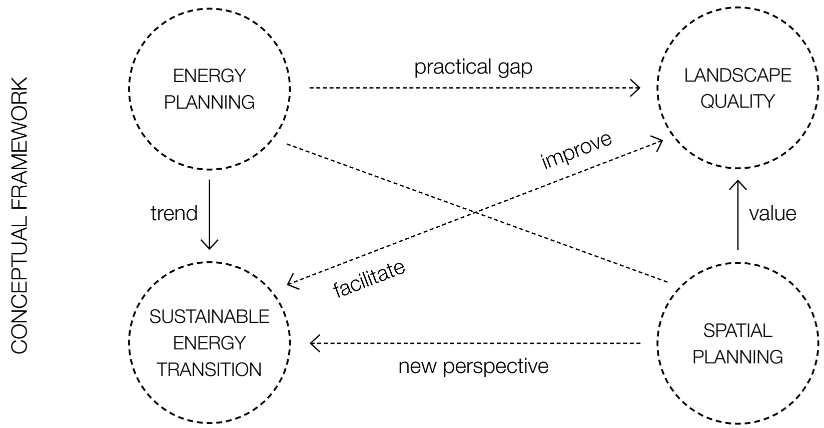


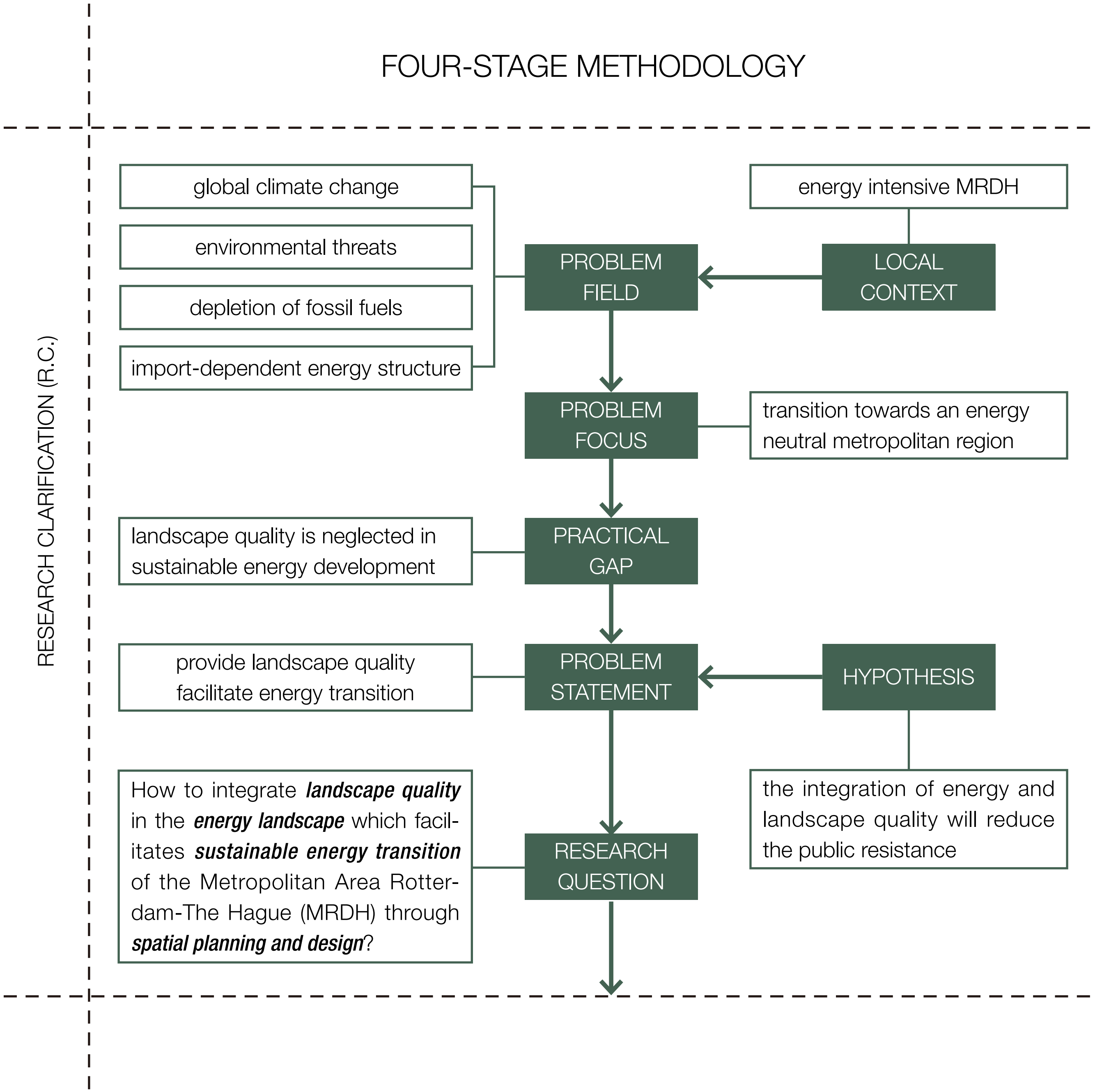
Diagram 6. Conceptual framework

This integrated methodology framework allows the research built from a landscape perspective, filling the practical gap between sustainable energy deployment, synergetic system and landscape quality, so that local inhabitants will be more aware and supportive to promote the transit towards sustainable energy landscape.

1. Research Clarification (R.C.)

In this stage, the main problem, questions and hypothesis is identified to narrow down the focus of the research and the final goal supposed to realize is addressed (Blessing, 2010). Started with the brief analysis of the current situation of the MRDH which reveals the fact that this region is relatively energy intensive and fossil fuel dependent, and is under the great pressure from both global climate change and fossil fuel depletion, the problem focus narrows down to 'the transition towards an energy neutral metropolitan region'. With literature review and phenomenon observation, a practical gap which brings public resistance against sustainable energy transition, that the potential impacts of renewable energy technologies on landscape quality are often neglected, is highlighted, and a hypothesis (the integration of energy and landscape quality will reduce the public resistance) is developed.

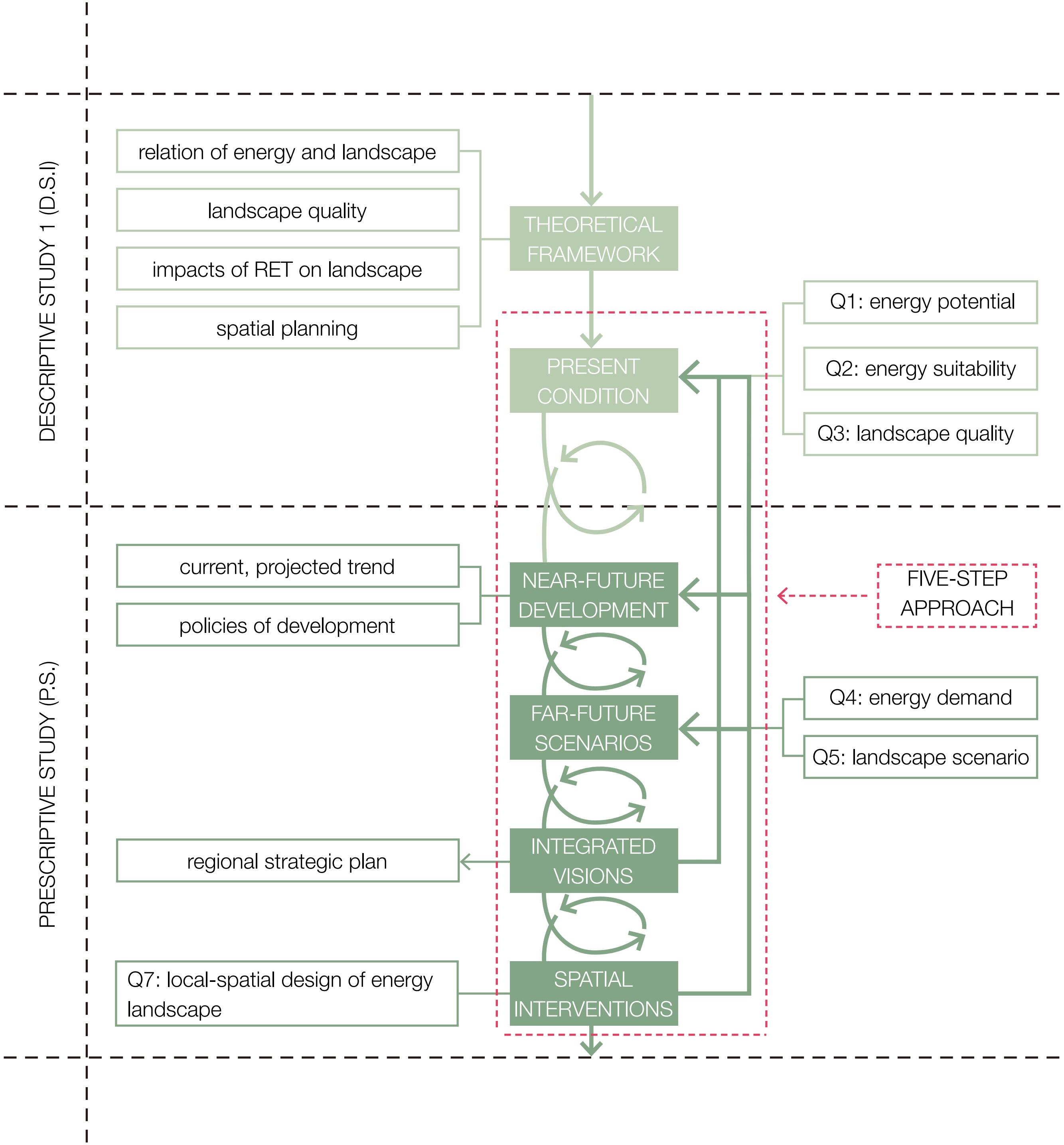
Therefore, when it comes to problem state-



ment, after defining the main conflict, which is the existing detached aspiration between government (energy perspective) and local inhabitants (landscape perspective), the main research question targeting at '*How to integrate landscape quality in the energy landscape which facilitates sustainable energy transition of the Metropolitan Area Rotterdam-The Hague (MRDH) through spatial planning and design?*' can be put forward. It provides a focus for the D.S.I stage in finding the factors that contribute to, hinder or prohibit success.

2. Descriptive Study I (D.S.I)

Literature review plays an important role in gaining a better understanding of key concepts of the research (Blessing, 2010). Theoretical framework firstly reveals how the relation between energy and landscape has changed throughout history. In the new generation of sustainable energy landscape, the relationship between energy and landscape is much closer than ever before, which makes the impacts on landscape quality also more obvious and perceptible. Secondly, the conceptualization of landscape quality is discussed, from which an assessment matrix is developed to define landscape quality by different criteria. By this matrix, same criteria will be used to analyze and access landscape quality in every case which makes the analogy or the comparison between land-



scapes more plausible. Last but not least, since the relationship between renewable energy and landscape has become very close, the possible impacts on landscape quality are discussed from both positive and negative sides, giving guidelines for further study and design. The clarification of some concepts also shows up in the theoretical part such as the difference between sustainable energy and renewable energy, and the conceptualization and establishment of the concept of spatial planning in the Netherlands.

After the establishment of theoretical framework, the five-step approach is integrated in order to develop possible visions. The role of the first step is to provide detailed analysis of the present condition. Sub-question 1: '*How to map the potential of renewable energy in the region?*' and sub-question 2: '*What are the general spatial implications of renewable energy technologies?*' are designed to understand the spatial requirements of each forms of renewable energy, together with the current or predicted future landscape typology, thus to have energy suitability maps. Then it comes to sub-question 3: '*What's the current landscape quality?*'. Derived from theoretical framework, only the landscape qualities that will be influenced by the deployment of renewable energy technologies are analyzed. This stage becomes the basis of the next Prescriptive Study stage because it addresses the factors that have strong influence on systematic design proposal (Blessing, 2010) on sustainable

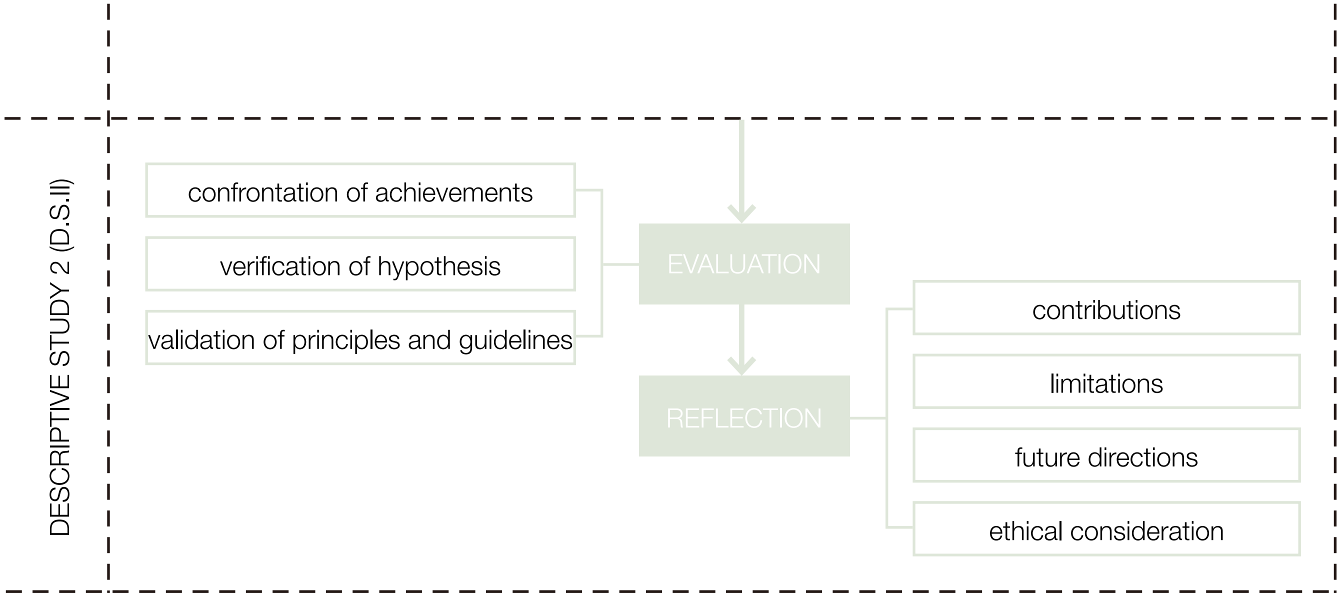


Diagram 7. Methodology framework

energy transit and energy landscape quality.

3. Prescriptive Study I (P.S)

According to Lucienne T. M. Blessing and Amaresh Chakrabarti, in this stage occurs the refinement of the desired situation, by putting forward a "vision on how addressing one or more factors in the existing situation would lead to the realization of the desired, improved situation" (Blessing & Chakrabarti, 2009). This stage consists of the next four steps of the five-step approach. Step 2 is mapping near-future developments according to current, projected trend or policies of development. The role of this step is to give a base for predicting far-future scenarios.

Then in step 3, sub-question 4:'*How much renewable energy production is required in order to realize energy neutrality?*' is interpreted into a regional sustainable energy scenario (as knowns as government aspiration). While sub-question 5:'*What are the expected scenarios of landscape quality for different urban realm?*' is put forward to meet the aspiration of landscape quality from local inhabitants.

After combining the two scenario together, an integrated regional strategic spatial plan, which provides the solution of energy neutrality as well as the local aspiration of landscape quality, is developed (step 4). It's not only one of the most important outcomes of this research but also the most conclusive one. It should also be noted that all these steps are not following a linear flow, but are iterative instead.

The last step of the five-step approach is spatial interventions which aim at visualizing and giving direct impression on the integrated energy landscape, where the sub-question 6:'*How to integrate energy production and landscape quality in spatial interventions?*' is answered. Another task is to assess the robustness of possible interventions, for instance through comparative analysis of the different visions. An intervention with high robustness usually means it appears in multiple visions (Stremke, 2009). Robust interventions are considered prior and are supposed to be implemented in the near-future because they are less possible to be influenced by critical uncertainties (Stremke, 2009). This classification among different spatial interventions gives an insight on how to choose key projects and how to divide them into different phases and time periods.

4. Descriptive Study II (D.S.II)

The Descriptive Study II stage helps to review the effects of design proposals and assess its achievements, limitations and applicability (Blessing & Chakrabarti, 2009). What's more, this stage also includes a general conclusion and an indication of further research (Blessing & Chakrabarti, 2009).

In this thesis it consists of two parts: evaluations and reflections. By evaluating the achievements, it helps to generalize and validate the principles and guidelines derived from the on-site research of the MRDH, revealing whether it's possible to apply the same principles in other regions or not. The reflections mainly focus on a description of the societal relevance, a reflection on the advantages and limitations of the chosen methodology, a discussion of possibilities to generalize the results of the research, a reflection on ethical issues and dilemmas encountered in doing the research and in potential applications of the results in practice.

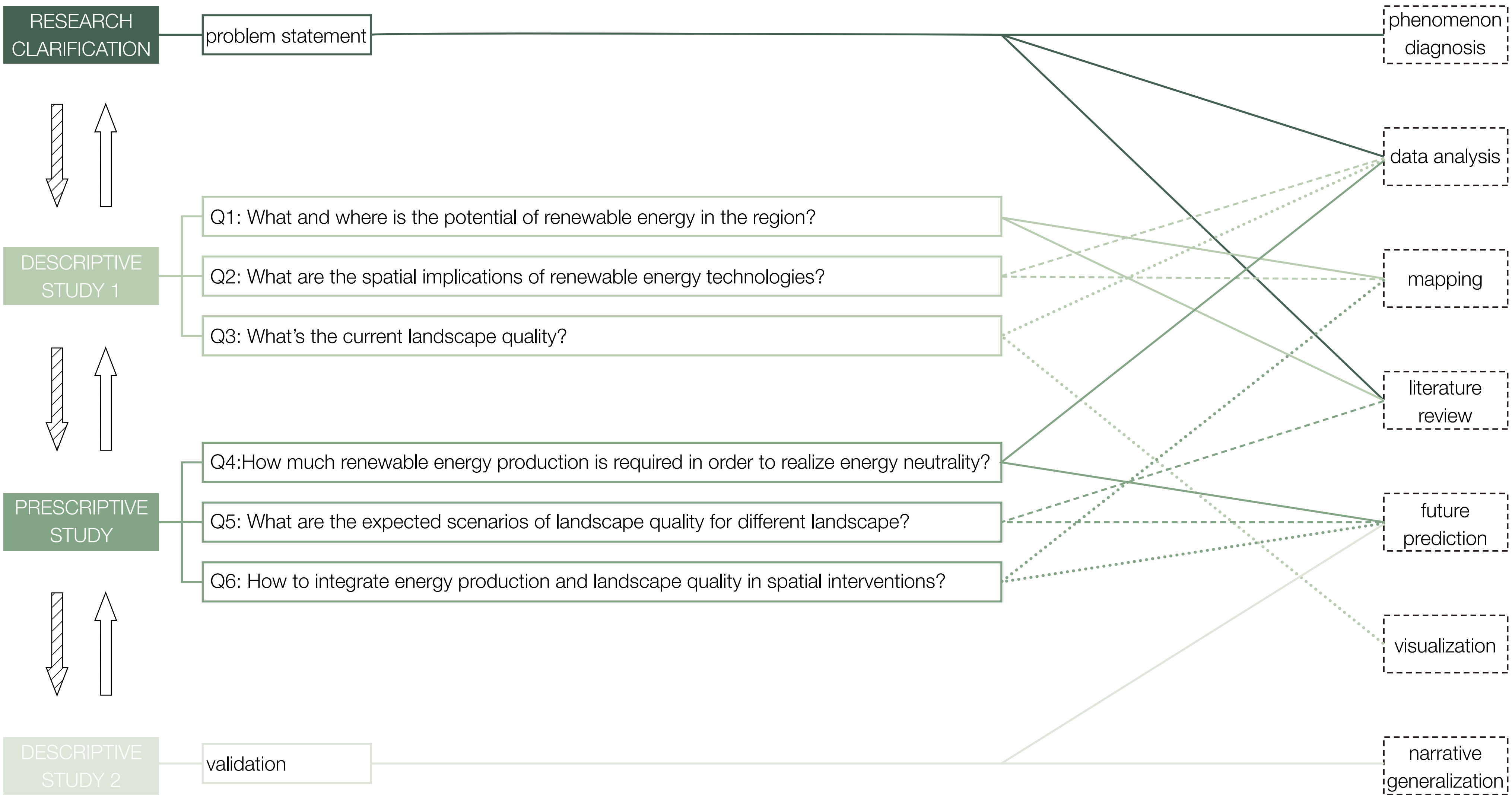
5. Conclusion

It's necessary to highlight that this methodology cannot be considered as a linear process. (Blessing & Chakrabarti, 2009). Naturally occurring within and among stages, iterations increase better understanding of both the current condition and the impact models (regional strategic plan and spatial interventions) built from research. It also brings the opportunity to test the models or to see how the existing condition and designed future will influence each other. Moreover, by the iterative design and evaluation, the research process becomes more efficient because it could avoid certain wrong directions. Because different studies can occur in parallel within stages, iterations are not exclusive even if they are stresses in the previous steps. With the development of the research, a same study can be enhanced at different period of work.

To sum up, this integrated methodology framework not only allows a complete research starting from problem observation to the final evaluation and reflection, but also leave it to an open end for any possible further studies.

5.3 Research Methods

Diagram 8. Research methods



5.4 Thesis Phases and Output

From the methodology framework showed above, At each stage of the research, a step-by-step outcome can be outlined. The main product of Research Clarification stage is a definitive research focus including problem field, practical gap, hypothesis, problem statement, aim of research and research questions.

In the Descriptive Study I stage, the outputs are divided into theoretical framework and analysis of the present condition. The theoretical framework consists of concepts clarification, definition of landscape quality and the impacts of renewable energy technologies on landscape, performing as fundamental knowledge for the following research steps. The present condition analysis consists of renewable energy potential analysis, spatial dimension of renewable energy infrastructure analysis. Energy suitability is mapped after overlapping these layers. Also, the assessment of landscape quality is mapped according to the matrix developed in the theory paper.

The outputs of the Prescriptive Study stage consist of three parts: possible far-future scenarios, integrated visions displayed as regional strategic spatial plans, and spatial interventions, visualized by making impressions and collages. All of them are interrelated and have reflections on each other. Phasing design also comes at this stage.

Finally, in the Descriptive Study II stage, principles and guidelines are developed to be applicable and useful in other regions that shares a certain degree of similarities with MRDH. Limitations, directions for future studies and potential ethical problems are also the intended outcomes.

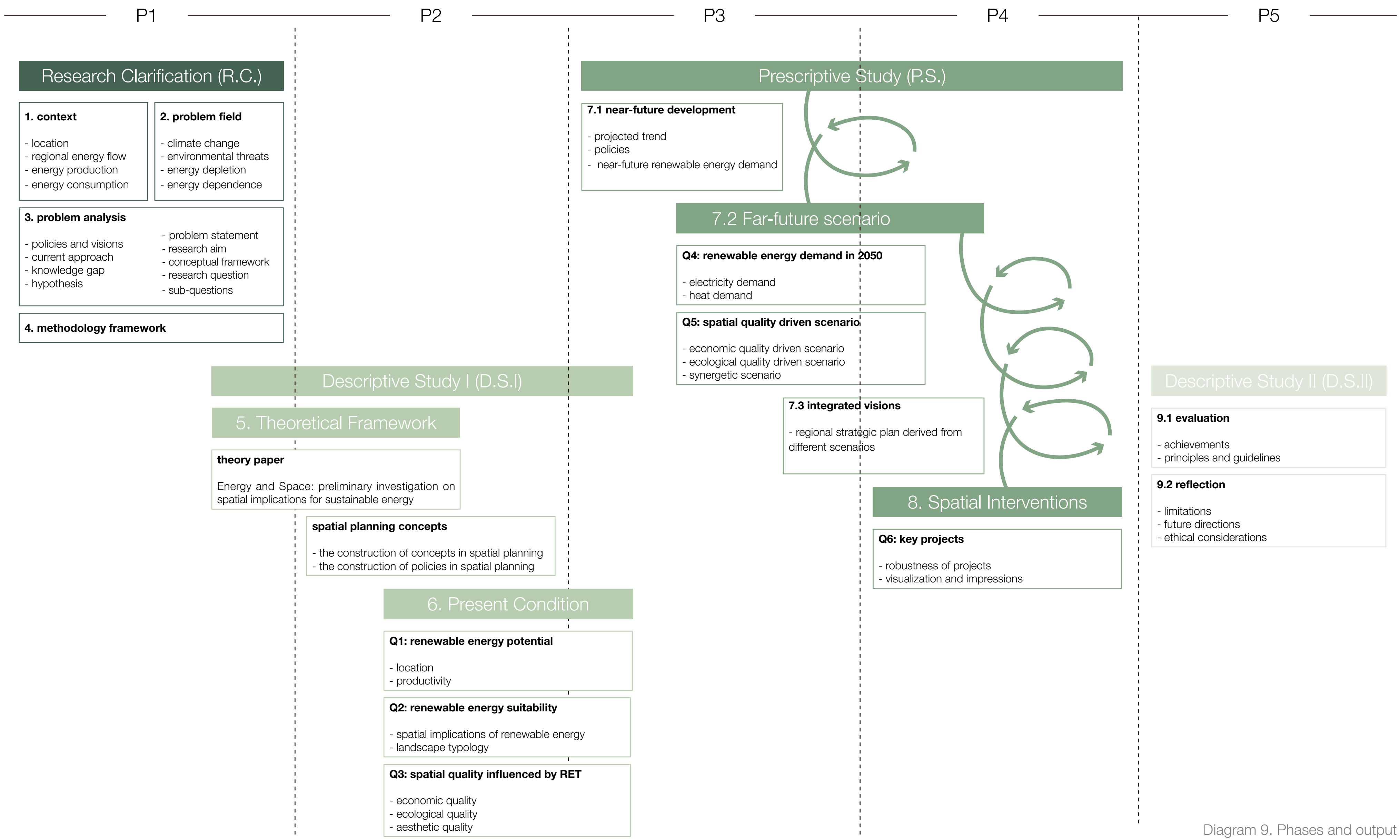


Diagram 9. Phases and output

5.5 Societal and Scientific Relevance

SOCIETAL REFERENCE

This thesis societal relevance at three different scales: neighborhood, regional and European scale. The largest relevance relies on the regional one. Climate change is never something that's happening far away from our daily life. Actually, in recent years, excessive precipitation, droughts and other extreme weather really have a significant negative affection on livability. For instance, Netherlands is currently under a great pressure of the rising sea level and flooding issue, both of which are not only environmental problem but also threatening the livability of this country. As the second largest metropolitan area in the Netherlands, MRDH aims at providing better life quality for its inhabitants. Through the approach towards a sustainable energy landscape integrated with landscape quality, this project will ideally provide a better urban structure and a more sustainable and resilient energy cycle and landscape vision to improve the livability within the re-gion.

On the other hand, since MRDH is inserted in the western Europe and has gained good reputation on energy innovation, the principles used in this project which are tested in MRDH can also be applicable in other European metropolitan area. With the significant depletion in fossil fuel reserves, it will become an inevitable trend that every country is heading towards a sustainable en-ergy landscape, which adds great values to the project.

For the neighborhood scale, another main characteristic of sustainable energy landscape is de-centralization. In contrast to centralized fossil fuel energy, energy from renewable sources can be generated on top of your house roof, in the neighborhood playground, and also in parks and other public spaces. It is more related to daily life and needs to be integrated into local landscapes which are perceived and sensed by people every day. The high visibility of these installations might cause conflicts with the existing landscape quality and therefore require cautious spatial planning (Boer, 2018). By integrating landscape quality into energy landscape, not only the public resistance against renewable energy will be decreased, but also the livability of neighborhoods is created. What's more, because of the decentralized system, it's more possible to achieve energy justice. Vulnerable groups who don't have enough access to the energy market can produce ener-gy on their own.

SCIENTIFIC REFERENCE

As mentioned above, 'sustainable energy landscape' has been a popular and necessary approach in Rotterdam, with many concept researches, principles and design practices spring up. The ideal of urban symbiosis incorporated within REAP which conducted on reducing energy demand, reusing waste energy streams and generating renewable energy becomes Dutch three-step energy approach towards carbon free scenario. However, although REAP can operates at four geographic scales: building, neighborhood, district and city, there still lacks design practice on city and regional scale. Also, POSAD has finished the proposal of energy landscape in Flemish Region, but mainly focus on energy production rather than landscape quality.

Ideally, this project will give a new insight on attaching landscape quality to sustainable energy transition, using landscape as urban infrastructure where energy can flow in a low-consumption, closed and renewable cycle. Also, a strategic plan which indicates how energy neutral is realized in a regional scale will be developed to provide a new understanding and practice to the field.

06
PRESENT CONDITION

Image 25. Barrier dune The Hague
Source: wmeac.org/construction-in-the-barrier-dune-sanctuary-pending/2013/

6.1 Energy Demand

Unit: PJ	TOTAL	BUILT ENVIRON-MENT	INDUSTRY	AGRICULTURE	MOBILITY	OTHER
HEAT NETWORK	—	8.53	—	—	0	—
ELECTRICITY	—	9.92	—	—	0.94	—
GAS	—	58.57	—	—	1.32	—
OIL	—	0	—	—	52.41	—
TOTAL	325.8	77.28	122.0	50.0	54.67	21.80

Table 2. Energy consumption in the MRDH (2016)
Data source: klimaatmonitor.databank.nl/

In order to develop a regional strategic plan which can achieve the goal of energy neutral by 2050 in the MRDH, this chapter (6.1) firstly gives a clear definition on what energy neutral means in this project. Secondly, energy demand of 2030 and 2050 are predicted. Many different future changes and technical innovations have been taken into consideration, thus to provide a more objective perspective on future energy scenario. Based on that, sustainable energy target can be set for both near future and far future.

WHAT IS ENERGY NEUTRAL?

Within urban planning field, terms such as energy neutral, CO2 neutral and climate neutral are frequently used. However, these terms and the difference in between haven't been clarified until the report "Uitgerekend Nul" was published and provided a guidance on the consistent use of terms and the underlying calculation method (Agentschap NL, 2010):

Energy neutral:
Energy use within project boundary = amount of renewable energy that is generated within project boundary or that can be allocated on the basis of external measures to project.

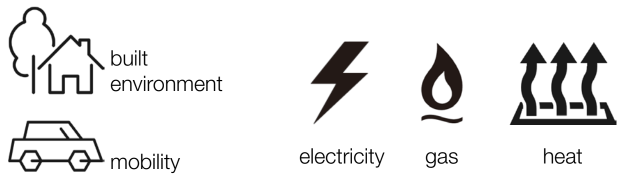
CO_2 neutral:
Greenhouse emission within project boundary = quantity of greenhouse gases that are recorded, stored or compensated within the system boundary on the basis of sustainable energy generation and that can be allocated to the project.

- Agentschap NL, 2010

Since this project focuses on sustainable energy landscape, the term 'energy neutral' is used.

WHICH ENERGY DEMAND IS INCLUDED?

According to a market research done by Agentschap NL, only building-related and use-related energy are included, not the energy used in industries or greenhouses to make products. In this project, energy neutral will be approached as self sufficient in heat, electricity and natural gas demand for built environment and mobility.



WHAT IS THE FUTURE ENERGY DEMAND?

Despite economic growth of an average 1.6% per year, final domestic energy consumption (excluding ambient heat) has fallen by 28% by 2050 compared to today's demand (Gasunie, 2018). Significant energy savings of around 45% are being achieved in the built environment and mobility sector in particular.

Although here is no specific data on future energy saving of the MRDH, since the proportion of different energy sources of each sector is similar in the Netherlands and efficiency improvements are happening all around, it can be considered that the trend of future energy of the MRDH corresponds to the trend of the whole country.

BUILT ENVIRONMENT SECTOR

The final energy consumption in the built environment will have fallen by more than 20% in 2030 and more than 45% in 2050 compared to the present demand.

Heat: In 2050, 25% of all buildings will be connected to a heat network and the remaining buildings will have a (hybrid) heat pump or an open loop ground sourced heat pump (Gasunie, 2018). Geothermal energy will be increasingly available after 2020 and this will significantly boost the continued development of heat networks.

Unit: PJ	2016		2030		2050	
	BUILT ENVIRONMENT	MOBILITY	BUILT ENVIRONMENT	MOBILITY	BUILT ENVIRONMENT	MOBILITY
HEAT NETWORK	8.53	0	8.16 (-4%)	0	10.14 (+18%)	0
ELECTRICITY	20.24	0.94	21.95 (+8%)	5.21 (+450%)	23.20 (+15%)	12.28 (+1200%)
NATURAL GAS	44.34	1.32	21.81 (-50%)	14.41 (+1000%)	0 (-100%)	0 (-100%)
GREEN GAS	3.59	0	7.59 (+110%)	4.99 (+500%)	7.62 (+112%)	19.42 (+2000%)
OIL	0	52.41	0	26.20 (-50%)	0	0 (-100%)
TOTAL	77.28	54.67	59.51 (-20%)	49.20 (-10%)	40.96 (-45%)	31.71 (-42%)

Table 3. Energy demand prediction in the MRDH
Data reference: Gasunie Survey 2050, (2018)

Electricity: The number of electrical appliances in households and utility buildings will have increased further by 2050 due to the use of electricity heat humps, but as a result of considerable efficiency improvements the final energy demand for lighting and other appliances (excluding heat pumps) will be a fraction lower than now.

Gas: In 2050, the gas demand of the built environment will be fully met by green gas. Green gas will be used to supply sufficient heat at times of high demand or in unforeseen circumstances; this will guarantee security of supply. Solid biomass will no longer be used as a fuel source for heat networks.

MOBILITY SECTOR

By 2030, there is estimated to be a significant (around 50%) decrease of fossil fuel consumption in mobility sector due to the popularization of battery-electric vehicles. By 2050, road transport will be CO2-neutral, the demand for fossil fuels having been reduced to zero in this sector.

Long distance freight transport will run partly on a combination of hydrogen and electricity (fuel cell electric vehicle), partly on biofuel and partly on green gas or bio-LNG. Also, the popularization of sharing economy also contributes to the energy reduction in mobility sector.

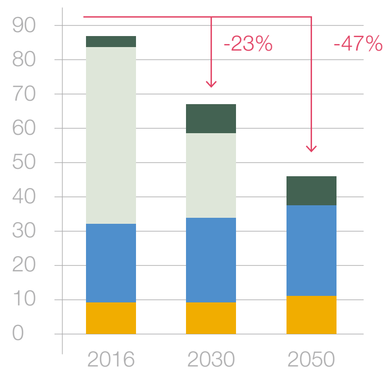
International aviation and shipping are not included in this project because they are not really domestic usage and will bring confusions in calculation.

WHAT IS THE SUSTAINABLE ENERGY TARGET?

In order to monitor the sustainable energy transition of the MRDH in a more clear perspective, the sustainable energy target (scenario) is also set for two time period: near-future scenario (2030) and far-future scenario (2050). And by 2050, the goal of energy neutral should be realized.

However, it might be too soon and too risky to jump into the prediction of, for example, how many percentage of total electricity demand in 2030 should be generated by wind turbines; or how many percentage of total heat demand should be produced with energy crop combustion. Therefore, in this project, instead of giving a certain prediction

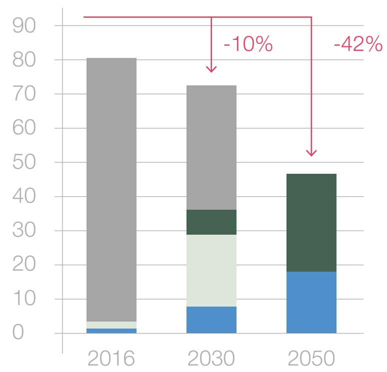
Final energy demand for built environment



	2030	2050
Green gas	+110%	+112%
Natural gas	-50%	-100%
Electricity	+8%	+15%
Heat	-4%	+18%

Figure 14. Final energy demand for built environment
Data reference: Gasunie Survey 2050, (2018)

Final energy demand for mobility



	2030	2050
Green gas	+500%	+2000%
Natural gas	+1000%	-100%
Electricity	+450%	+1200%
Oil	-50%	-100%

Figure 15. Final energy demand for built environment
Data reference: Gasunie Survey 2050, (2018)

of proportion for each sustainable energy sources, first of all calculations of maximum condition will be done. Questions such as 'how many wind turbines should be deployed if all the electricity demand is generated by wind energy?' and 'how many hectares of PV panels should be installed if all the electricity demand is generated by solar energy?' will be answered in the following Chapter 6.2.

This step aims at giving a preliminary impression on how many sustainable energy technologies should be integrated into the landscape to satisfy the future energy demand. Compared with the actual number of sustainable energy technologies that can be deployed in this region (this will be concluded in the design chapter after introducing landscape quality into design process), it is one of the evaluation standards deciding whether the MRDH can realize energy neutral or not.

6.2 Renewable Energy and Technologies

The MRDH has promising potentials and possibilities to exploit renewable energy from wind, solar, biomass and geothermal sources.

The following chapter 6.1 firstly shows regional on-shore renewable energy potential through mapping, providing a direct impression of the intensity of energy sources, which will become the initial layer of location choosing for installing renewable energy technologies. Secondly, the technical standards and spatial requirements of producing energy from each sources mentioned above are discussed and demonstrated in 3D models. Together with the analysis of spatial characteristics of different landscape typologies (chapter 6.2), it can tell whether a certain type of technology can be integrated in this landscape or not.

It's important to know that in chapter 6.1 and 6.2, the value of landscape quality has yet not be attached. All the fitness discussed is in pure technical and spatial dimension.

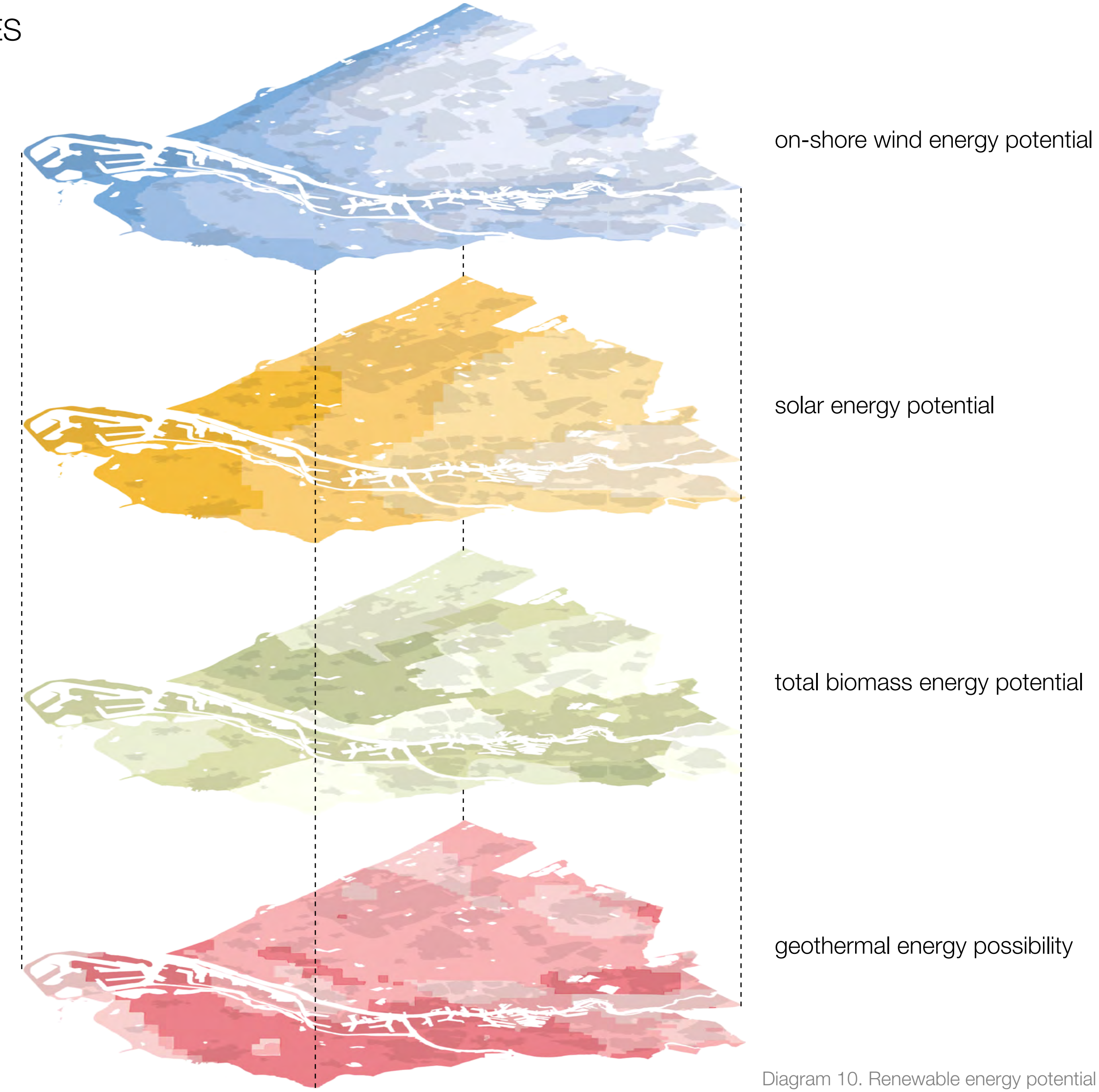
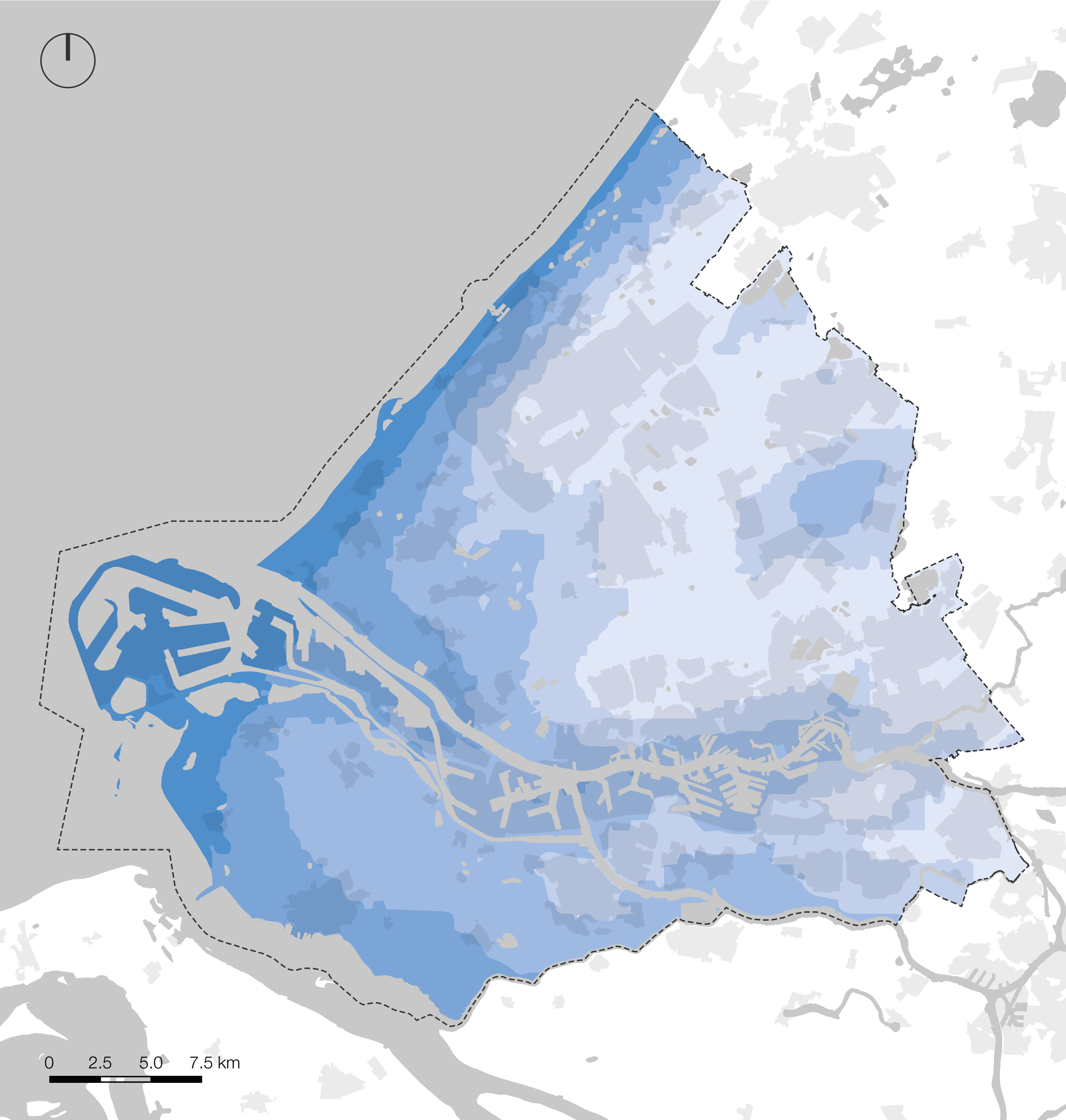


Diagram 10. Renewable energy potential



6.2.1 Wind Energy

As a coast-located metropolitan area, the MRDH shows a great potential of wind energy with wind power density from 325W/m2. According to Wind Resource Assessment Handbook, grid cells designated as Class 4 or greater are generally considered to be suitable for most wind turbine applications.

	30 m (98 ft)		50 m (164 ft)	
Wind Power Class	Wind Power Density (W/m²)	Wind Speed m/s (mph)	Wind Power Density (W/m²)	Wind Speed m/s (mph)
1	≤160	≤5.1 (11.4)	≤200	≤5.6 (12.5)
2	≤240	≤5.9 (13.2)	≤300	≤6.4 (14.3)
3	≤320	≤6.5 (14.6)	≤400	≤7.0 (15.7)
4	≤400	≤7.0 (15.7)	≤500	≤7.5 (16.8)
5	≤480	≤7.4 (16.6)	≤600	≤8.0 (17.9)
6	≤640	≤8.2 (18.3)	≤800	≤8.8 (19.7)
7	≤1600	≤11.0 (24.7)	≤2000	≤11.9 (26.6)

Table 4. Classes of wind power density
Source: wind resource assessment handbook

Class	H=100m	H=50m
1	625 W/m²	400 W/m²
2	525 W/m²	325 W/m²
3	425 W/m²	275 W/m²
4	375 W/m²	225 W/m²
5	325 W/m²	175 W/m²

Map 7. Wind energy potential
Data source: global wind atlas

WIND TURBINE

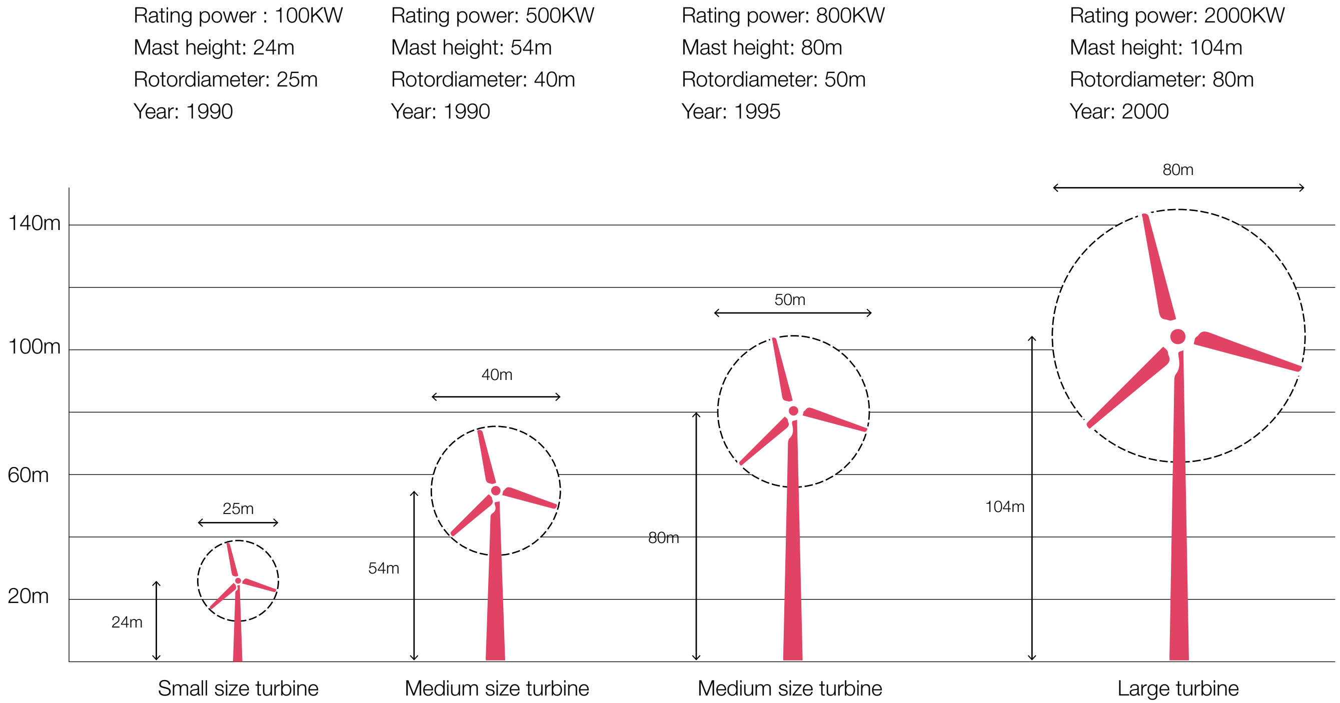
There are wind turbines in many different heights, of which the largest on-shore turbines can have a mast height of 104 meters. Wind turbines must be at a certain minimum distance from each other. A basic rule for the distance is 5 times the diameter of the rotor. For the concerns about noise pollution and shadow flicker issue, the distance between a turbine and a village should be at least 4 times the diameter of the rotor.

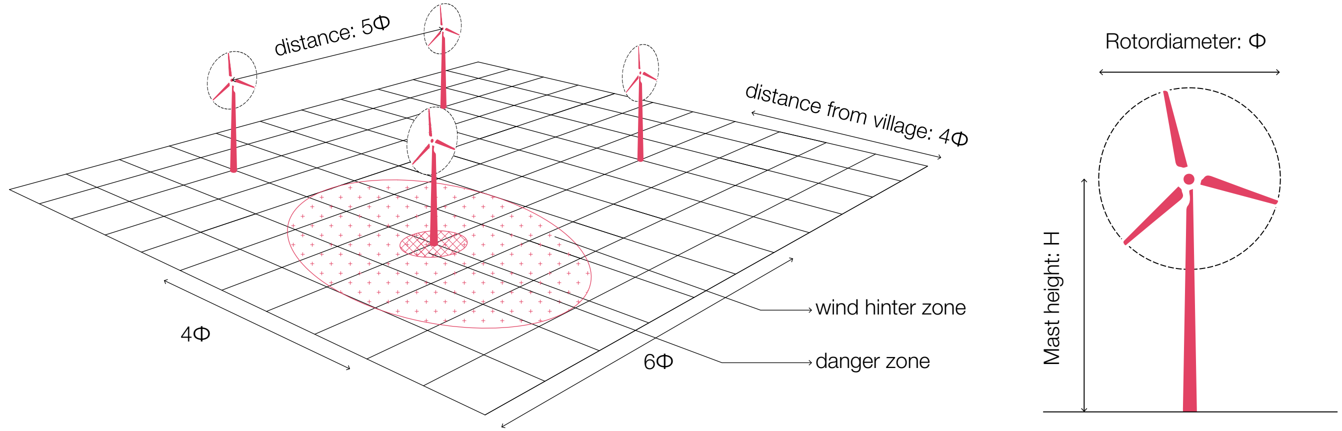
EFFICIENCY

The power rating showed in the diagram beside is the highest power input allowed to flow through particular wind turbine. Thus, the actual power produced by generators should be less than the power rating, otherwise it will harm the equipment. Generally, the average wind efficiency (η) of turbines is between 35-45%. In this project η= 40%. Use the formula $P_{(actual)} = P_{(wind\ power\ density)} \times S_{(swept\ area)} \times \eta$ to have the table below.

