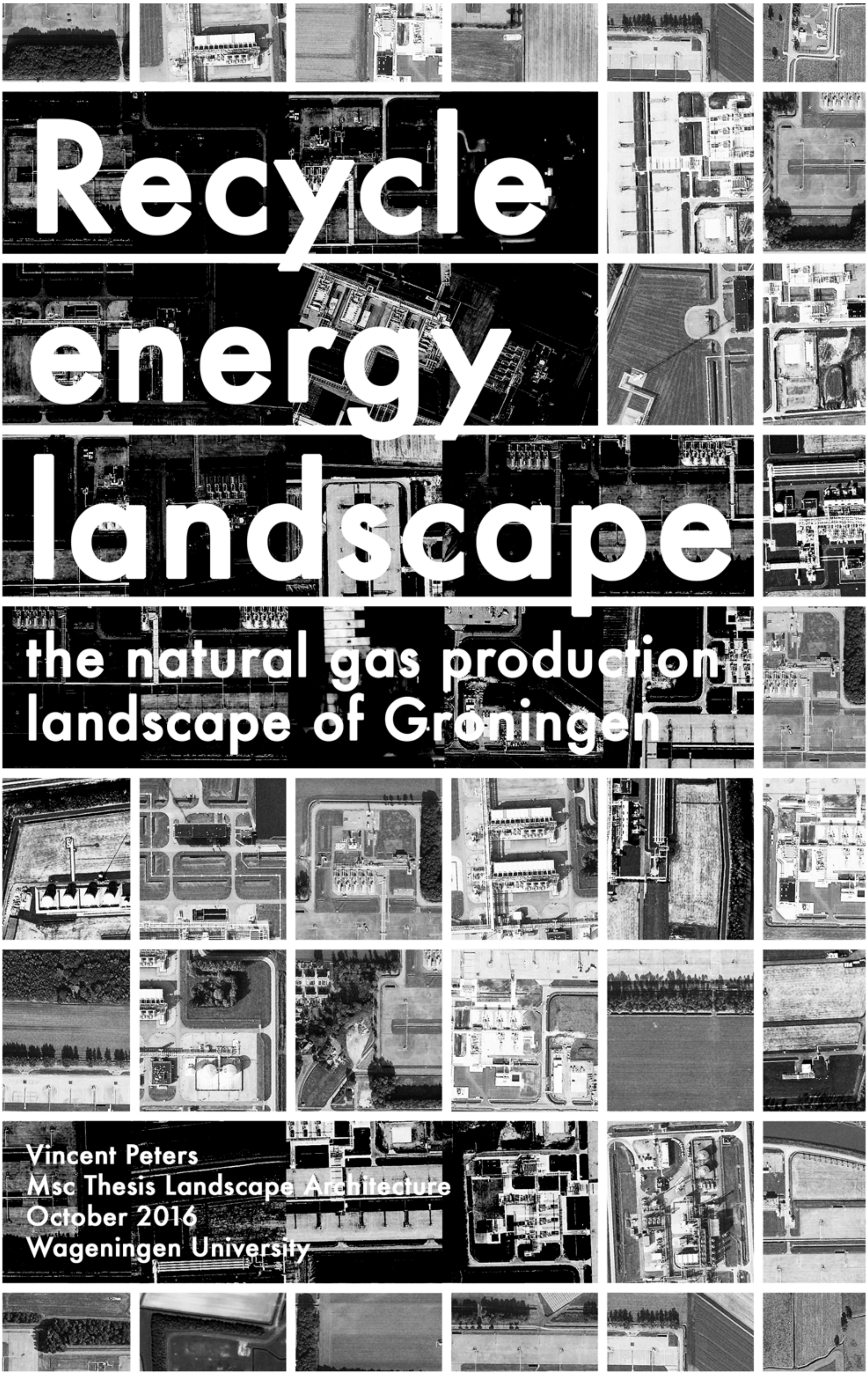

Recycle energy landscape

the natural gas production landscape of Groningen

Vincent Peters
Msc Thesis Landscape Architecture
October 2016
Wageningen University

Recycling energy landscape

the natural gas production landscape of Groningen

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COLOPHON

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October 2016
Landscape Architecture Group

Contact information:
Postbus 47
6700 AA Wageningen
The Netherlands
Phone: +31 317 484 056
Fax: +31 317 482 166
E-mail: office.lar@wur.nl

Author
© Vincent Peters
Phone: + 31 6 49922280
E-mail: vsbpeters@gmail.com
Student nr.: 900713 649 030

First supervisor
dr.ing. S (Sven) Stremke

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PREFACE

Energy plays an important role in our existence. The modern world relies heavily on the supply of non-renewable energy sources to fuel everything from transportation to communication, to security and health systems. As the availability of non-renewable resources has passed its peak, the need for renewable resources will be as vital as ever. A transition towards renewables will have a major impact on the landscape, as the provision of renewable energy is expected to occupy a substantial part of the physical environment. Energy provision will become a much more tangible and visible aspect in everybody's living environment. But people are attached to their living environment, and this is why renewable energy projects are often met with great public resistance. A major challenge therefore lies in the sustainable integration of renewable energy in the existing landscape.

Fascinated by the challenges of the energy transition I started this thesis. The concept of recycling intrigued me, as it can provide a way to prevent abandonment of the landscapes of fossil fuel, while accomodating a sustainable transition towards renewable energy. The exploration of this concept was therefore an interesting and inspiring process.