	H=24m	H=54m	H=80m	H=104m
Class 1	39.3KW	201.1KW	392.72KW	1256.6KW
Class 2	31.9KW	163.4KW	329.84KW	1055.6KW
Class 3	27.0KW	138.2KW	267.04KW	854.5KW
Class 4	22.1KW	113.1KW	235.6KW	754.0KW
Class 5	17.2KW	88.0KW	204.24KW	653.5KW

Table 5. Actual power of turbines in different wind power density
Source: wind resource assessment handbook





How many wind turbines should be deployed in the region if all the future electricity demand is generated by wind energy?

Given a certain amount of electricity that should be generated by wind turbines, the number of turbines and the area they occupy can be calculated. If we use the actual power of turbines when the wind power density is Class-3 (please refer to Table X in P.54) to make an average assumption:

$N_{\text{(the number of wind turbines)}} = E_{\text{(electricity)}} \times (2.778 \times 10^8) / [P_{\text{(actual)}} \times 24 \times 365]$

$S_{\text{(area occupied)}} = N_{\text{(the number of wind turbines)}} \times (5 \times D/2)^2$

Unit:
$E_{\text{(electricity)}}$: PJ
$P_{\text{(actual)}}$: kW
$S_{\text{(area occupied)}}$: ha
D: m

The table shows that wind turbine of 800KW power rating occupies the least land area among all the types when generating the same amount of electricity. In other word, it has the highest land efficiency. Therefore, in this project, 800KW wind turbines will be deployed.

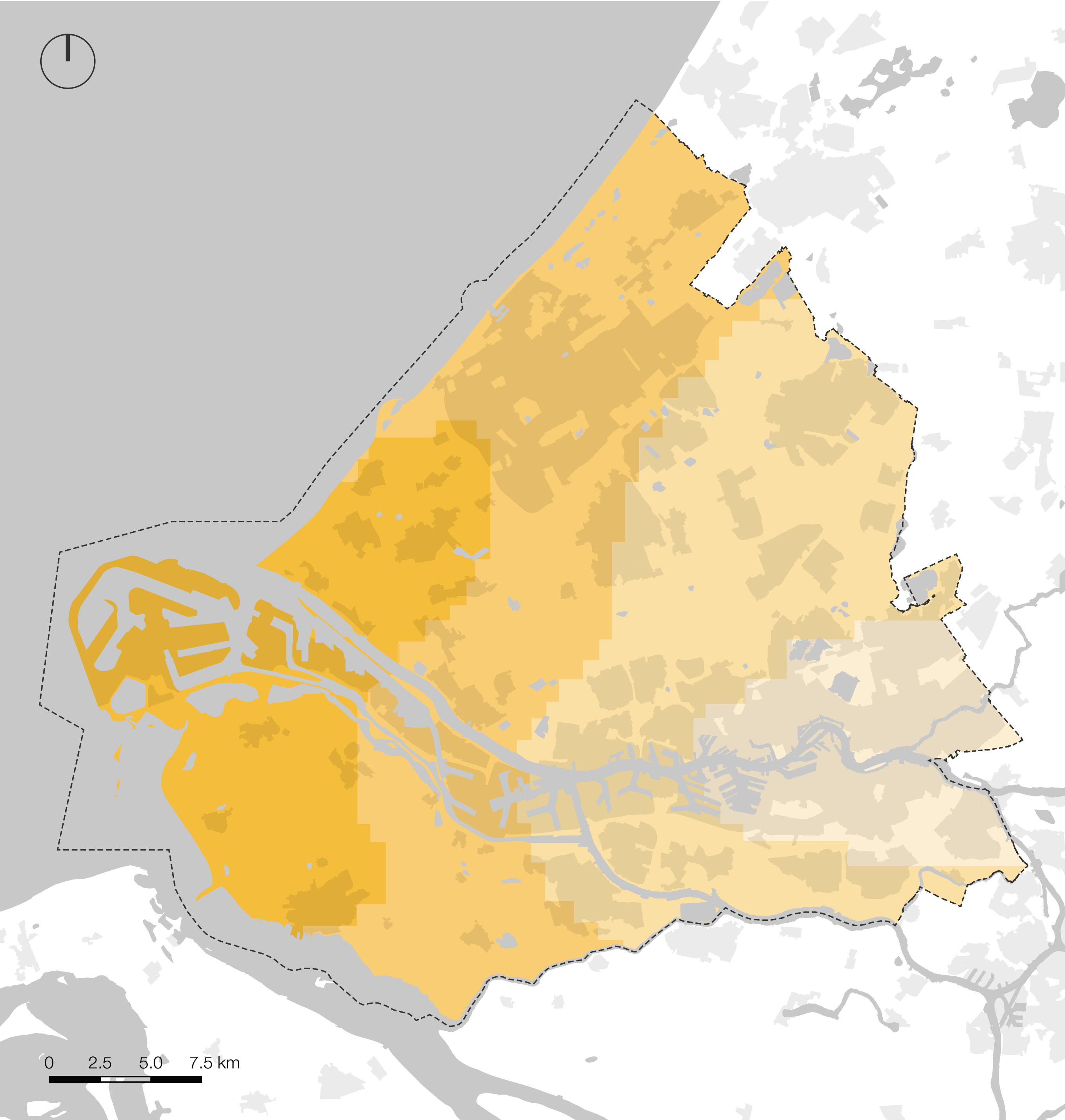
What if all the future electricity demand is generated by wind?						
Wind turbines			100KW (D=25m)		500KW (D=40)	
	Year	Electricity demand (PJ)	Number	Area (ha)	Number	Area (ha)
	2030	27.16	31900	49844.15	6152	24608.77
	2050	35.48	41672	65113.05	8037	32147.24
			800KW (D=50)		2000KW (D=104)	
	Year	Electricity demand (PJ)	Number	Area (ha)	Number	Area (ha)
	2030	27.16	2871	17943.89	907	24515.51
	2050	35.48	3751	23440.70	1184	32025.42

Table 6. Wind turbine demand to reach electricity neutral

6.2.2 Solar Energy

Solar power in the Netherlands has an installed capacity of around 2,040 megawatt (MW) of photovoltaic as of the end of 2016. With around 525 MW of new capacity installed during 2016, the Netherlands ranked the third highest place in Europe for that year (EurObserv'ER, 2019).

It's demonstrated in the map that the MRDH has a promising potential of solar energy. The average quantity of global radiation per year ranges from 1025 kWh/m2 to 1100 kWh/m2, which makes it makes the region possible to produce both electricity and heat from solar power.



1100 kWh/m²
1075 kWh/m²
1050 kWh/m²
1025 kWh/m²

Map 8. Average quantity of global radiation per year
Data source: solargis.com/maps-and-gis-data/overview/

There are two types of power generators. photovoltaic (PV) panels and solar thermal collector.

PV PANELS

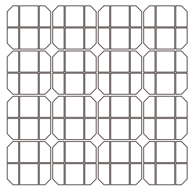
Solar panels, also known as PV panels, can convert the sunlight into electricity, considered as an easily applicable, and environmentally friendly technique to generate electricity. A surplus of electricity can be easily delivered to the grid. Also, more and more products are on the market in which solar cells are integrated in building materials such as roof or facade elements (Energielandschap Vlaanderen, 2015).

The most efficient slope for placing solar panels is 30° - 40°. It's most profitable when the roof is oriented south, southwest and southeast. When there are panels to be placed on a flat roof, the distance between the edge of the roof and the panel must be as large as the height of the panel.

SOLAR THERMAL COLLECTOR

A solar collector is a device that collects and/or concentrates solar radiation from the Sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use (Energy Education, 2004). It's important to know that the device is not able to provide enough heat for a housing.

PV panels



Standard dimension of this kind of PV panel is 99 x 165 cm.

Yield: electricity
Efficiency: 15%~18%
Production: 90 kWh/m^2*year

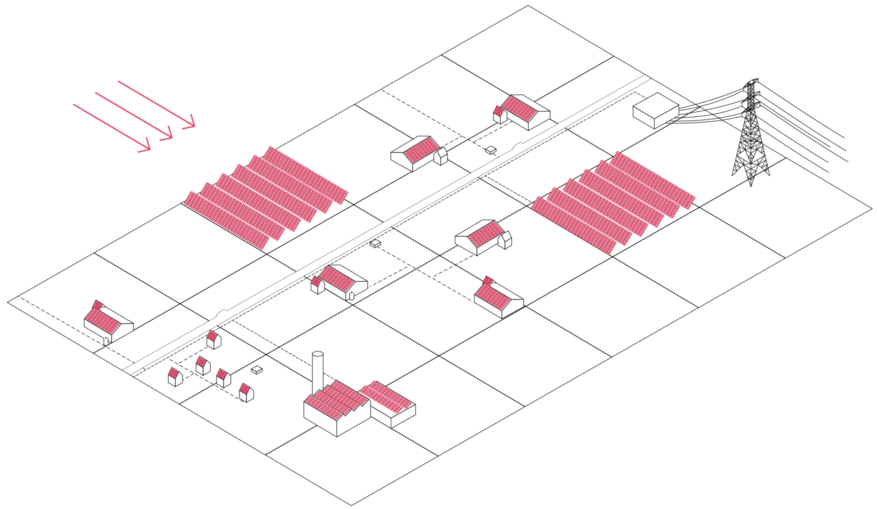
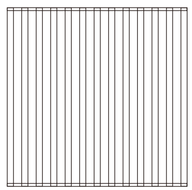


Diagram 11. Sspatial integration photovoltaic panels
Source: Energy landscape Flemish - POSAD

Solar thermal collector



A solar thermal collector collects heat by absorbing sunlight.

Yield: heat
Efficiency: 60%~80%
Production: 400 kWh/m^2*year

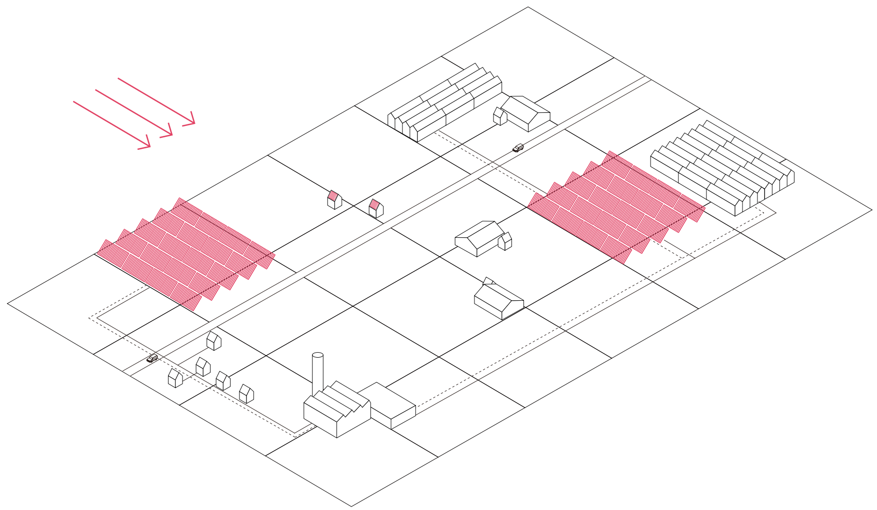
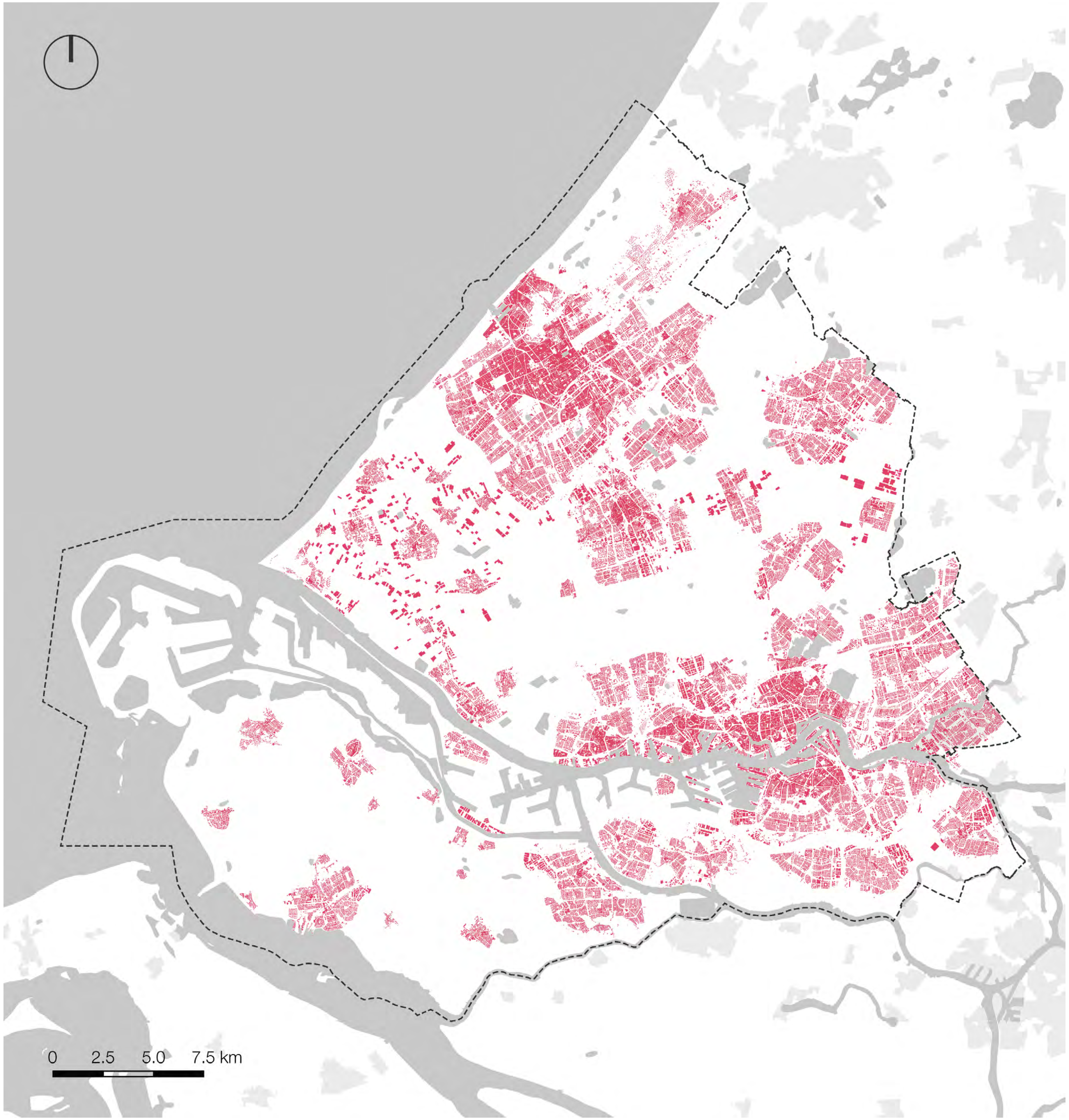


Diagram 12. Spatial integration solar collector
Source: Energy landscape Flemish - POSAD



ROOFTOP AREA

The gross rooftop area that is suitable for solar panels are 95,200,000 m^2. However, considering the limitation of orientation, the condition of buildings and corner space that cannot be used as productive area, for estimate purpose, only 50% of rooftop area can be used for panel's installation (Sustainability Outlook, 2019).

PV panel yield: 90 kWh/m^2*year
Annual yield: = 15.42PJ

This means if all the potential rooftops are installed with PV panels, the annual production of electricity will be 20PJ.

Map 9. Potential locations for solar panels
Data source: www.nationaleenergieatlas.nl/

How many PV panels should be deployed in the region if all the future electricity demand is generated by solar energy?

Given a certain amount of electricity that should be generated by PV panels, the area of panels can be calculated. In Netherlands, the average annual yield of 1m^2 PV panel is 90 kWh.

$S_{(PV\ panels)} = E_{(electricity)} \times (2.778\times10^{8})/90/10000$

Unit:
$S_{(PV\ panels)}$: ha
$E_{(electricity)}$: PJ

What if all the future electricity demand is generated by solar energy?			
	Year	Electricity demand (PJ)	Area (ha)
PV panels	2030	27.16	8383.39
	2050	35.48	10951.49

Table 7. PV panel demand to reach electricity neutral

How many solar collectors should be deployed in the region if all the future heat demand of heat network is replaced by solar energy?

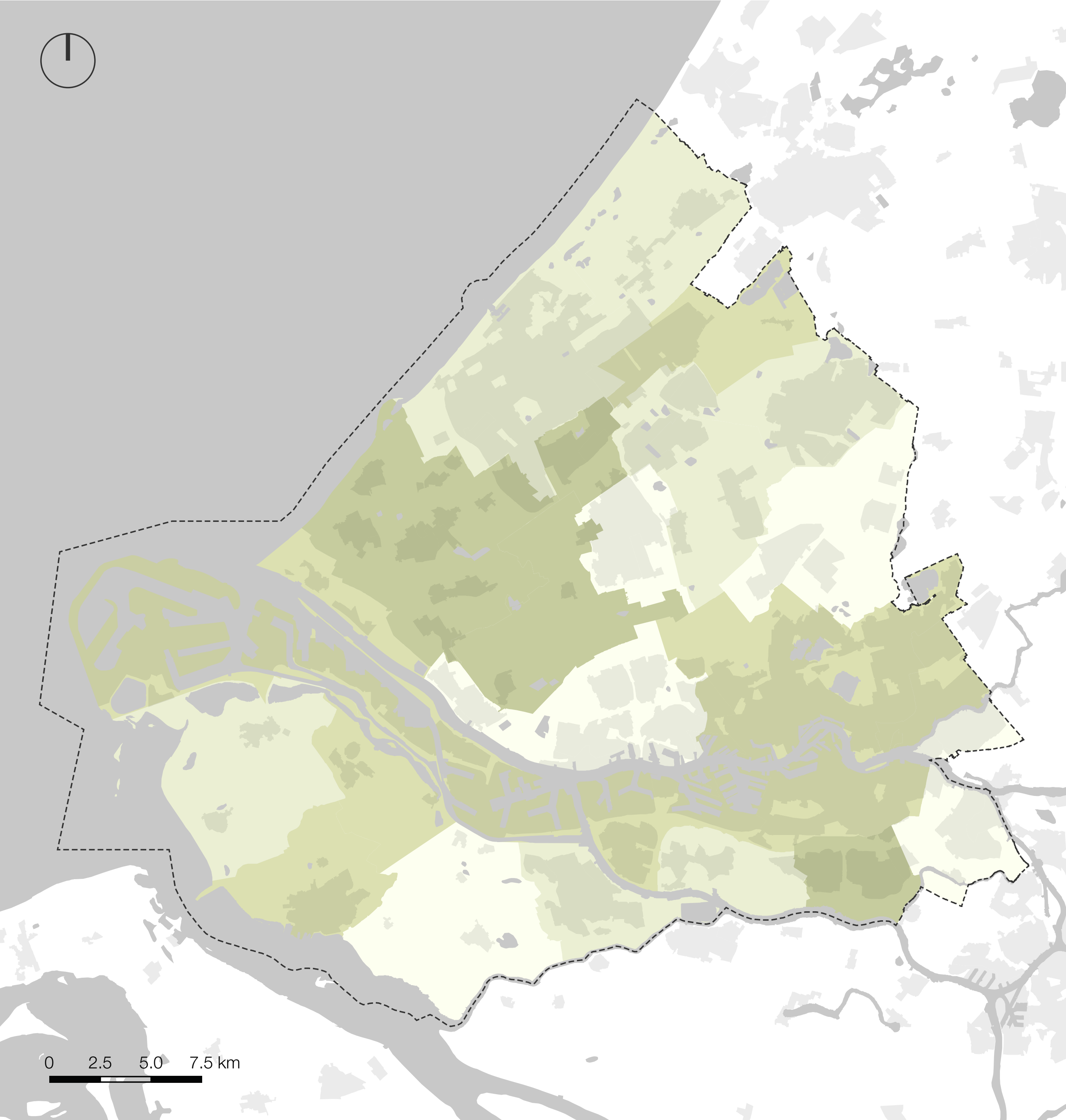
Given a certain amount of heat that should be generated by solar thermal collectors, the area of solar collectors can be calculated. In Netherlands, the average annual yield of 1m^2 solar collector is 400 kWh.

$S_{(solar\ thermal\ collectors)} = E_{(heat)} \times (2.778\times10^{8})/400/10000$

Unit:
$S_{(solar\ thermal\ collectors)}$: ha
$E_{(heat)}$: PJ

What if all the future heat demand in heat network is replaced by solar energy?			
	Year	Heat demand in network (PJ)	Area (ha)
Solar thermal collectors	2030	8.16	566.71
	2050	10.14	704.22

Table 8. Solar thermal collectors demand to reach heat demand



6.2.3 Biomass Energy

Biomass is waste material from plants or animals that cannot be used for food or feed. Considered as one of the important and widespread sources of renewable energy, it can be used for direct combustion which generates heat or electricity, or it can be treated in landfills and biodigesters which generate biogas.

Although the combustion of biomass will produce CO_2, the whole process is considered to be CO_2 neutral if we start from the beginning of a plant. The CO_2 released during combustion of biomass has been absorbed from the atmosphere by the plant before. Therefore, it can be seen as a closed, circular system.

The total biomass potential of the MRDH region is estimated 1.24 PJ.

12.7~19.3 GJ/Ha
7.0~12.7 GJ/Ha
2.2~7.9 GJ/Ha
0~2.2 GJ/Ha

Map 10. Total biomass potential
Data source: Biomassapotentieel - Warmteatlas

		Annual yield (t/ha)	CH_4 yield (m^3/ha)
Maize		9~30	3573~18540
Sweet sorghum		8~25	2360~9300
Elephant grass		8~25	1432~5450
Sunflower		6~8	929~3200
Canary grass		5~11	1700~4730
Alfalfa		7.5~16.5	2250~8250

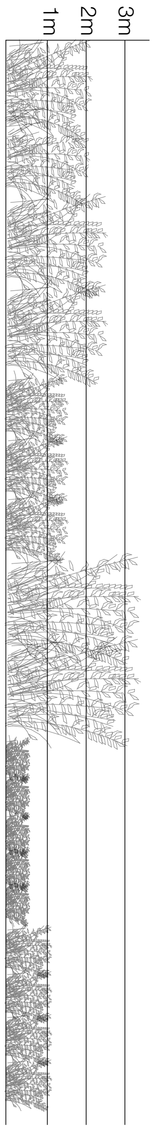


Table 8. Range of estimated crop and methane yields
Source: Biogas from Energy Crop Digestion

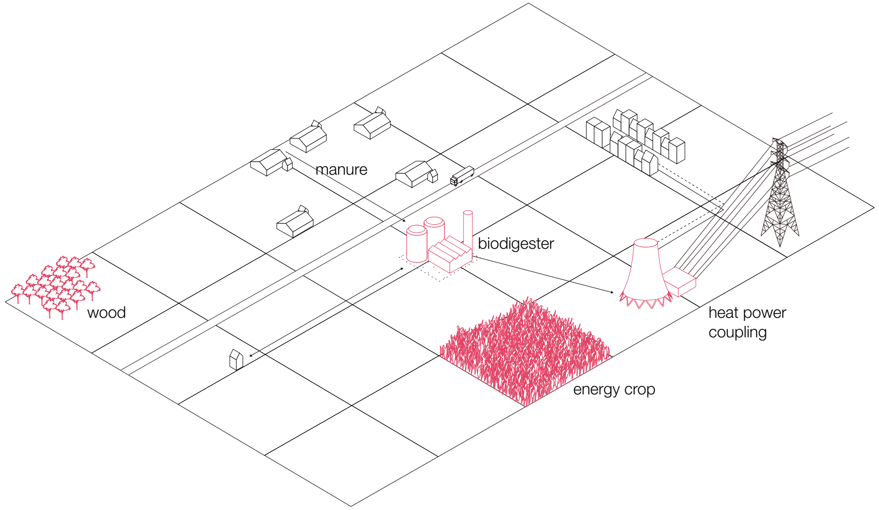


Diagram 13. Spatial integration biomass field and digester
Source: Energy landscape Flemish - POSAD

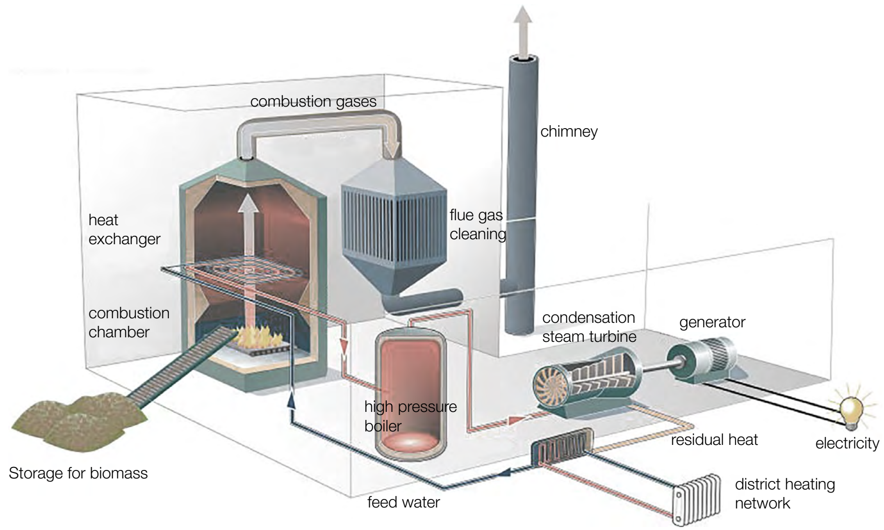


Diagram 14. Biomass power plant
Source: Public domain

How many biomass field should be cultivated in the region if all the future green gas demand is generated by energy crops?

Given a certain amount of green gas that should be generated by energy crops, the area of biomass cultivation can be calculated. As the annual CH_4 yield (m^3) per hectare differs according to different ways of cultivation, the minimum and maximum area of cultivated field are calculated respectively.

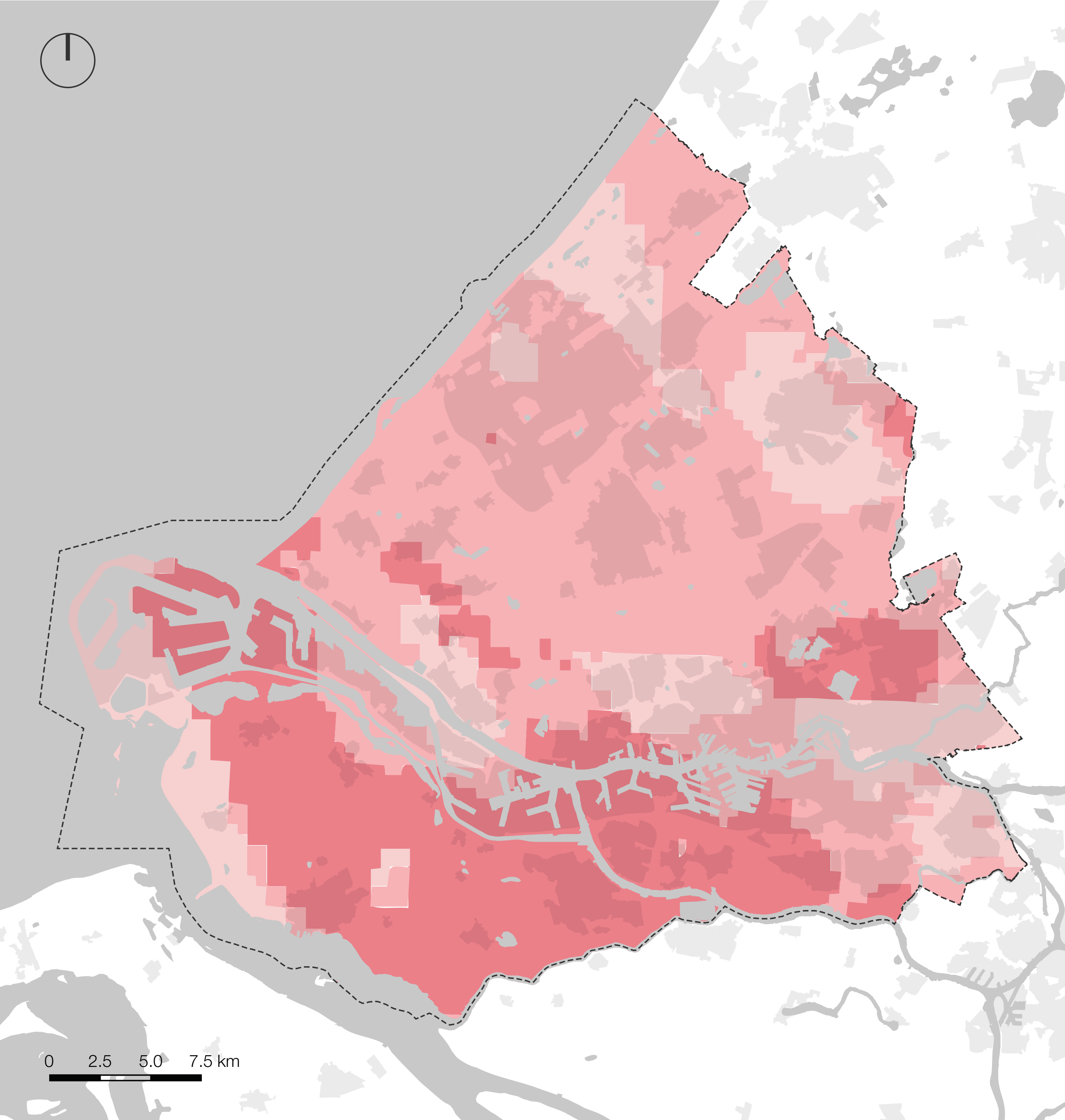
$S_{(biomass\ field)} = E_{(green\ gas)} \times 10^9 / q_{(CH4)} / P_{(CH4\ yield)}$

Unit:
$S_{(biomass\ field)}$: ha
$E_{(green\ gas)}$: PJ
$P_{(CH4\ yield)}$: m^3/ha
$q_{(CH4)}$ = calorific value of methane, 38 MJ/m^3

The table shows that maize, sweet sorghum and alfalfa have the highest efficiency of biogas production. However, even we choose maize to generate biogas at its maximum capacity, the land occupation will be 178 km^2, 18% of the total land area of the MRDH region. As one of the most densly populated region, the MRDH might need to rely on green gas imports if there is no alternative of green gas.

what if all the green gas demand is generated by energy crops?						
Energy crop	CH_4 yield (m^3/ha)		Year	Green gas demand (PJ)	Area (ha)	
	min	max			min	max
Maize	3573	18540	2030	12.58	17856.13	92653.97
			2050	27.04	38380.74	199154.48
Sweet sorghum	2360	9300	2030	12.58	35597.06	140276.54
			2050	27.04	76513.87	301516.50
Elephant grass	1432	5450	2030	12.58	60743.60	231182.01
			2050	27.04	130564.94	496912.67
Sunflower	929	3200	2030	12.58	103453.95	356353.75
			2050	27.04	222368.42	765962.27
Canary grass	1700	4730	2030	12.58	69989.99	194736.84
			2050	27.04	150439.52	418575.85
Alfalfa	2250	8250	2030	12.58	40127.59	147134.50
			2050	27.04	86251.99	316257.31

Table 9. Energy crop cultivation to reach green gas demand



6.2.4 Geothermal Energy

Considered as a potential sustainable source of heat for quite a long time, it was until 2017 that it was finally taken into production in the Netherlands (NLOG, 2018).

Until now, all geothermal energy recovered in the Netherlands has been from highly permeable and porous aquifers with temperatures ranging from 40°C to around 100°C (NLOG, 2018). There is about 3000 PJ heat in place below the Westland municipality. However, the limitation of geographical distribution of heat supply has brought the potential down to 26.8 PJ in 2020.

50% chance of > 5MW

30%~50% chance of > 5MW

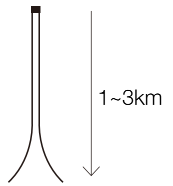
0~30% chance of > 5MW

Map 11. Geothermal potential
Data source: www.nationaleenergieatlas.nl

Geothermal energy can be used for generating both electricity and heat. However, the thermal efficiency of geothermal electricity stations is relatively low, around 7~10%, because geothermal fluids are at a low temperature compared with steam from boilers (Schavemaker and Sluis, 2008). In Netherlands, hydrothermal energy is the mainstream and has been mainly used in greenhouse area, providing heat for agricultural production.

As elaborate further, geothermal energy can be integrated into district/regional heating network. Together with the residual heat from harbor industrial complex, the demand pressure required from other energy sources can be much relieved.

Hydrothermal energy



Thermal energy of deep layers with hot water, steam or a combination of both under pressure.

Maturity: This technology has reached a reliable level of maturity.

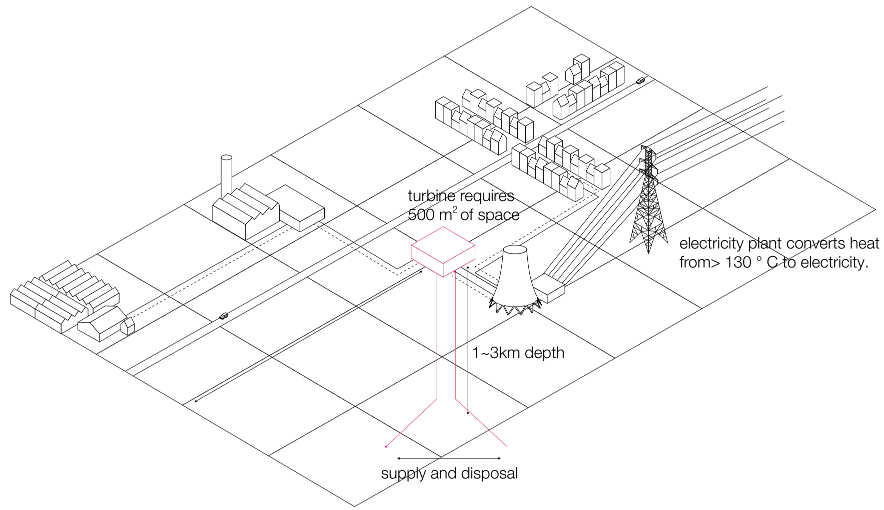
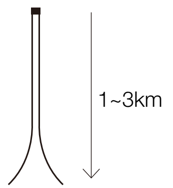


Diagram 15. Spatial integration geothermal energy
Source: Energy landscape Flemish - POSAD

Petrothermal energy



A vast store of thermal energy is contained within hot - but essentially dry - impervious crystalline basement rocks found almost everywhere deep beneath the earth’s surface.

Maturity: This technique is still in its infancy.

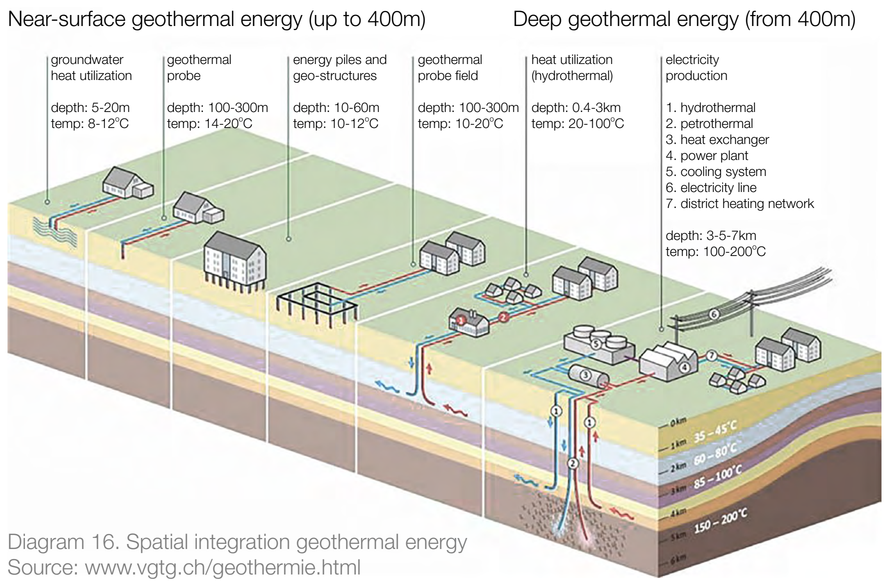
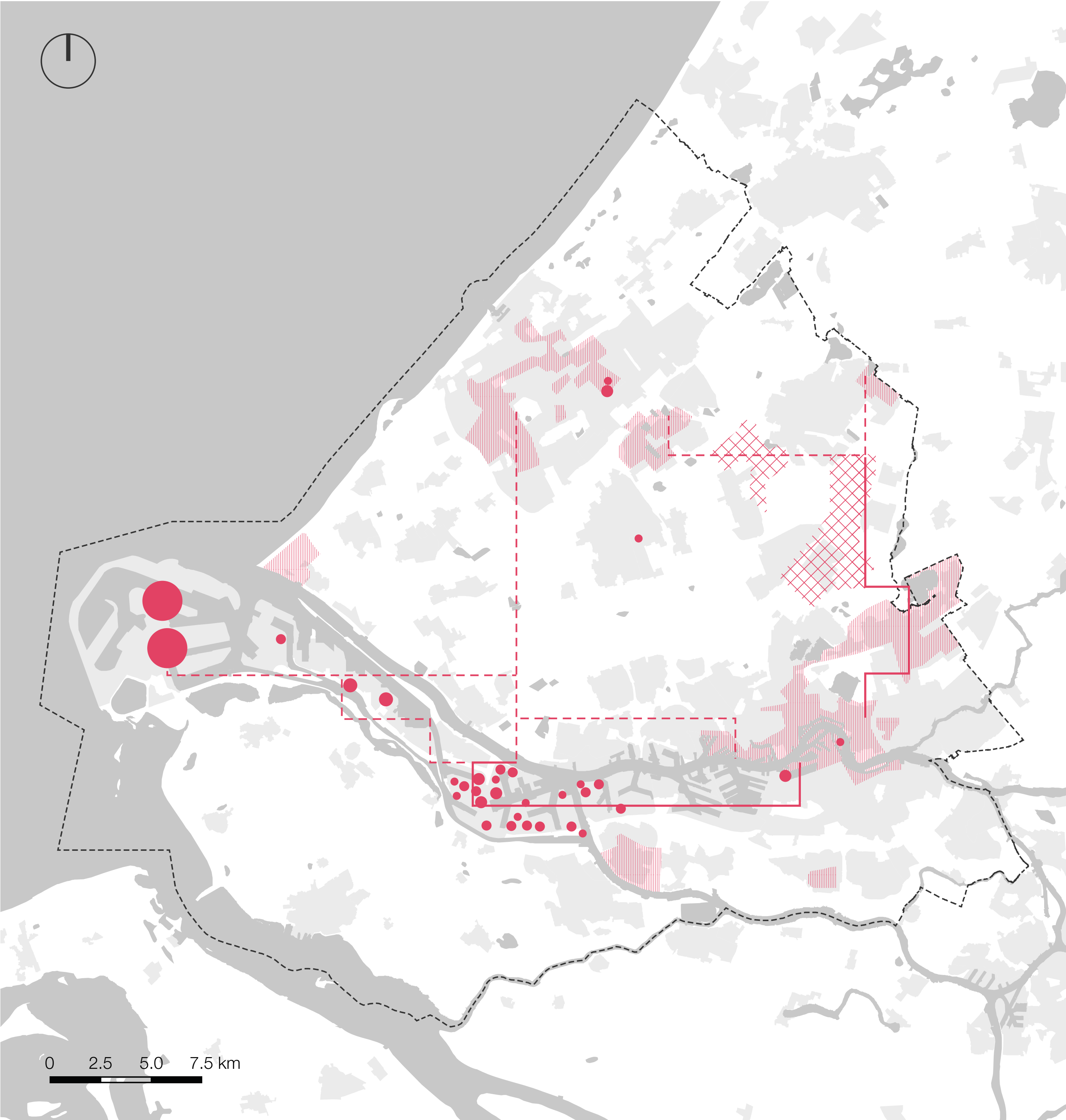


Diagram 16. Spatial integration geothermal energy
Source: www.vgtg.ch/geothermie.html

6.2.5 Available Residual Heat

Although residual heat is not a renewable energy source, it can be considered as one of the most important sustainable heat sources.

Calculations of CE Delft (2002) estimate an energy availability, in the form of hot water, of 17.5 PJ in the Maasvlakte, 8.3 PJ in the Botlek, 5.6 PJ in Pernis, and 5.2 PJ in the Europoort. This waste heat can be used sustainably by transporting this to the Westland horticultural area and the The Hague municipality; this is a distance similar to a waste heat pipeline being under construction in the Rotterdam area (De Nieuwe Warmteweg, 2013).



Map 12. Available residual heat potential
Data source: Ruimte & Energie - Zuid-Holland

6.2.6 Conclusion

In conclusion, maximum prediction (if all the energy demand is satisfied with single energy source) has been done to give an initial impression on how many renewable energy units should be implemented or how many areas of land will be occupied in order to meet the future energy demand by 2030 and 2050.

Also, different technologies can be the backup for each other. For example, if PV panels are the only measure to generate electricity and heat, regional energy system might break down during bad weahther days. Therefore, it's essential and necessary to have different renewable energy technologies as well as smart grid to enhance supply security.

Energy type	Year	Energy source	Number	Area (ha)
Electricity	2030	Wind turbine	2871	17943.89
		OR		
		PV panel	—	8383.39
	2050	Wind turbine	3751	23440.7
		OR		
		PV panel	—	10951.49
Heat	2030	Solar thermal collector	—	566.71
	2050		—	704.22
Biogas	2030	Maize	min	17856.13
	2050		min	38380.74
	OR			
	2030	Sweet sorghum	min	35597.06
	2050		min	76513.87
	OR			
	2030	Alfalfa	min	40127.59
	2050		min	86251.99

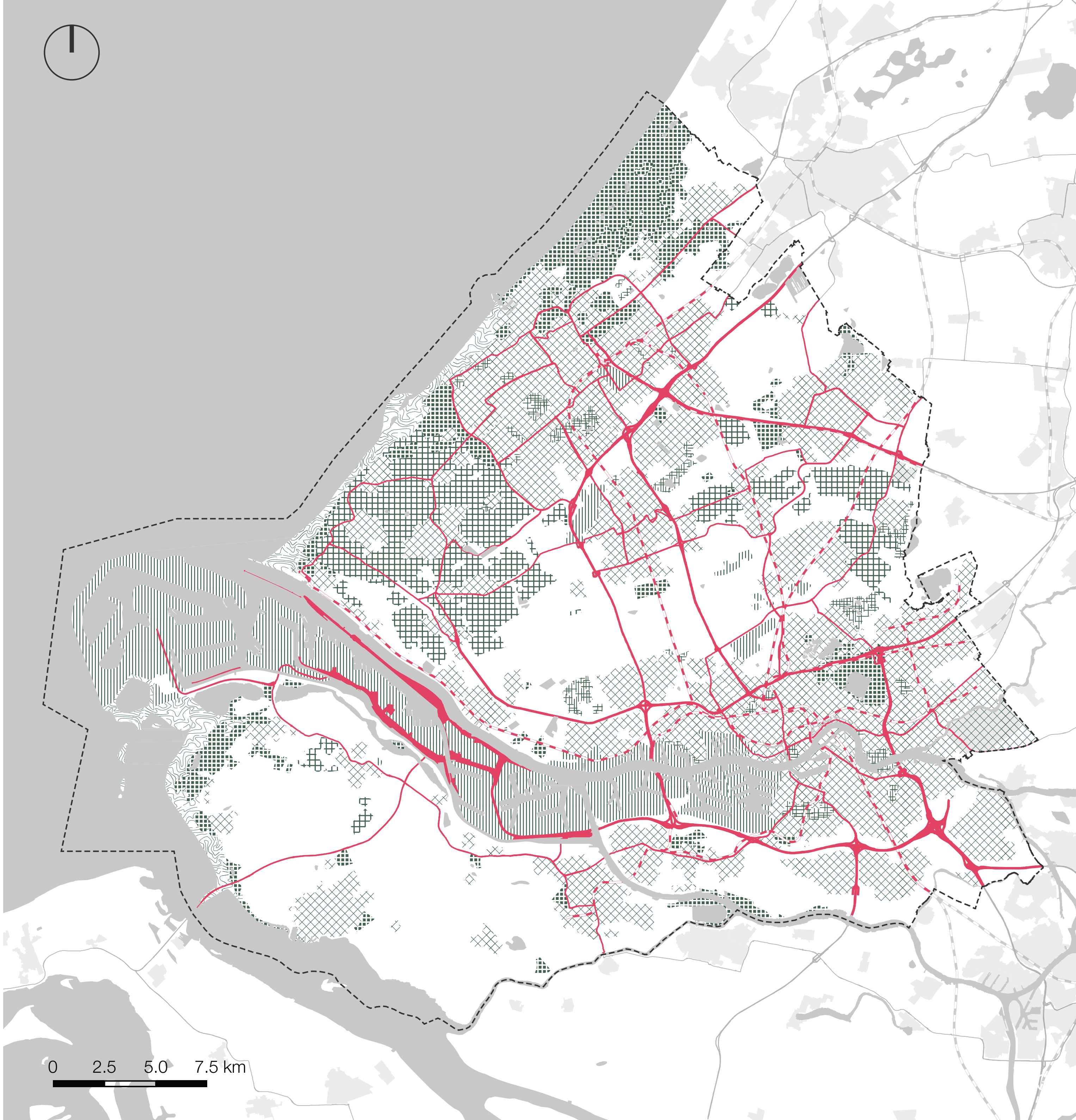
Table 10. Renewable erngy installations or cultivations to achieve energy neutral

6.3 Landscape Typology

The MRDH covers 990 km^2 of land and a diversity of landscapes can be identified within. As the relation between energy production and landscape has become close again in the third generation of renewable energy, the urban environment is approached as an organism in the field of Urban Metabolism. Thus, it's important to understand the existing landscape typologies within the MRDH.

This chapter illustrates the spatial characteristics of landscape typologies in the MRDH with general plan, 3D models and sections. Therefore, based on the spatial rules of renewable energy technologies discussed in chapter 6.1, a conclusion of spatial-technical fitness can be drawn.

Greenhouse landscape
Industrial landscape
Forest landscape
Peak Meadow landscape
Water
Urban green landscape
Dune barrier landscape
Urban construction landscape
Mobility landscape



Map 13. Urban landscape

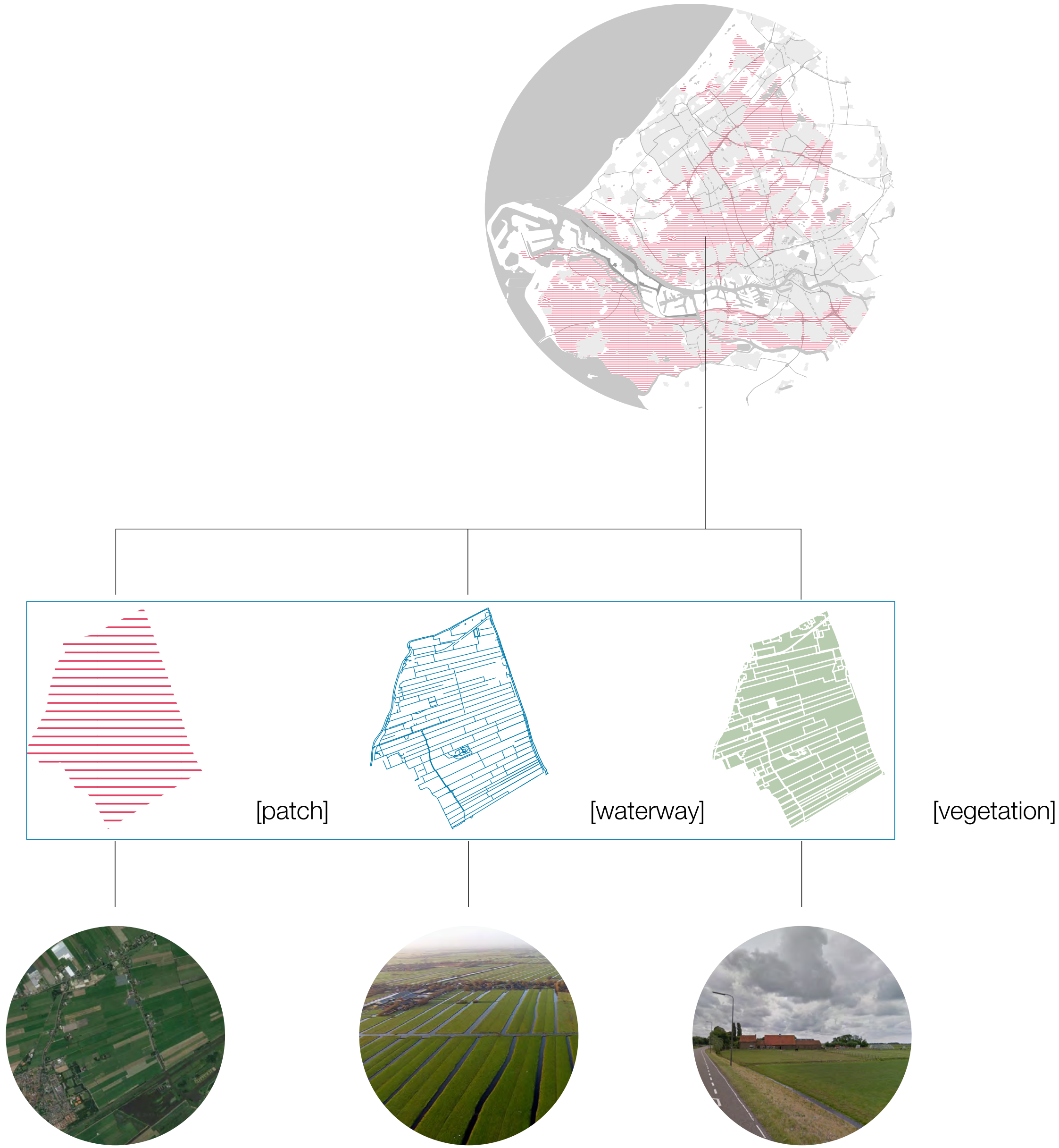
6.3.1 Polder Landscape

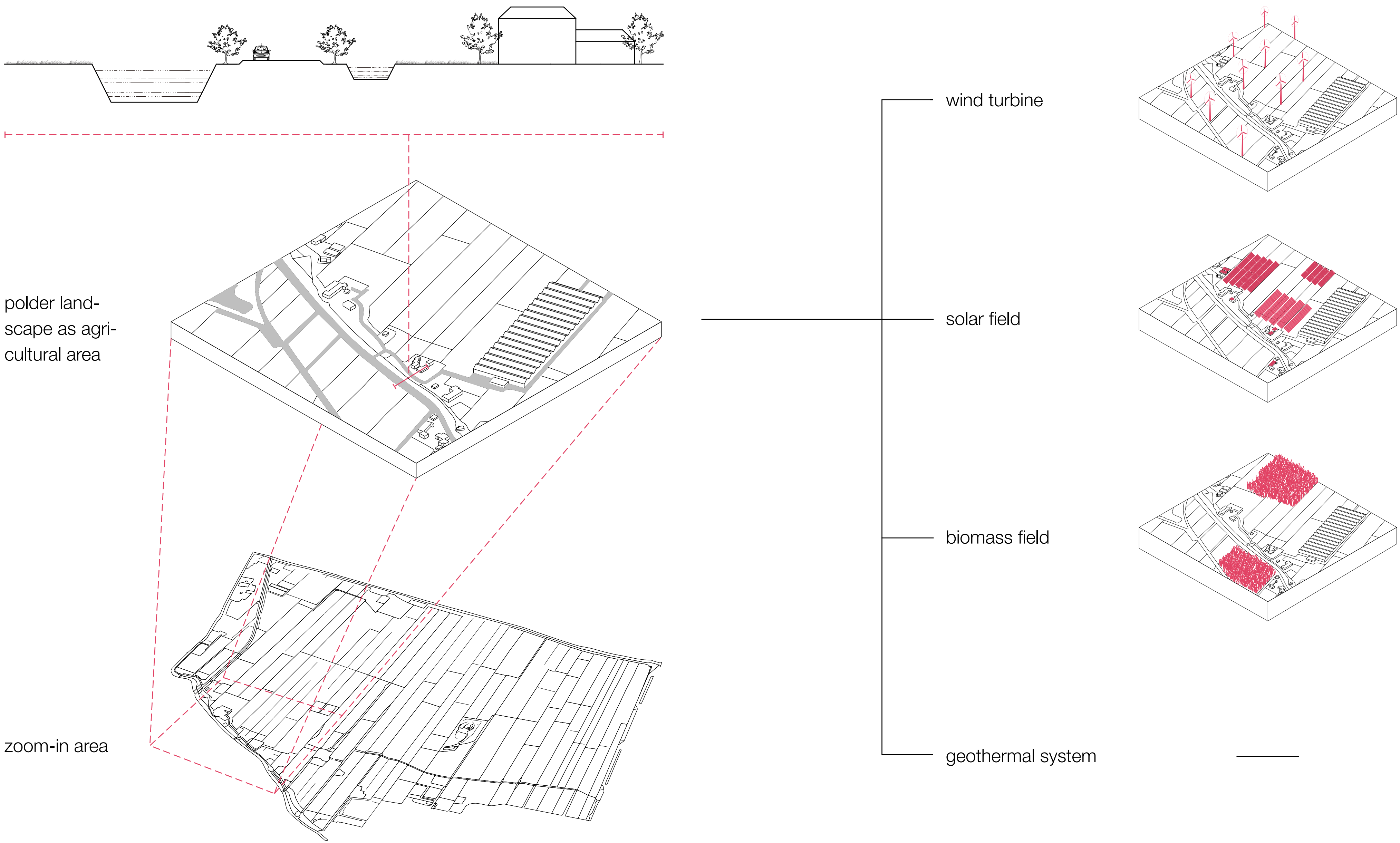
As an artificial hydrological realm enclosed by dikes, a polder is a lower land detached from outside water network and needs manually operated devices.

'There are three types of polder: (1) Land reclaimed from a body of water, such as a lake or the sea bed; (2) Flood plains separated from the sea or river by a dike; (3) Marshes separated from the surrounding water by a dike and subsequently drained.'

-- Wikipedia

Most of the polder landscape in the MRDH is agricultural area or has recreational function.



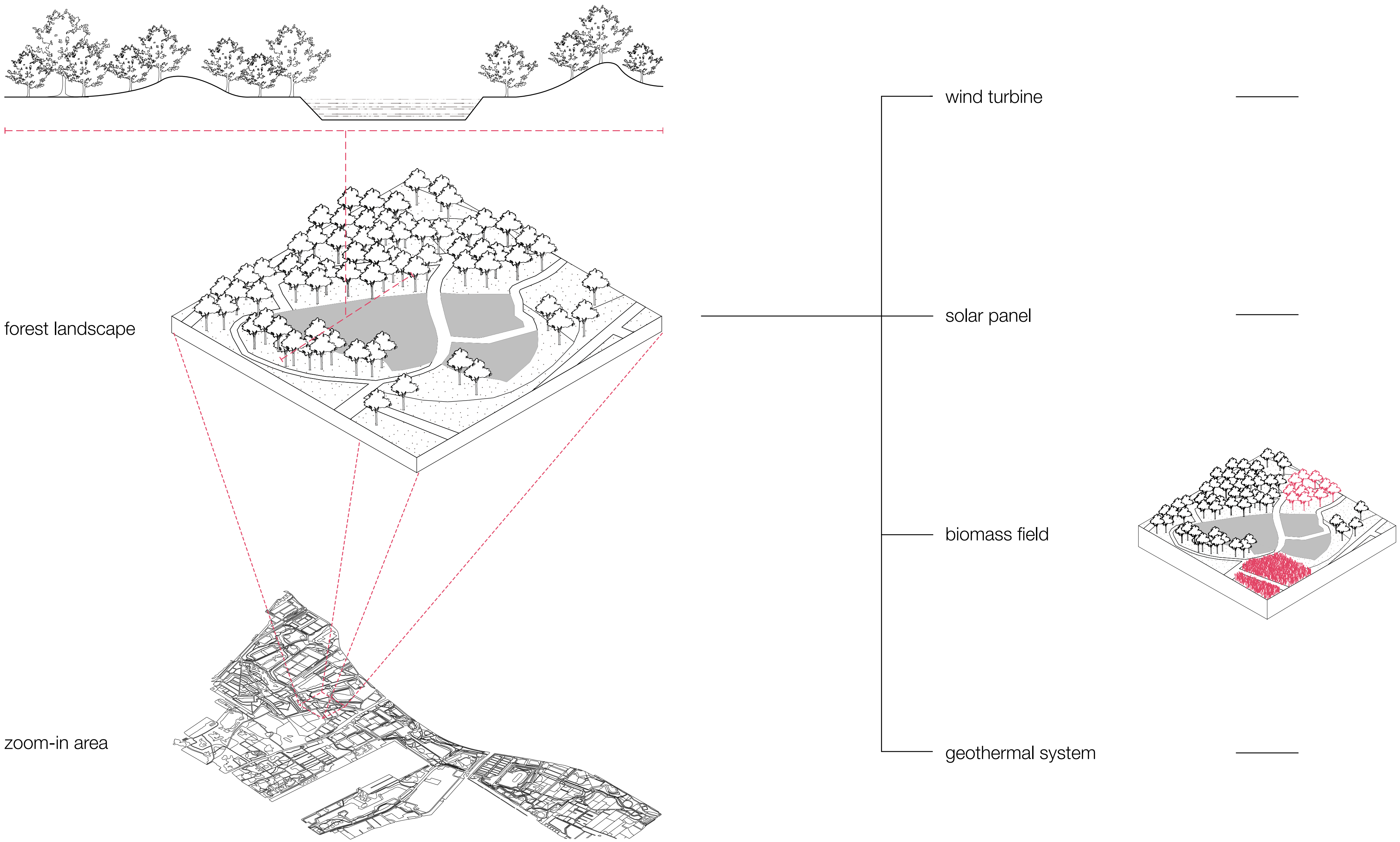


polder land-
scape as agri-
cultural area
zoom-in area
wind turbine
solar field
biomass field
geothermal system

6.3.2 Forest Landscape

A forest is a wide area covered by trees which interacts with human society in both positive and negative ways: forests provide ecosystem services, but human activities, including harvesting forest resources, can negatively affect them.

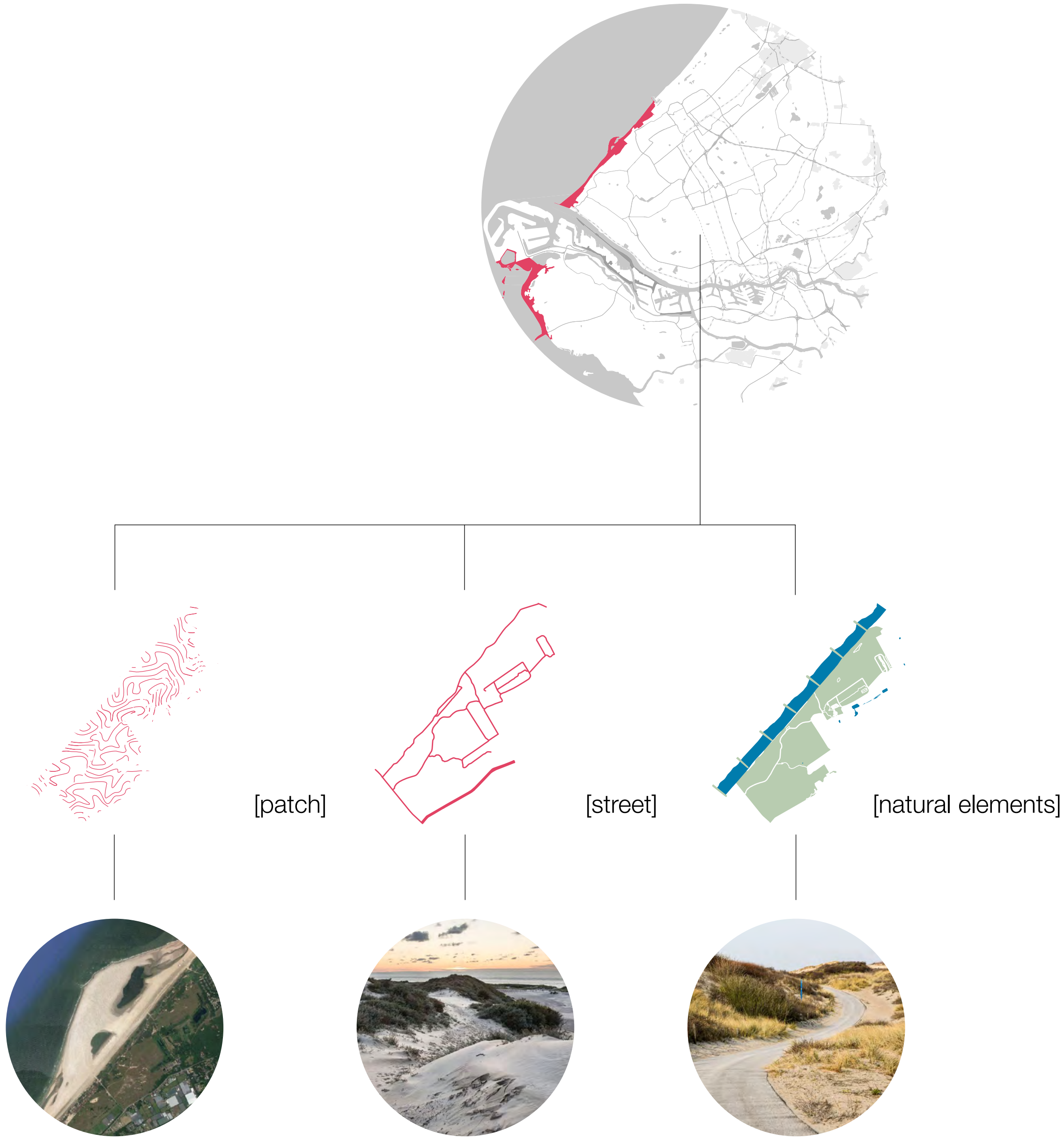
The forest landscape is located in the far northwest of the MRDH and along the sea coast. As a result from the latest ice age, it has quite some topography that is covered with trees and heath. There is very limited agricultural activity and a lot of opportunities for recreation.

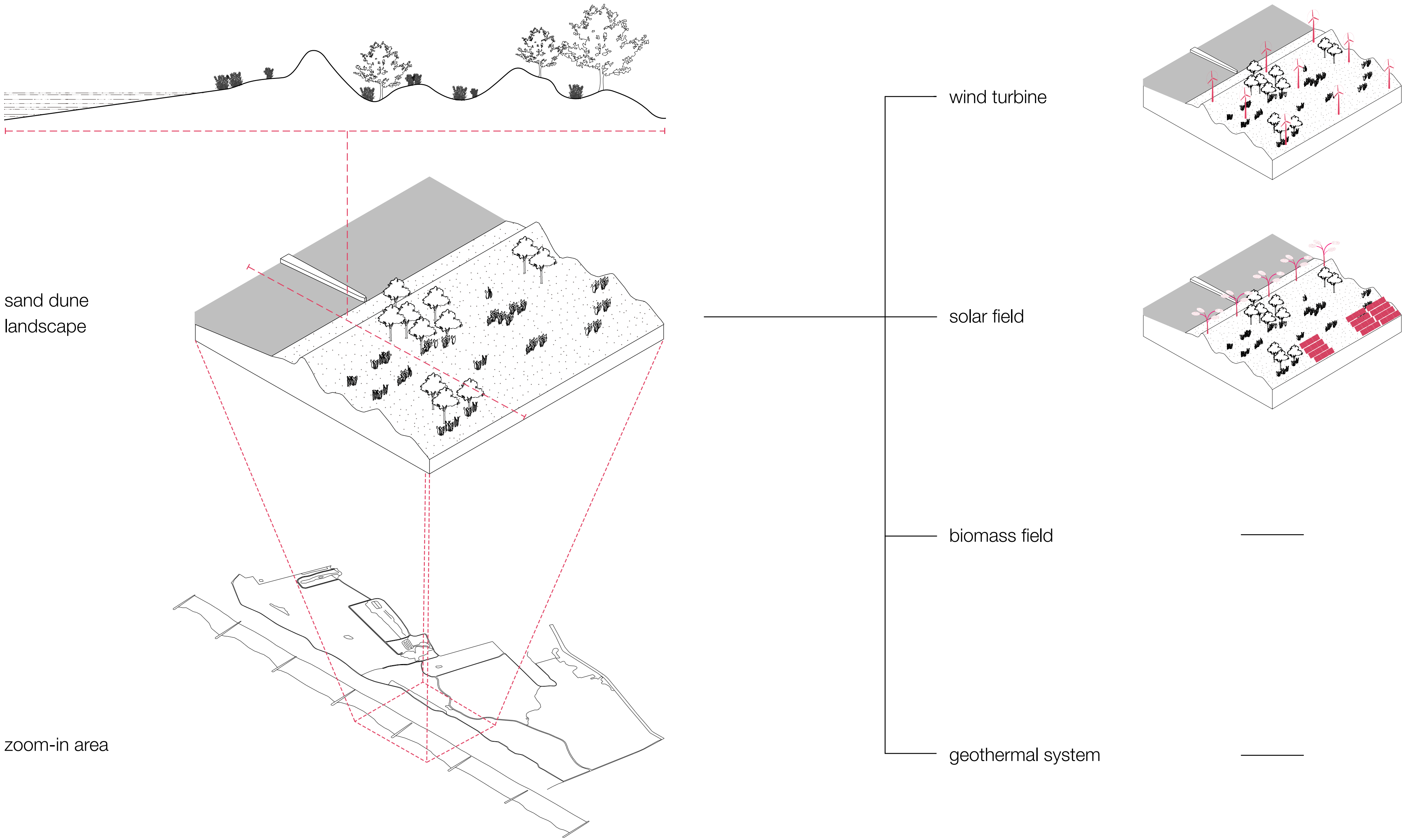

forest landscape
zoom-in area
wind turbine
solar panel
biomass field
geothermal system

6.3.3 Barrier Dune Landscape

The barrier dune landscape along the coast of South Holland is formed by sedimentation and erosion which causes a small level of topography (Sloss et al., 2012). Small puddles with salt water inside can be found in between.

There is high grass and forests in further inlands. The function of landscape is mostly nature preservation and recreational sites. Small housing areas are either concentrated in villages or scattered.



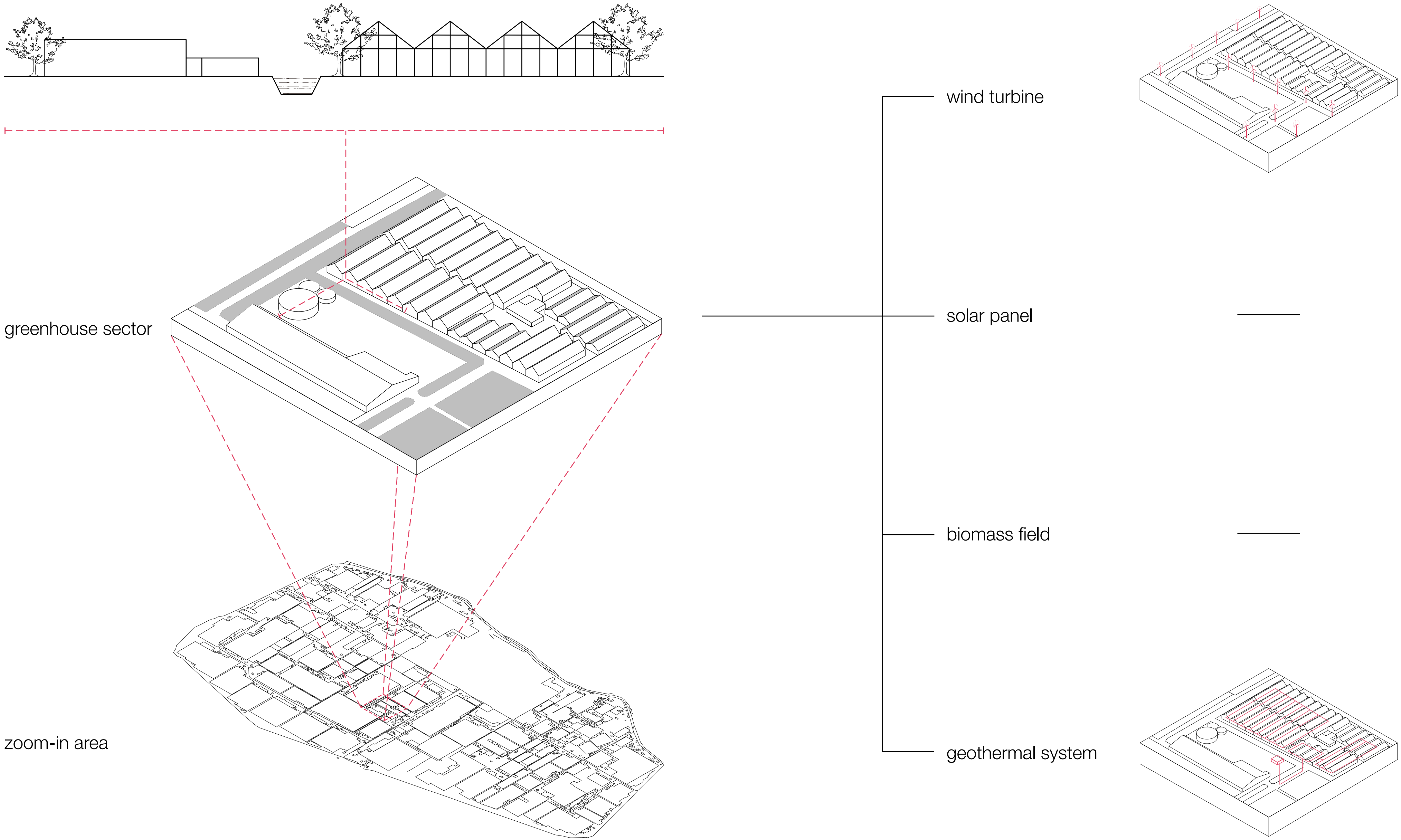


sand dune
landscape
zoom-in area
wind turbine
solar field
biomass field
geothermal system

6.3.4 Greenhouse Landscape

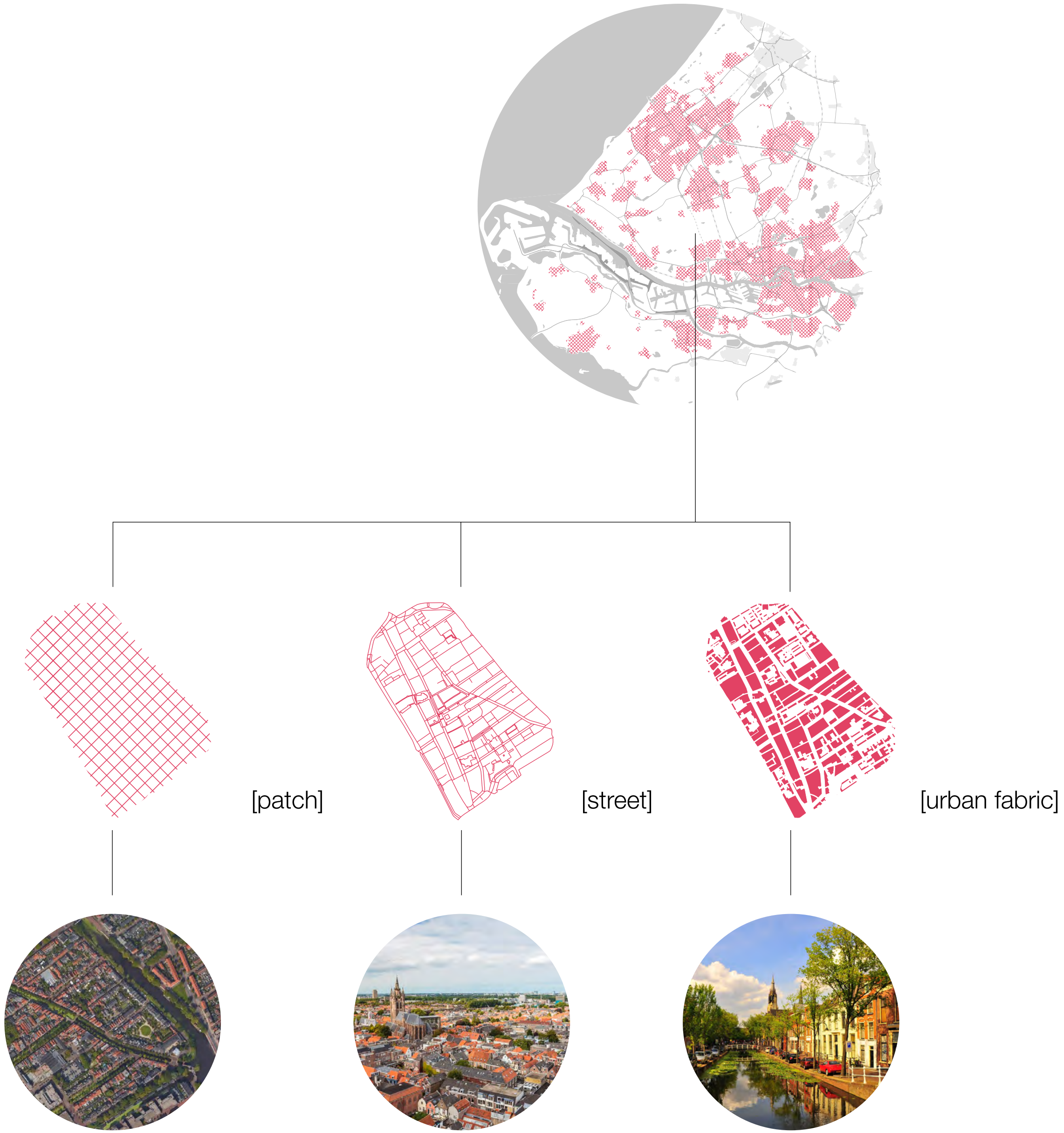
Dutch horticultural sector has the highest horticultural production rate and presents a leading food and flower export in the world.

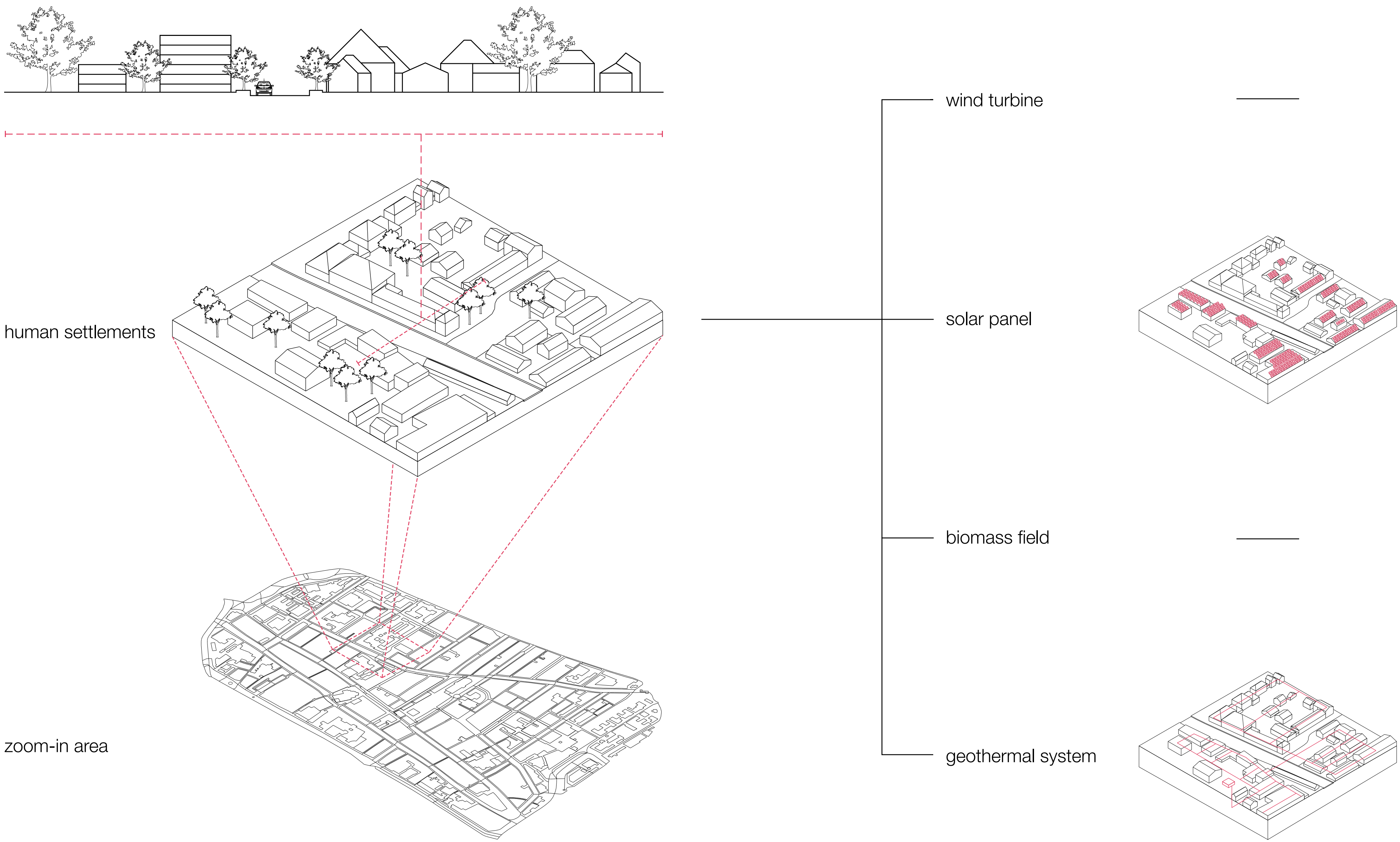
The MRDH accommodates the majority of the extensive and energy intensive Dutch greenhouse sector, as known as 'The Greenport', located in the southwest of the region. This type of landscape is also concentrated around Pijnacker and Bleiswijk, with small capacity scattered in Vierpolders and Tinte.


greenhouse sector
zoom-in area
wind turbine
solar panel
biomass field
geothermal system

6.3.5 Urban Construction Landscape

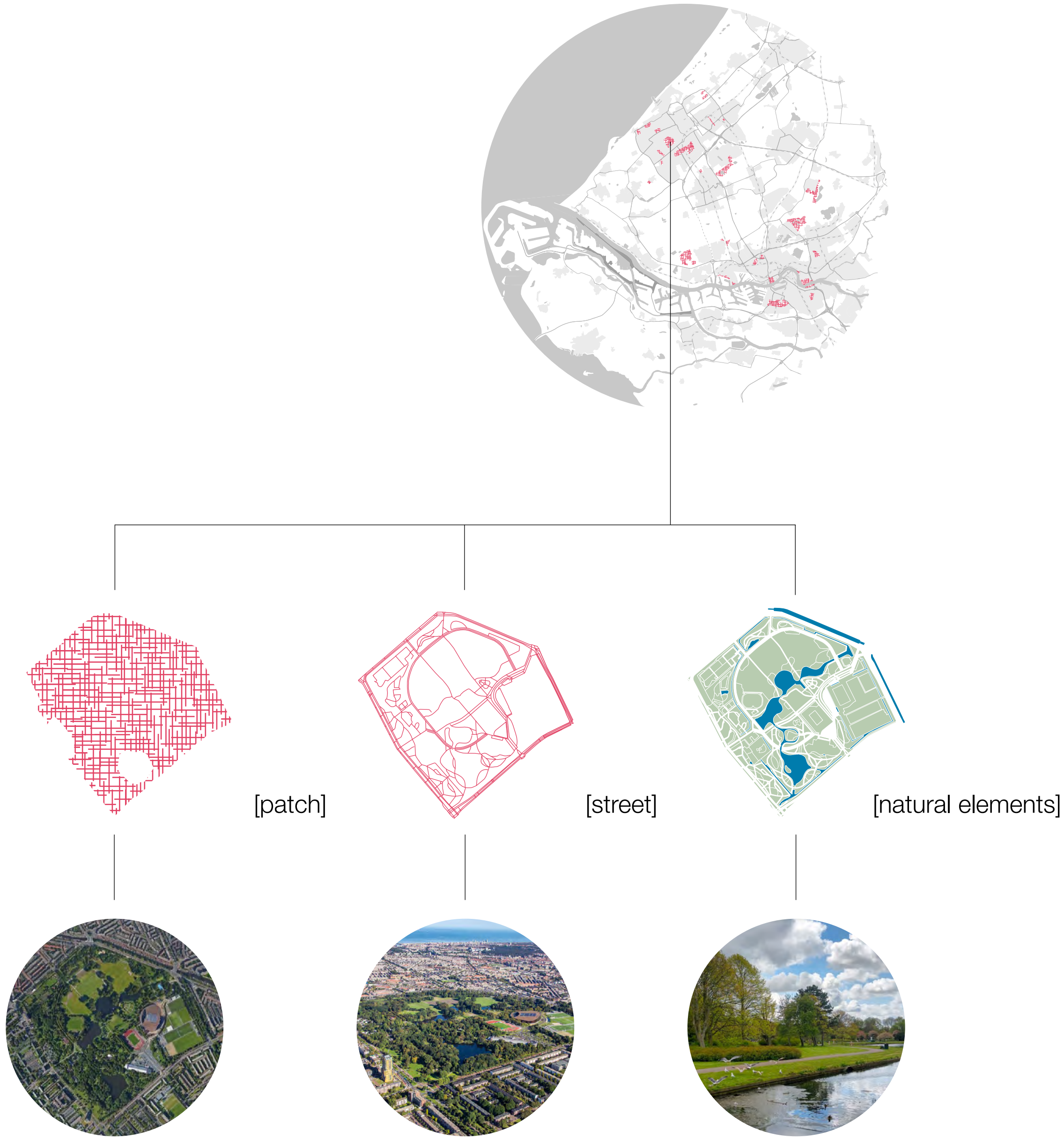
The urban construction landscape is spread across the MRDH. In general this is concentrated, as in just a few landscapes urbanization in the from of ribbons or scattered patterns appears. The region has two major urban areas - The Hague and Rotterdam at 20km distance from each other, surrounded by smaller towns and villages, counting for 3.6 million citizens on 3400 km^2 surface area. It is the most densely populated area in the Netherlands.

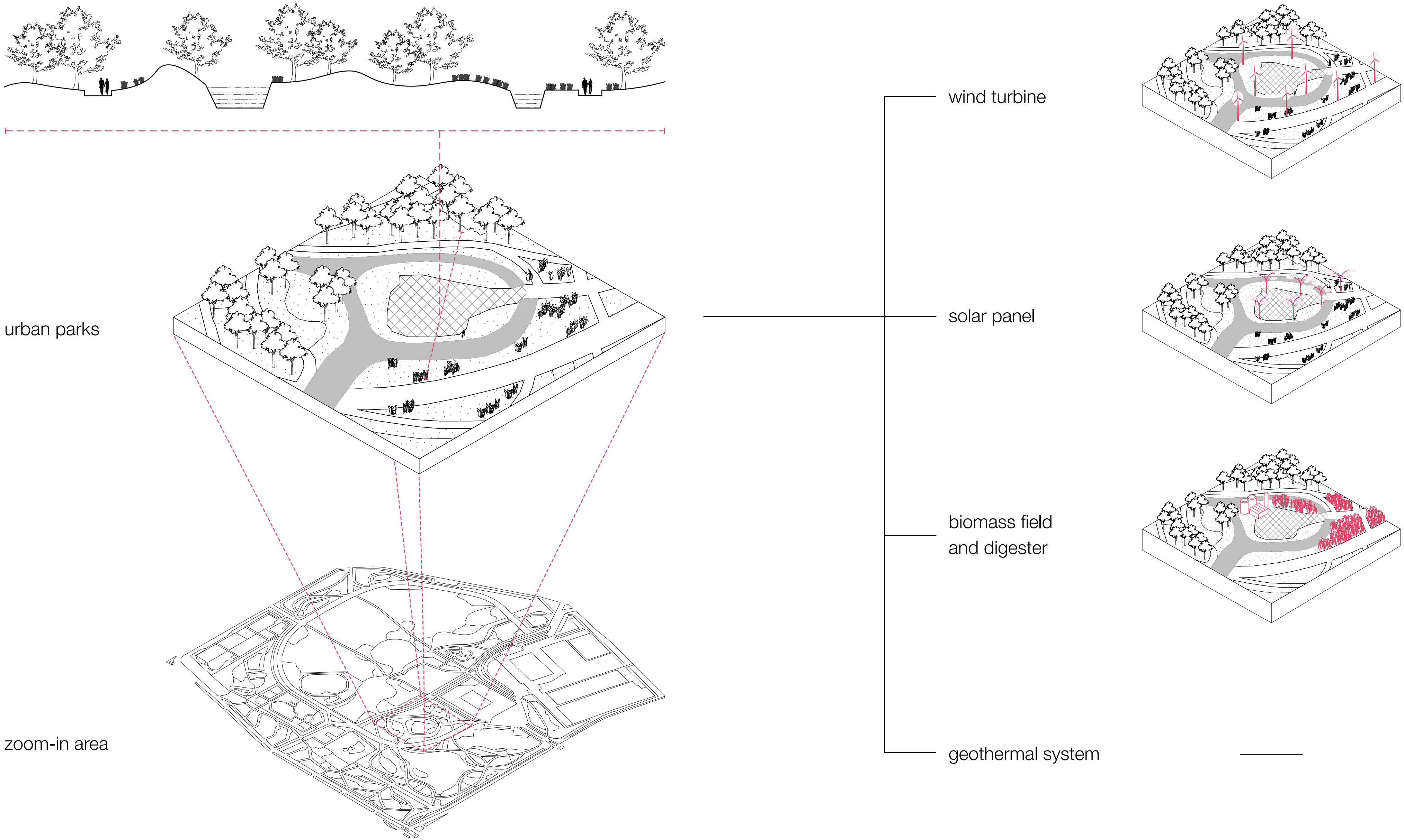



human settlements
zoom-in area
wind turbine
solar panel
biomass field
geothermal system

6.3.6 Urban Green Landscape

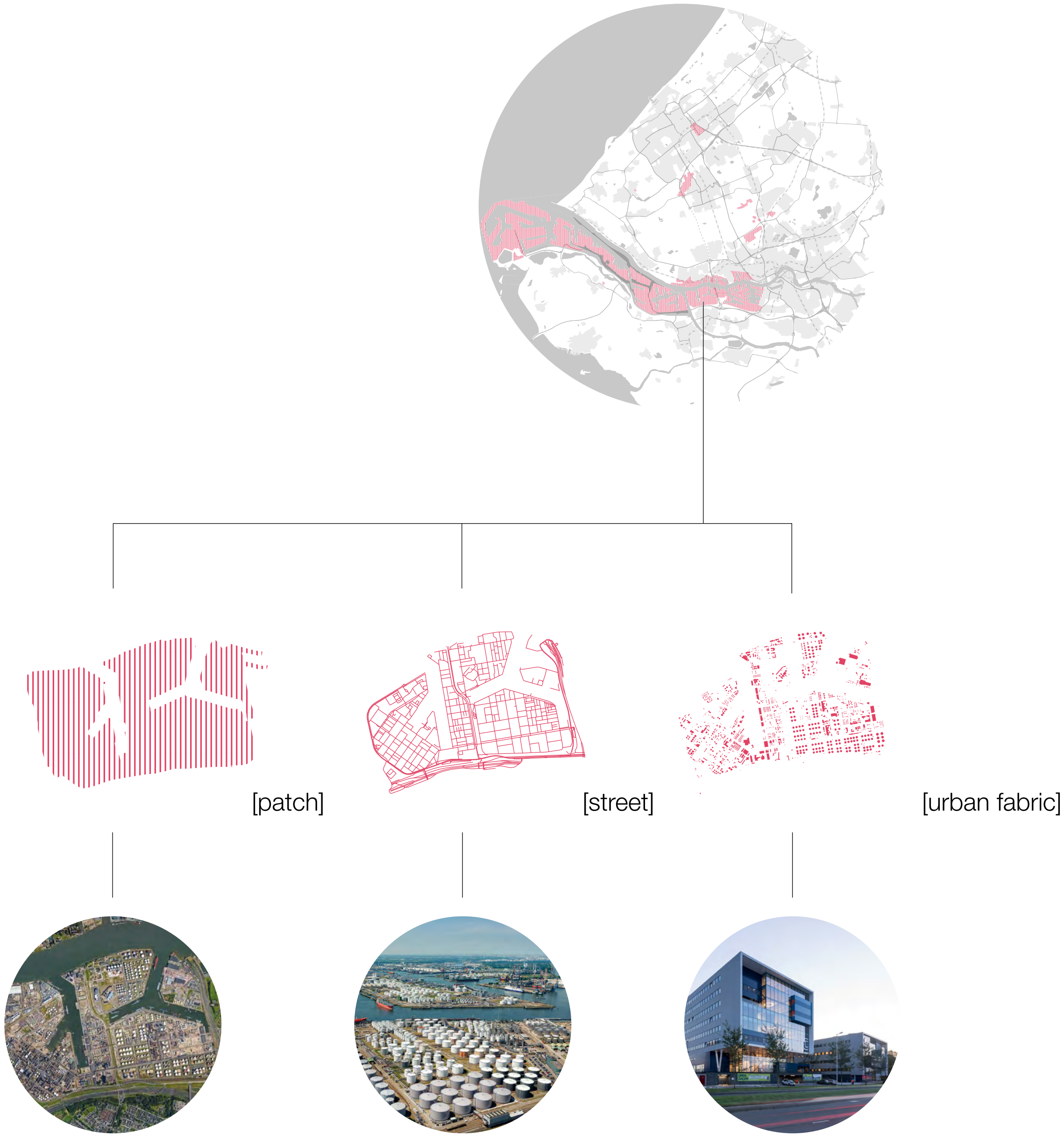
The urban green landscape has spatial characteristics of both forest and polder landscape, as it usually consists of clusters of trees and meadows. Attached with recreational or cultural functionality, it also provides ideal spatial condition for displaying innovative renewable energy projects, performing as educational sites.

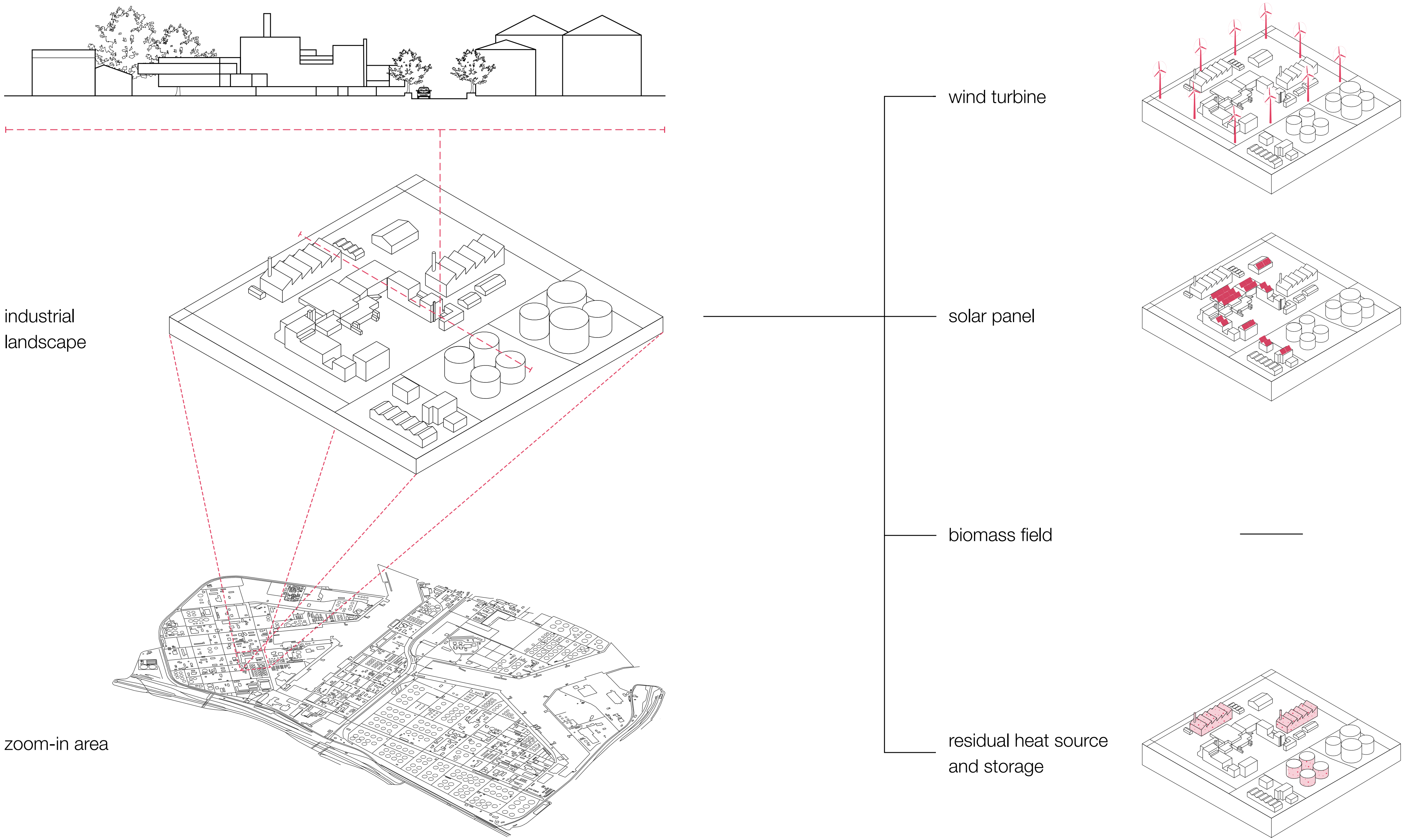



urban parks
zoom-in area
wind turbine
solar panel
biomass field
and digester
geothermal system

6.3.7 Industrial Landscape

The Rotterdam harbor is the largest port in Europe, with the most extensive petrochemical based industrial complex in the world. It is an industrialized and highly urbanized landscape which intersects the Province of South Holland between Spijkenisse and Rotterdam with especially large business areas that developed alongside the industries. At the same time it is also a highly populated residential area which makes it a dynamic environment.



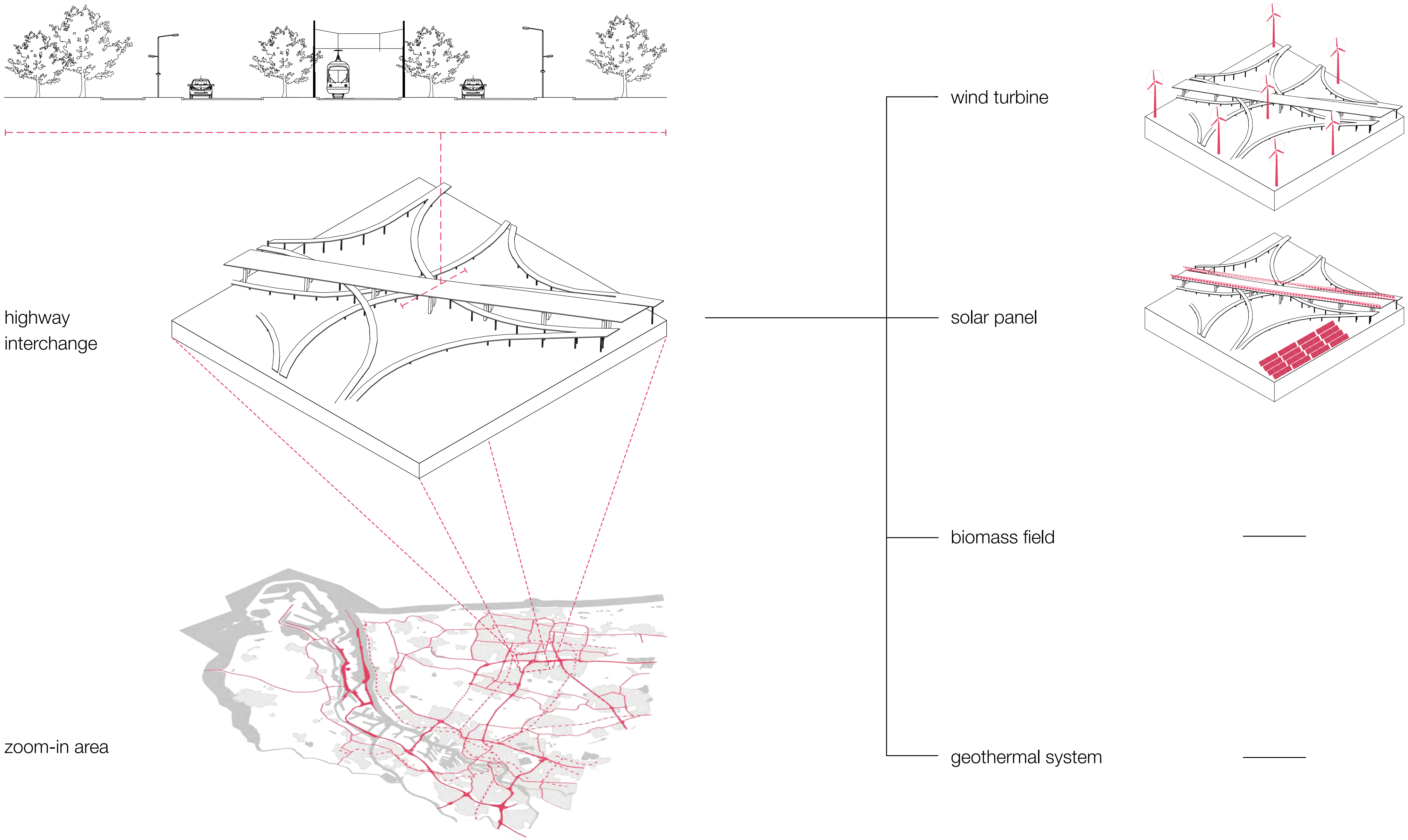


industrial landscape
zoom-in area
wind turbine
solar panel
biomass field
residual heat source and storage

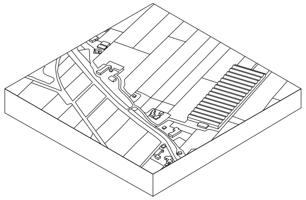
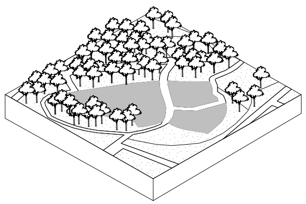
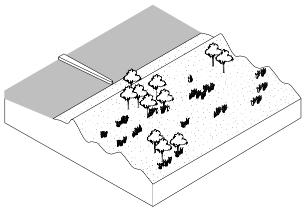
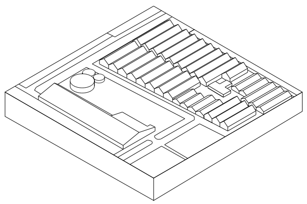
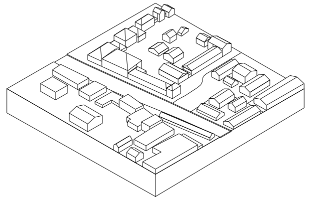
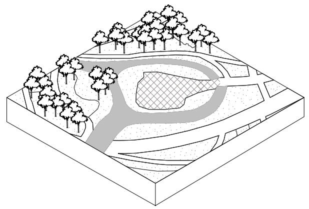
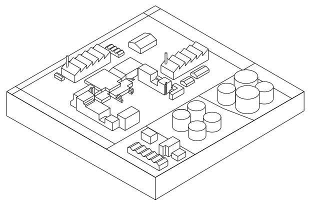
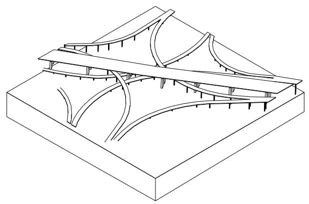
6.3.8 Mobility Landscape

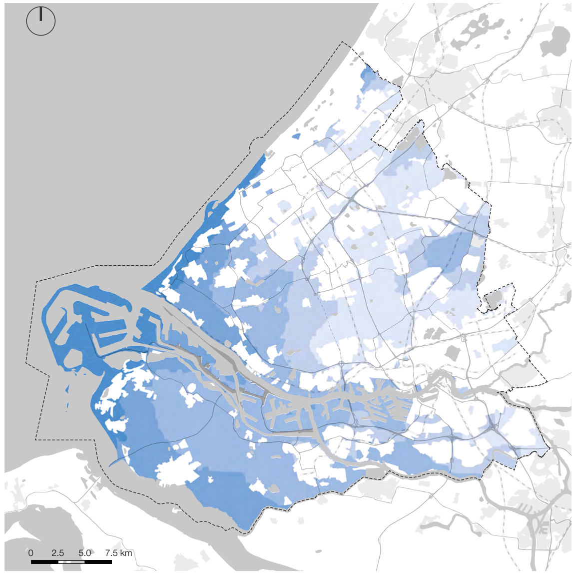
As a landscape of infrastructures, the mobility landscape spreads itself across the region. It mainly consists of three different linear system across or paralleled with each other: the railway infrastructure, highways and motorways.

Therefore, many elements such as dikes, tunnels and bridges, sound barriers, lighting system and vegetation are included. The airports will be included in this landscape in the future as well, because it's also a form of transportation.


highway
interchange
zoom-in area
wind turbine
solar panel
biomass field
geothermal system

6.3.9 Conclusion - Spatial Fitness of RET

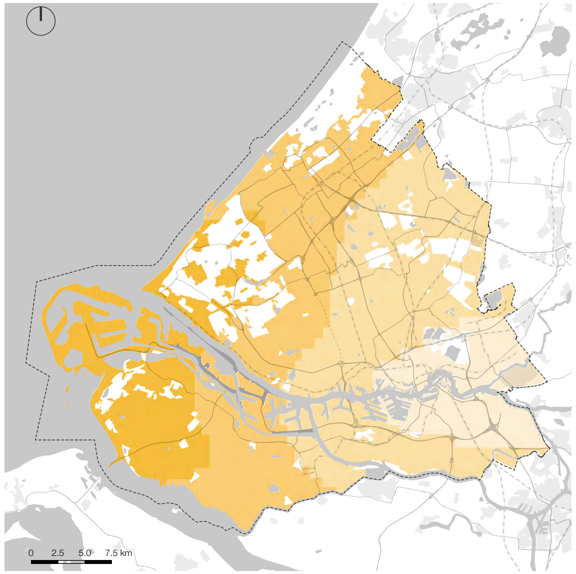
Landscape		wind	solar	biomass field	geothermal
Polder landscape		○	○	○	—
Forest landscape		—	—	○	—
Barrier dune landscape		○	○	—	—
Greenhouse landscape		○	—	—	○
Urban construction landscape		—	○	—	○
Urban green landscape		○	○	○	—
Industrial landscape		○	○	—	○
Mobility landscape		○	○	—	—



Spatial fitness of wind turbine

1. polder landscape
2. barrier dune landscape
3. greenhouse landscape
4. urban green landscape
5. industrial landscape
6. mobility landscape

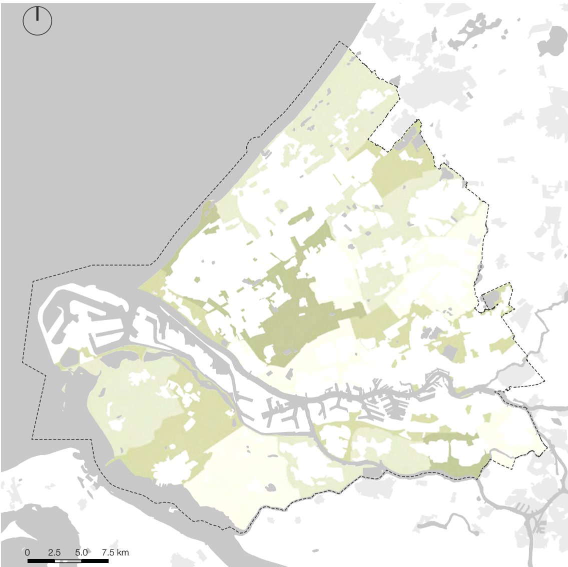
Map 14. Spatial fitness of wind turbine



Spatial fitness of PV panel

1. polder landscape
2. barrier dune landscape
3. urban construction landscape
4. urban green landscape
5. industrial landscape
6. mobility landscape

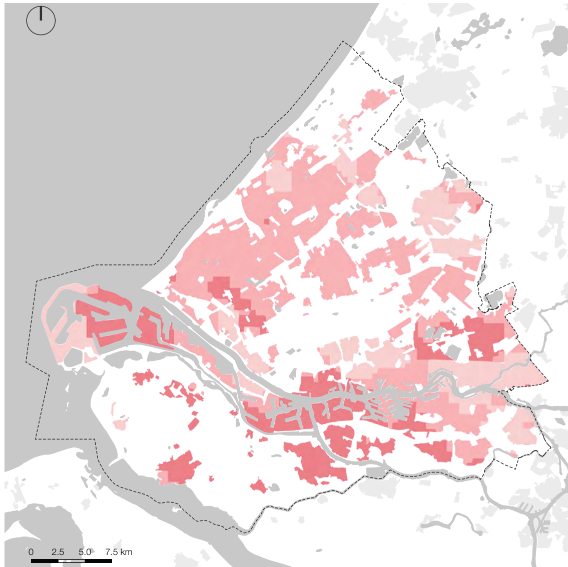
Map 15. Spatial fitness of PV panel



Spatial fitness of biomass field

1. polder landscape
2. forest landscape
3. urban green landscape

Map 16. Spatial fitness of biomass field



Spatial fitness of geothermal technique

1. greenhouse landscape
2. urban construction landscape
3. industrial landscape

Map 17. Spatial fitness of geothermal technique

6.4 Landscape Quality Influenced by RET

Landscape quality influenced by renewable energy technologies. (Table 11.)
(green-positive impact; red-negative impact)

	Economic Quality	Ecological Quality	Cultural/aesthetic Quality
Use value	Land productivity (biomass cultivation, PV field) Multi functionality (combine with existing infrastructure) Reuse of vacant space (brownfield, abandoned space)	Ecological corridor (limited construction)	
Perception value	Fine-tuning function (energy parks)	Transparent air (biodigester) Acoustic wellness (wind turbine, PV panel along traffic lines)	Aesthetic quality (depending on location and style)
Future value	Adaptation and stablity	Biodiversity (wind turbine, PV field)	

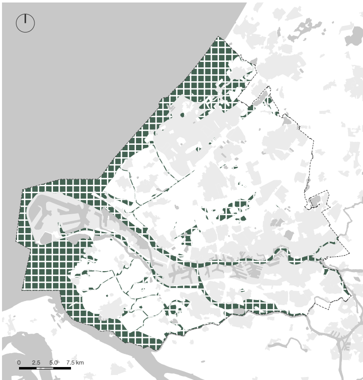
ECONOMIC QUALITY

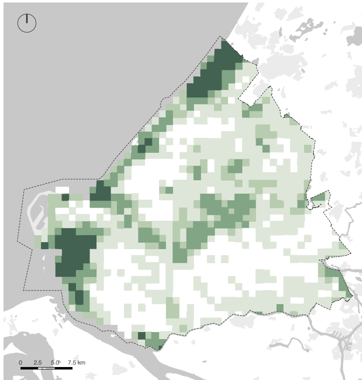

Agriculture

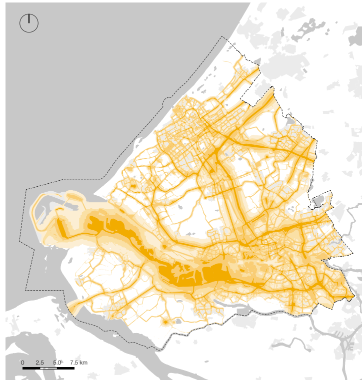

Greenhouse


Recreation

ECOLOGICAL QUALITY

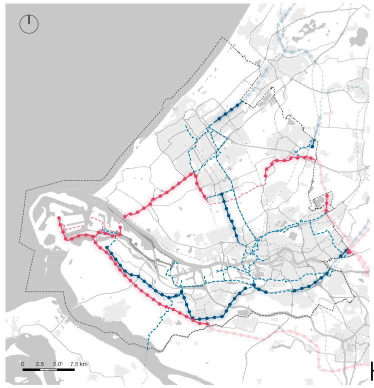

Ecological corridor

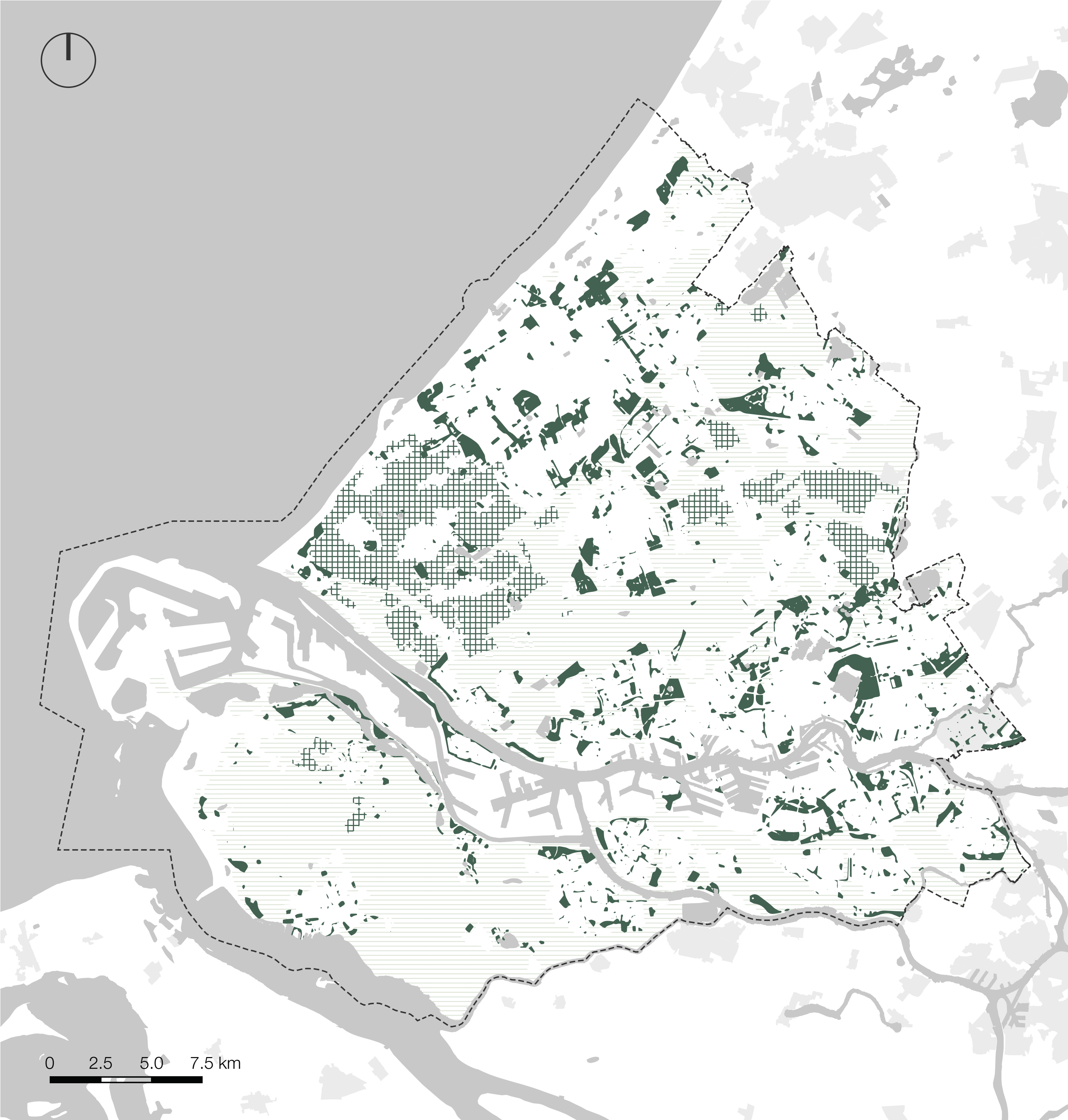

Species density


Noise map

AESTHETIC QUALITY

Naturalness, Stewardship, Disturbance, Historicity, Visual Scale, Imageability, Ephemera, Coherence and Complexity.


High voltage



6.4.1 Economic Quality

ECONOMIC QUALITY

According to the theory paper in Chapter 5.2, economic quality mainly refers to the goods and services provided by landscape which can bring economic values (Heide & Heijman).

Productivity of agriculture landscape is considered as one of the main economic qualities because it solidifies the base of food market. Ideally, the multi-functionality should consist of configurations that can sustain the fine-tuning outputs that society appreciates and highly values. Function adaptability is also attached to economic quality for it shows the stability to possible future changes.

Therefore, in the MRDH region, agricultural landscape, greenhouse landscape and recreational landscape are considered to have economic value.

Agriculture land
Greenhouse land
Recreational land

Map 18. Land use map
Data source: www.cbsinuwbuurt.nl

PRESENT CONDITION OF ECONOMIC LANDSCAPE

Image 26. Farmland

Image 27. Greenhouse

Image 28. Golf club

Source: all from public domain

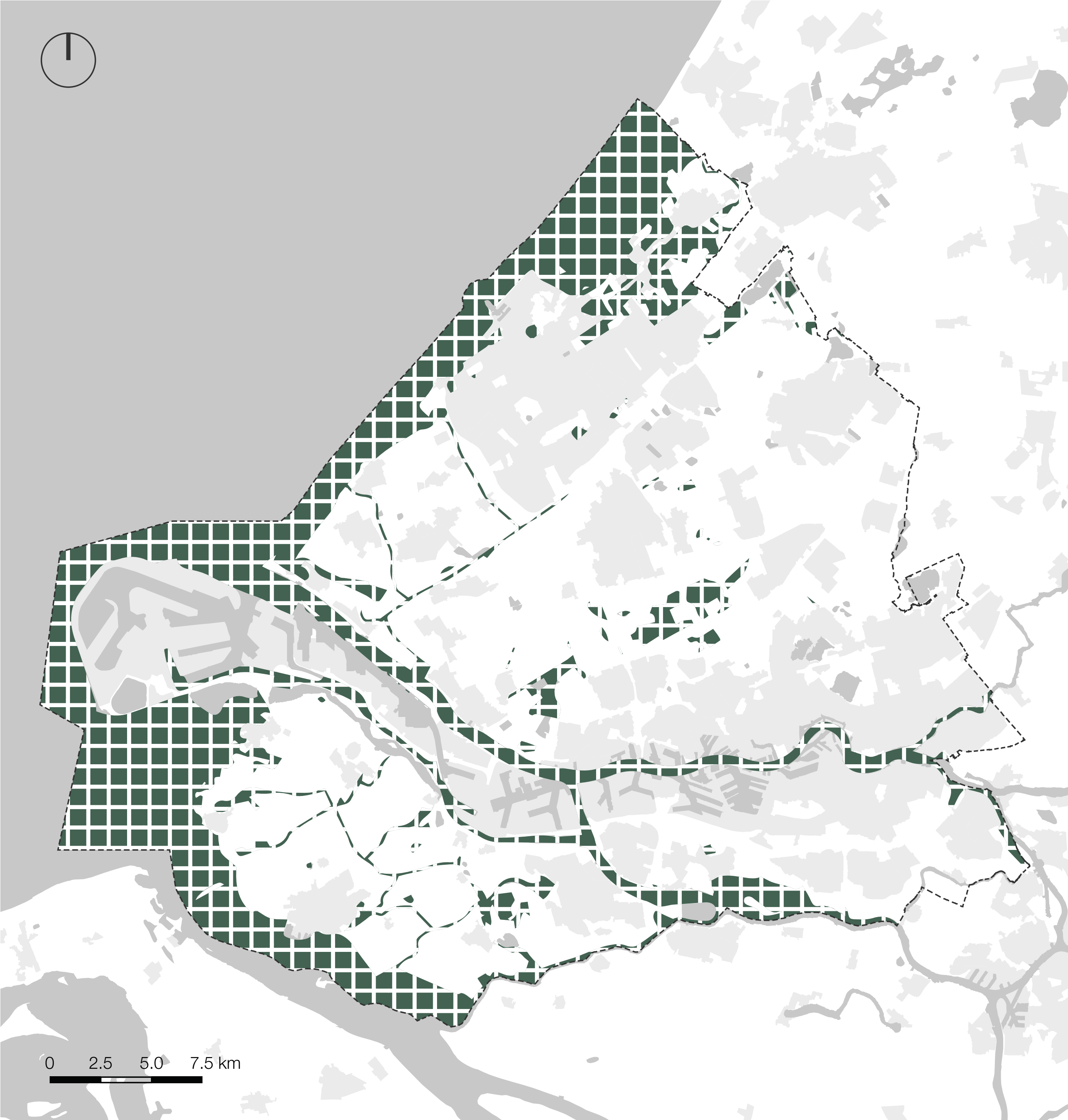
HOW TO ADD ECONOMIC VALUE?

Image 29. Multi functionality
(wind turbines alone dune)

Image 30. Reuse of vacant space
(from brownfield to solar field)

Image 31. Fine-tuning function
(energy park)

Source: all from public domain



6.4.2 Ecologic Quality

ECOLOGICAL CORRIDOR

An ecological corridor, also known as wildlife corridor, habitat corridor, or green corridor, is an area of habitat connecting wildlife populations from the separation of human activities or structures (such as transportation infrastructures, housing projects, industrial areas).

'This allows an exchange of individuals between populations, which may help prevent the negative effects of inbreeding and reduced genetic diversity (via genetic drift) that often occur within isolated populations. Corridors may also help facilitate the re-establishment of populations that have been reduced or eliminated due to random events (such as fires or disease).'

--Wikipedia

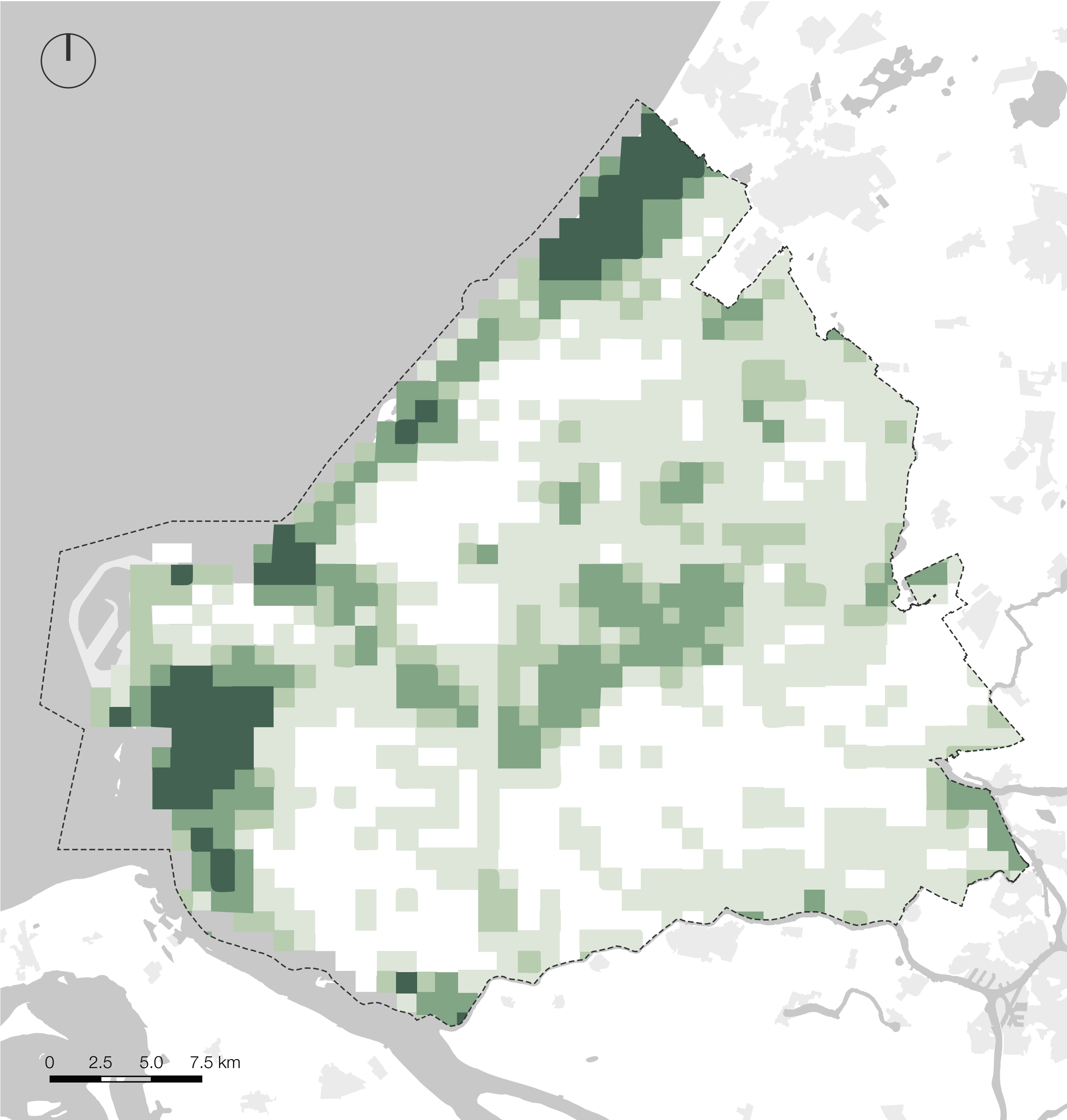
In the MRDH region, the ecological corridor is mostly located along the coast and Meuse river, with small branches extending into hinterland. These are areas where construction activities are limited.

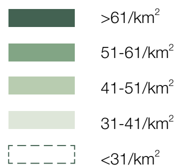
Map 19. Ecological corridor
Data source: www.atlasleefomgeving.nl/kaarten

REDLIST SPECIES DENSITY

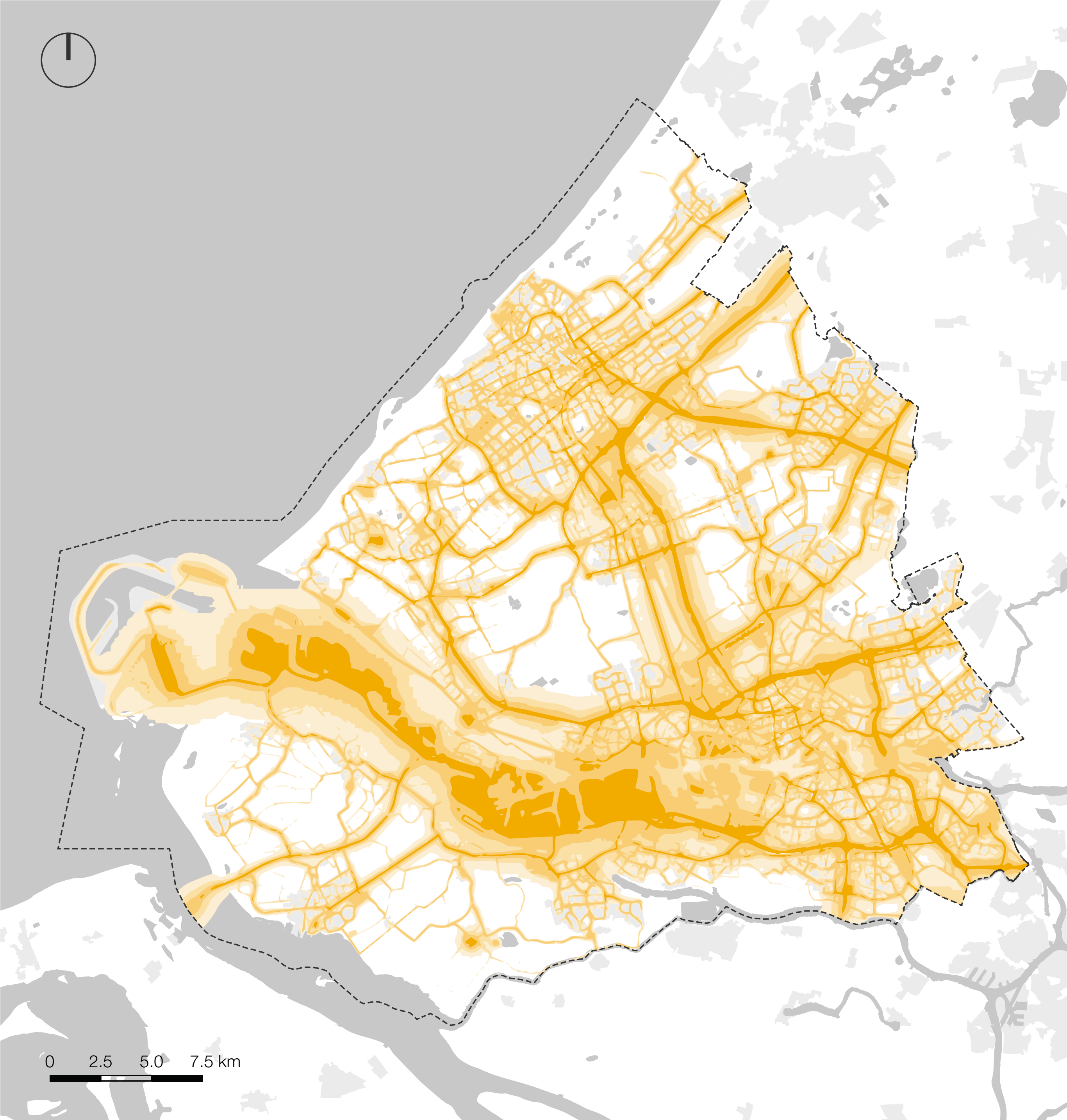
The redlist species density map shows a relation with ecological corridor. Areas with a higher density of redlist species and biodiversity are located in places performing as nature preserve.

In those areas, the deployment of wind turbines, large PV fields and the cultivation of energy crops need to be limited or even forbidden because they might end up in land degradation and habitat loss, which heavily influences the diversity of local fauna and flora.





Map 20. Redlist species density
Data source: www.atlasleefomgeving.nl/kaarten



NOISE LEVEL

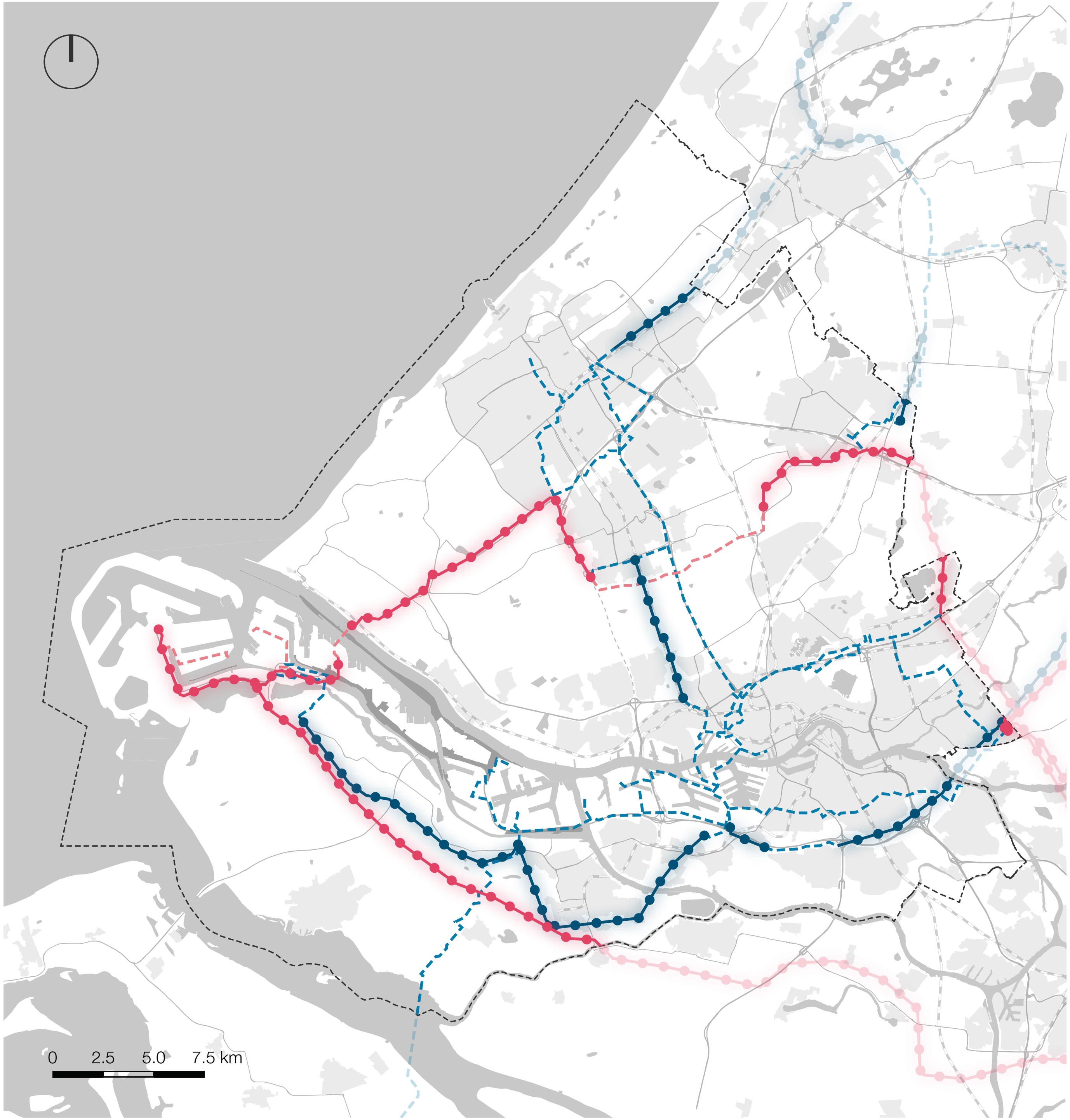
Acoustic wellness is also considered as one of the most important ecological value since noise can highly influence people's mental health and the behavior of certain specious such as bats or insects.

However, this noise level map shows another possibility of dealing with the noise pollution that might caused by the deployment of wind turbines: the installation can be in those spaces with a higher noise level, so that it won't deteriorate the existing condition.

Also, PV panels can serve as sound barriers which lowers the noise pollution from the traffic when installed along the busy traffic roads or railways.

>70 db
60~70 db
55~60 db
50~55 db
<50 db

Map 21. Noise level
Data source: www.atlasleefomgeving.nl/kaarten



HIGH VOLTAGE BUFFER ZONE

When high voltage lines cross land, for ecological reason there should be buffer zones along the lines. However, high voltage masts are also disturbance to landscape views. With the development of energy decentralization, more and more energy demand will be satisfied with roof PV panels or wind turbines, and some of these high voltage lines will be abandoned. It should also be taken into consideration that how the existing energy system can change with the development of renewable energy landscape.

363-420 kV line
146-170 kV line
363-420 kV cable (underground)
363-420 kV cable (underground)
Hight voltage mast

Map 22. High voltage line
Data source: webkaart.hoogspanningsnet.com/

PRESENT CONDITION OF ECOLOGICAL LANDSCAPE

Image 32. Nature preserve

Image 33. Bird watching area

Image 34. Railway

Source: all from public domain

HOW TO PRESERVE ECOLOGICAL VALUE?

Image 35. Eco-energy park

Image 36. Reuse of buffer-zone

Image 37. Sound barrier

Source: all from public domain

6.4.3 Aesthetic Quality

What is aesthetic value of landscape?

Landscapes are important to people. They have been integrated into our everyday life as dynamic expressions of the interaction between the natural environment and human activities since very ancient time (Antrop, 1998). The European Landscape Convention defines a landscape as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors' (Council of Europe, 2003).

Aesthetic value, also known as visual quality or scenic beauty, is derived from people's landscape perception and their landscape preferences (Tveit et al., 2018). Thus, aesthetic value of landscape is rather obscure and subjective, which might differ from observer to observer even when they are confronted with the same landscape.

Aesthetic value assessment approaches

In order to study aesthetic landscape quality, several approaches are developed (Daniel, 2001). Lothian (1999) proposed 'that landscape quality assessment may be approached on the basis of two contrasting paradigms, one which regards quality as inherent in the physical landscape, and the other which regards quality as a product of the mind - eye of the beholder. These are termed, respectively, the objectivist and subjectivist paradigms.'

Daniel and Vining (1983) have distinguished five approaches or 'models' to study visual aesthetic quality of landscape, which can be placed on a dimension ranging from objectivist to subjectivist:

ECOLOGICAL MODEL, an objectivist approach, defines landscape quality as independent of the observer and entirely determined by ecological or biological features in the landscape. Within this model the observer is seen as a user of the landscape and a potential disturbance.

FORMAL AESTHETIC MODEL, also an objectivist approach, characterises landscapes in terms of formal properties, such as form, line, unity and variety. These properties are seen as inherent characteristics of the landscape that can be assessed by appropriately trained individuals (e.g. landscape architects).

PSYCHOPHYSICAL MODEL takes a position between the objectivist and subjectivist approach. It aims to establish general relationships between

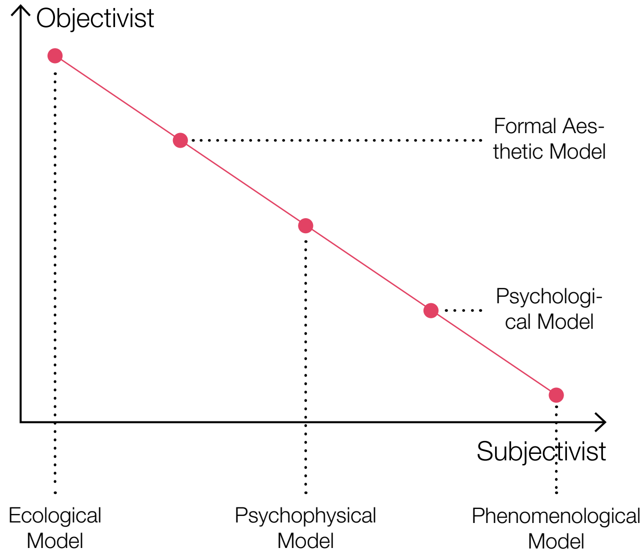


Figure 16: Five models studying aesthetic
Source: Daniel and Vining, 1983.

measured physical characteristics of a scene (taken from photographs or geographical databases) and landscape preferences.

PSYCHOLOGICAL MODEL, a subjectivist approach, characterises the landscape in subjective terms by relying on human judgements of complexity, mystery, legibility, etc. These judgements are then related to an array of cognitive, affective and evaluative dimensions of landscape experiences.

PHENOMENOLOGICAL MODEL is the most subjectivist model. It focuses on how each individual assigns personal relevance to landscape attributes in personal interpretations of landscape encounters.

Measuring and mapping aesthetic quality

Aesthetic quality of landscape can be accessed through several methods and frameworks in order to provide tools for decision support and landscape monitoring.

A more recent method is the **VISULANDS FRAMEWORK** (Tveit et al., 2006). This framework is a psychophysical framework linking visual indicators to theories of landscape perception and preference. It identifies nine key visual landscape


Image 38. (a) natural


Image 39. (b) artificial

NATURALNESS The ecological perspective states that the natural, unmodified ecosystem carries the greatest aesthetic value of all (Cheng, 2007).


Image 40. (a) well maintained


Image 41. (b) neglected

STEWARDSHIP Perceived human care for nature and landscape through active and careful management.


Image 42. (a) coherent

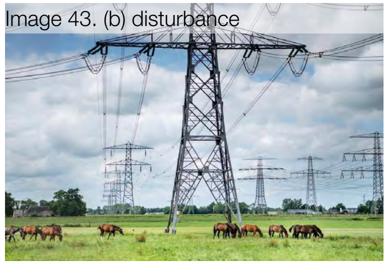


Image 43. (b) disturbance

COHERENCE Order and organization, "the patterns of brightness, size, and texture" in the scene. Immediate understanding of how elements in the environment fit together.


Image 44. (a) modern


Image 45. (b) historic

HISTORICITY Historical continuity and historical richness, different time layers, amount and diversity of cultural elements.

Source: all from public domain

aspects: naturalness, stewardship, disturbance, historicity, visual scale, imageability, ephemera, coherence and complexity. For each of these aspects, landscape attributes and elements contributing to its expression in the visual landscape are identified, as well as currently used visual indicators to assess it.

The VisuLands framework has presented a comprehensive approach to describing visual landscapes and assessing visual effects of landscape change using data sources such as photographs, land cover data, airborne photographs and field observations (Ode, Tveit, & Fry, 2010). Research has identified strong relationships between the nine key aspects and landscape preferences, although their relative importance and interpretation may vary across groups (Tveit et al., 2006).


Image 46. (a) intimate


Image 47. (b) open

VISUAL SCALE Degree of openness, size of perceptual units.


Image 48. (a) memorial


Image 49. (b) boring

IMAGEABILITY Landscapes or landscape elements making landscapes distinguishable and memorable, creating a strong visual impression.


Image 50. (a) summer


Image 51. (b) winter

EPHEMERA Views which can change with seasons or weather are considered as higher aesthetic quality.


Image 52. (a) complex


Image 53. (b) homogeneity

COMPLEXITY The number of different visual elements in a scene: how intricate the scene is; its richness.

Source: all from public domain

HOW TO PRESENT AESTHETIC QUALITY OF RENEWABLE ENERGY TECHNOLOGIES?

Image 54. Wind kite

Image 55. Solar flag

Image 56. Wind flag

Source: all from public domain

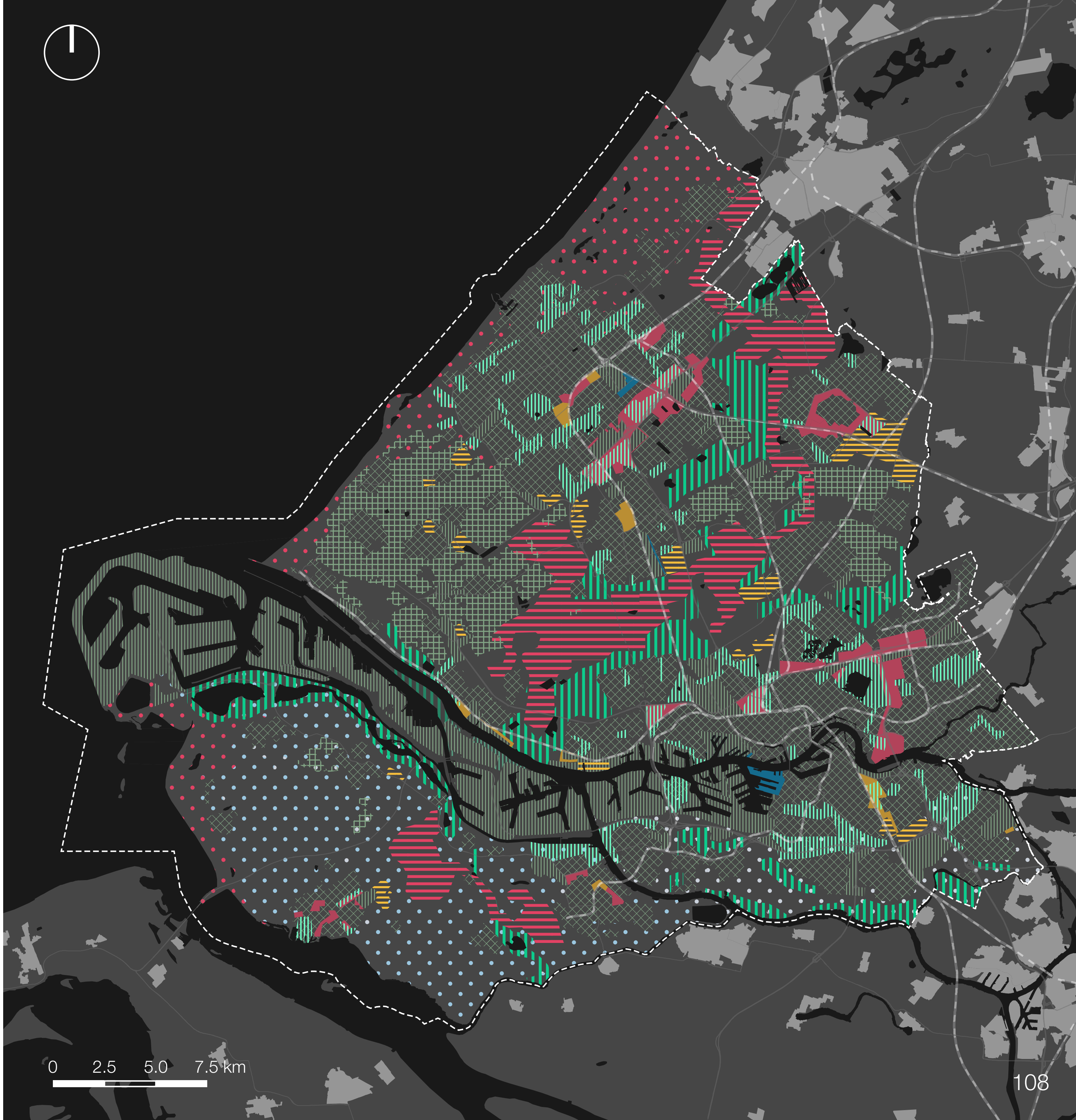
07
DESIGN THE FUTURE

Image 57. Golden Roots
Source: Ronny Zschörper, Franziska Adler (LAGI 2014)

7.1 Regional Scenarios

The designing research from five perspectives into the spatial implications of the energy transition in the MRDH shows that integrating renewable energy technologies while preserving or attaching landscape quality is feasible. In this chapter, various energy transition projects that contribute to the sustainability of the energy supply but also shows landscape quality to make people more aware and supportive were researched and designed. By working out the challenge on the basis of five different aspirational perspectives and by scaling up concrete projects, insight is gained into the possible transition paths and their spatial consequences.

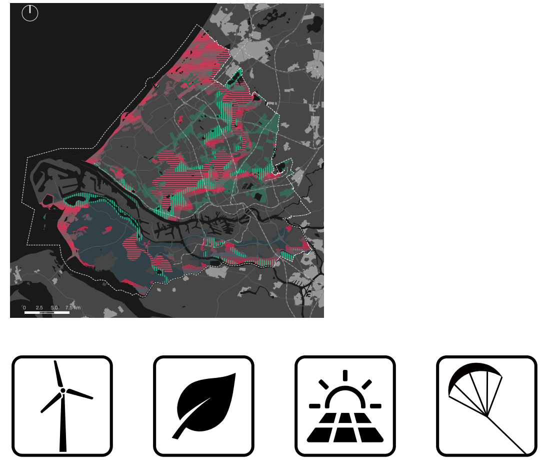
- River delta landscape
- Coastal landscape
- Meadow bird preservation (no construction)
- Recreational area
- Existing roof landscape
- Urban green
- Future-proof neighborhoods investment
- Develop nodes
- Focuses on transformation areas
- Industrial and business area
- Hard planned business park
- Greenhouse area

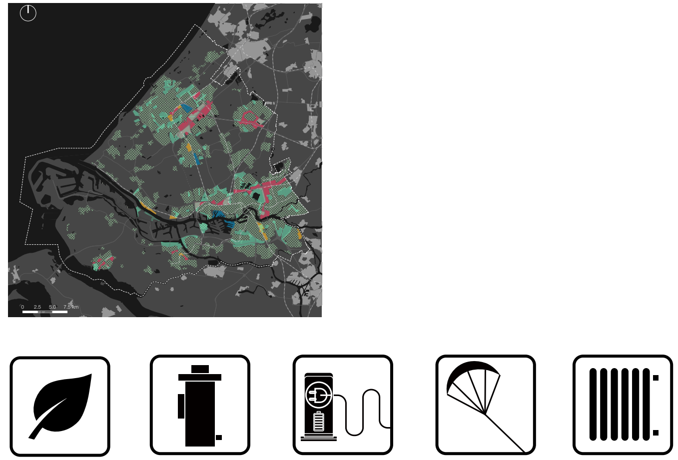


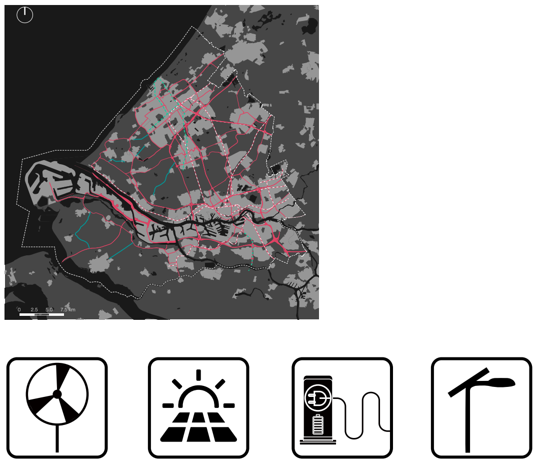
Map 23. Urban landscape of the MRDH 2050
Data source: ruimtelijkeplannen.zuid-holland.nl

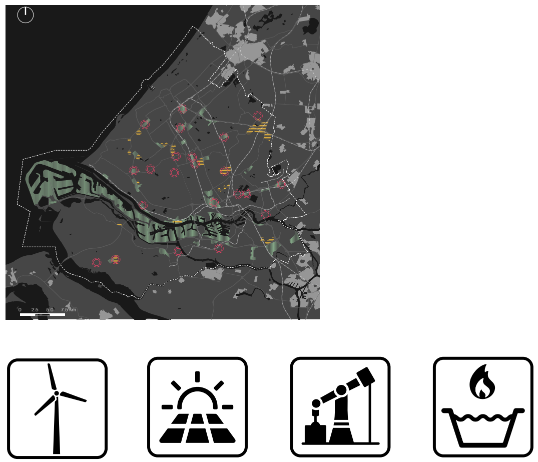
According to the regional developing goal, future scenarios of each realm are mapped to perform as base maps where sustainable energy solutions can be integrated.

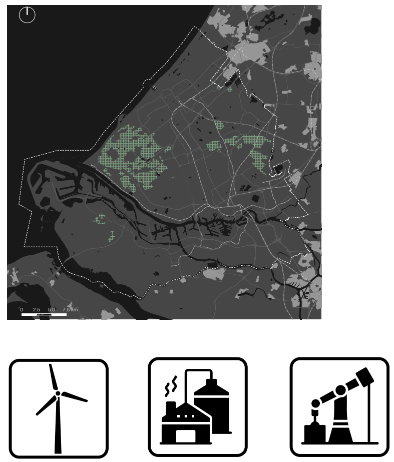
For different realms, due to their specific and unique characteristics, sustainable energy solutions also differ from one place to the other. Finally a regional energy vision is drawn from the collection of solutions.



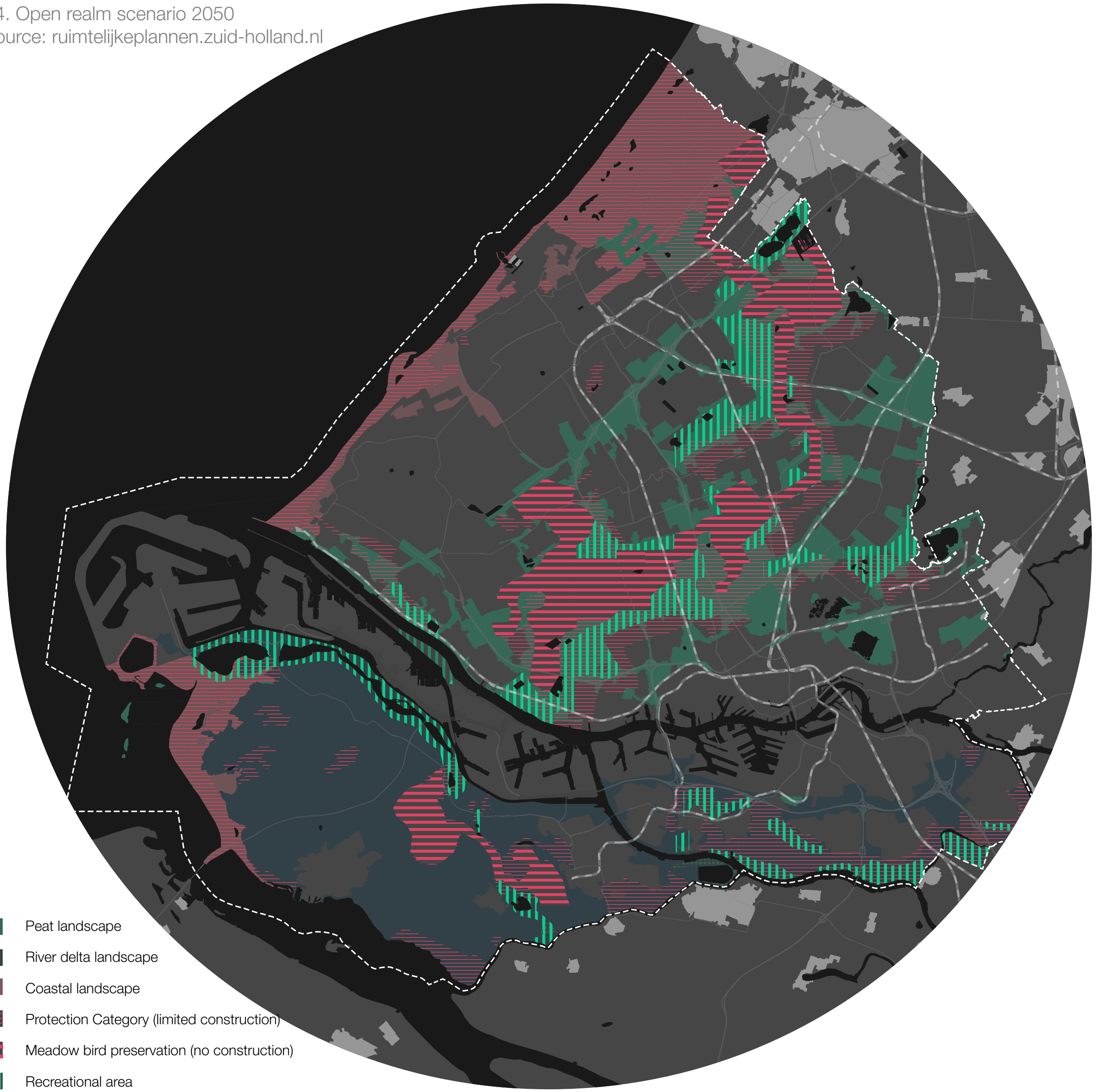








Map 24. Open realm scenario 2050
Data source: ruimtelijkeplannen.zuid-holland.nl



Peat landscape
River delta landscape
Coastal landscape
Protection Category (limited construction)
Meadow bird preservation (no construction)
Recreational area

7.2 Open Realm Scenarios

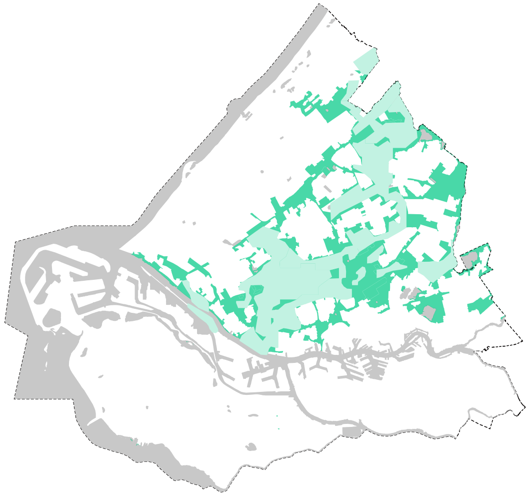
Image 58.
Food production

Image 59.
Relaxation and tourism site

Image 60.
Barrier (ecological corridor)

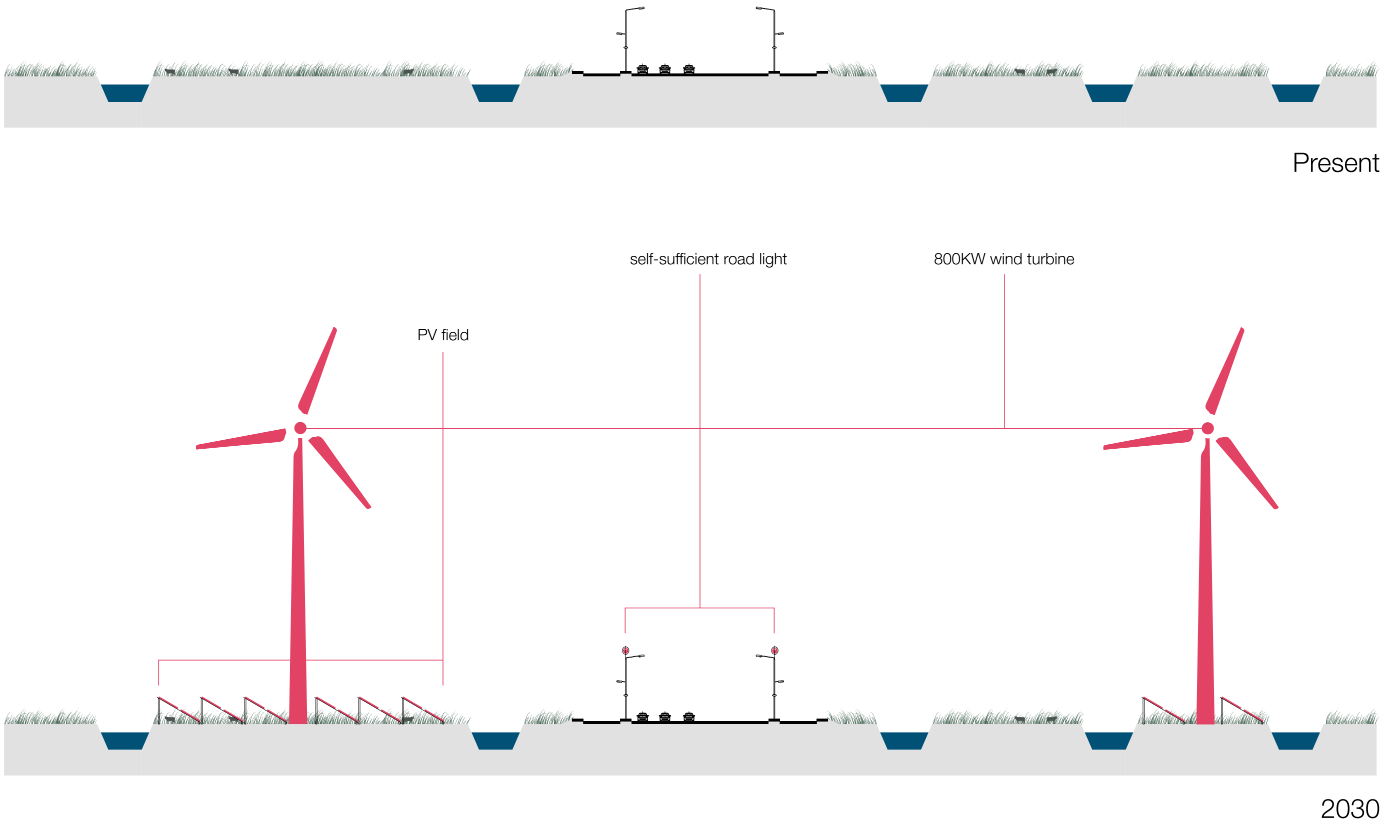
Image 61.
Buffer zone

7.2.1 Agriculture Land



PEAT LANDSCAPE

Although peatland is partially decayed in terms of vegetation and other organic matter, it can serve as the most efficient carbon sink on the earth (Hugron et al., 2013). On the other side, within this area there are several meadow bird preservations, protection categories and recreational sites, which will highly limit the integration of renewable energy technologies.



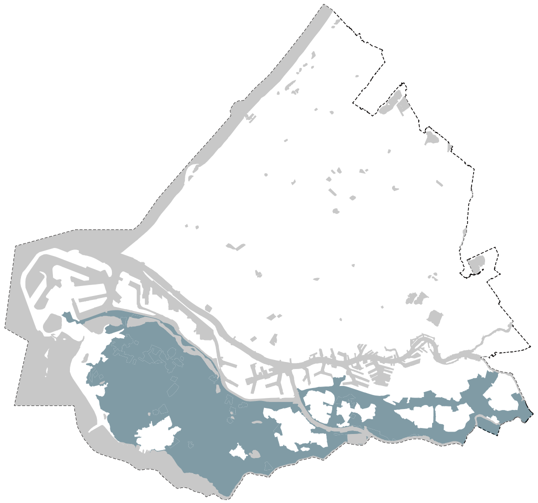
At present, apart from the meadow bird preservations, protection categories and recreational sites mentioned above, the peatland which allows a large scale of renewable energy construction is mainly used as pastures that are suitable for grazing animals, especially cattle or sheep. It presents the economic quality of landscape and of which the visual is mainly demonstrated in its openness and naturalness.

Therefore in 2030, 800KW wind turbines will be installed to generate electricity since they only occupy a very little area of land. Vacant and abandoned spaces are transformed into PV fields which also adds value to the land.

Present (2020)

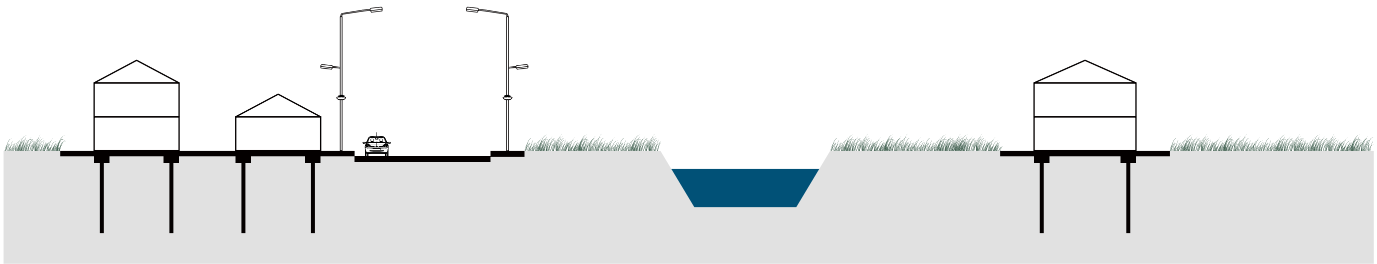
Image 62. Present condition of peatland
Source: www.agv.nl/werk-in-uitvoering/calamiteitenberging-polder-de-ronde-hoep/

Visualization 2. Sustainable energy solution of peatland 2030

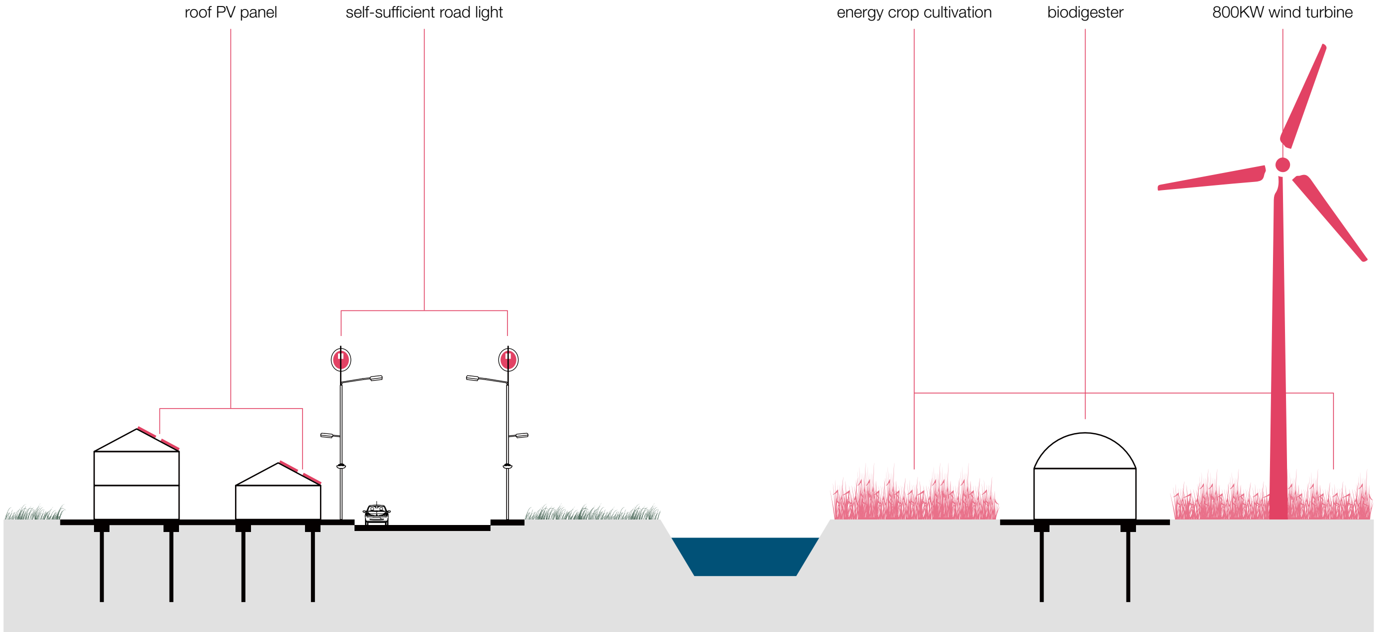


RIVER DELTA LANDSCAPE

When a river flow leaves its mouth and enters slower-moving or stagnant water, the deposition of sediment it carries forms a river delta (Elliot, 1986). In the MRDH region, river delta landscape is to the south of the Meuse River, with cultivation land and farms located within its border.



Present



2030

With the two main functions of cultivation and grazing, river delta landscape is the largest food production are of the MRDH region. Thus it requires the preservation of its economic value which limits the installation of large scale PV fields. But on the other side, the residual of cultivation industry provides a considerable potential for biomass energy, presenting the idea of circular economy.

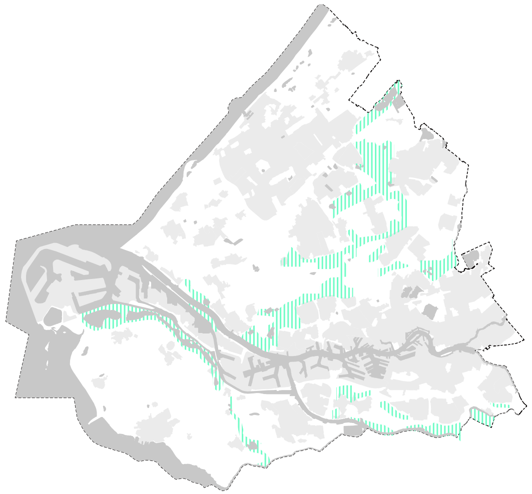
In 2030, 800KW wind turbines will be installed to generate electricity, while some of the agricultural land that is seasonally vacant will be transformed to cultivate energy crops, which to a certain extent increases the land use efficiency and economic value. Besides, small scale biodigesters are built to meet the daily green gas demand for farmland.

Present (2020)

Image 63. Present condition of delta river landscape
Source: pxhere.com/en/photo/1022647

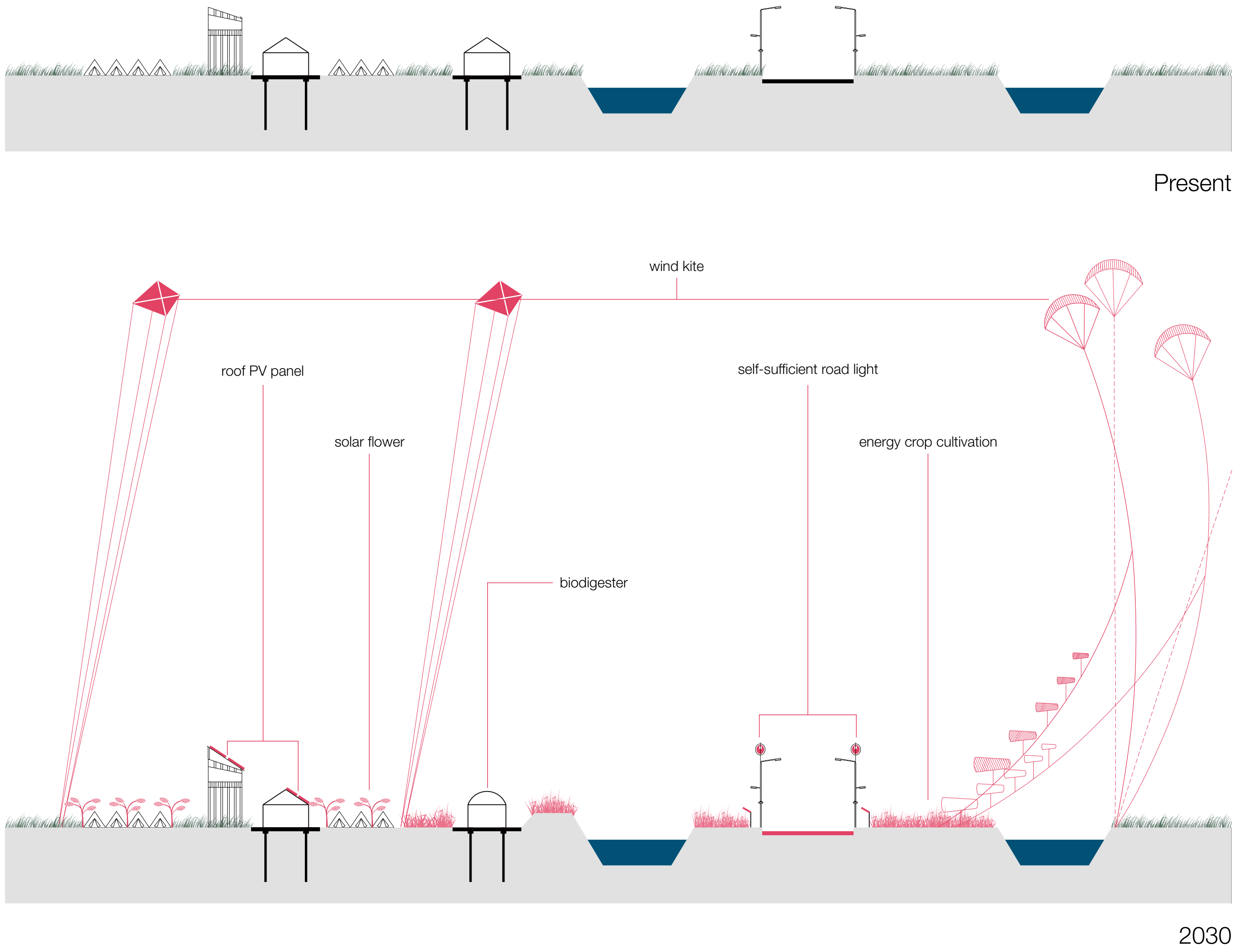
Visualization 3. Sustainable energy solution of river delta landscape 2030

7.2.2 Recreational Land



CAMPSITE AND GOLF PARK

The recreational land of the MRDH region is mainly located within the peat landscape, near natural preservations. Compared with other area of the peatland, the number of people visiting recreational sites is relevant high, which makes them not only ideal spaces of combining energy production with land art, but also suitable for educational function.



In the Netherlands, most of the campsites are equipped with recreational vehicles and are also known as RV parks. Usually placed quite close to each other, these vehicles don't really provide tourists with good memory to experience the nature.

In the near future of 2030, naturalness is addressed and highlighted in the transformation of campsites in order to improve the quality of tourism, while strict rules and regulations are set to protect the nature. Road lights are equipped with PV panels, and wind kites, not only electricity generators but also land art, are installed to provide energy for the campsites as well as attract more tourists.

In the far future of 2050, more innovative technologies will be developed. For example, transparent PV panels with aesthetic quality will be more widely used in these areas as shelters.

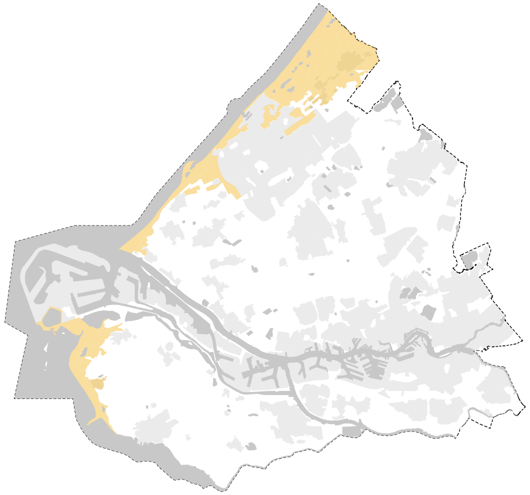
Present (2020)

Image 64. Present condition of a campsite
Source: www.kampeermagazine.nl/

Visualization 4. Sustainable energy solution of campsites 2030
Wind flag design: Sock Farm (Nandini Bagchee, Artur Dabrowski, Andrew Swingler, 2012)
Source: andartgenerator.org/LAGI-2012/SOC26010/

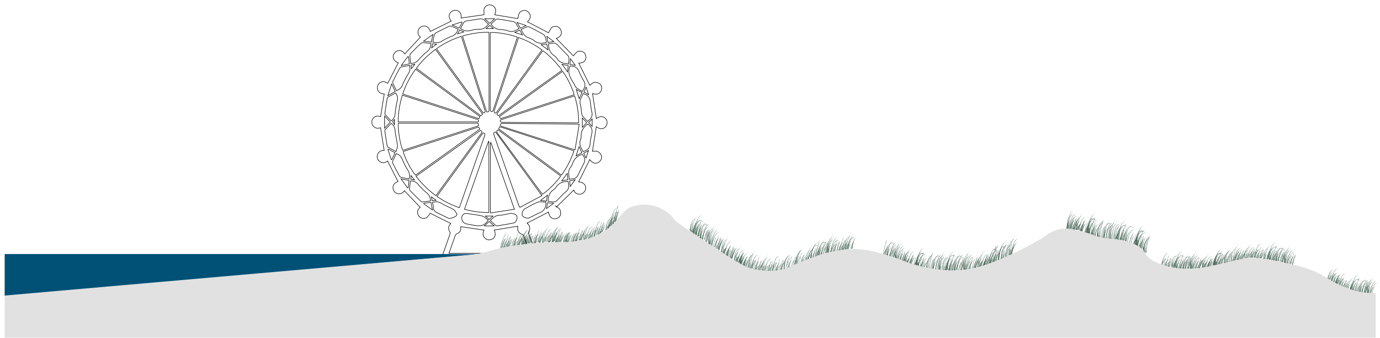
Visualization 5. Sustainable energy solution of campsites 2050
Transparent solar panel design: Head in the Clouds (Yuxun Emmeily Zhang, Alexandra Siu, Liyang Zhang, 2018)
Source: landartgenerator.org/LAGI-2018/2018/10/02/head-in-the-clouds/

7.2.3 Barrier Dune

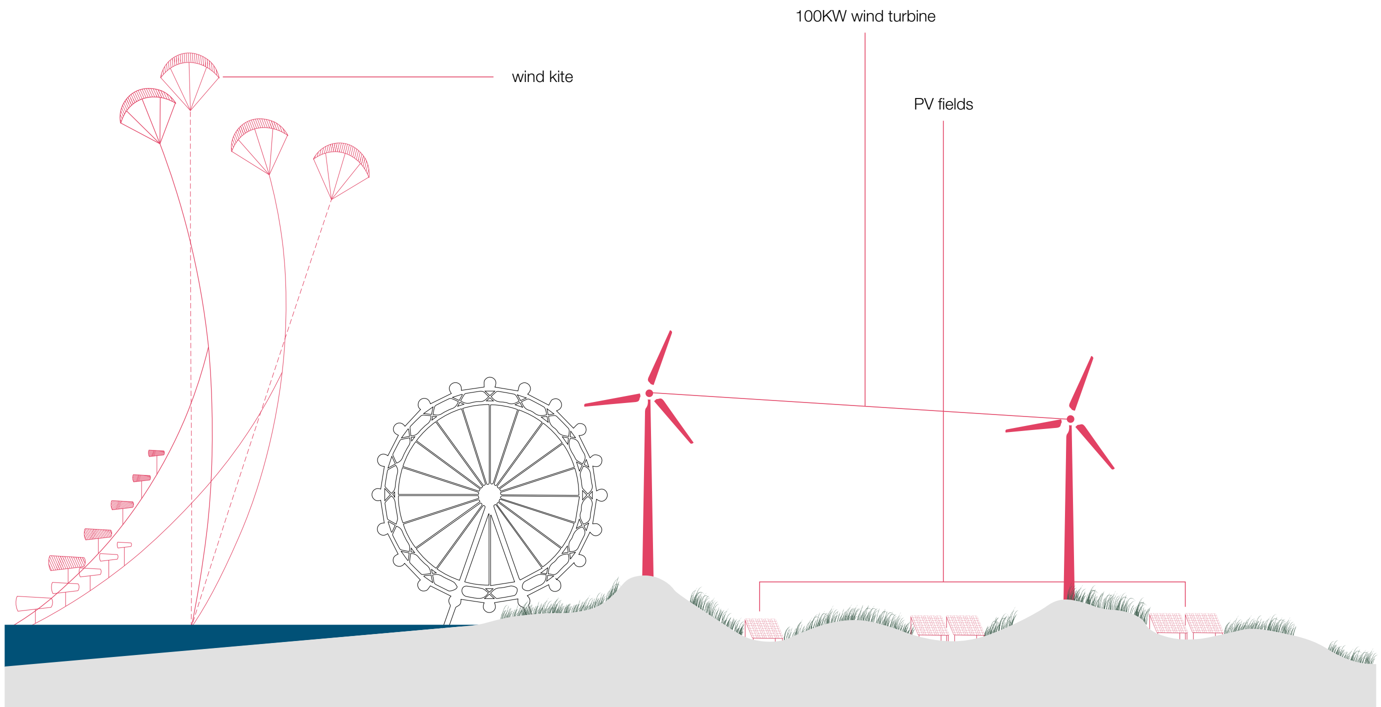


SAND BARRIER AND BEACH

Stretching along the coast, a barrier beach is a deposition of sediment with narrow body, permanently exposed above sea level to protect the hinterland from flooding (LangfordSmith). In the MRDH region, besides its main function, it also serves as an ecological corridor and recreational beach area, which highly limits the construction of renewable energy technologies.



Present



2030

The sand barrier along the coast is the most important ecological corridor in this region, with a higher density of redlist species living inside. Preserving the ecological quality becomes a priority. Only wind turbines smaller than 100KW are suitable for this area. It's also important to control the density of wind turbines. In this thesis, the proposal is only 1/4 of the projected density in order to give enough space to animals.

Present (2020)

Image 65. Present condition of sand barrier
Source: takethehague.nl/en/location/west-dune-park

Visualization 6. 100KW wind turbines on sand barrier 2030

As the most famous and popular seaside resort in South Holland, Scheveningen has an abundance of attractions. With its long, wide boulevard, excellent beaches and stylish beach pavilions, it draws a crowd for it's a great place for walking, sunning and swimming, as well as surfing, visiting events and enjoying great food.

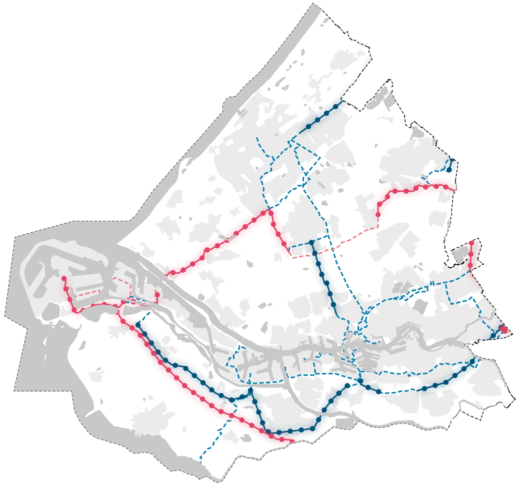
The aesthetic value of the beach should be preserved as it brings economic profits, and if possible, the interventions of sustainable energy should become new landscape arts to attract and educate people. In 2050, with the innovation of energy technologies, clouds-like balloons are installed to generate electricity from both wind and sunlight, together with reef-like solar facilities.

Present (2020)

Image 66. Present condition of Scheveningen Beach
Source: rustholkarhu.fi/tag/beach/

Visualization 7. Land art generator on the beach 2050
Technical design: landartgenerator.org/LAGI-2018/2018/10/02/head-in-the-clouds/

7.2.4 Buffer Zone



Present

HIGH VOLTAGE BUFFER ZONE

A high voltage buffer zone is generally a zonal area that lies along a high voltage line to segregate electricity transmission and other area (often, but not necessarily, agricultural land and residential area) for security reasons.

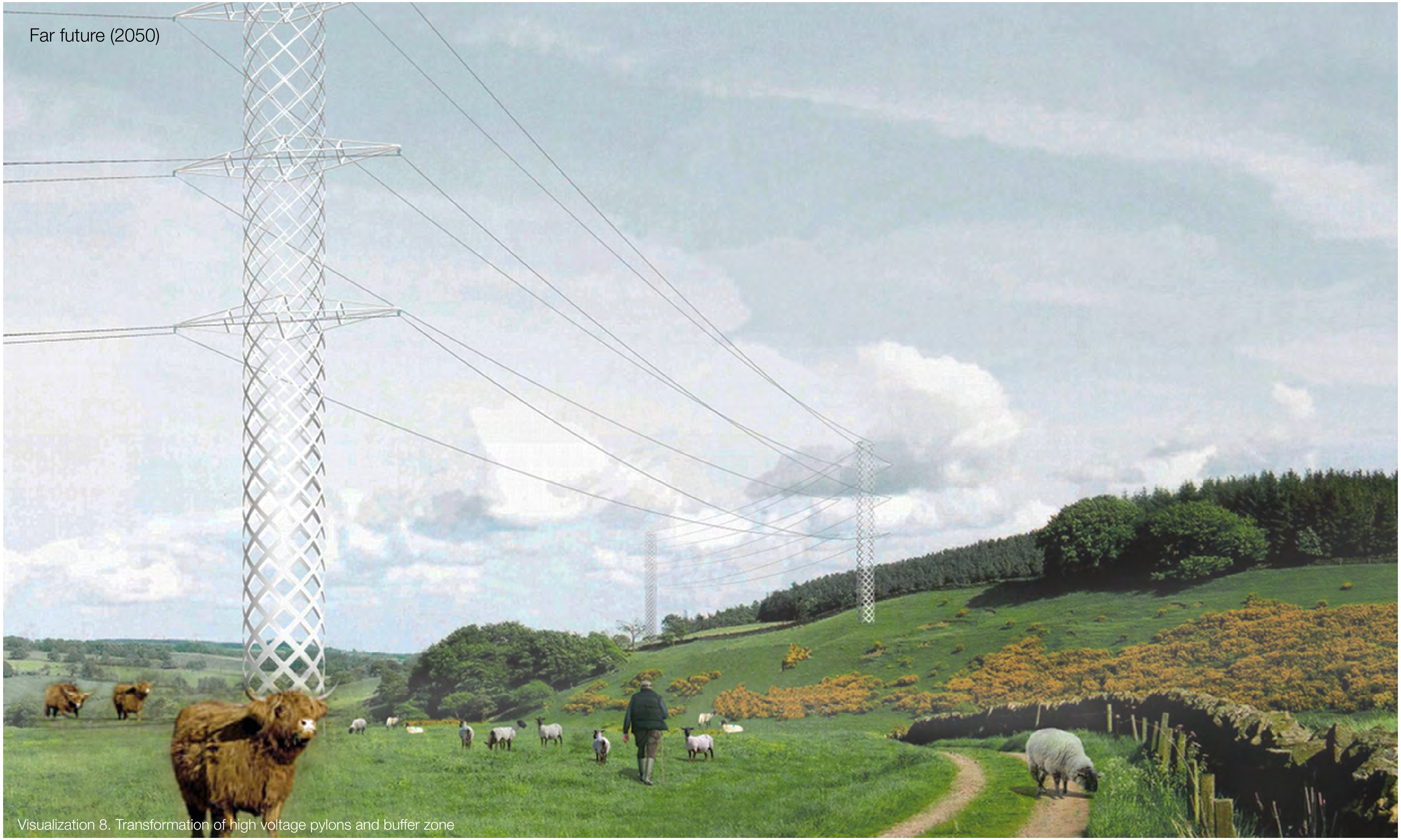
2030

At present, high voltage electricity transmission in the MRDH region is through specific high volt lines and pylons. Although the areas along the lines are not suitable for energy facilities, there still are some other chances. For example, due to the progress of energy decentralization, many villages or neighborhoods will become self-sufficient and will no longer rely on the centralized energy system. Thus some of the high voltage lines might be abandoned in the future.

The original buffer zones can be transformed into ecological corridors. If it goes through a neighborhood, it can also become a linear public park.

Present (2020)

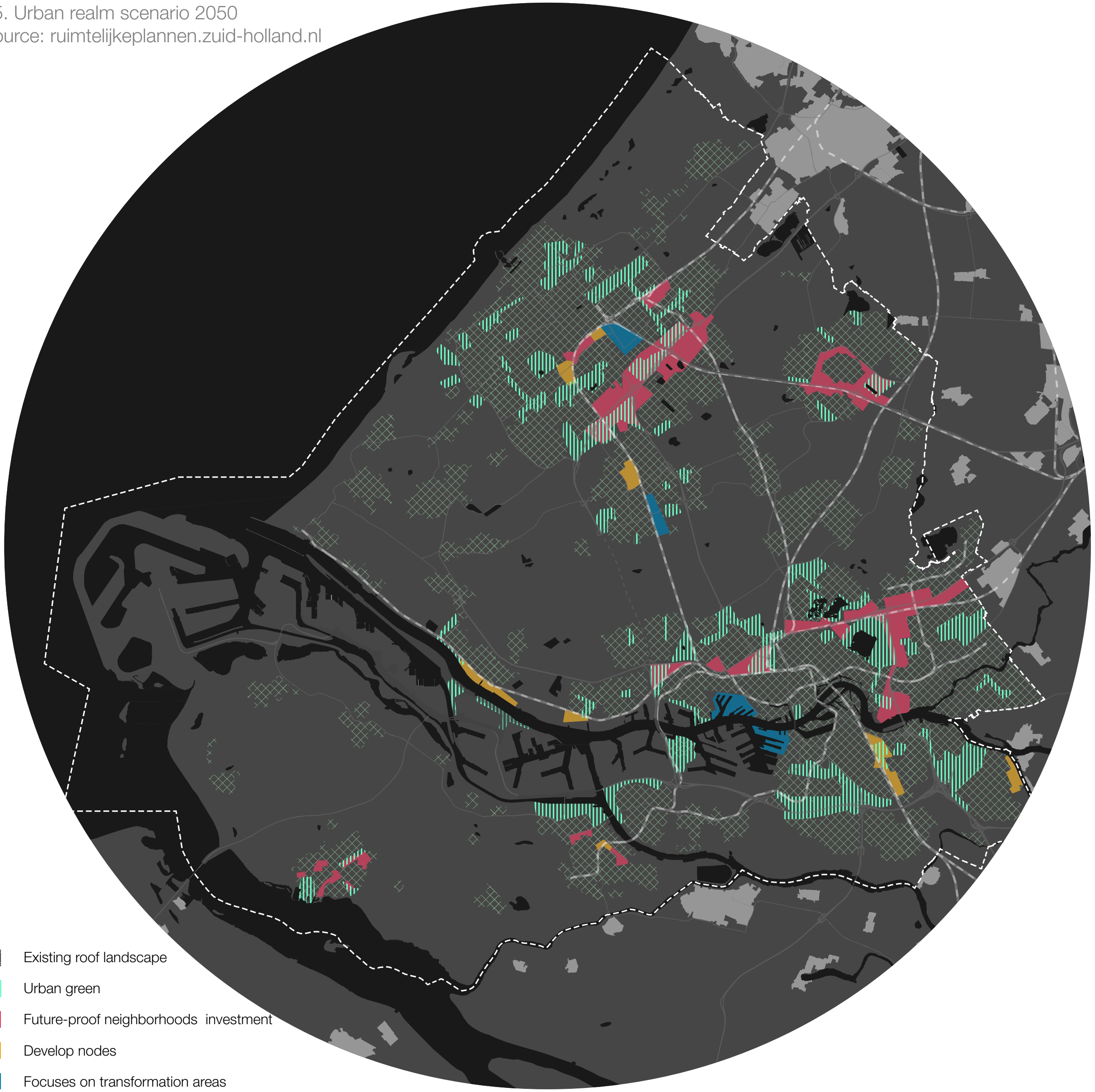
Image 67. Present condition of high voltage lines
Source: www.wemadethis.co.uk/blog/2011/10/t-pylon/



Visualization 8. Transformation of high voltage pylons and buffer zone

7.3 Urban Realm Scenarios

Map 25. Urban realm scenario 2050
Data source: ruimtelijkeplannen.zuid-holland.nl

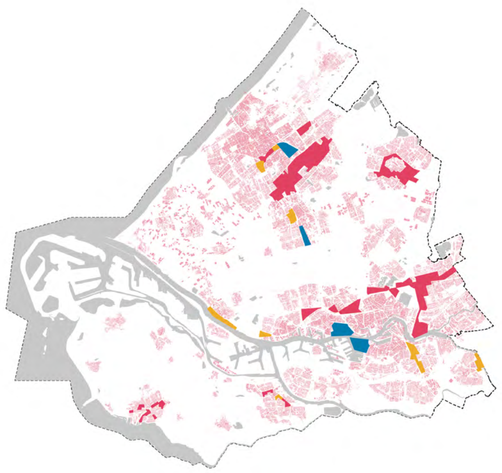


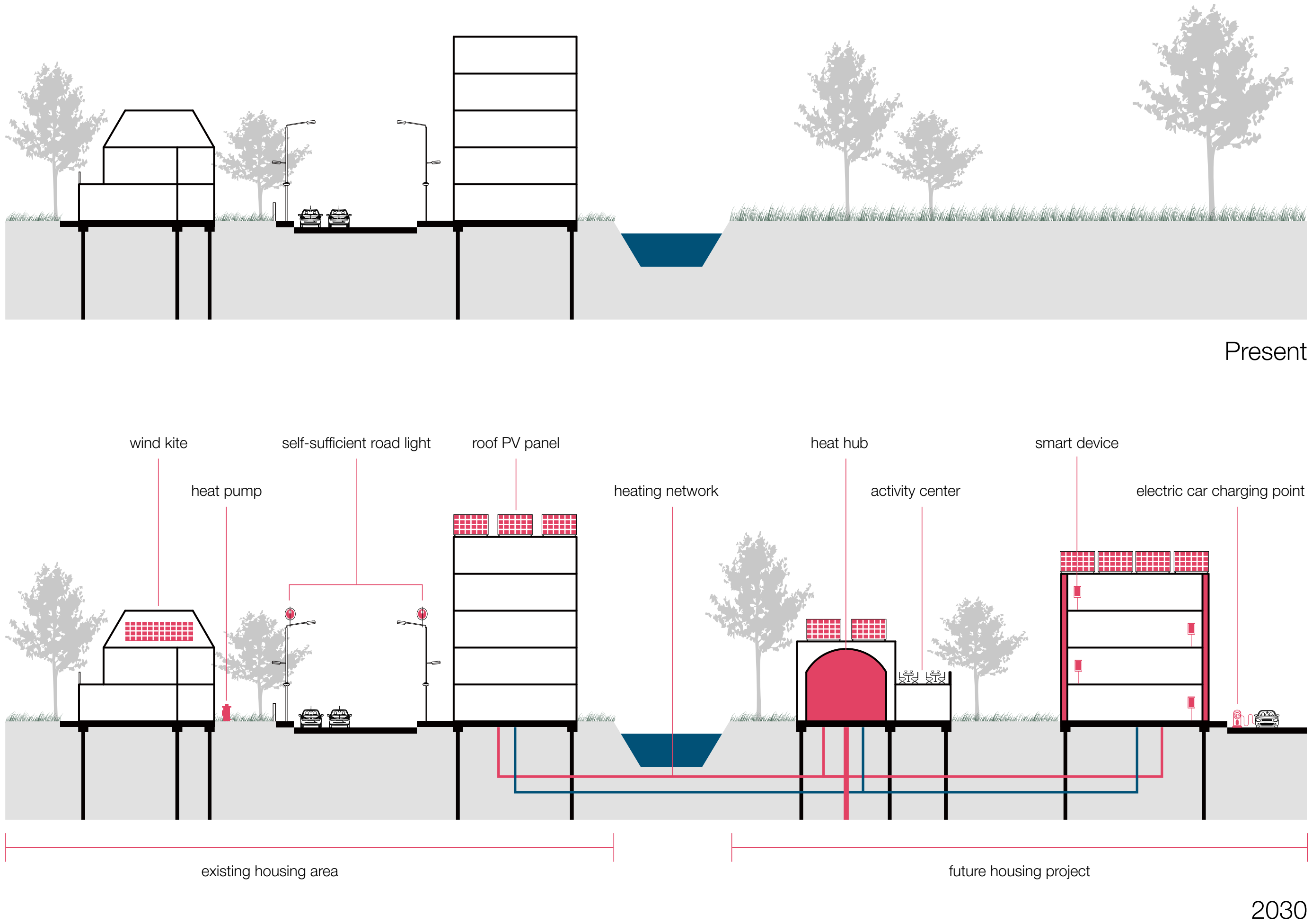
Existing roof landscape
Urban green
Future-proof neighborhoods investment
Develop nodes
Focuses on transformation areas

Image 68.
Housing

Image 69.
Urban park

7.3.1 Housing





HOUSING PROJECTS

The municipality of MRDH is planning several new housing projects in 2030. The densification projects are mostly located in the outer side from the city center, interacting with urban green area, while transformation areas are former industry or business sites.

Sustainable energy solutions will differ according to housing conditions. For existing single Dutch houses, PV panels are installed on the rooftop to generate electricity, and heat pumps in yards can provide sufficient heat for each house. As for apartments and row houses, apart from rooftop PV panels, they can be attached to district heating network.

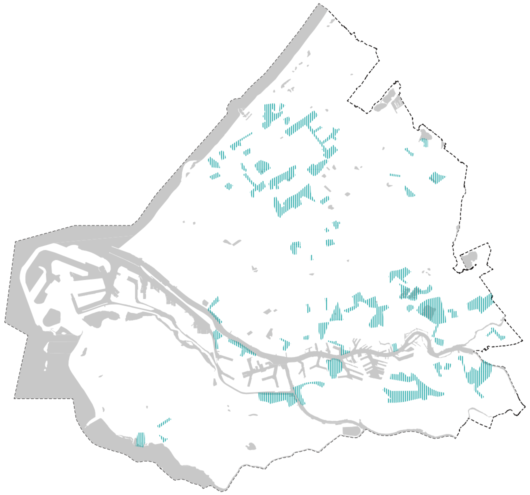
On the other side, for those new housing projects or densification areas, the concept of passive building is integrated. Better insulation materials can reduce the heat demand, while smart devices help increase energy efficiency. As a transfer station of district heating, a heat hub is usually combined with a neighborhood center where people have chances to interact, communicate and enhance their public network.

Present (2020)

Image 70. Present condition of housing area
Source: www.funda.nl/koop/rotterdam/appartement-86456074-stadhoudersplein-11-c/

Visualization 9. Sustainable energy solution of new housing project

7.3.2 PARK



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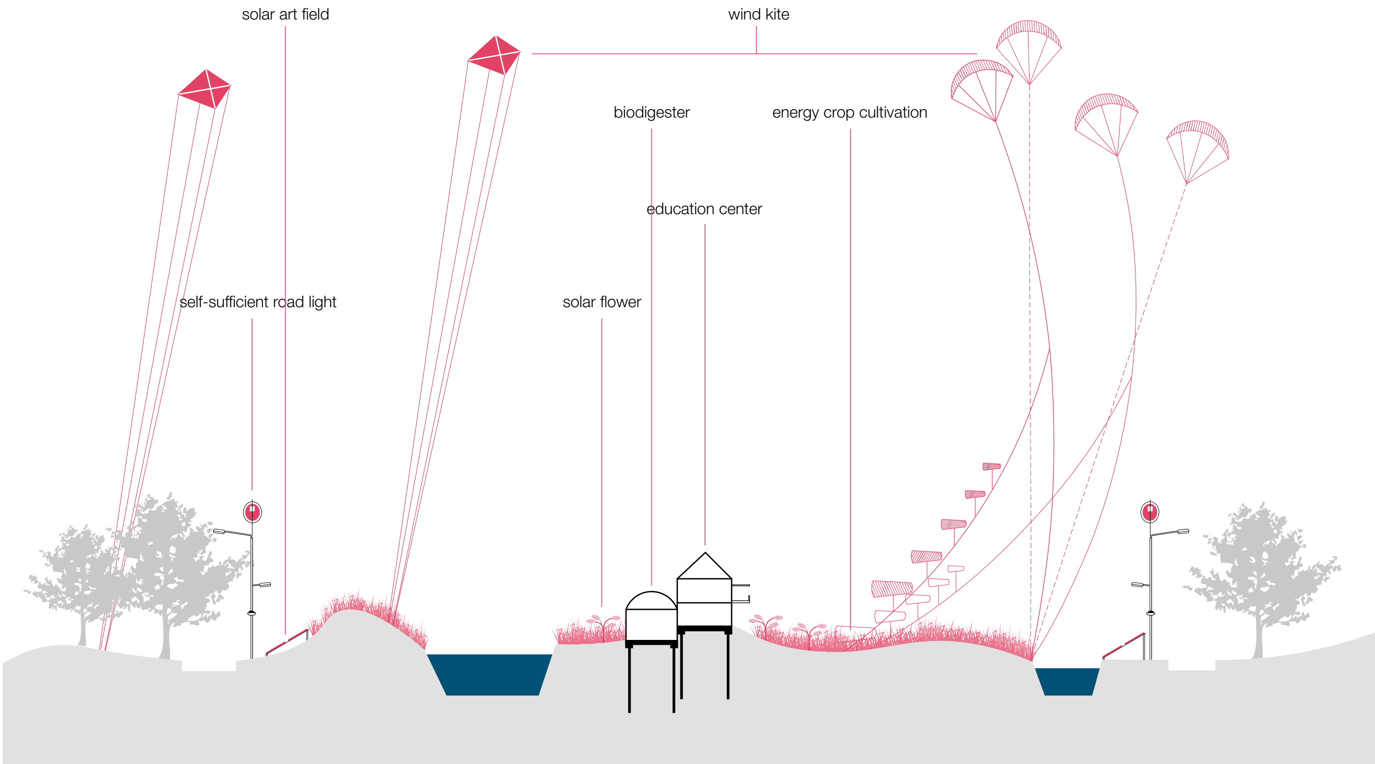


2030

URBAN PARKS

Different from the recreational lands outside the city, urban parks are usually equipped with more service facilities and artificial structures even it is a natural park. Common features of urban parks include playgrounds, gardens, hiking, running and fitness trails or paths, bridle paths, sports fields and courts, public restrooms, boat ramps, and/or picnic facilities.

As discussed above, sustainable energy solutions are usually conflicting with the ecological value of landscape. However, under certain circumstances, energy facilities and naturalness can be combined together without competing each other. Eco-energy park is one of the possibilities.

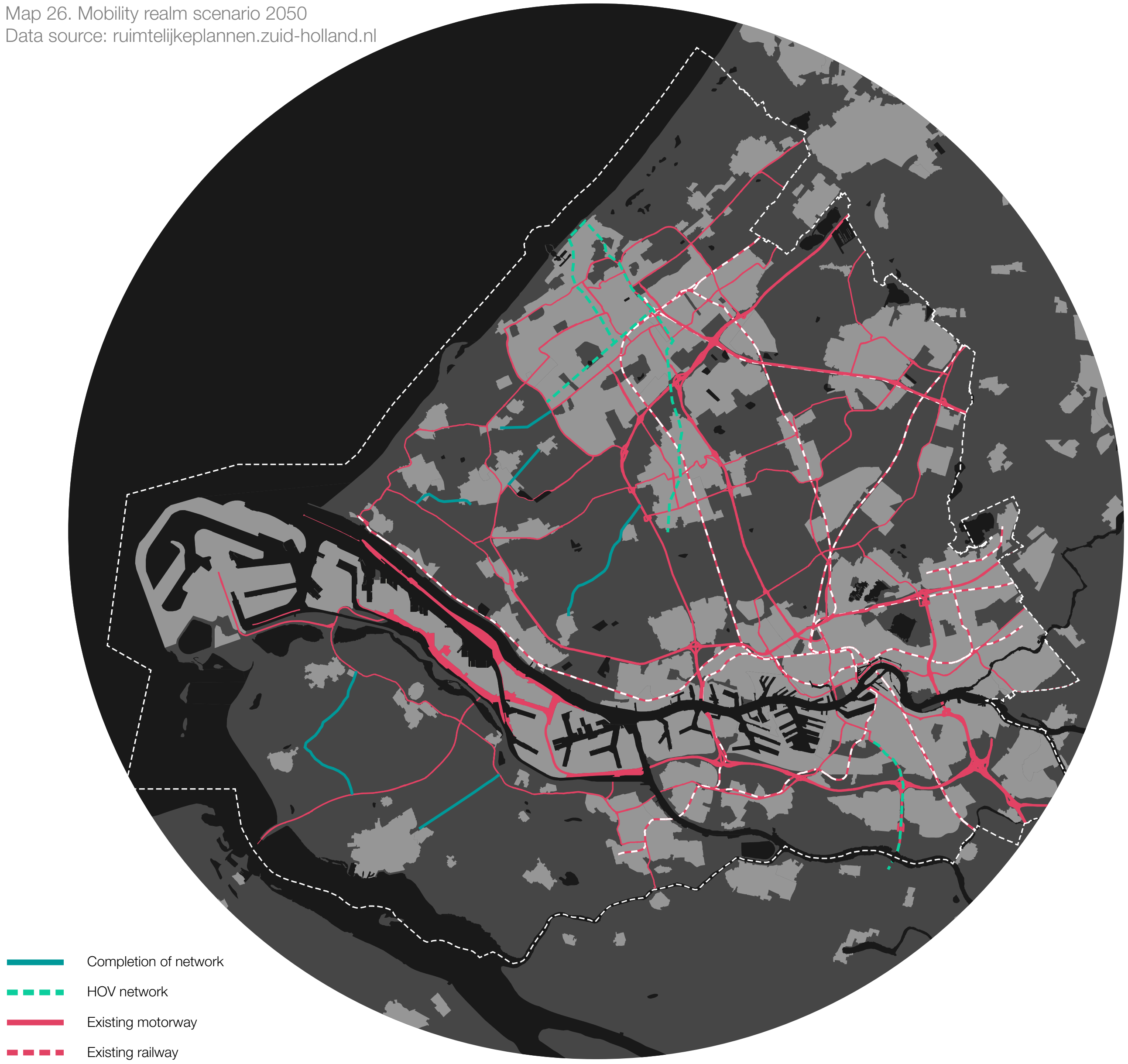
In an Eco-energy park, ecosystem services of landscape is preserved, while small scale renewable energy technologies are integrated. Wind turbines can be considered as art sculptures and walking paths covered with PV panels can generate energy without any negative consequence.

Present (2020)

Image 71. Present condition of an urban park
Source: www.fieldoperations.net/project-details/project/urban-metabolism-2014-rotterdam-biennale-research-exhibition.html

Visualization 10. Eco-energy park

Map 26. Mobility realm scenario 2050
Data source: ruimtelijkeplannen.zuid-holland.nl



7.4 Mobility Realm Scenarios


Image 72.
Railway


Image 73.
Highway

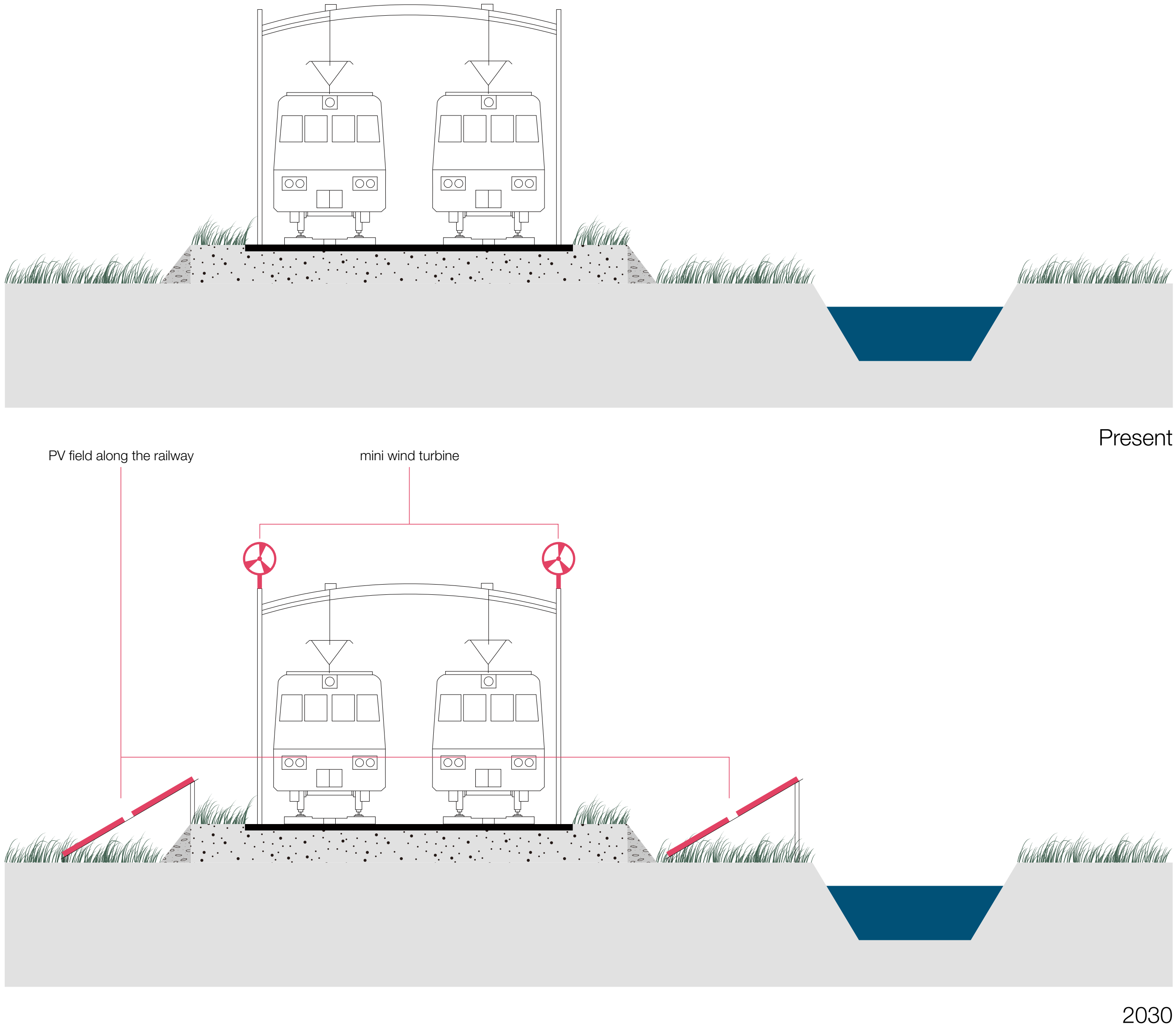

Image 74.
Station


Image 75.
Bicycle lane

7.4.1 RAILWAY

RAILWAYS

According to the transportation development plan published on the official website of Zuid Holland, there is no particular goal for the railways set by the MRDH.



The transportation infrastructure is already there and the landscape is purely used for mobility. The surrounding land is now wasted as it provides no quality of life due to its proximity to the railway. Solar panels are low and will not obstruct vision.

The solution is to place small wind turbines on the electricity lines and solar panels in the waste lands along the railway, creating a production landscape.

Present (2020)

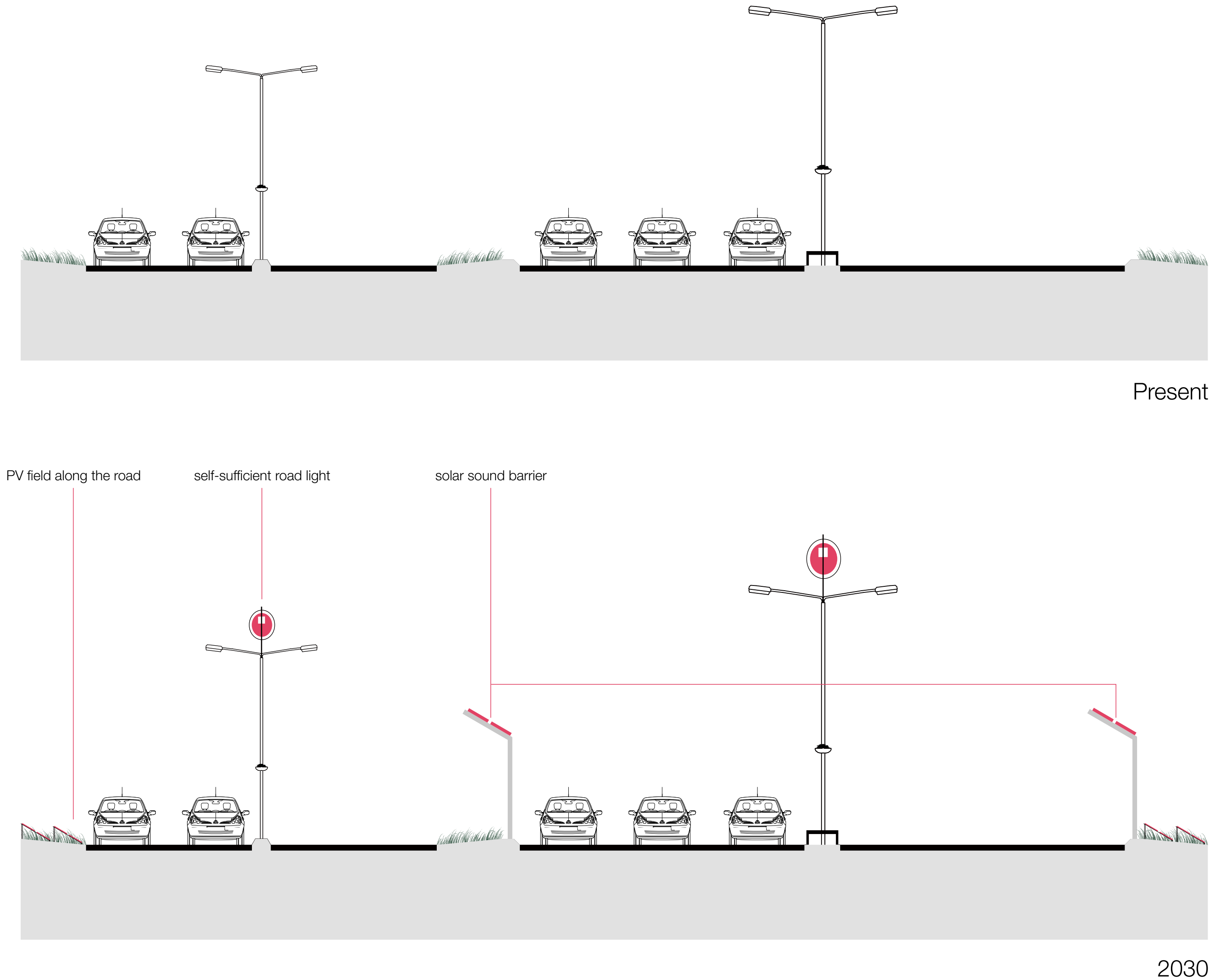
Image 76. Present condition of railway
Source: www.globalrailnews.com/2018/03/02/ns-to-refurbish-more-double-deck-emus/

Visualization 11: Sustainable energy solution along railway

7.4.2 Motorway

MOTORWAYS

There is no particular goal for the highways set by the MRDH. However, several motorways will be constructed to complete the mobility network.



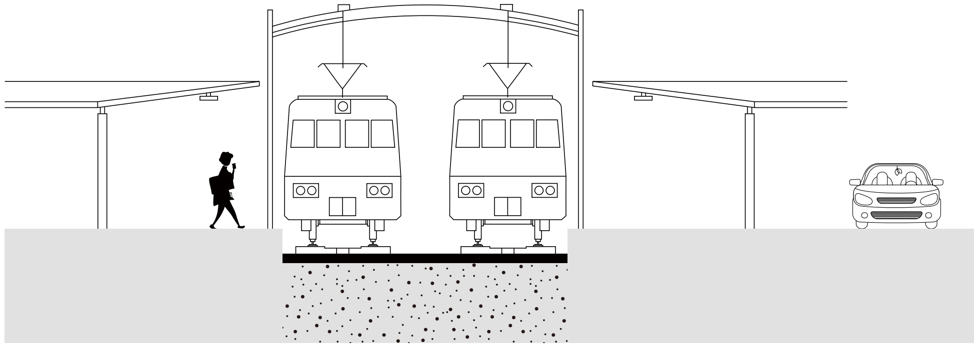
Similar to the railway landscape, sustainable energy interventions along motorways will not disturb the original views. By placing self-sufficient lanterns, solar panels along motorways and solar sound barrier, not only a productive landscape is created, but also the noise pollution is controlled, therefore adding value to acoustic wellness of ecological quality.

Present (2020)

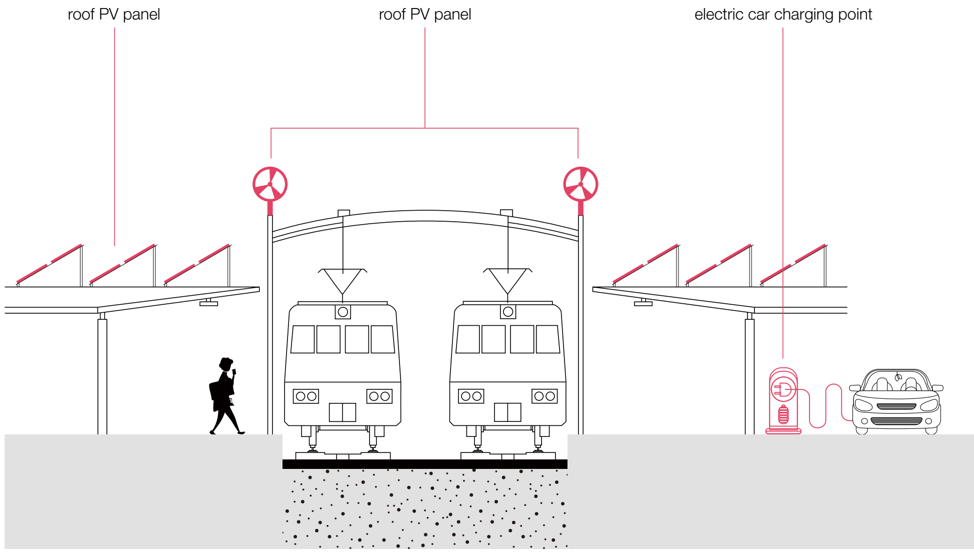
Image 77. Present condition of highway
Source: Google map street view

Visualization 12. Sustainable energy solution along highway

7.4.3 Station



Present

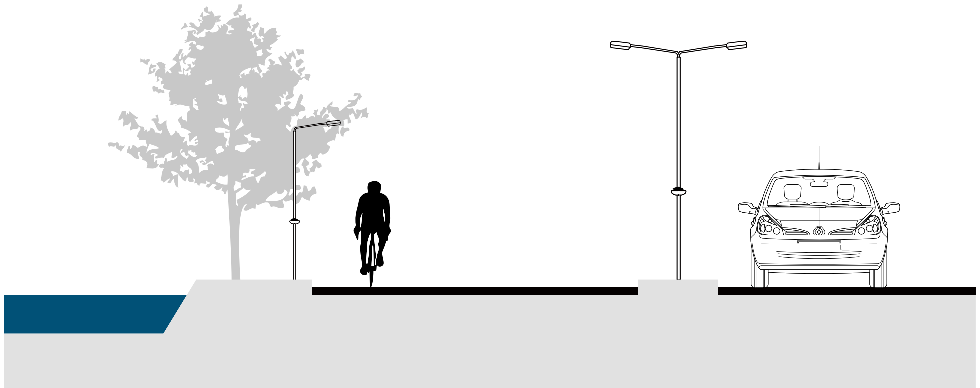


2030

Image 78. Present condition of railway station
Source: www.prorail.nl/nieuws/station-delft-zuid-gaat-delft-campus-heten

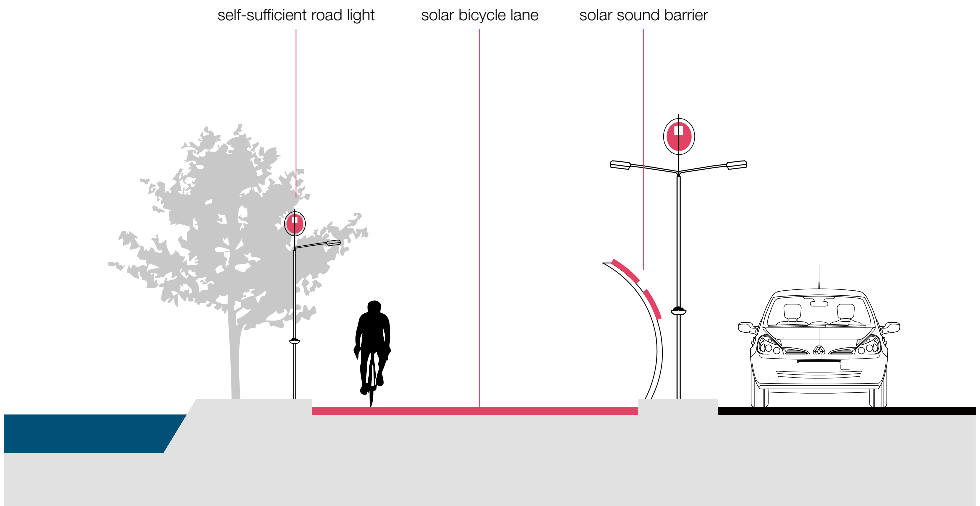
Visualization 13. Sustainable energy solution of train station

7.4.4 Bicycle Lane



Present

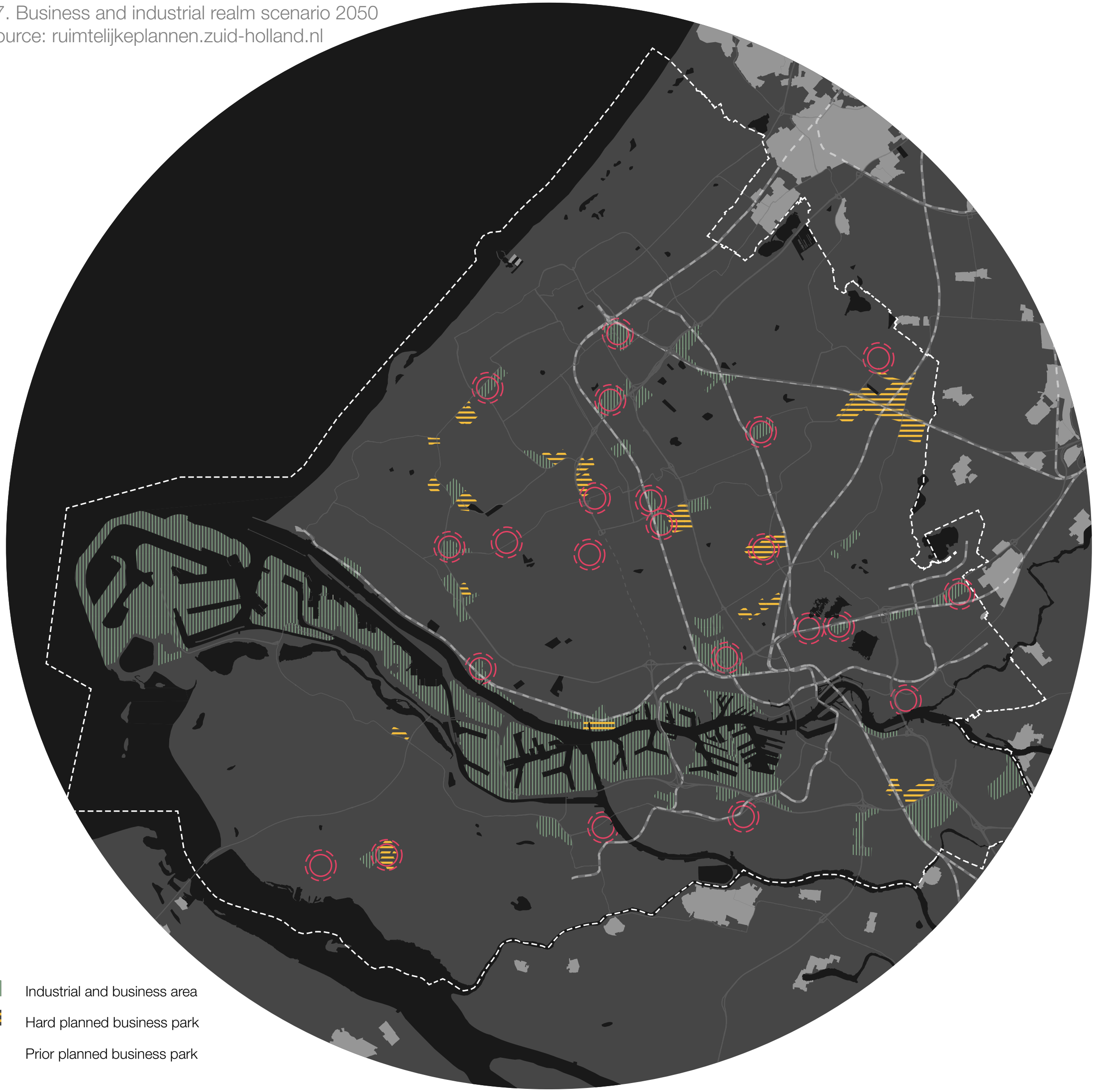
Image 79. Present condition of bicycle lane
Source: www.heeswijk.nl/nieuws/viaducten-over-rijksweg-a4-leidschendam&lang=en



2030

Visualization 14. Sustainable energy solution of bicycle lane

Map 27. Business and industrial realm scenario 2050
Data source: ruimtelijkeplannen.zuid-holland.nl



7.5 Business and Industrial Realm Scenarios

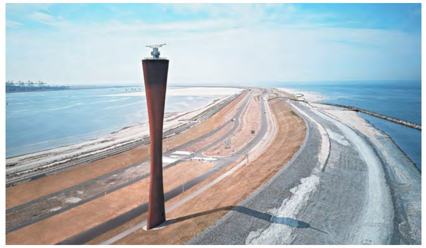
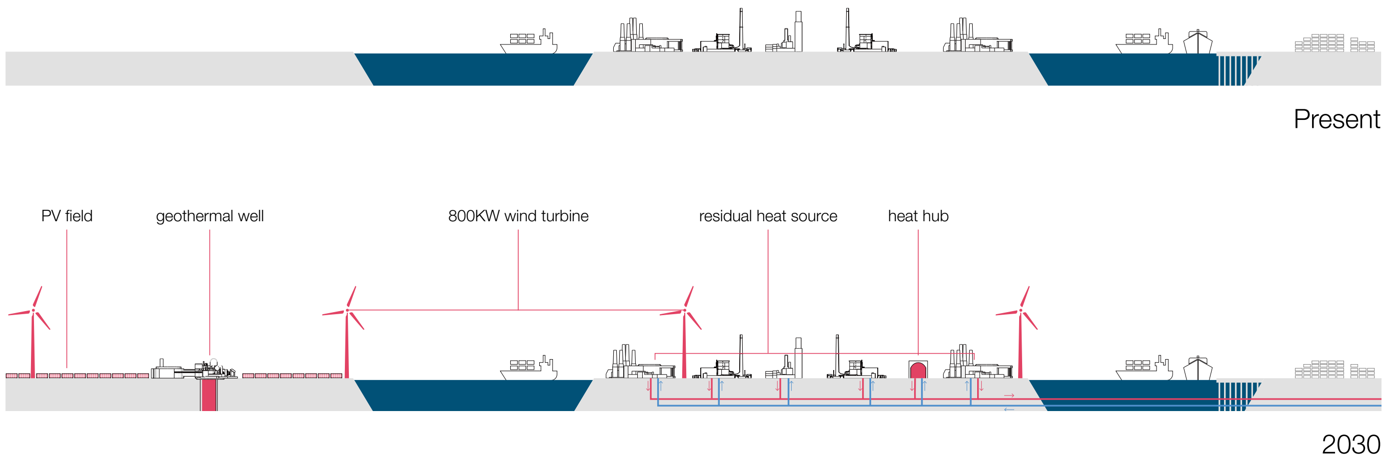


Image 80.
Harbor industry

Image 81.
Business park

7.5.1 Harbour Industry



ARTIFICIAL ISLAND AND FACTORIES

The Port of Rotterdam is the largest port in Europe. Covering 105 square kilometers It consists of the city center's historic harbour area, including Delfshaven; the Maashaven/Rijnhaven/Feijenoord complex; the harbours around Nieuw-Mathenesse; Waalhaven; Vondelingenplaat; Eemhaven; Botlek; Europoort, situated along the Calandkanaal, Nieuwe Waterweg and Scheur; and the reclaimed Maasvlakte area, which projects into the North Sea (Port of Rotterdam, Wikipedia).

In 2030, space has been reserved for wind turbines and solar panels. Obsolete wind turbines in the port area will be replaced by turbines with more capacity (Port of Rotterdam, 2019). The seawall of Maasvlakte 2 is one of the most important new locations for wind energy. Vacant spaces are transformed into solar PV fields to generate electricity.

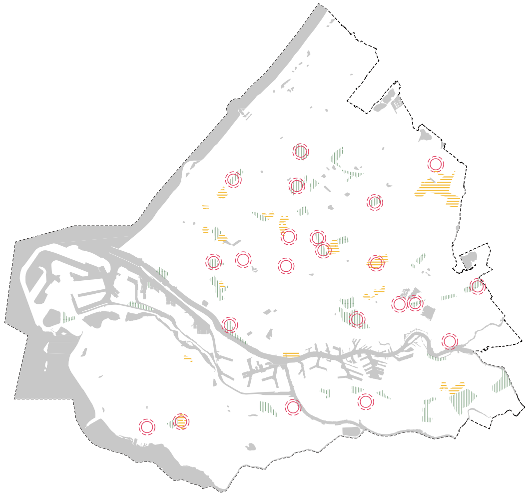
Since this artificial island doesn't have public functions, the installation of renewable energy technologies won't influence the existing landscape value.

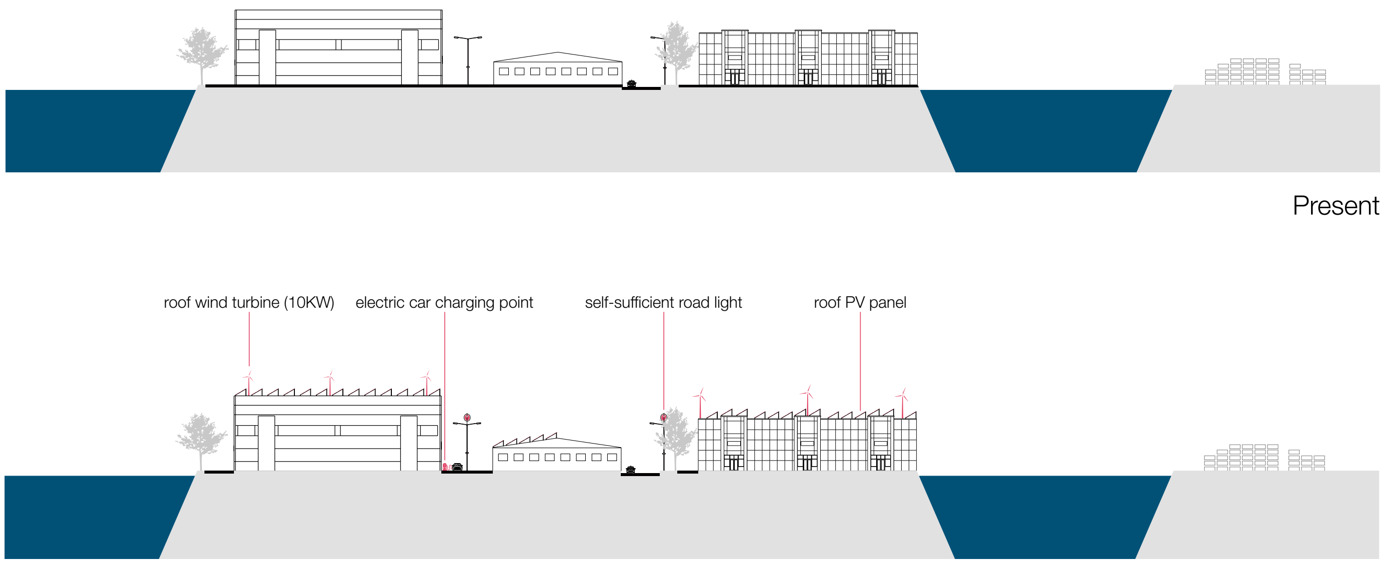
Present (2020)

Image 82. Present condition of harbor industry area
Source: sybvanbreda.com/project/radar-tower-maasvlakte-2/

Visualization 15. Sustainable energy solution of Maasvlakte area

7.5.2 Business Park





BUSINESS PARK

Global trends can be seen in the 250 industrial areas of the MRDH digitization, technological innovations, sustainability and increasing circularity. Spatially, further concentration of similar functions is visible, such as large-scale

logistics and maritime activities, and an increasing mix of functions on mainly the many regular-mixed / classic small-scale sites.

The multi-core structure of the MRDH can be seen in the various accents and dynamics per sub-region. To do justice to this spatial-economic diversity we distinguish 15 hard-planned business parks and 23 priority business parks (including both transformation and newly construction areas). The buildings are usually more than three floors and occupy a large area of land.

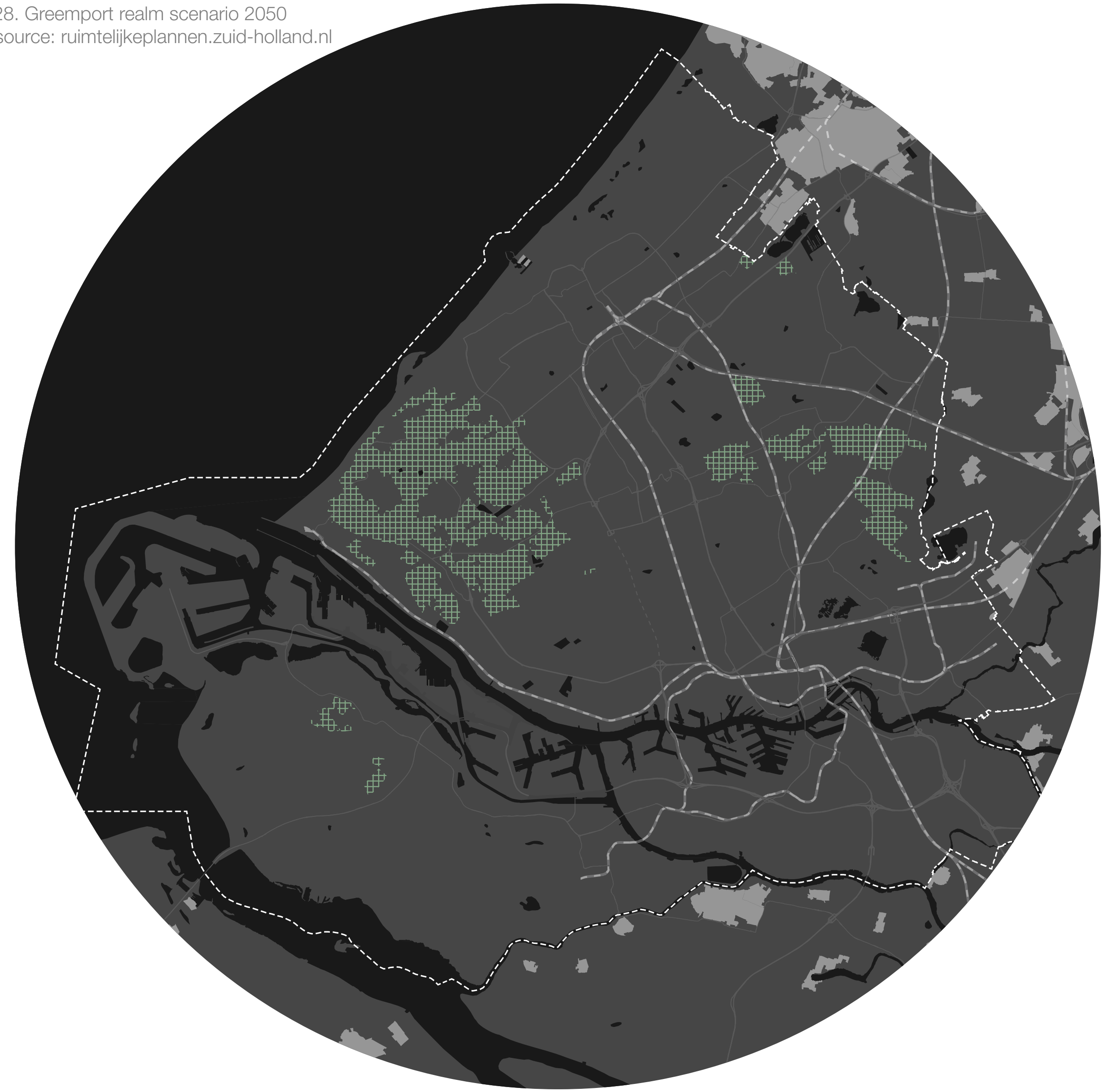
Therefore, the roof areas of business locations can be used to generate solar energy on a large scale. The installation of PV panels and small scale wind turbines (less than 10KW) won't disturb views from a human perspective.

Present (2020)

Image 83. Present condition of business park
Source: Park 20|20

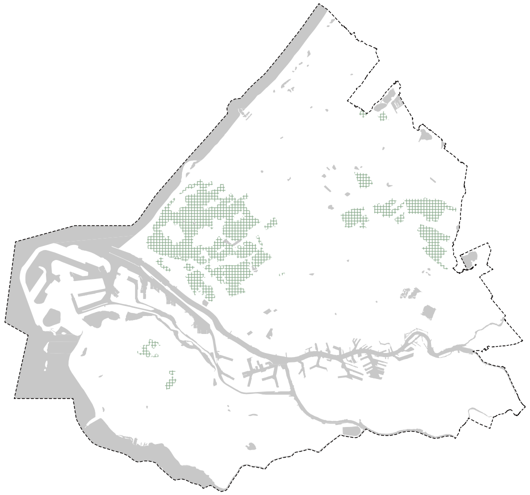
Visualization 16. Sustainable energy solution of business park

Map 28. Greemport realm scenario 2050
Data source: ruimtelijkeplannen.zuid-holland.nl



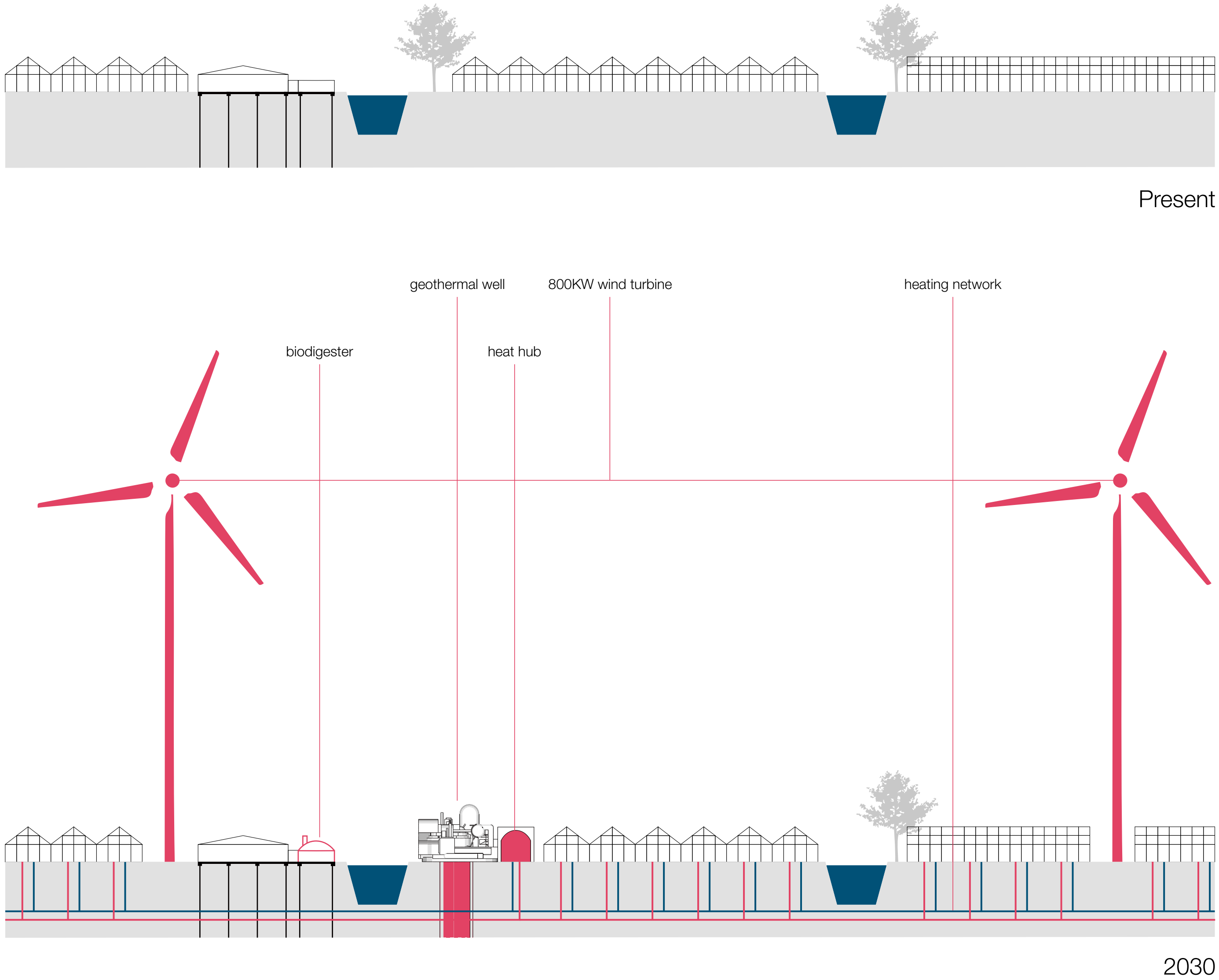
7.6 Greenport Realm Scenarios

Image 84.
Greenhouse



GREENHOUSES

The MRDH accommodates the majority of the extensive and energy intensive Dutch greenhouse sector, as known as 'The Greenport', located in the southwest of the region. This type of landscape is also concentrated around Pijnacker and Bleiswijk, with small capacity scattered in Vierpolders and Tinte. There is no specific goal or proposed future development of greenhouse realm in this region.



The Netherlands has around 4,000 greenhouse enterprises that operate over 9,000 hectares of greenhouses and employ some 150,000 workers, producing €7.2 billion worth of vegetables, fruit, plants, and flowers, some 80% of which is exported. That's why the ecological quality of greenhouse realm is the priority that needs to be preserved. Besides, the clusters of greenhouses are presenting a special and unique view of Dutch landscape.

Within this realm, 800KW wind turbines are installed, while geothermal wells and heat hubs are built to provide heat for vegetations and crops. The residual of greenhouse cultivation is the main source of biomass. For certain areas, greenhouses can be transformed into other functions such as public activity center or education center.

Present (2020)

Image 85. Present condition of greenhouse area
Source: cordis.europa.eu/news/rcn/131226/en

Visualization 17. Sustainable energy solution of greenhouse area

7.7.1 Wind Energy Vision 2050

In 2050, 800KW wind turbines are installed in river delta landscape, westland greenhouse area and harbor industrial area, while 100KW wind turbines are installed in certain protection area. Recreational land and parks are suitable for land art generators such as wind kites or wind flags. Interventions in natural preservations are strictly forbidden. Rooftop wind turbines on business buildings become another way of energy production.

	Scale	Number	Yield (PJ)
Wind Electricity	800KW	2700	25.66
	100KW	1480	1.26
	land art generator	665	1.05
	rooftop turbine	2400	0.38
	Total: 28.35PJ/year		

Table 12. Wind electricity production 2050

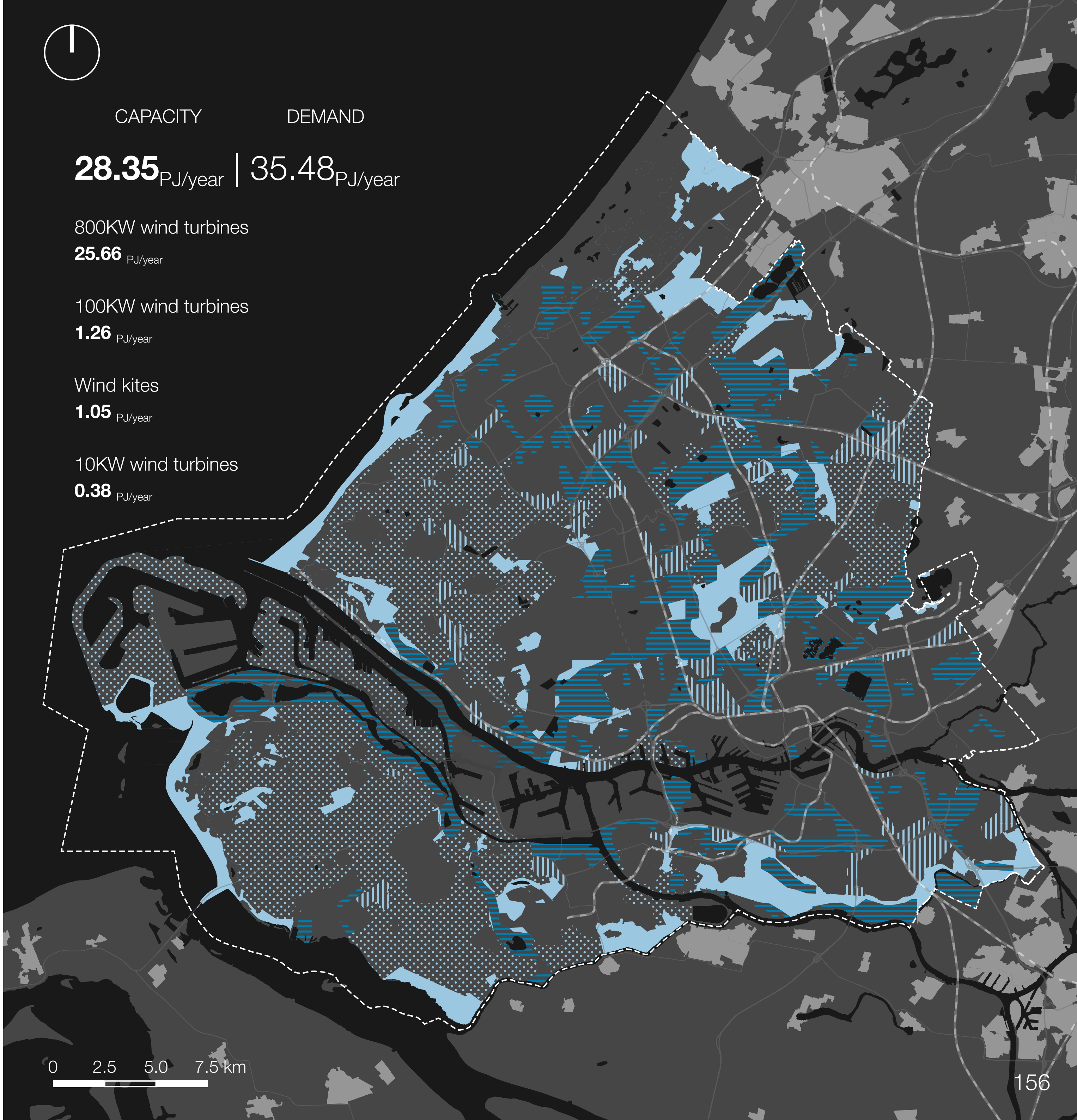
800KW wind turbines

100KW wind turbines

Wind kites

10KW rooftop wind turbines

Map 29. Wind energy vision 2050



7.7.2 Solar Energy Vision 2050

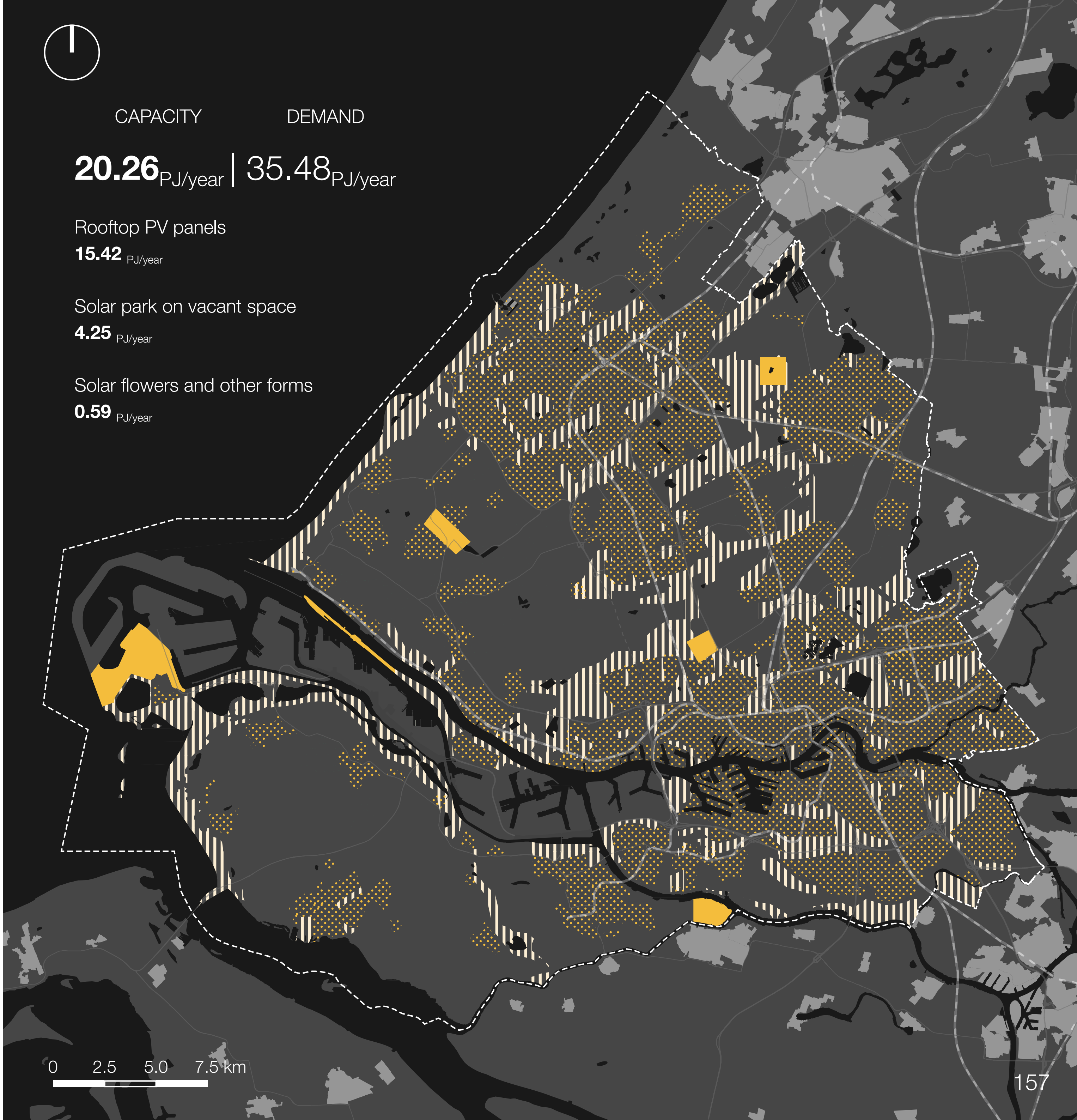
In 2050, it's proposed that all the rooftops that have proper orientation and are suitable for installation will be covered with PV panels (50% of total roof area of the MRDH region). Vacant spaces are transformed into PV fields, counting for more than 20% of solar electricity production. Furthermore, land art generators such as solar shelters or flowers are integrated in recreational land and parks.

	Scale	Area (ha)	Yield (PJ)
Solar Electricity	rooftop PV panel	476.0	15.42
	land art generator	18.2	0.59
	PV field on vacant space	131.2	4.25
	Total: 20.26PJ/year		

Table 13. Solar electricity production 2050

Rooftop PV panels
Solar flowers and other forms
Solar park on vacant space

Map 30. Solar energy vision 2050



7.7.3 Biomass Energy Vision 2050

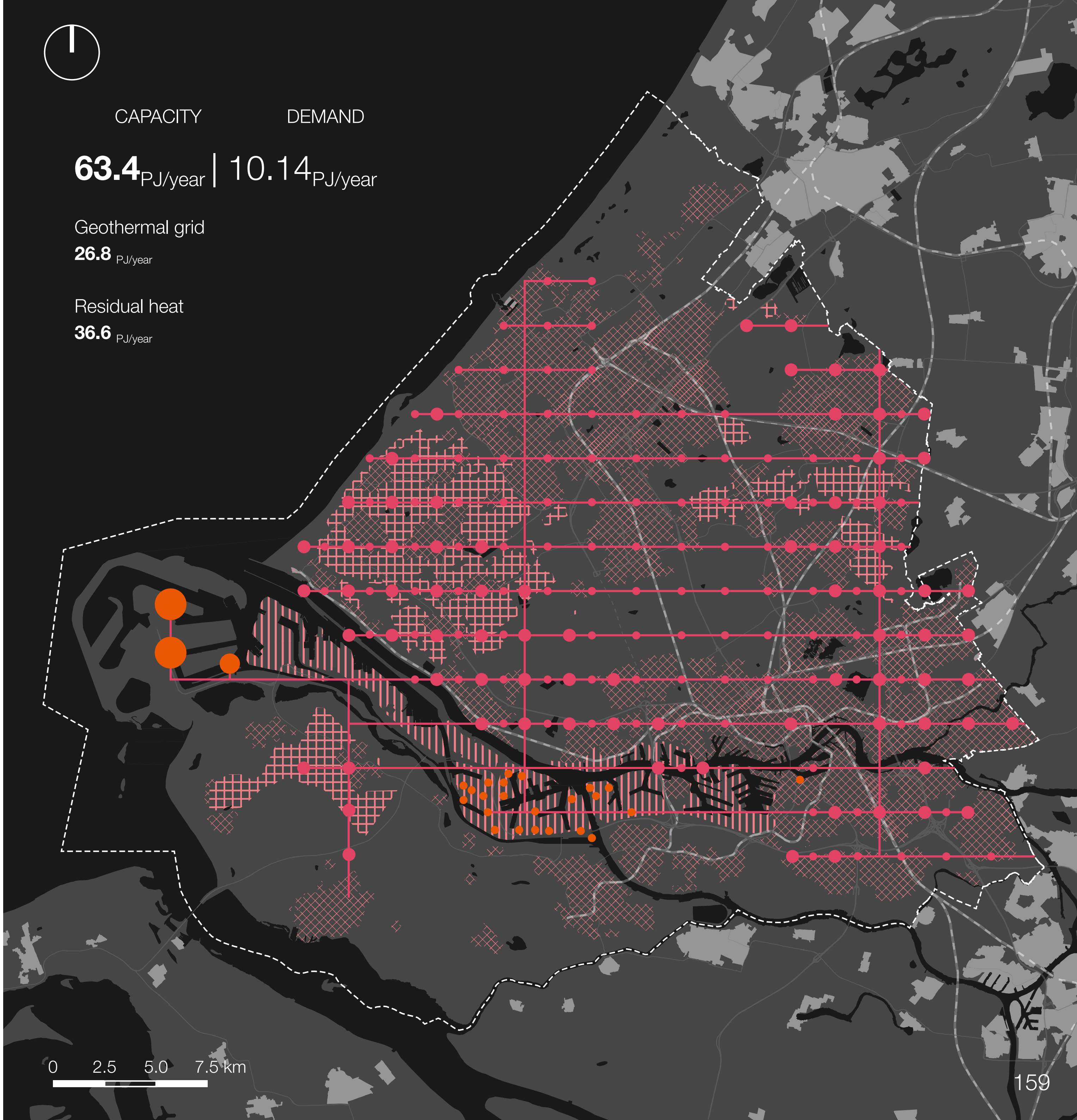
From the analysis in Chapter 6, the biogas potential from manure, food waste and cultivation residual is only 1.24PJ/year, while 2.5% of recreational land and parks will be used to grow energy crops, with an annual yield of 0.23PJ. Therefore, according to 2050 green gas demand, there will still be a shortage of 25.57PJ/year which should rely on biomass import, or the gap can be filled with electricity. For example, electric cars and buses will be more widely used in the future.

- Manual and food waste
- Residual vegetation
- Energy crops
- Biomass energy power plant
- RWZI with biogas production
- RWZI/AWZI with digester
- GFT composting installation

Map 31. Biomass energy vision 2050

7.7.4 District Heating 2050

The district heating demand of the MRDH region in 2050 is 10.14PJ/year. With a total geothermal and residual heat potential of 63.4PJ/year, the heat demand of built environment and mobility sector can be fully satisfied. The greenhouse sector is also attached to district heating network.



Map 32. District heating 2050

08 KEY PROJECTS

Image 86
Source: Beyond the Wave (LAGI 2014)

8.1 Strategic Map

Based on energy vision 2050, the strategic map illustrates the deployment of sustainable energy if the potential has been fully exploited.

Meadow bird preservations are strictly protected from construction activities, while agricultural land, greenhouse areas and artificial islands in the harbor industrial complex are installed with 800KW wind turbines. Rooftops are covered with PV panels and vacant lands are transformed to PV fields. With the main biomass installations in the harbor, residual waste and energy crops are collected and processed there. District heating pipes are subsoil and only geothermal wells are visible.

Recreational lands, parks and business parks are considered as comprehensive energy generation area, for these areas are suitable for multiple energy solutions.

800 KW Wind turbine area

Roof PV panel area

PV field area

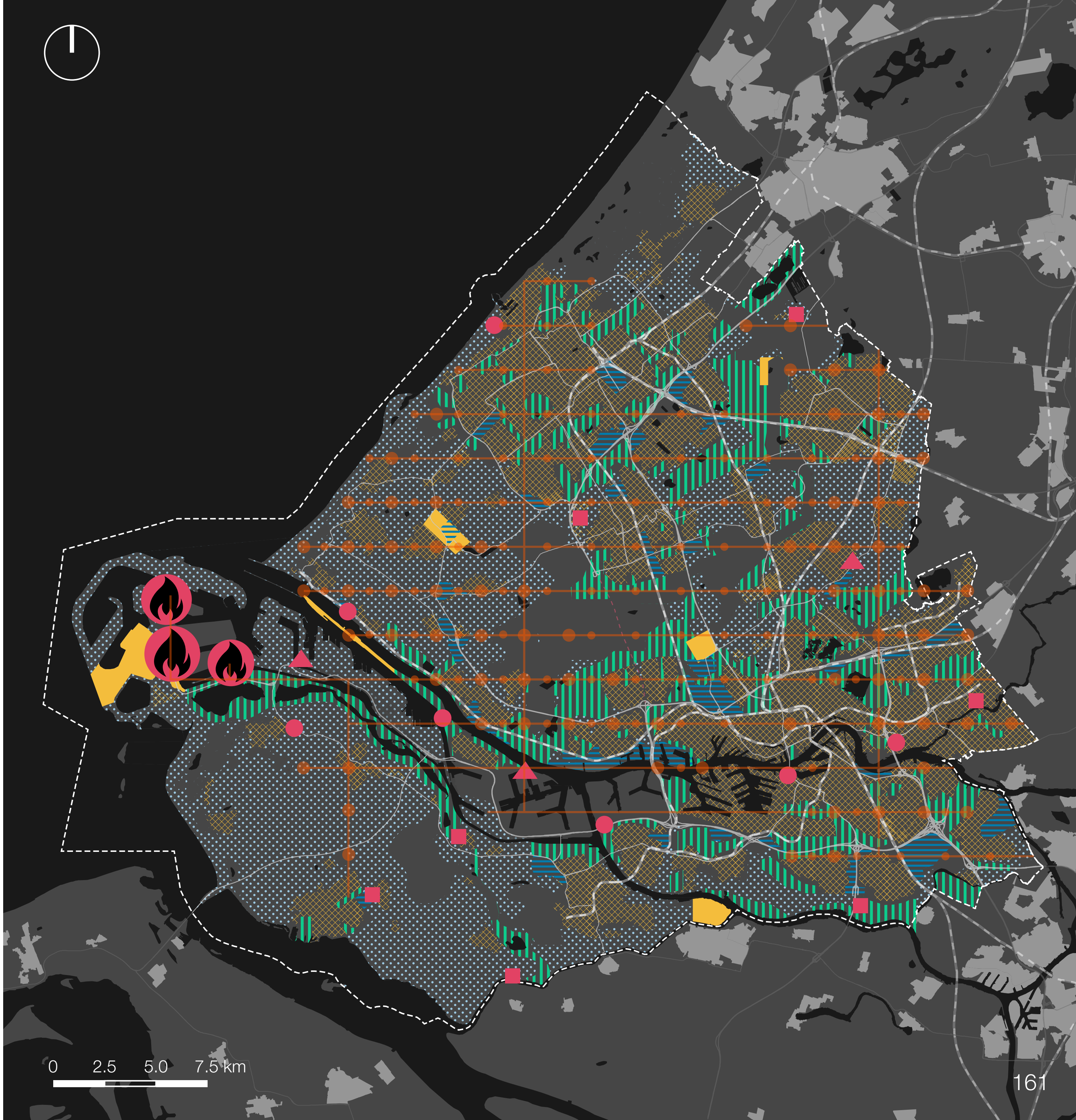
Biomass installations

Comprehensive energy generation area

Energy generation in business area

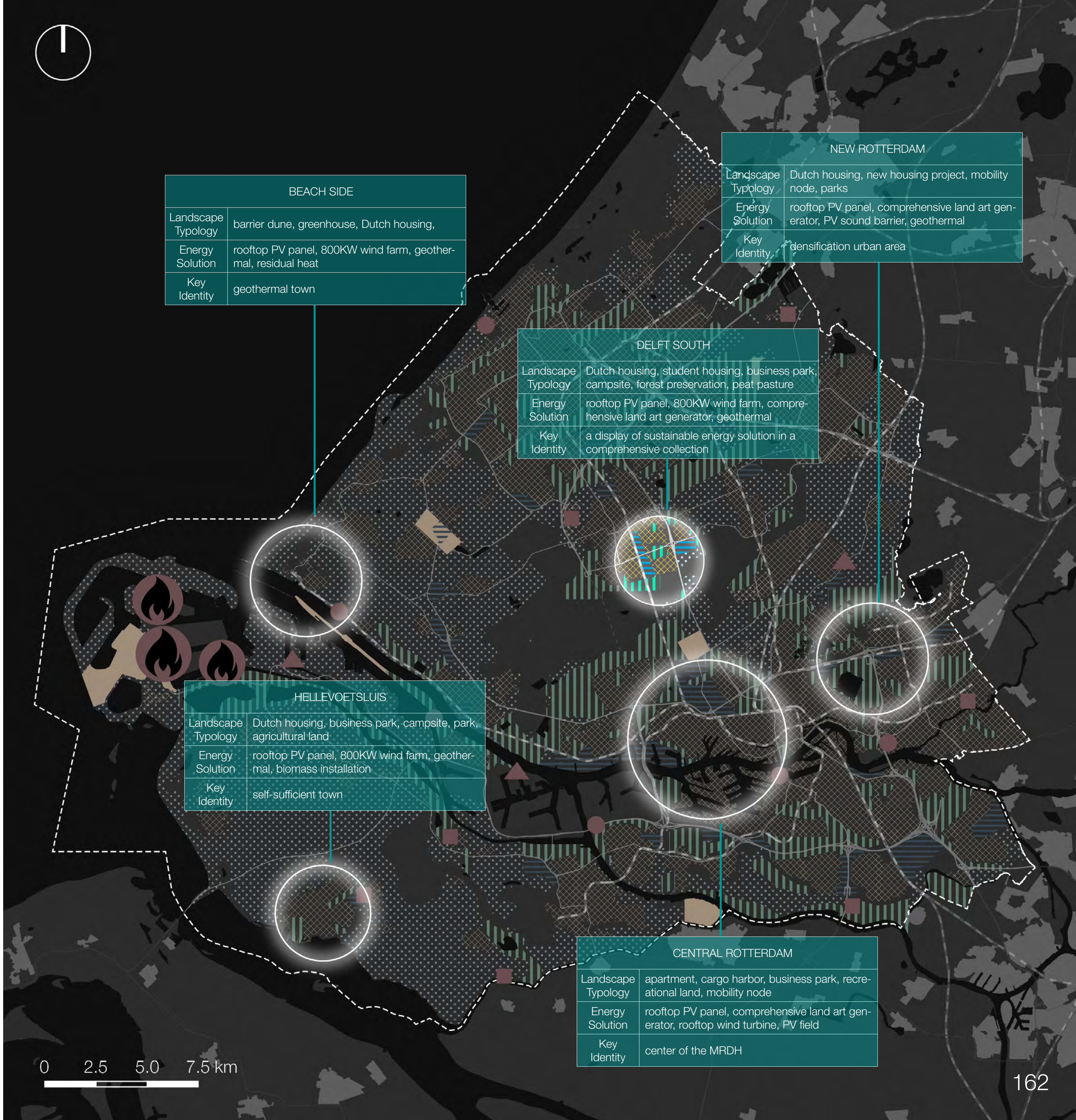
District heating

Map 33. Strategic map



8.2 Key Sites

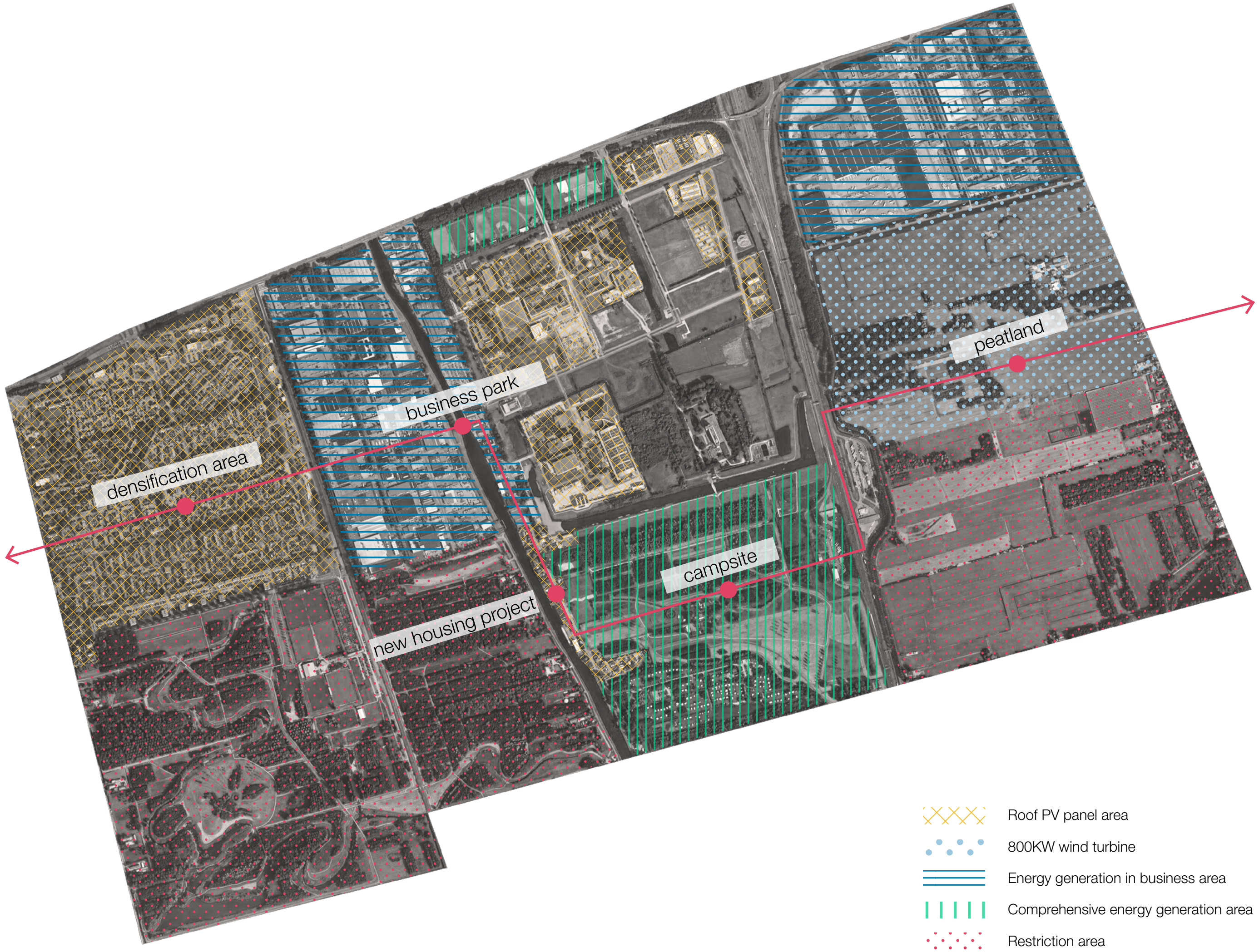
In this research, five areas are defined as key sites, for they shows a wide range of landscape typologies, sustainable energy solutions, becoming pilot demonstrations that attract people and help to rise public awareness. A special identity is attached to each key site to make them distinguished from each other. Here I choose Delft South as prior key site to elaborate further.



Map 34. Key sites map

8.3 Delft South

Surrounded by the largest natural preservation area in the MRDH region, Delft South shows a wide combination of different urban landscape typologies. Dutch neighborhoods, student housing projects, university buildings, business parks, peak land pastures, a forest preservation and a campsite become the patchwork of this area, which makes it a suitable site to demonstrate various sustainable energy solutions.



Map 35. Sustainable energy solution

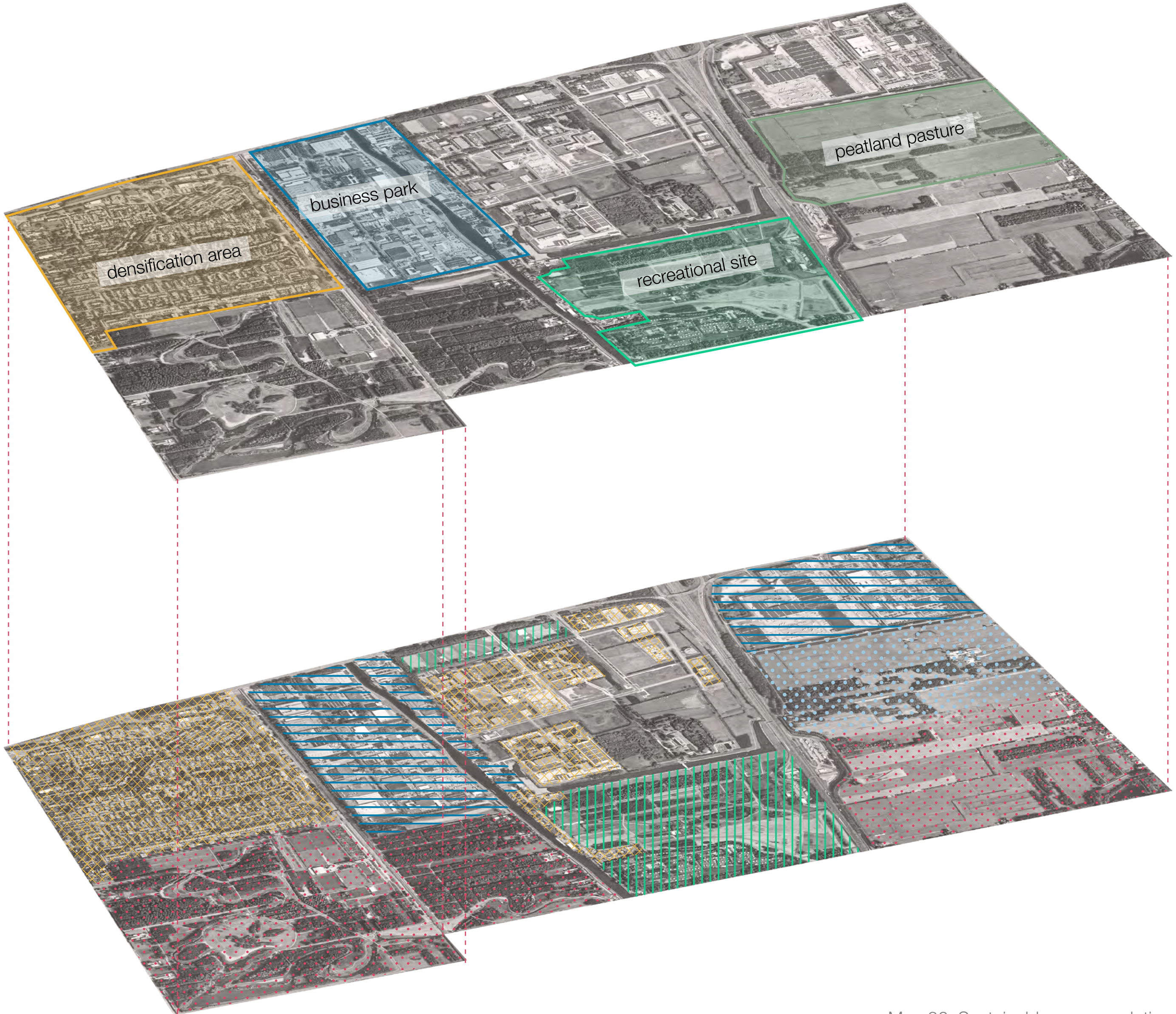
Energy demand per 3000 dwellings:

Elektricity: 10,5 $GWh_{(e)}$
Heating: 26,5 $GWh_{(th)}$ (aeq)

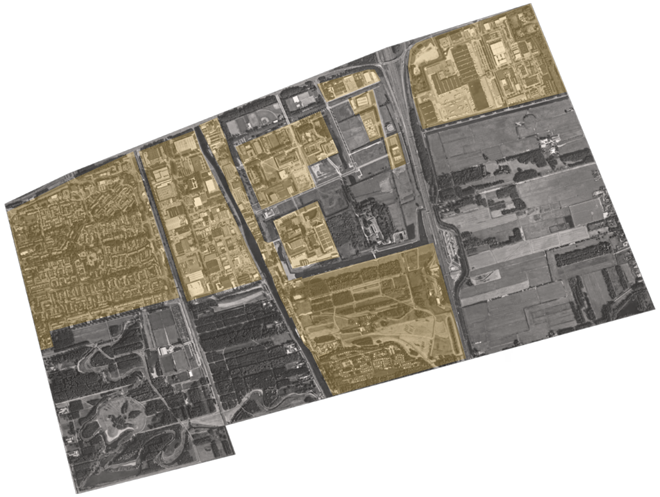
From: Prof. Andy van den Dobbelsteen ,
Delft University of Technology

INFORMATION		
Area (ha)	825	
Households	3243	
Energy demand (GWh)	Electricity	34.05
	Heat	28.65
Energy production capability (GWh)	Electricity	43.78
	Heat	>28.65
	Biogas	3.84

Table 14. Basic information of Delft South
Data source: www.cbsinuwbuurt.nl/



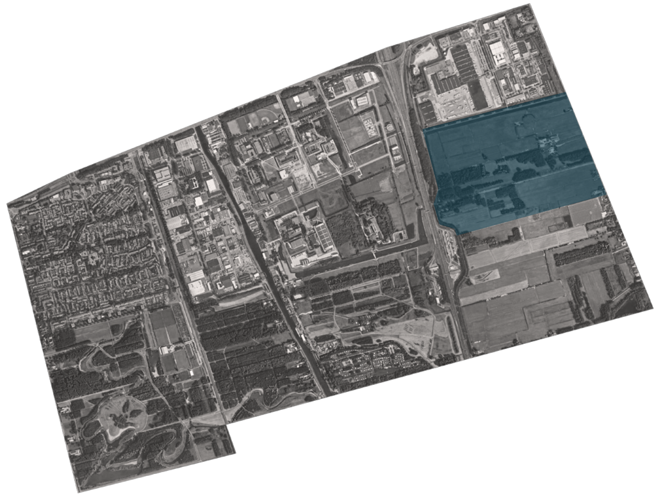
Map 36. Sustainable energy solution



SOLAR POTENTIAL

$40m^2$ PV panels can be installed per household. Building density of business area is 0.1, only 50% of roof is suitable for installation.

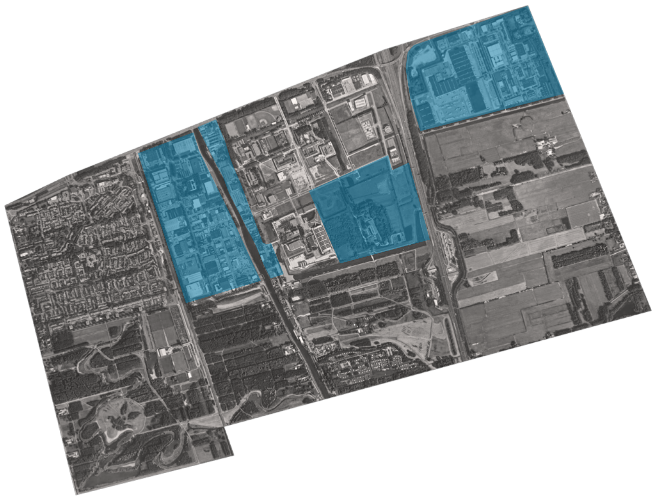
Electricity production
Housing: 15.57 GWh
Business: 7.66 GWh



800KW TURBINE

Average power density: 0.23 GWh/ha

Electricity production: 16.10 GWh



10KW TURBINE

Average yield per turbine at 30m: 5 MWh

Electricity production: 2.65 GWh

WIND KITE

Average power density: 0.025 GWh/ha

Electricity production: 1.80 GWh

WASTE

Per household: 0.57 ton (326 KWh)

Electricity production: 1.06 GWh

BIOMASS INCINERATION

From maintenance of
parks: 4.7 MWh/ha
gardens: 18.9 MWh/ha

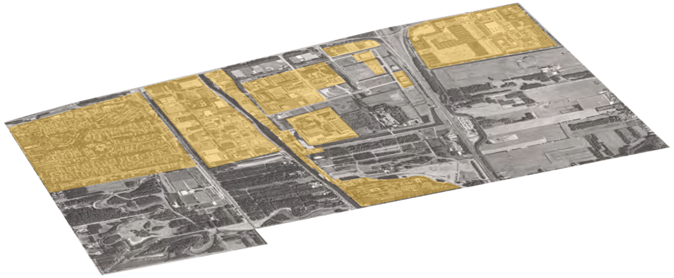
Energy production: 2.78 GWh

RESIDUAL HEAT

There is no residual heat potential in this area.

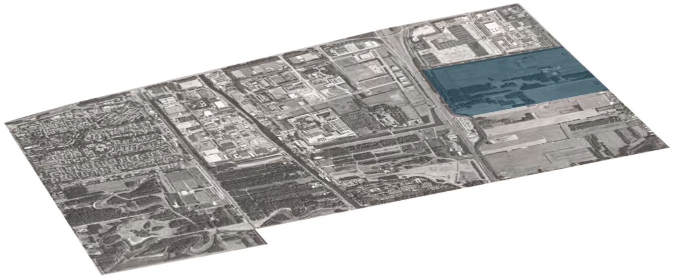
GEOTHERMAL

Connected to the district heating network, the heat demand of this area can be fully satisfied with geothermal heat.



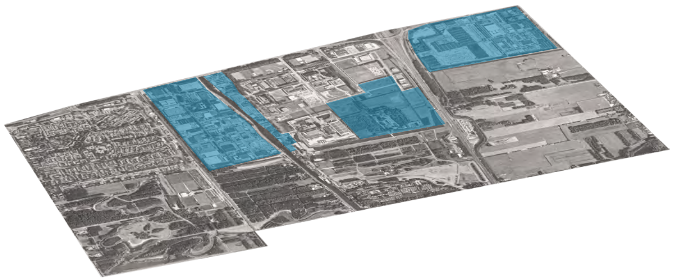
SOLAR

23.22 GWH



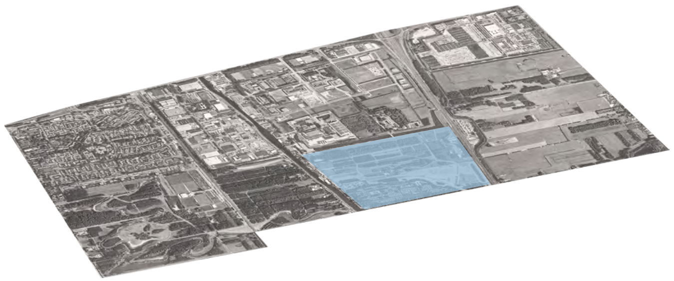
800KW TURBINE

16.10 GWH



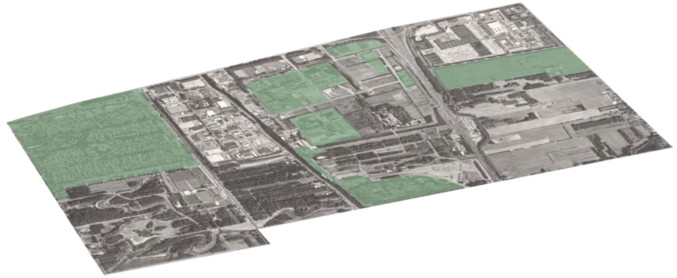
10KW TURBINE

2.65 GWH



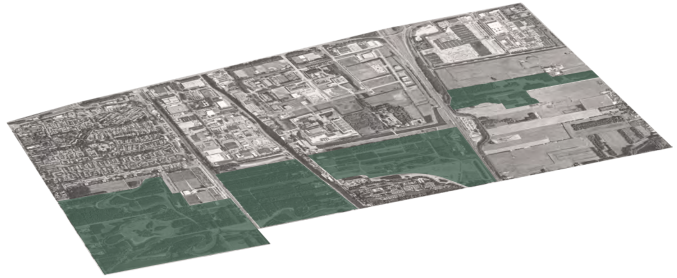
WIND KITE

1.8 GWH



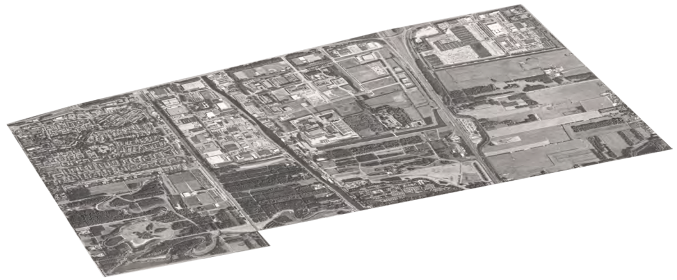
WASTE

1.06 GWH



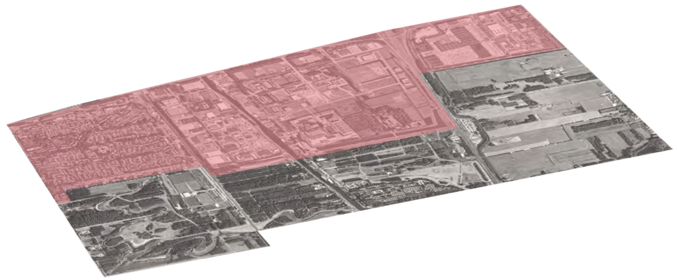
ENERGY CROP

2.78 GWH



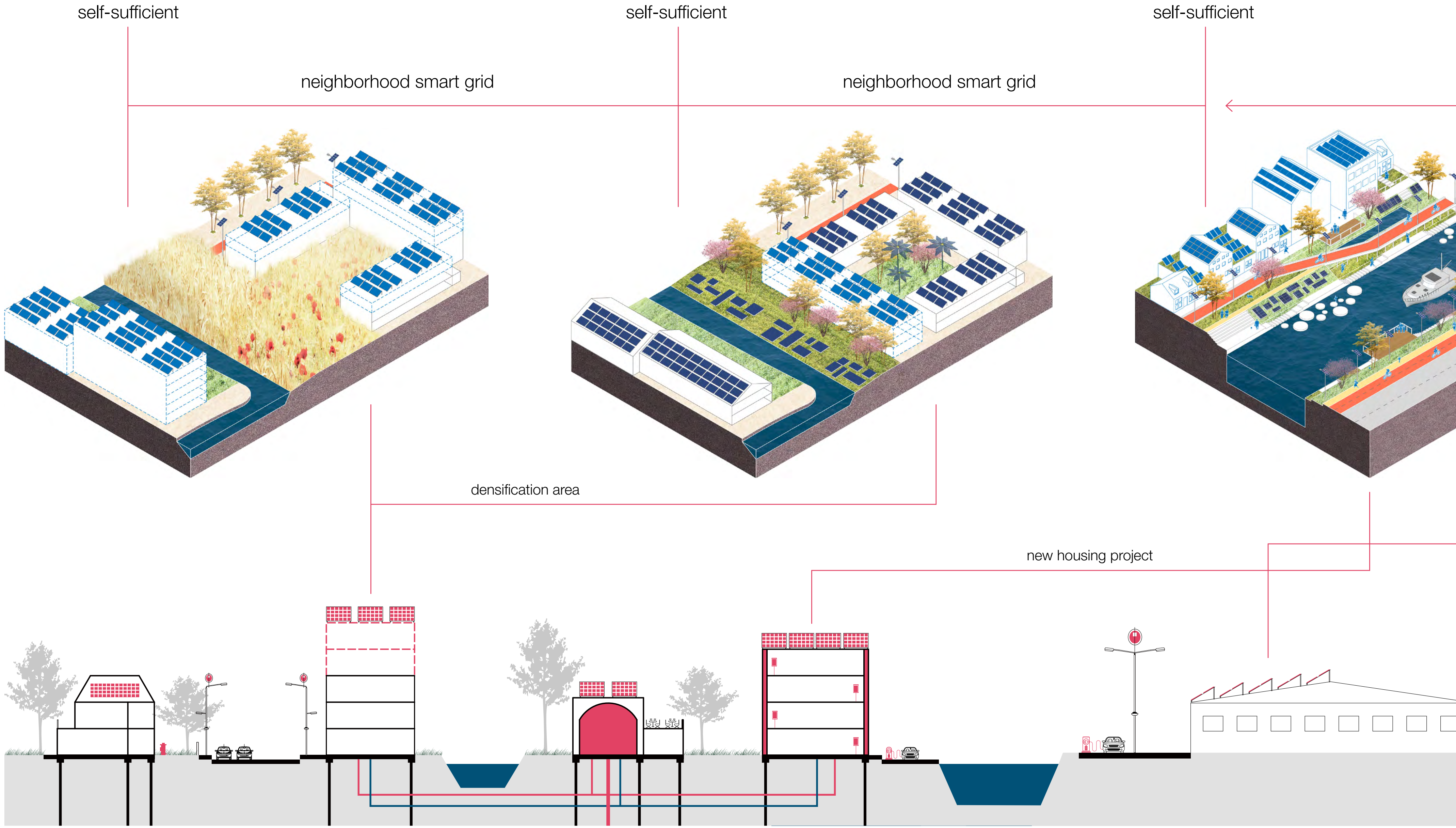
WASTE HEAT

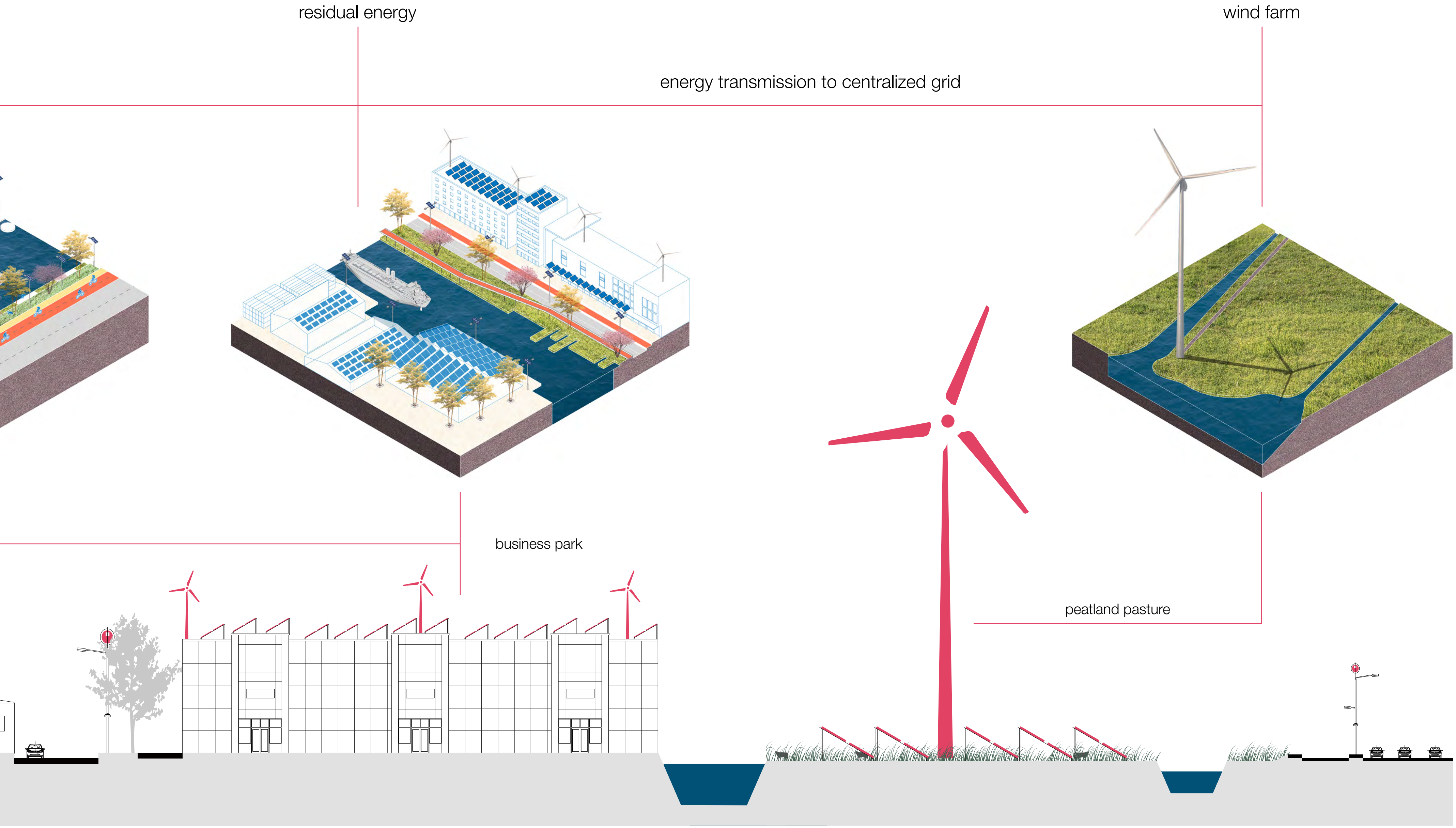
0 GWH



GEOTHERMAL

28.65 GWH


self-sufficient
self-sufficient
self-sufficient
neighborhood smart grid
neighborhood smart grid
densification area
new housing project


residual energy
wind farm
energy transmission to centralized grid
business park
peatland pasture

DENSIFICATION AREA

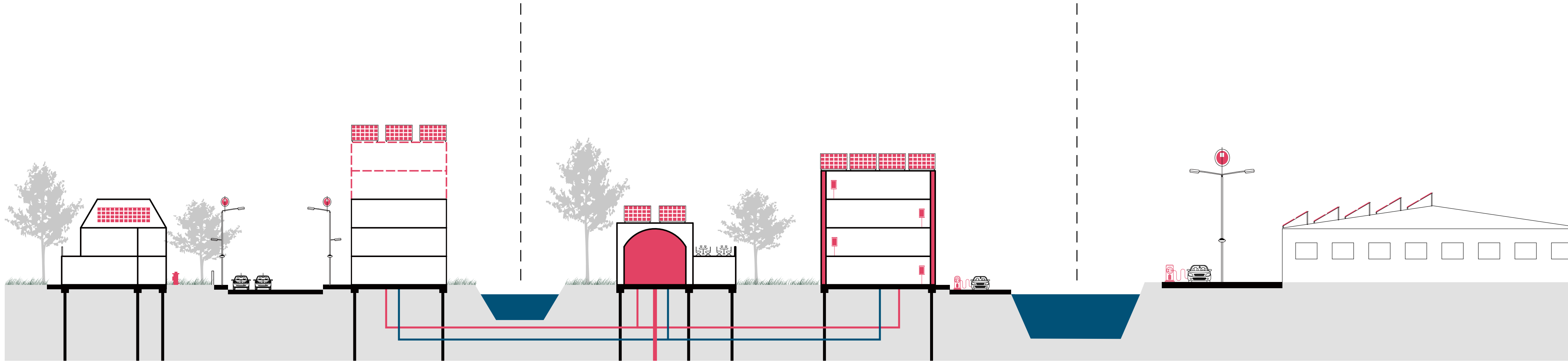
Resident: I'm glad to live in a house or apartment installed with roof PV panels because then I can access to energy market with a lower payment since it is generated on site. Smart devices will help me use energy in a more efficient and energy-saving way. Also, the neighborhood heat hub becomes a public center where local inhabitants enjoy and built their social connection.

Proponents	MRDH Municipality, residents
Opponents	/
Fence Sitters	housing cooperation, infrastructure sector

NEW HOUSING PROJECT

Housing cooperation/real estate company: Though we're supportive to take the responsibility to attribute to sustainable energy landscape, the investment in the beginning is a heavy burden for us. The good thing is that we can make profit from renewable energy installations, but still it would be better if Municipality of the MRDH can provide a subsidy.

Proponents	MRDH Municipality, residents
Opponents	/
Fence Sitters	real estate company



BUSINESS PARK

Company owners: We have already started the process of putting PV panels and small wind turbines on the rooftop to generate energy for ourselves. And we are willing to keep on this trend to generate more renewable energy, contributing to the decentralization energy network.

Proponents	MRDH Municipality, company owners
Opponents	/
Fence Sitters	/

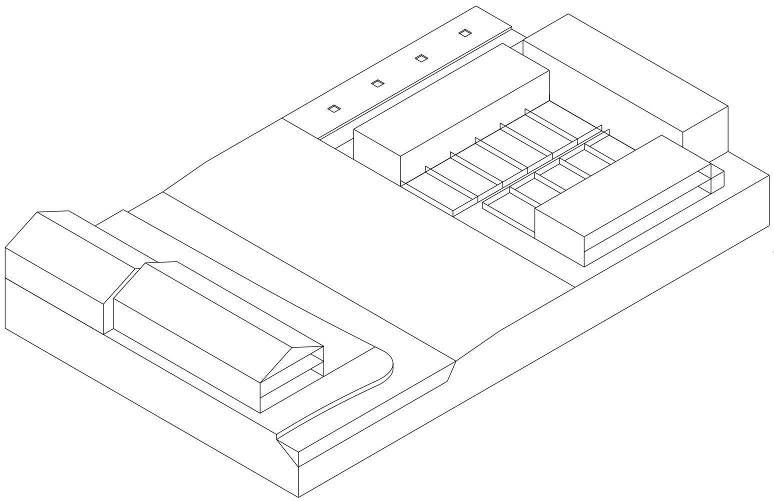
PEATLAND PASTURE

Land owner and farmer: I don't really mind if government install wind turbines or PV panels in my pasture as long as they won't affect my livestocks.

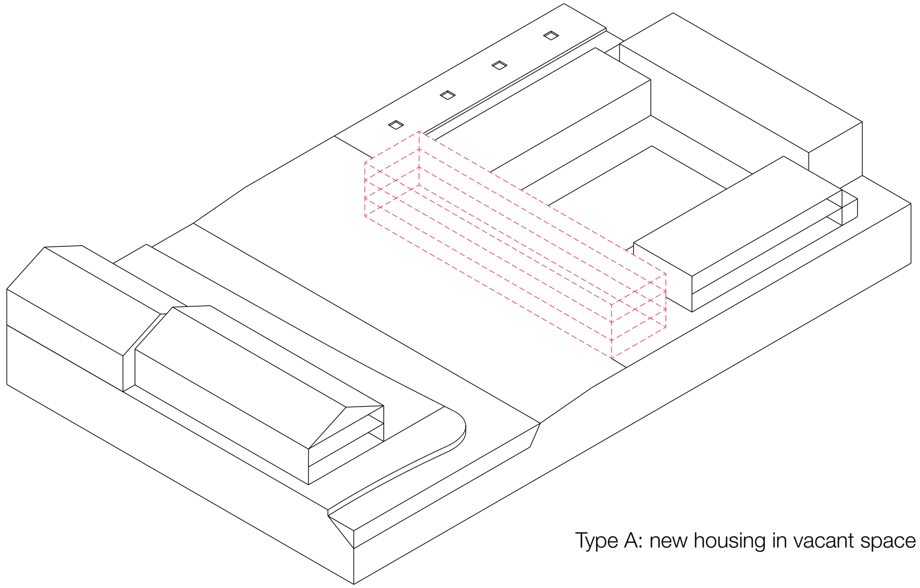
Environmentalist: There are some natural preservations in peatland area which need to be highly protected from disturbance. That's why I'm also against the installation near those areas in order to protect our nature.

Proponents	MRDH Municipality
Opponents	Natuurmonumenten, environmentalist
Fence Sitters	land owners, farmers

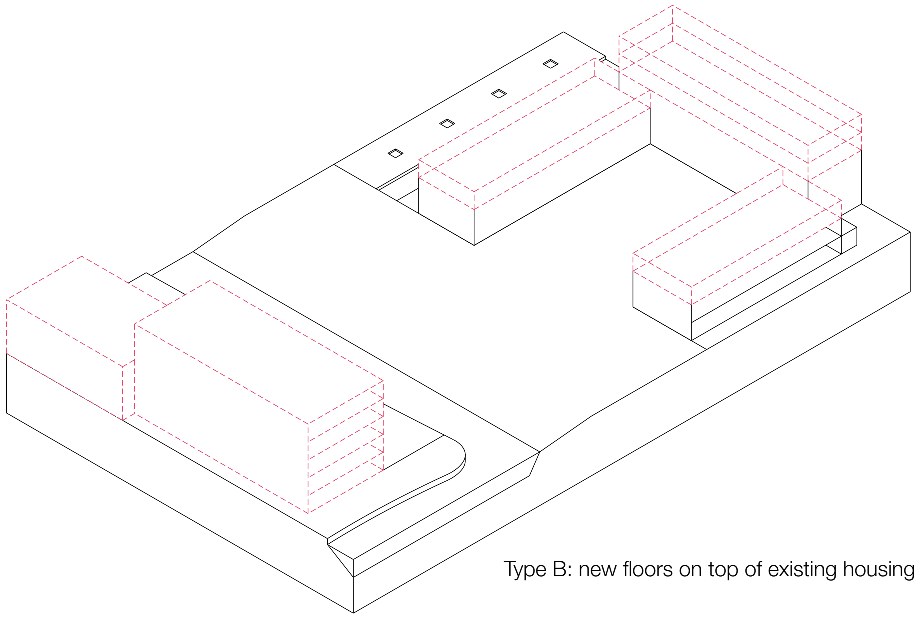
8.2.1 Densification Area



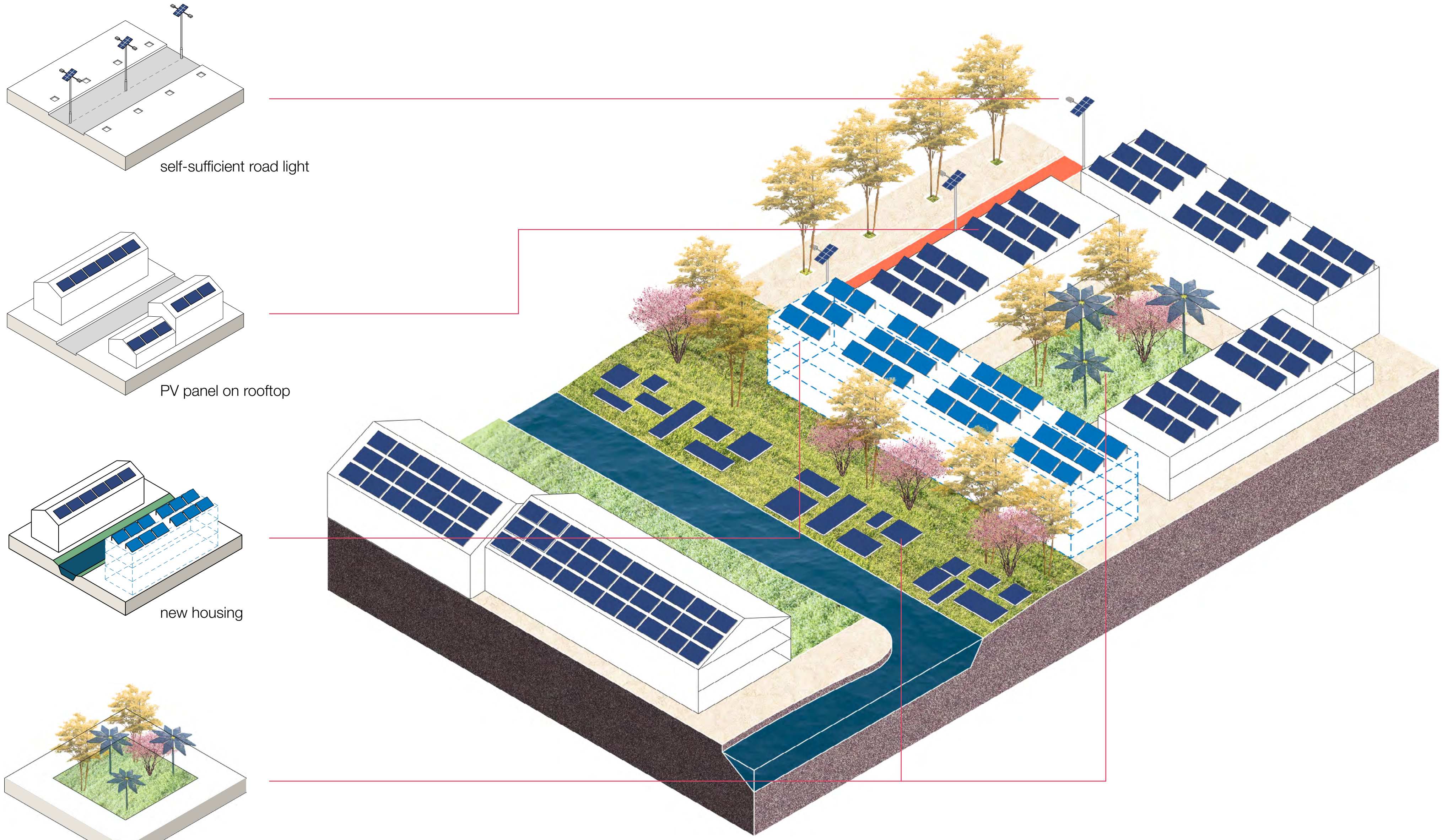
Current condition



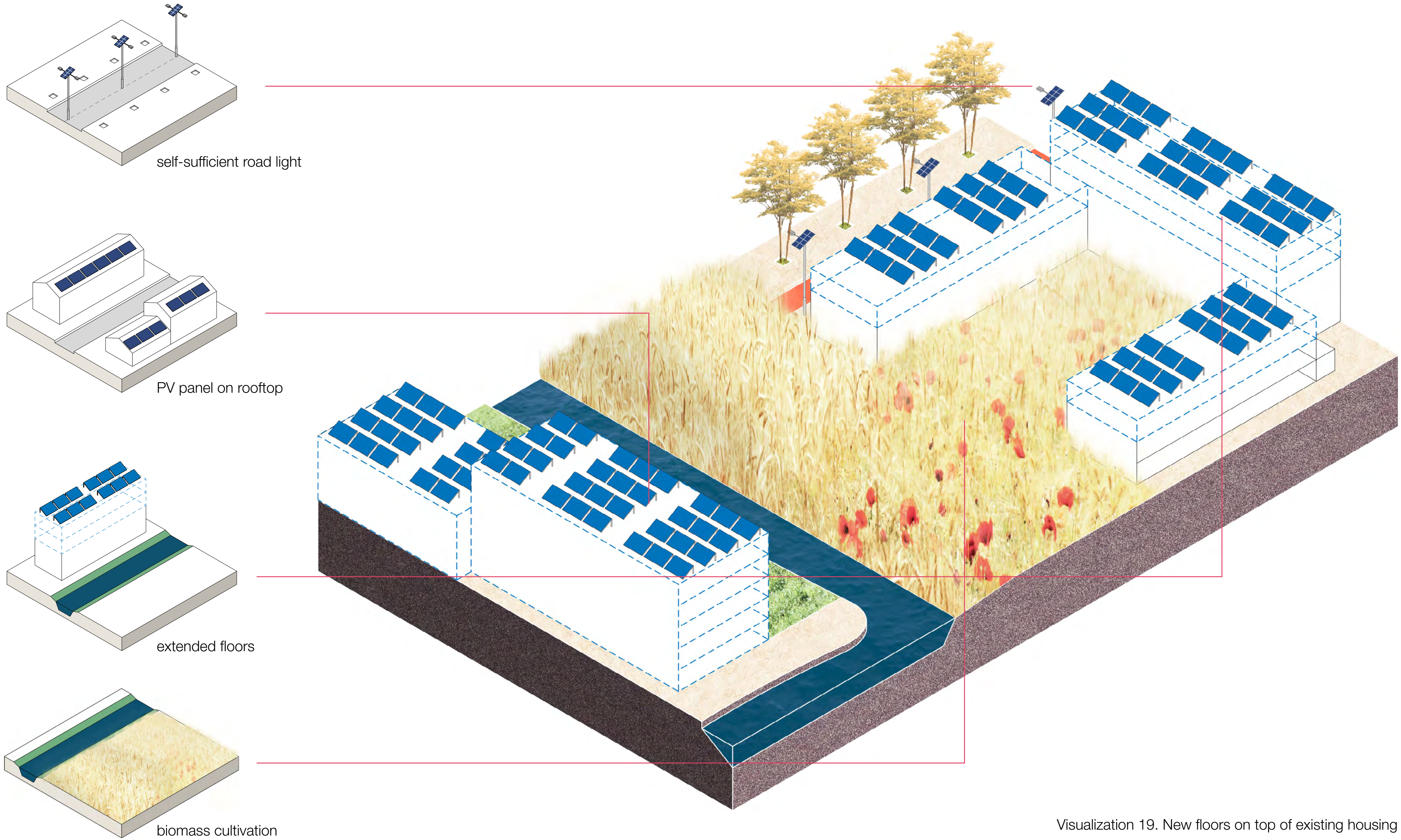
Type A: new housing in vacant space



Type B: new floors on top of existing housing

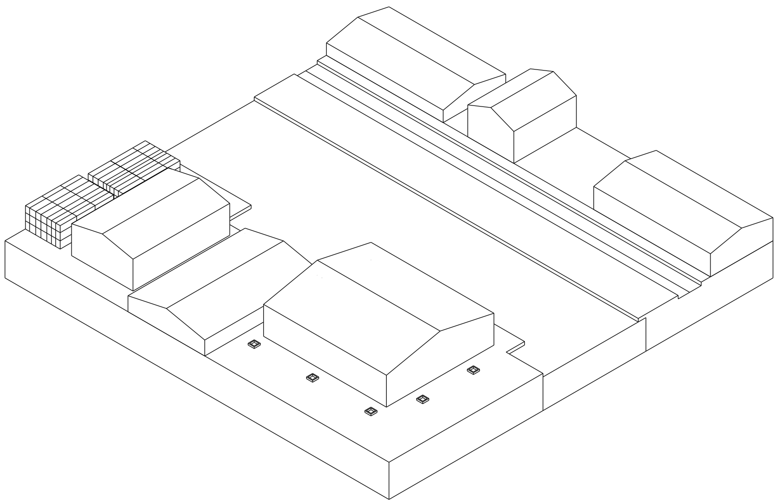


Visualization 18. New housing in vacant space

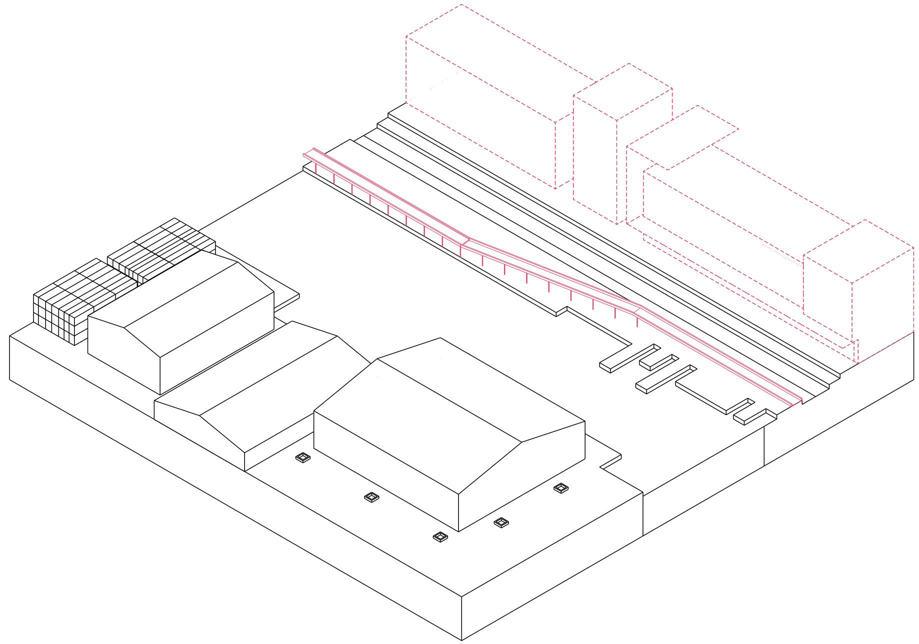


Visualization 19. New floors on top of existing housing

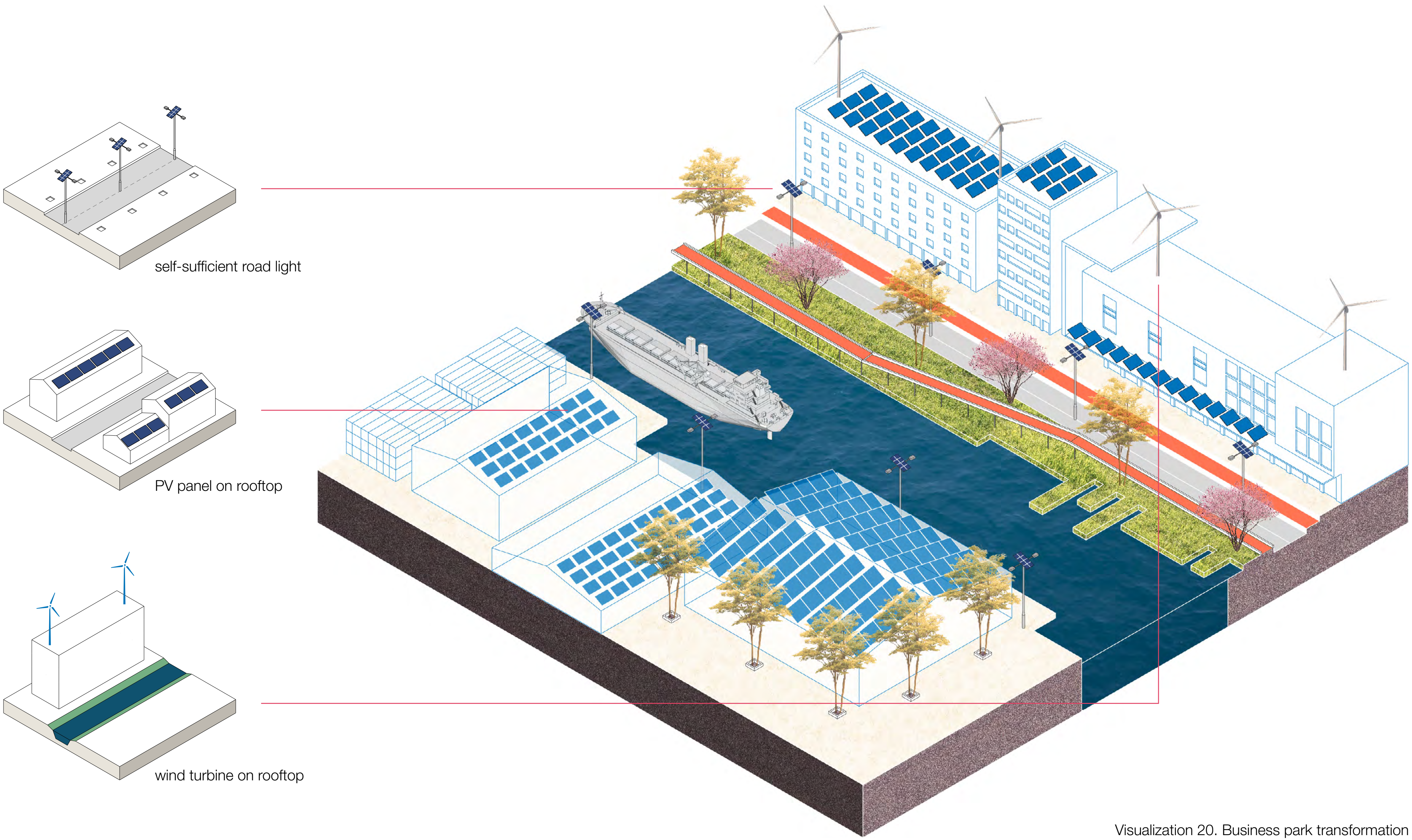
8.2.2 Business Area



Current condition

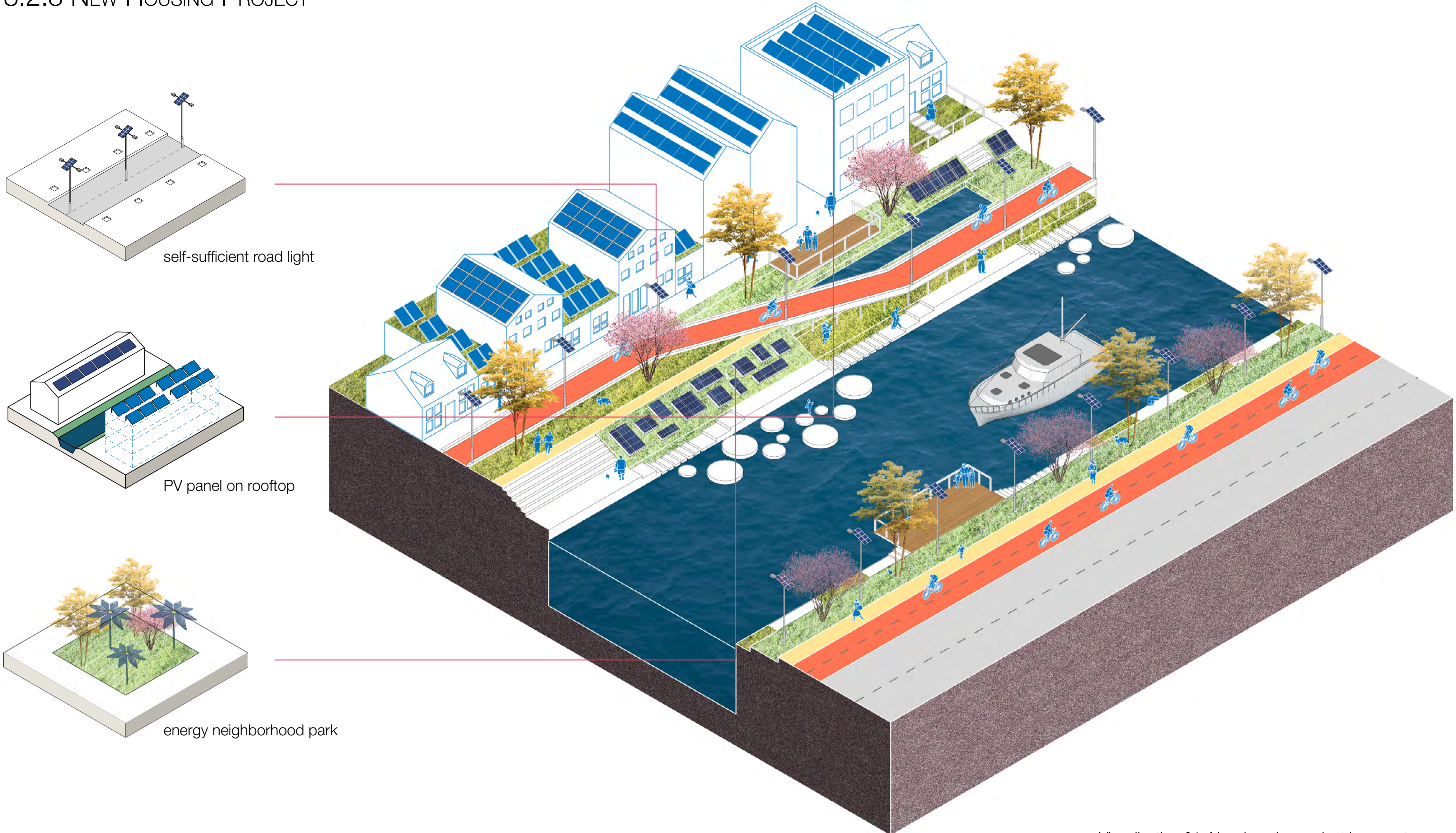


Business park transformation



Visualization 20. Business park transformation

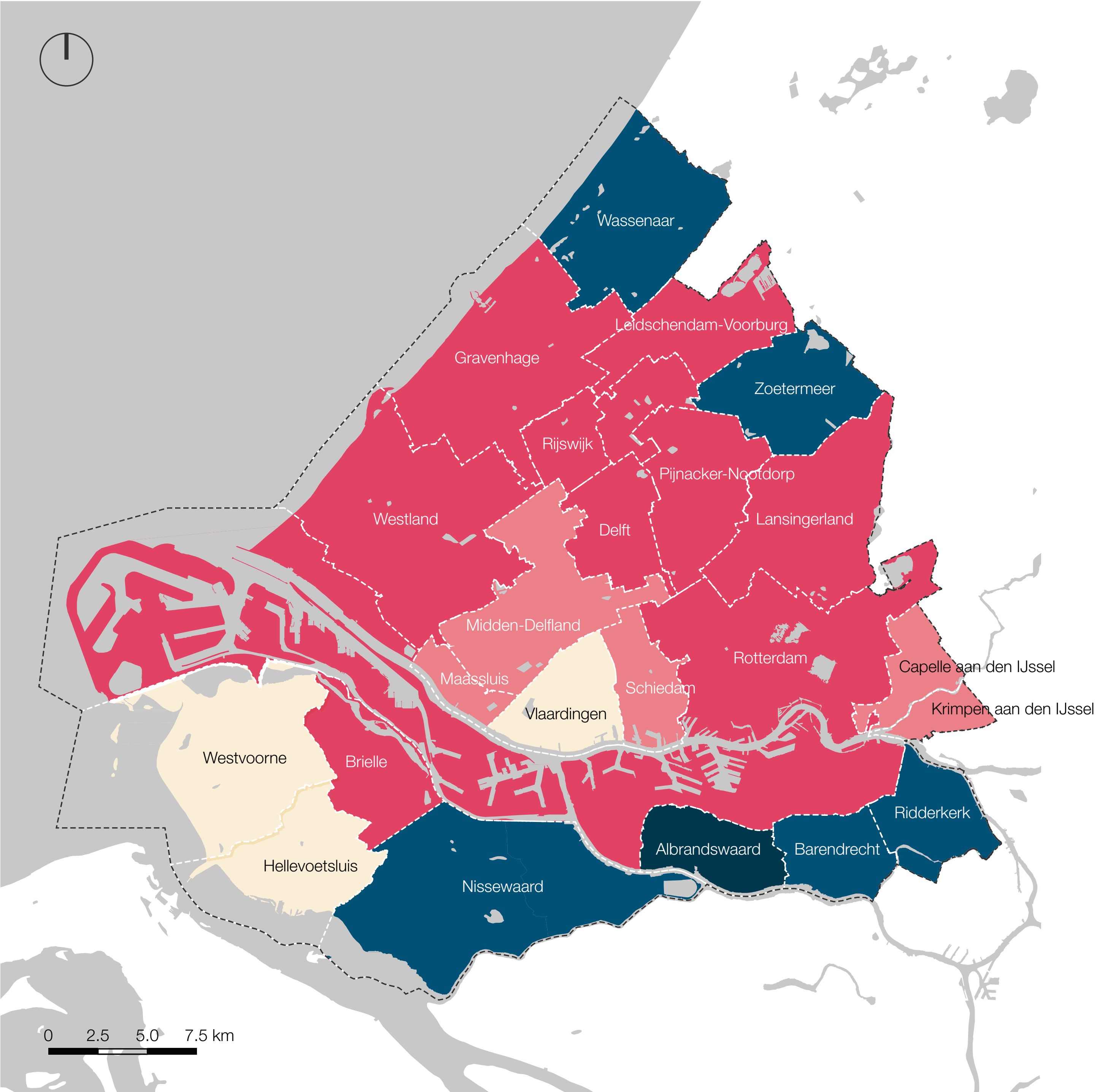
8.2.3 New Housing Project



Visualization 21. New housing project in vacant space

09 EVALUATION AND REFLECTION

Image 87.
Source:



9.1 Evaluation

This chapter consists of two parts: the evaluation of energy production and consumption; and the evaluation from different actors.

For the first part, it's essential to predict the future population in the MRDH region in order to calculate personal energy usage. It is demonstrated in the map that in the next following decades, there will be a significant increase of population because of further development in economy and living environment. Though there are 6 municipalities shows a decrease in the population, most of the municipalities will have a huge increase of more than 10%.

On the other hand, the evaluation of landscape quality is rather subjective. Only the methods of assessment is demonstrated to show how I put glasses of different stakeholders.

Map 37. Population change
Data source: www.pbl.nl/themasites/regionale-bevolkingsprognose/bevolkingsprognoses-2015-2040 bevolking

MUNICIPALITY	POPULATION 2015	CHANGE	POPULATION 2050
Rotterdam	635389	+10% ~ +15%	(698928, 7306970)
The Hague	527748	+10% ~ +15%	(580522, 606910)
Zoetermeer	124971	-10% ~ -2.5%	(112474, 121847)
Westland	106752	+10% ~ +15%	(117427, 122765)
Delft	101400	+10% ~ +15%	(111540, 116610)
Nissewaard	84929	+10% ~ +15%	(93422, 97668)
Schiedam	77920	+2.5% ~ +10%	(79868, 85712)
Leidschen-dam-Voorburg	74788	+10% ~ +15%	(82267, 86006)
Vlaardingen	71972	-2.5% ~ +2.5%	(70173, 73771)
Capelle aan den IJssel	66712	+2.5% ~ +10%	(68380, 73383)
Lansingerland	60904	+10% ~ +15%	(66994, 70040)
Pijnacker-Nootdorp	53420	+10% ~ +15%	(58762, 61433)

MUNICIPALITY	POPULATION 2015	CHANGE	POPULATION 2050
Rijswijk	51742	+10% ~ +15%	(56916, 59503)
Barendrecht	48474	-10% ~ -2.5%	(43627, 47262)
Ridderkerk	45743	-10% ~ -2.5%	(41169, 44599)
Hellevoetsluis	38778	-2.5% ~ +2.5%	(37809, 39747)
Maassluis	32493	+2.5% ~ +10%	(33305, 35742)
Krimpen aan den IJssel	29120	+2.5% ~ +10%	(29848, 32032)
Wassenaar	26101	-10% ~ -2.5%	(23492, 25448)
Albrandswaard	25163	-15% ~ -10%	(21389, 22647)
Midden-Delfland	19244	+2.5% ~ +10%	(19725, 21168)
Brielle	16976	+10% ~ +15%	(18674, 19522)
Westvoorne	14463	-2.5% ~ +2.5%	(14101, 14825)
Total	2335202	—	(2480810, 2609340)

Table 15. Population changes by 2050
Source: www.pbl.nl/themasites/regionale-bevolkingsprognose/bevolkingsprognoses-2015-2040 bevolking

YEAR		POPULATION	ENERGY CONSUMPTION	ENERGY USAGE PER PERSON	ENERGY PRODUCTION CAPACITY	MAXIMUM ENERGY USAGE PER PERSON
2015		2,335,200	131.95 PJ	56.50 GJ		
2050	MILD	+ 144,800 2,480,000	72.67 PJ	29.30 GJ	113.72 PJ	45.85 GJ
	EXTREME	+ 264,800 2,600,000		27.95 GJ		43.73 GJ
MAXIMUM POPULATION		+ 1,733,500 4,068,700				

Table 16. The relation between population, energy production and personal usage

With a current population of 2,335,202 and an annual energy consumption (only including the built environment and mobility sector) of 131.95 PJ, the personal energy usage of the MRDH region is 56.50 GJ/year.

In 2050, the probable increase in the population of the MRDH region ranges from 144,800 to 264,800 people. On the other hand, according to the Gasunie Survey 2050, the annual energy demand will be brought down to only 72.67 PJ, due to possible technical innovation which improves energy efficiency and the public awareness of saving energy. Therefore, the energy usage per person should be lowered to around 28 GJ/year.

Considering renewable energy production, the capacity is 113.72 PJ according to the regional energy vision 2050. Given this amount of energy, the maximum energy usage per person will be around 45 GJ/ year.

In conclusion, if all the on-site renewable energy generated in the MRDH is used within this region, there should be at least 10.65 GJ decrease in personal energy consumption yearly in order to achieve energy neutral. Also, with the optimistic development in energy efficiency and people's awareness of energy saving, if the personal energy usage can be lowered to 28GJ/year, then the on-site renewable energy generated in the region will be sufficient to supply 1,733,500 more people, which provides the MRDH with an advantage of attracting more people living here. Or the residual energy can be transferred to the centralized grid, supplying other regions.

Image 88. AGRICULTURAL LAND BEFORE

Image 89. AGRICULTURAL LAND 2030

ACTORS	ADDED VALUE	DECREASED VALUE
farmer	selling energy crops wind electricity biogas	agricultural profit noise visual disturbance
municipality	wind electricity biogas	investment

Image 90. HOUSING BEFORE

Image 91. HOUSING 2030

ACTORS	ADDED VALUE	DECREASED VALUE
resident	solar electricity district heating public space	
housing cooperative	solar electricity	investment

Image 92. PARK BEFORE

Image 93. ECO-ENERGY PARK 2050

ACTORS	ADDED VALUE	DECREASED VALUE
visitor	visual beauty public space	
environmentalist		ecological value
municipality	attractiveness	investment

Image 94. HIGHWAY BEFORE

Image 95. HIGHWAY 2030

ACTORS	ADDED VALUE	DECREASED VALUE
citizen	noise control road light	
infrastructure sector	solar electricity	investment

9.2 Conclusion

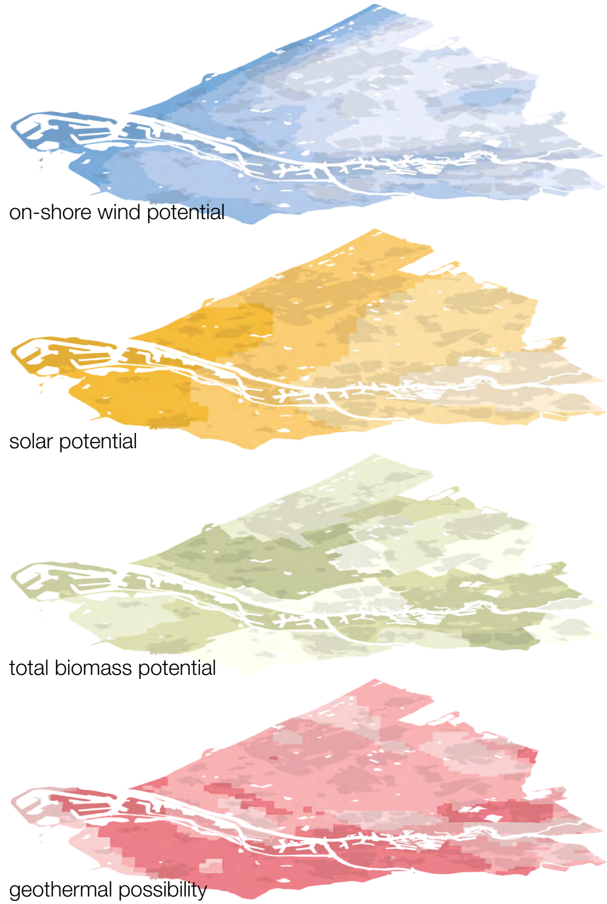
This graduation thesis has been referred to the research field of Urban Metabolism. In this perspective of design, a city or an urban environment is considered as a living organism where all the processes, as known as flows, are in constant movement. These flows are water, waste, energy, food, people, mobility and material flow respectively. The aim of this theory is to organize and manage these flows in a more circular, efficient and sustainable way, which contributes to creating resilient urban environment.

In this research, the flow of energy has been addressed in the first place. As the threats of global warming are becoming more serious and non-negligible, the chief culprit, as known as greenhouse gases which relates to the wide use of fossil fuel energy, has drawn a lot of public attention and rise discussions on the topic of how to reduce the amount of emissions. Therefore, the transition towards sustainable energy production is essential. In the MRDH region, only 2.7% of the total energy consumption came from renewable sources in 2016. Although it seems quite clear that the MRDH region needs sustainable energy solution, still, it's not only a matter of investment or construction. There are some obstacles and back forces against the transition, which relates to the urban landscape where people and renewable energy installations have to share. All these considerations have resulted in the following question that formed the foundation of this thesis:

How to integrate landscape quality in the energy landscape which facilitates sustainable energy transition of the Metropolitan Area Rotterdam-The Hague (MRDH) through spatial planning and design?

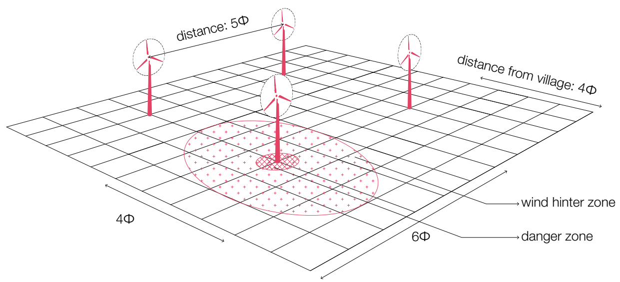
Throughout the thesis, an energy landscape refers to the sustainable supply, demand and infrastructure for energy within a landscape that simultaneously establishes a link between its quantitative energy flows and their spatial footprints, as well as between the perception within its environment and its interaction with the human scale (Wiggers, 2018). Besides, to answer this main research question, six sub-questions are developed. Three of them are descriptive questions which help analyzing and understanding the current conditions of both sustainable energy potential and urban landscape; while the rest three questions are prescriptive questions which aims at building future scenarios and design proposals.

The first descriptive question is '**how to map the potential of renewable energy in the region?**' which

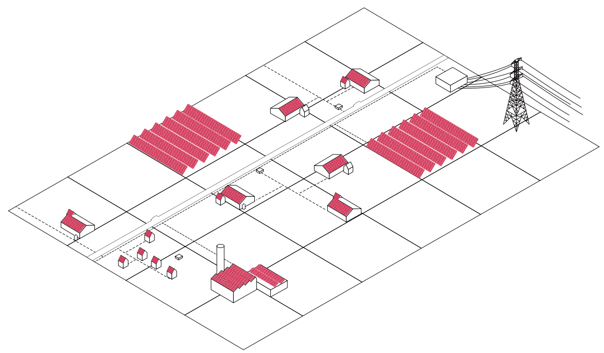


evolves around the possibility of developing renewable energy production in the MRDH but also collaborates with the methods that are being used. The conclusion can be drawn from the mappings that the region not only has an optimistic potential of wind and solar energy, but is also rich in geothermal energy and residual heat potential due to the harbor industrial complex. The annual yield of wind energy depends on the height of wind turbines, while if all the potential rooftops are installed with PV panels, the annual production of electricity will be 20PJ. The total biomass potential of the MRDH region is estimated 1.24 PJ, and the geothermal potential that is suitable for heat distribution 26.8 PJ in 2020. As for residual heat, in the form of hot water, the total potential is estimated 36.6PJ.

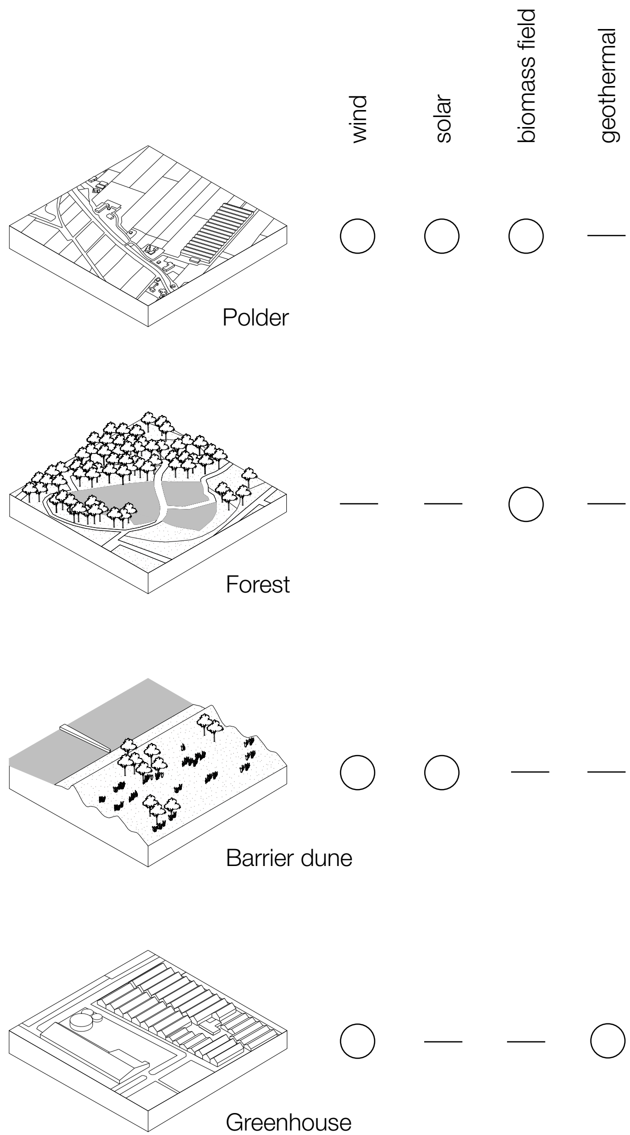
After calculating the potential of renewable energy, the general spatial implementations of renewable energy technologies are defined. For different scales of wind turbines, wind hinter zones, which is 5 times of rotordiameter, are measured to ensure the maximum productivity of turbines. Solar panels should be placed at the most efficient slope of 30° - 40°, and oriented south, southwest and southeast. Standard dimension of normal PV panel is 99 x 165 cm, with an annual production of 90 kWh/m2. For biomass energy, biomass digester and combustion plants don't occupy much space, but cultivating energy crops will take a certain amount of agricultural land. Geothermal energy has the least spatial consequence since almost all the pipes are subsoil, which won't be noticed by most residents and animals. Then the spatial characteristics of urban landscape typologies are illustrated to define the spatial fitness of each renewable energy technology. There are 8 technologies, which are Greenhouse landscape, industrial landscape, forest landscape, peak meadow landscape, urban green landscape, dune barrier landscape, urban construction landscape, mobility landscape respectively.



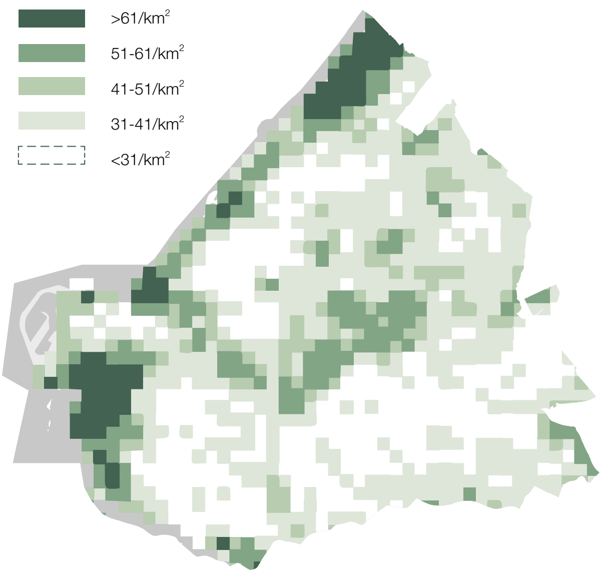
spatial requirement of wind turbine
source: Energy landscape Flemish - POSAD



spatial integration photovoltaic panels
source: Energy landscape Flemish - POSAD



As the term 'landscape quality' has been addressed in the main question, the aim of the third descriptive question is to analyze the current condition of landscape quality. In Theory Chapter, landscape quality that will be influenced by renewable energy technologies is define as economic quality (agricultural land, greenhouse area and recreational land), ecological quality (ecological corridor, species density, acoustic wellness and high voltage buffer zone) and aesthetic quality. Since aesthetic quality is rather subjective and difficult to quantify, a psycho-physical framework called 'Visualands Framework' is used to define the criteria for aesthetic quality. It



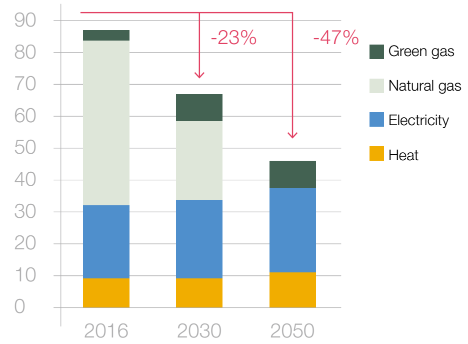
Redlist species density

identifies nine key visual landscape aspects: naturalness, stewardship, disturbance, historicity, visual scale, imageability, ephemera, coherence and complexity. For each of these aspects, landscape attributes and elements contributing to its expression in the visual landscape are identified, as well as currently used visual indicators to assess it.

When three descriptive questions have been answered, prescriptive questions are risen to create design proposals for the future. Firstly, it's essential to predict energy demand of the MRDH region in order to reach energy neutrality. According to a market research done by Agentschap NL, only building-related and use-related energy are included. In this project, energy neutral will be approached as self-sufficient in heat, electricity and natural gas demand for built environment and mobility. The final energy consumption in the built environment will have fallen by 23% in 2030 and 47% in 2050 compared to the present demand, while by 2030, there is estimated to be a significant (around 50%) decrease of fossil fuel consumption in mobility sector due to the popularization of battery-electric vehicles.

The second prescriptive question is 'what are the expected scenarios of landscape quality for different urban realm?' According to the regional developing goal, future scenarios are mapped to perform as base maps where sustainable energy solutions can be integrated. Meadow bird preservations are highlighted where no construction is allowed,

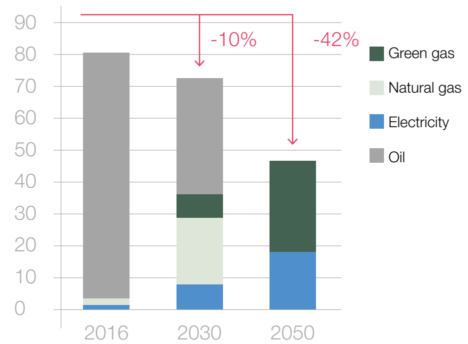
Final energy demand for built environment



	2030	2050
Green gas	+110%	+112%
Natural gas	-50%	-100%
Electricity	+8%	+15%
Heat	-4%	+18%

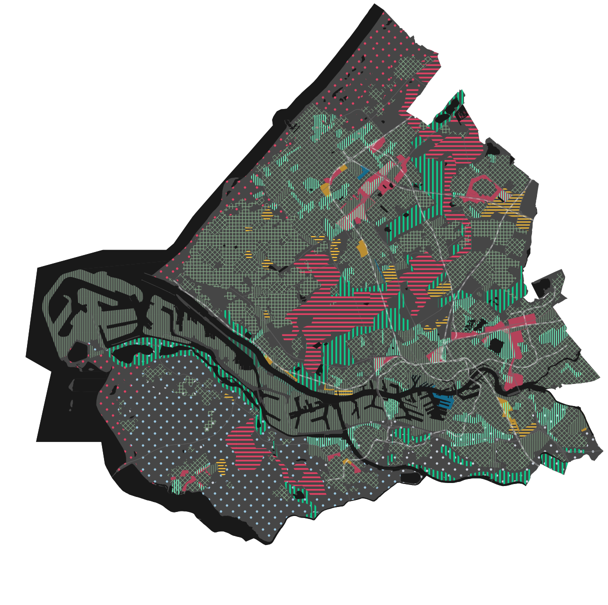
Final energy demand for built environment
Data reference: Gasunie Survey 2050, (2018)

Final energy demand for mobility



	2030	2050
Green gas	+500%	+2000%
Natural gas	+1000%	-100%
Electricity	+450%	+1200%
Oil	-50%	-100%

Final energy demand for built environment
Data reference: Gasunie Survey 2050, (2018)



River delta landscape
Coastal landscape
Meadow bird preservation (no construction)
Recreational area
Existing roof landscape
Urban green
Future-proof neighborhoods investment
Develop nodes
Focuses on transformation areas
Industrial and business area
Hard planned business park
Greenhouse area

Urban landscape of the MRDH 2050

while in protection category and recreational area, installations of renewable energy technologies are limited. Also, future neighborhood investments and business parks are mapped because these areas are in good potential of developing sustainable energy solution. For different realms, due to their specific and unique characteristics, sustainable energy solutions also differ from one place to the other. Then a regional energy vision is drawn from the collection of solutions.

The last prescriptive question is 'how to integrate energy production and landscape quality in spatial interventions?' To answer this question, firstly it's important to define which landscape quality should be preserved or demonstrated in a certain landscape. In order to preserve economic quality, only wind turbines are installed in agricultural land and greenhouse areas because they don't occupy land space. PV field are only deployed in abandoned or vacant space. In recreational land, land art generators are used to not only generate energy but also provide visual beauty to visitors. For ecological quality, natural preservations are strictly protected from any construction activity, while PV panels are placed along railways and highways to perform as sound barriers, which contributes to the acoustic wellness. What's more, impressions are illustrated to show the difference between before and after scenes of sustainable energy solutions.

Image 96. Eco-energy Park

Image 97. Self-sufficient residential district

Image 98. Geothermal greenhouse town

In conclusion, in 2050, 800KW wind turbines are installed in river delta landscape, westland greenhouse area and harbor industrial area (25.66PJ), while 100KW wind turbines are installed in certain protection area (1.26PJ). Recreational land and parks are suitable for land art generators such as wind kites or wind flags (1.05PJ). Interventions in natural preservations are strictly forbidden. Rooftop wind turbines on business buildings become another way of energy production (0.38PJ). The annual production capacity of wind energy is 28.35PJ. On the other hand, it's proposed that all the rooftops that have proper orientation and are suitable for installation will be covered with PV panels (50% of total roof area of the MRDH region, 15.42PJ). Vacant spaces are transformed into PV fields, counting for more than 20% of solar electricity production (4.25PJ). Furthermore, land art generators such as solar shelters or flowers are integrated in recreational land and parks (0.59PJ). The annual production capacity of solar energy is 20.26PJ. With the demand of 35.48PJ in the term of electricity, it can be fully satisfied by wind and solar energy.

The biogas potential from manure, food waste and cultivation residual is only 1.24PJ/year, while 2.5% of recreational land and parks will be used to grow energy crops, with an annual yield of 0.23PJ. Therefore, according to 2050 green gas demand (27.04PJ), there will still be a shortage of 25.57PJ/year which should rely on biomass import, or the gap can be filled with electricity. For example,

CAPACITY DEMAND

WIND ENERGY

28.35PJ/year | 35.48PJ/year

800KW wind turbines
25.66 PJ/year

100KW wind turbines
1.26 PJ/year

Wind kites
1.05 PJ/year

10KW wind turbines
0.38 PJ/year

SOLAR ENERGY

20.26PJ/year | 35.48PJ/year

Rooftop PV panels
15.42 PJ/year

Solar park on vacant space
4.25 PJ/year

Solar flowers and other forms
0.59 PJ/year

CAPACITY DEMAND

BIOMASS ENERGY

1.71PJ/year | 27.04PJ/year

From manure and food waste
1.24 PJ/year

From energy crops
0.23 PJ/year

Shortage (based on future import)
25.57 PJ/year

DISTRICT HEATING

63.4PJ/year | 10.14PJ/year

Geothermal grid
26.8 PJ/year

Residual heat
36.6 PJ/year

electric cars and buses will be more widely used in the future. The district heating demand of the MRDH region in 2050 is 10.14PJ/year. With a total geothermal and residual heat potential of 63.4PJ/year, the heat demand of built environment and mobility sector can be fully satisfied. The greenhouse sector is also attached to district heating network. Even with the possible decay in the industrial sector which might bring down residual heat, the district heating demand can be met with geothermal energy.

Strategic map

9.3 Reflection

The open curiosity over global climate change has become one of the main incentives to start my graduation thesis in Urban Metabolism studio. It is more and more widely acknowledged that global climate change is really threatening the dignity of life of all the species on the earth. Extreme weathers and negative changes in natural characteristics have been observed in many areas of the world. For instance, with 26% of its land lying below the sea level, the Netherlands is under a great pressure of the rising sea level and the change of precipitation pattern. The chief culprit is the greenhouse gas emissions which relates to the use of fossil fuel energy without restraint, calling for an urgent transition from traditional energy system towards a more sustainable one.

With an essential concept of sustainable development, Urban Metabolism aims at researching and developing more innovation and efficient ways of resource management. In terms of energy, it is interpreted into three main topics: (1) renewable energy production; (2) reduce energy demand; (3) create a close loop of energy cycle. My interest towards sustainable energy topic arose after Q3-Studio, when I for the first time tried to decentralize the existing energy network of AMA by promoting neighborhood on-site renewable energy production. Therefore, in my graduation thesis, I would like to continue the research of regional sustainable energy landscape in Urban Metabolism studio, choosing the MRDH region as project site.

With the largest European port and the majority of Dutch greenhouse sector residing within its borders, the MRDH region is the most energy intensive area of the Netherlands. However, only 2.7% of the total energy consumption came from renewable sources in 2016. Although it seems quite clear that the MRDH region needs sustainable energy solution, still, it's not only a matter of investment or construction. There are some obstacles and back forces against the transition. In order to define what the back forces are and structure the whole research process, I developed a 7-stage methodology derived from the 4-step methodology published by Lucienne T. M. Blessing and Amaresh Chakrabarti and the 5-step approach by Stremke:

1. Defining the existing back force
2. Analyzing the current condition
3. Illustrating future scenarios
4. Creating a catalog of general solutions
5. Developing regional energy visions
6. Identifying key spatial interventions
7. Reflecting upon the process

The first step was to define what the possible back force are and whether it can be decreased or eliminated through urban planning and design. Only the problem that is related to space can become the topic of my research. After going through many news and literatures, I found out a practical gap between governmental aspiration on renewable energy generation and local aspiration on landscape quality, which will slow the installation of renewable energy facilities. Therefore, I came up with my research question 'How to integrate spatial quality in the energy landscape which facilitates sustainable energy transition of the Metropolitan Area Rotterdam-The Hague (MRDH) through spatial planning and design?'

After defining the main research question, it comes to the second step: analyzing the current condition. This step provides me with the basic understandings of the MRDH region in terms of renewable energy potential, landscape typology and landscape quality. The data of renewable energy potential is collected from online open sources and demonstrated in mappings, while 3D models and sections are made to analyze landscape typologies in order to draw the spatial fitness maps of renewable energy technologies. The most difficult part is the analysis force landscape quality. Economic quality and ecological quality have objective measurement and can be mapped based on online data sources. However, the aesthetic quality is rather subjective and might differ from person to person. It's almost impossible to quantify and assess the aesthetic quality of landscape. I tried to overcome this problem with the generalization of aesthetic quality criteria. After literature review, I decided to choose a method called 'Visualand Framework' by Tveit, which summarizes 8 criteria to define aesthetic quality. Although it can't cover every aspect, it provides with basic standards on 'what does a good view look like'.

The third step is illustrating future scenarios. Since sustainable energy can't be detached from landscape, it's necessary to predict the future urban landscape of the MRDH region. Data collection for this part is the most difficult one in the whole graduation period, because there's no specific or clear vision on future landscape, and many policies haven't been translated into spatial consequences yet. I reviewed the official web site of South Holland and tried to combine its ecological policies, new housing and business projects, densification areas and recreational sites to develop a comprehensive urban landscape for 2030. The limitation is that the vision I developed is not fixed, so there might be other possibilities or it might change during the development of the region.

Based on the future landscape scenarios, a catalog of general solutions can be developed. The region is divided into 5 different realms. And for each realm, renewable energy technologies are integrated in a form that not only fits the landscape typology but also preserves or improve landscape quality. For example, natural preservation areas should be strictly protected and no construction activity is allowed there, while in recreational areas land art generators are installed to produce energy as well as provide visual beauty. However, although the design proposals in the catalog are supposed to reveal landscape quality, still it's impossible to meet everyone's satisfaction. In order to make the research more reliable, there needs to be an interactive feedback and review session. Ideally, by showing the before and after comparisons to local inhabitants, it can provide a stronger reason why the decision maker should follow the plan or if there needs to be any other change.

Together with the catalog of spatial solutions, regional energy visions are also developed to calculate whether the planning proposal can make the MRDH region energy neutral. The conclusion is that energy generated from wind and solar sources can meet the electricity demand in 2050 and the two sources should be the alternative for each other in case there's no wind or solar. With good geothermal and residual heat potential, the district heating demand can also be fully satisfied. And the overflow heat can be transported to surrounding areas. Only biomass energy capacity is far less than the regional demand which should rely on biomass import, or the gap can be filled with electricity. For example, electric cars and buses will be more widely used in the future.

The last step of design is to identify key spatial interventions. Two key sites will be chosen to have detailed spatial design and test whether the design proposal is coherent with regional vision. The first key site is located in Delft South. I chose this area because it composes with different urban landscape typologies: densification area, business transformation area, natural preservation, railway, highway and peak landscape, which makes it an ideal place to test sustainable energy solutions and draw synergy in between. The problem or the limitation I'm facing is that the existing buildings and environment might change a lot in the future, but if I design a completely new project, it will lose its unique spatial identity. So, what I did is just based on current situation and provide different solutions on sustainable energy, trying to make other elements simpler and more general.

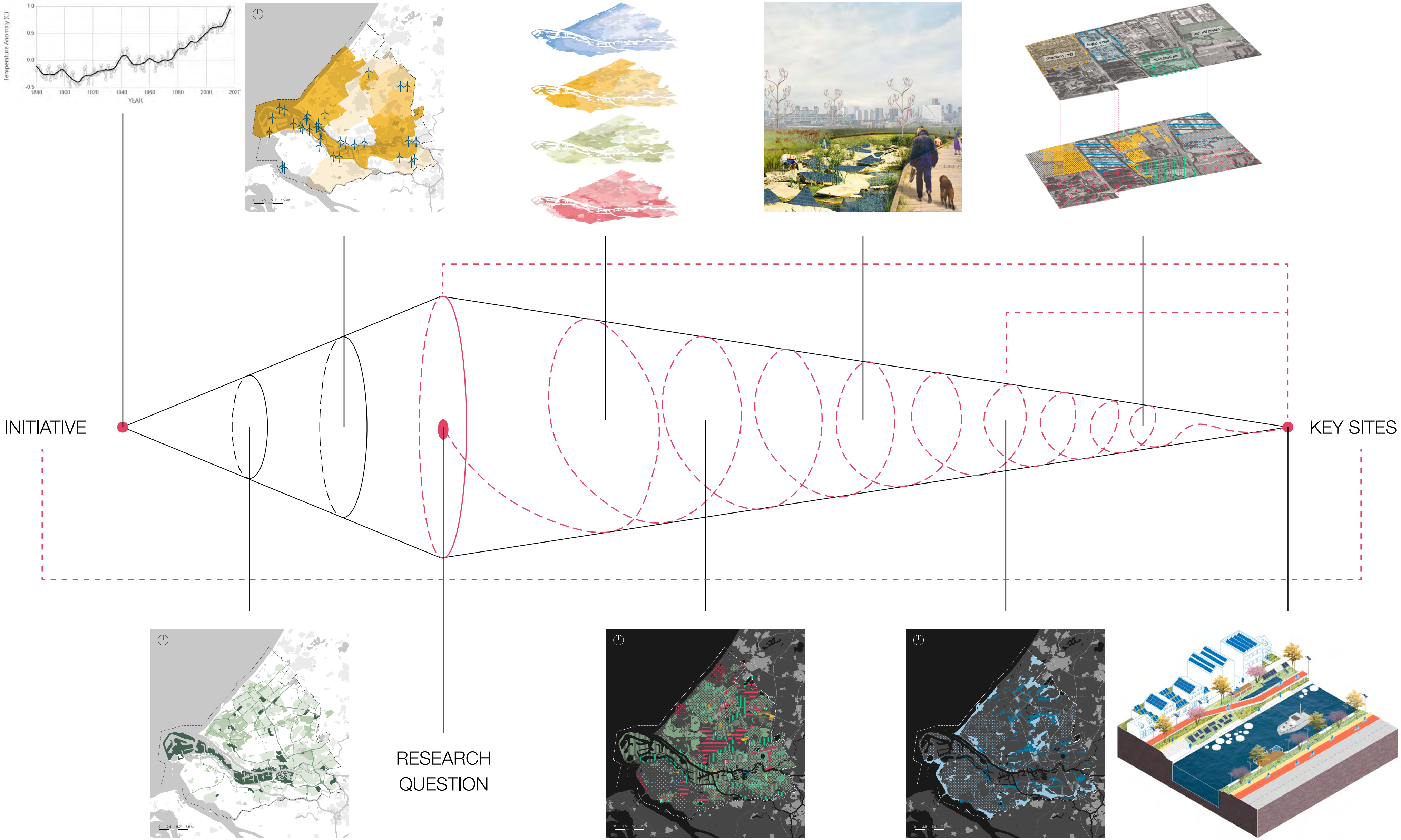
The societal relevance of this theses is revealed at three different scales: neighborhood, regional and European scale. The largest relevance relies on the regional one. The design of sustainable energy landscape will not only generate local on-site energy to make this region more energy independent, but also preserve or improve landscape quality to contribute to creating a more livable MRDH.

In neighborhood scale, one of the main characteristics of sustainable energy landscape is decentralization (on-site production). Energy from renewable sources can be generated on top of your house roof, in the neighborhood playground, and also in parks and other public spaces. It is much closer to our daily life and needs to be integrated into local landscapes which are perceived and sensed by people every day. The high visibility of these installations might cause conflicts with the existing landscape quality and therefore require cautious spatial planning (Boer, 2018). What's more, because of the decentralized system, it's more possible to achieve energy justice. Vulnerable groups who don't have enough or fair access to the energy market can produce energy on their own.

In the larger European or even worldwide scale, the societal relevance is mainly related to generalizing the results of the research. In my research project, the generalization will be possible because I summarized urban landscape typology and developed a general catalog of sustainable energy solutions. The design proposal tested in the MRDH region can be easily duplicated in any other area of the world as long as it demonstrates similar landscape characteristics. If the spatial conditions are very different from the MRDH region, the methodology I used in this project can still be applied. It provides a relatively comprehensive way of integrating landscape quality into the design of sustainable energy landscape.

For the ethical issues, the biggest dilemma is how to balance sustainable energy production and landscape quality. While aesthetic quality can be preserved or added based on the Visualand Framework criteria, economic quality and ecological quality might need to be sacrificed to some extent because sustainable energy generation occupies land space. Then it becomes an ethical problem since different stakeholders stand in different positions. For instance, pasture owners might be against to the installation of wind turbines on their farmland when they are worried about the negative effects on livestock. What's more, since it's a long-term spatial intervention, which area should be the priority is still a problem. In my opinion, vulnerable groups which have trouble accessing energy market need to be taken into special consideration because it's an important part of social justice.

To summarize, I review my research project as a comprehensive solution on sustainable energy landscape design, filling the gap between the governmental aspiration of sustainable energy production and local aspiration of a better living environment.


INITIATIVE
KEY SITES
RESEARCH
QUESTION
YEAR

REFERENCE

Image 99.
Source: en.rotterdam.info/about-rotterdam/architecture/

References

[1] Arriaza, M., Cañas-Ortega, J. F., Cañas-Madueño, J. A., & Ruiz-Aviles, P. (2004). Assessing the visual quality of rural landscapes. Landscape and Urban Planning, 69(1), 115–125. https://doi.org/10.1016/j.landurbplan.2003.10.029

[2] Assink, M., & Groenendijk, N. (2009, April 6). Spatial quality, location theory and spatial planning. Presented at the Regional Studies Association Annual Conference 2009: Understanding and Shaping Regions: Spatial, Social and Economic Futures. Retrieved from https://research.utwente.nl/en/publications/spatial-quality-location-theory-and-spatial-planning

[3] Atlas of the MRDH. (2014). Retrieved from https://mrdh.nl/nieuws/tweede-editie-atlas-mrdh

[4] Bailey, B. H., McDonald, S. L., Bernadett, D. W., Markus, M. J., & Elsholz, K. V. (1997). Wind resource assessment handbook: Fundamentals for conducting a successful monitoring program (No. NREL/SR--440-22223, ON: DE97000250, 486127). https://doi.org/10.2172/486127

[5] Barnett, J., & Adger, W. N. (2007). Climate change, human security and violent conflict. Political Geography, 26(6), 639–655. https://doi.org/10.1016/j.polgeo.2007.03.003

[6] Bazilian, M., Onyeji, I., Liebreich, M., MacGill, I., Chase, J., Shah, J., … Zhengrong, S. (2013). Re-considering the economics of photovoltaic power. Renewable Energy, 53, 329–338. https://doi.org/10.1016/j.renene.2012.11.029

[7] Bech-Danielsen, C. (2013). Vitruvian Perspectives on Architectural Quality: Developing a Vitruvian discussion on green architecture – a starting point for an upcoming research project. Presented at the AESTHETICS, THE UNEASY DIMENSION IN ARCHITECTURE. Retrieved from http://vbn.aau.dk/en/publications/vitruvian-perspectives-on-architectural-quality(954fa26b-017b-4551-b639-20e2cd16501f)/export.html

[8] Benefits of Renewable Energy Use. (2017). Retrieved from Union of Concerned Scientists website: https://www.ucsusa.org/clean-energy/renewable-energy/public-benefits-of-renewable-power

[9] Bindoff, & Willebrand. (2007). Chapter 5: Observations: Oceanic Climate Change and Sea Level - AR4 WGI. Retrieved from https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch5.html

[10] Biomass - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration. (n.d.). Retrieved November 27, 2018, from https://www.eia.gov/energyexplained/?page=biomass_home

[11] Blaschke, T., Biberacher, M., Gadocha, S., & Schardinger, I. (2013). 'Energy landscapes': Meeting energy demands and human aspirations. Biomass and Bioenergy, 55, 3–16. https://doi.org/10.1016/j.biombioe.2012.11.022

[12] Boer, J. de. (2018). An area-based research approach to energy transition (University of Groningen). Retrieved from https://www.rug.nl/research/portal/en/publications/an-areabased-research-approach-to-energy-transition(0b05b909-54a5-4a21-9a35-8a97cee8bb59).html

[13] Bogucki, P. (1996). The Spread of Early Farming in Europe. American Scientist, 84(3), 242–253.

[14] BP. (2004). Statistical Review of World Energy.

[15] Braun, R., Weiland, P., & Wellinger, A. (n.d.). Biogas from Energy Crop Digestion. 20.

[16] Correljé, A., & van der Linde, C. (2006a). En-

ergy supply security and geopolitics: A European perspective. Energy Policy, 34(5), 532–543. https://doi.org/10.1016/j.enpol.2005.11.008

[17] Correljé, A., & van der Linde, C. (2006b). Energy supply security and geopolitics: A European perspective. Energy Policy, 34(5), 532–543. https://doi.org/10.1016/j.enpol.2005.11.008

[18] Daniel, T. C. (2001). Whither scenic beauty? Visual landscape quality assessment in the 21st century. Landscape and Urban Planning, 54(1), 267–281. https://doi.org/10.1016/S0169-2046(01)00141-4

[19] Daniel, T. C., & Boster, R. S. (n.d.). Measuring landscape esthetics: The scenic beauty estimation method. 75.

[20] Dauber, J., Jones, M. B., & Stout, J. C. (2010). The impact of biomass crop cultivation on temperate biodiversity. GCB Bioenergy, 2(6), 289–309. https://doi.org/10.1111/j.1757-1707.2010.01058.x

[21] Dramstad, W. E., Tveit, M. S., Fjellstad, W. J., & Fry, G. L. A. (2006). Relationships between visual landscape preferences and map-based indicators of landscape structure. Landscape and Urban Planning, 78(4), 465–474. https://doi.org/10.1016/j.landurbplan.2005.12.006

[22] Dröge, P., & Messer, P. (2012). European power struggles: Can public resistance be overcome? Retrieved from http://www.pacitaproject.eu/wp-content/uploads/2012/01/SpecialReport.pdf

[23] Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. Renewable and Sustainable Energy Reviews, 39, 748–764. https://doi.org/10.1016/j.rser.2014.07.113

[24] Energielandschappen, de 3de generatie. (2011). Provincie Drenthe.

[25] Environmental impact of biomass | The Renewable Energy Hub. (n.d.). Retrieved November 29, 2018, from https://www.renewableenergyhub.us/biomass-boiler-information/environmental-impact-of-biomass-boilers.html

[26] ENVIRONMENTAL IMPACTS OF GEOTHERMAL ENERGY Based on “A Guide to Geothermal Energy and the Environment” GEA and “The Environmental Impact of the Geothermal Industry” CRES. (n.d.).

[27] Environmental Impacts of Wind Power. (n.d.). Retrieved November 27, 2018, from Union of Concerned Scientists website: https://www.ucsusa.org/clean-energy/renewable-energy/environmental-impacts-wind-power

[28] Extreme Precipitation | GLISA. (n.d.). Retrieved from http://glisa.umich.edu/climate/extreme-precipitation

[29] Extreme Precipitation and Climate Change. (2017, October 11). Retrieved from Center for Climate and Energy Solutions website: https://www.c2es.org/content/extreme-precipitation-and-climate-change/

[30] Extreme precipitation in the Netherlands: An event attribution case study. (n.d.). https://doi.org/10.1016/j.wace.2018.07.003

[31] Flood risks for the Netherlands - PBL Netherlands Environmental Assessment Agency. (2007). Retrieved from http://www.pbl.nl/en/dossiers/Climatechange/content/correction-wording-flood-risks

[32] Franssen, G. (n.d.). Embedding Spatial Quality. 162.

[33] Fthenakis, V., & Kim, H. C. (2009). Land use and electricity generation: A life-cycle analysis. Renewable and Sustainable Energy Reviews, 13(6), 1465–1474. https://doi.org/10.1016/j.rser.2008.09.017

[34] Gasunie. (2018). Gasunie Survey 2050 discussion paper. Retrieved from https://webcache.googleusercontent.com/search?q=cache:N51C-MLfUT5YJ:https://www.gasunie.nl/en/library/

gasunie-survey-2050-discussion-paper+&c-d=1&hl=en&ct=clnk&gl=nl

[35] Gil, A., Calado, H., & Bentz, J. (2011). Public participation in municipal transport planning processes – the case of the sustainable mobility plan of Ponta Delgada, Azores, Portugal. Journal of Transport Geography, 19(6), 1309–1319. https://doi.org/10.1016/j.jtrangeo.2011.06.010

[36] Hare, B., Rocha, M., & Sferra, F. (2016). What does the Paris Climate Agreement mean for Finland and the European Union? Retrieved from https://climateanalytics.org/media/ca_paris_agreement_finland_eu.pdf

[37] Heide, C. M. van der, & Heijman, W. (2013). The Economic Value of Landscapes. Routledge.

[38] Hofman, E. (2015). Social Acceptance of Renewable Energy | Climate Policy Info Hub. Retrieved from https://climatepolicyinfohub.eu/social-acceptance-renewable-energy

[39] Hugron, S., Bussières, J., & Rochefort, L. (2013). Tree plantations within the context of ecological restoration of peatlands: a practical guide.

[40] IPCC - SR15. (n.d.). Retrieved October 19, 2018, from http://www.ipcc.ch/report/sr15/

[41] Janssen-Jansen, L. B., Klijn, E. H., & Opdam, P. (2009). Ruimtelijke kwaliteit in gebiedsontwikkeling. Retrieved from https://dare.uva.nl/search?identifier=d2173f61-47cb-458c-86f5-f0464f8cc371

[42] Klimaat, M. van E. Z. en. (2016, April 28). Energy Report Transition to sustainable energy - Report - Government.nl [Rapport]. Retrieved from https://www.government.nl/documents/reports/2016/04/28/energy-report-transition-tot-sustainable-energy

[43] klimaat_nederland_verandert_sterk.pdf. (n.d.). Retrieved from https://cdn.knmi.nl/system/data_center_publications/files/000/068/525/original/klimaat_nederland_verandert_sterk.pdf?1495621240

[44] Langford-Smith, T. (1969). Coastal sand barrier. Australian Geographer, 11(2), 176–178. https://doi.org/10.1080/00049186908702550

[45] Laurentis, C. D. (2015). Innovation and Policy for Bioenergy in the UK: A Co-Evolutionary Perspective. Regional Studies, 49(7), 1111–1125. https://doi.org/10.1080/00343404.2013.834320

[46] Laurie, I. C. (1974). Aesthetic Factors in Visual Evaluation. University of Manchester, Landscape Evaluation Research Project.

[47] Leeuw, D. P. J. de. (2014, February 3). The energy transition in Dutch spatial planning: two case studies of implementing wind farms in The Netherlands [Bachelor thesis]. Retrieved October 28, 2018, from http://dspace.library.uu.nl/handle/1874/289656

[48] Lemaire, X., & Lemaire, X. (2004). Glossary of Terms in Sustainable Energy Regulation. 11.

[49] Lothian, A. (1999). Landscape and the philosophy of aesthetics: is landscape quality inherent in the landscape or in the eye of the beholder? Landscape and Urban Planning, 44(4), 177–198. https://doi.org/10.1016/S0169-2046(99)00019-5

[50] Louw, E., Needham, B., Olden, H., Pen, C. J., & Haag, D. (2010). 'De toekomst van bedrijventerreinen: van uitbreiding naar herstructurering' Gusta Renes, Anet Wetering, Hugo Gordijn Den Haag: PBL, 2009. 12.

[51] Maas, N., Donker, J., Volkerts, M., Hoondert, W., & d'Huy, K. (2016). Smart Energy Delta. Retrieved from https://mrdh.nl/system/files/projectbestanden/Smart%20Energy%20Delta.pdf

[52] Metropolitan Region Rotterdam The Hague. (2016). Roadmap Next Economy. Retrieved from https://mrdh.nl/system/files/projectbestanden/engels/Roadmap%20Next%20Economy%20in%20brief.pdf

[53] NASA: Climate Change and Global Warming. (n.d.). Retrieved from https://climate.nasa.gov/

[54] NI, A. (2010). Taal, Rekenmethode en Waarde voor CO2 cq. energieneutrale utiliteitsgebouwen. 39.

[55] Oil and gas fields overview | NLOG. (n.d.). Retrieved from https://www.nlog.nl/en/oil-and-gas-fields-overview

[56] Palz, W. (2013). Solar Power for the World: What You Wanted to Know about Photovoltaics. CRC Press.

[57] Pasqualetti, M. J. (2012, September 12). Reading the Changing Energy Landscape. https://doi.org/10.1201/b13037-7

[58] PBL Netherlands Environmental Assessment Agency, J. G. van Minnen, W.Ligtvoet, R. Franken, & L. van Bree. (2013). The effects of climate change in the Netherlands: 2012. The Hague: Netherlands Environmental Assessment Agency.

[59] Photovoltaic barometer 2018 | EurObserv'ER. (n.d.). Retrieved January 10, 2019, from https://www.eurobserv-er.org/photovoltaic-barometer-2018/

[60] Polder. (2019). In Wikipedia. Retrieved from https://en.wikipedia.org/w/index.php?title=Polder&oldid=892667688

[61] Port of Rotterdam. (2019). In Wikipedia. Retrieved from https://en.wikipedia.org/w/index.php?title=Port_of_Rotterdam&oldid=884271542

[62] REN21. (2010). Renewables 2010 Global Status Report. 80.

[63] Saidur, R., Rahim, N. A., Islam, M. R., & Solangi, K. H. (2011). Environmental impact of wind energy. Renewable and Sustainable Energy Reviews, 15(5), 2423–2430. https://doi.org/10.1016/j.rser.2011.02.024

[64] Sathaye, J., Lucon, O., Rahman, A., Christensen, J., Denton, F., Fujino, J., … Kadner, S. (2011). Renewable Energy in the Context of Sustainable Development. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, … C. von Stechow (Eds.), Renewable Energy Sources and Climate Change Mitigation (pp. 707–790). https://doi.org/10.1017/CBO9781139151153.013

[65] Schavemaker, P., & Sluis, L. van der. (2008). Electrical Power System Essentials. John Wiley & Sons.

[66] Schmidhuber, J., & Tubiello, F. N. (2007). Global food security under climate change. Proceedings of the National Academy of Sciences, 104(50), 19703–19708. https://doi.org/10.1073/pnas.0701976104

[67] Sheffield, P. E., & Landrigan, P. J. (2011). Global Climate Change and Children's Health: Threats and Strategies for Prevention. Environmental Health Perspectives, 119(3), 291–298. https://doi.org/10.1289/ehp.1002233

[68] Sloss, C. R., Shepherd, M., & Hesp, P. (2012). Coastal Dunes: Geomorphology.

[69] Slufterdam wind farm upgrade: more power from fewer turbines. (2019, March 15). Retrieved May 14, 2019, from Port of Rotterdam website: https://www.portofrotterdam.com/en/news-and-press-releases/slufterdam-wind-farm-upgrade-more-power-from-fewer-turbines

[70] Solar collector - Energy Education. (n.d.). Retrieved January 10, 2019, from https://energyeducation.ca/encyclopedia/Solar_collector#cite_note-boyle-2

[71] SRREN Report. (n.d.). Retrieved October 25, 2018, from IPCC-WG3 website: http://www.ipcc-wg3.de/srren-report/

[72] Stremke, S. (2010). Designing sustainable energy landscapes: concepts, principles and procedures.

[73] Stremke, S., Van Kann, F., & Koh, J. (2012). Integrated Visions (Part I): Methodological Framework for Long-term Regional Design. European Planning

Studies, 20(2), 305–319. https://doi.org/10.1080/09654313.2012.650909

[74] Tainter, J. (1990). The Collapse of Complex Societies. Cambridge University Press.

[75] Tillie, N. (2018). Synergetic urban landscape planning in Rotterdam: liveable low-carbon cities. Delft: Delft University of Technology.

[76] Tsoutsos, T., Frantzeskaki, N., & Gekas, V. (2005). Environmental impacts from the solar energy technologies. Energy Policy, 33(3), 289–296. https://doi.org/10.1016/S0301-4215(03)00241-6

[77] Tuan, Y.-F. (1979). Thought and landscape. In: Meining, D.W. (Ed.), The interpretation of ordinary landscapes. Oxford University Press.

[78] Tveit, M., Ode, Å., & Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. Landscape Research, 31(3), 229–255. https://doi.org/10.1080/01426390600783269

[79] Tveit, M. S., Ode Sang, Å., & Hagerhall, C. M. (2018). Scenic Beauty: Visual Landscape Assessment and Human Landscape Perception. In L. Steg & J. I. M. de Groot (Eds.), Environmental Psychology (pp. 45–54). https://doi.org/10.1002/9781119241072.ch5

[80] UPDATE 1-Dutch government confirms cut in Groningen gas output. (2016, September 23). Reuters. Retrieved from https://www.reuters.com/article/netherlands-gas-groningen-idUSL8N1BZ3LT

[81] UPDATE 4-Dutch to cut output from huge Groningen gas field. (2014, January 17). Reuters. Retrieved from https://www.reuters.com/article/netherlands-gas/update-4-dutch-to-cut-output-from-huge-groningen-gas-field-idUSL5N0K-R1C820140117

[82] Wang, S., & Wang, S. (2015). Impacts of wind energy on environment: A review. Renewable and Sustainable Energy Reviews, 49, 437–443. https://doi.org/10.1016/j.rser.2015.04.137

[83] Whaley, J. (2009, April 1). The Groningen Gas Field. Retrieved from GEO ExPro website: http://www.geoexpro.com/articles/2009/04/the-groningen-gas-field

[84] When Will Fossil Fuels Run Out? - Ecotricity. (n.d.). Retrieved from https://www.ecotricity.co.uk/our-green-energy/energy-independence/the-end-of-fossil-fuels

[85] Wildlife corridor. (2019). In Wikipedia. Retrieved from https://en.wikipedia.org/w/index.php?title=Wildlife_corridor&oldid=893866409