I would like to thank my supervisor Sven Stremke for his helpful and always critical feedback. Furthermore, I would like to thank my fellow students from the NRGlab who inspired me with their work and motivated me to keep moving forward. Finally, I want to thank my friends and family for their continuous help and support.

Vincent Peters
Wageningen, September 25, 2016

Course: LAR-80436 Thesis Landscape Architecture

First supervisor: dr.ing. S (Sven) Stremke
Assistant Professor Landscape Architecture
Wageningen University

....

Examiner: prof.dr.ir. A (Adri) van den Brink
Professor and chair of the Landscape Architecture Group
Wageningen University

....

Examiner: ir. R (Rudi) van Etteger MA
Assistant Professor Landscape Architecture
Wageningen University

....

ABSTRACT

The discovery of a large natural gas field in 1959 has made the Netherlands highly dependent on natural gas as an energy source. The extraction of natural gas does however cause soil subsidence and earthquakes, mostly in the province of Groningen. Furthermore, the consumption of natural gas contributes to climate change. This shows there is a need for a transition towards more sustainable energy sources. The reliance on a depleting fossil fuel also makes a change inevitable. A transition like this will be reflected in the landscape, as the provision of renewable energy is expected to occupy a substantial part of the physical environment. Energy transitions have happened before and have often been linear developments, ending in disrupted and abandoned landscapes. This thesis tends to find out how a transition towards renewable energy sources can be made while preventing the origination of abandoned landscapes.

The main research question "How can the current natural gas production dominated energy landscape be recycled when production of natural gas diminishes in the near future?" is addressed in three parts. First a content analysis on the social and political aspects of the natural gas extraction was conducted along with a physical analysis. A deep understanding of the life-cycle of the natural gas production landscape was derived from this. Second, the municipality of Menterwolde was analysed. Future developments and trends were identified. Furthermore, the future energy demand was estimated and the potentials for renewable energy were mapped. This resulted in designs for sustainable energy landscapes based on landscape types identified. Third, a design for a natural gas extraction facility was made. The concept of recycling was applied in order to capture the history of the site. Artefacts of the natural gas extraction proved to have cultural value in the design.

KEY WORDS:
renewable energy, recycling, natural gas extraction, sustainable energy landscape, Groningen, Menterwolde, content analysis.

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INTRODUCTION

1.1 PROBLEM CONTEXT

In 1959 drilling workers of the *Nederlandse Aardolie Maatschappij* (NAM) made a discovery that would bring an unprecedented change to the Dutch energy system. The large natural gas field that was discovered, in the subsoil of the province of Groningen, proved to be one of the largest natural gas fields in the world (Correljé & Odell 2000). The discovery of this natural gas field, that became known as the Slochteren field, led to a rapid energy transition. In a few years' time almost every municipality in the Netherlands was connected to the new source of natural gas and natural gas quickly accounted for a large share of the energy consumption (Mourik & Burger 2003). Currently, natural gas is the most important source of energy in the Netherlands, as it accounts for 40% of the total gross energy consumption (Figure 1). For decades the Slochteren field, combined with smaller fields discovered both onshore and offshore, provided the Dutch economy with a relatively cheap fuel source. The revenues the Dutch state was able to collect allowed for the creation and maintenance of the generous Dutch welfare state (Correljé & Verbong 2004). However, the extraction and use of natural gas also has some severe negative impacts.

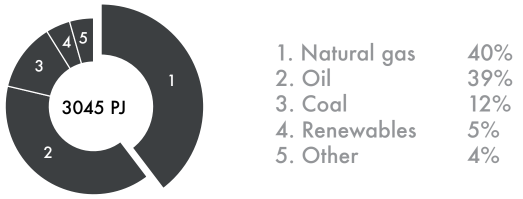


Figure 1: Total annual energy consumption in the Netherlands. Based on CBS (2016)

Although the spatial footprint of natural gas extraction is relatively low in comparison to other sources of energy (Sijmons 2014), all on-shore extraction facilities in the Neherlands combined occupy roughly 8,7 km^2. In comparison, the direct industrial footprint of natural gas is larger than the surface area of the city centre of Amsterdam (8,0 km^2). These natural gas extraction facilities are scattered across the country, but more than half of all these facilities are located in the province of Groningen. Next to the visible, above ground infrastructure, there is a vast invisible network of pipelines for underground transportation and distribution of the natural gas. Because of safety regulations, certain land uses are prohibited on top of, or in the near vicinity, of natural gas pipelines. Because of this, the underground network adds greatly to the spatial claim of natural gas as an energy source.

In the Netherlands natural gas is mostly contained in porous sandstone layers approximately 3km below the earths' surface. As gas is being extracted, these porous sandstone layers compact. This process occurs usually very gradually and leads to soil subsidence (van der Voort & Vanclay 2015). Currently the natural gas induced subsidence has lowered the surface of Groningen by up to 30cm. By 2070, this is expected to be 47cm in the most severely affected locations (NAM 2010). As soil subsidence happens very gradually and over a wide area, the impact on the build environment is expected to be low (Commissie Bodemdaling 2014). However, the soil subsidence does cause a relatively higher groundwater table, often unwanted. Compensating for this by lowering the groundwater table can cause even more soil subsidence through oxidation of the soil (Deltares 2011). Furthermore, the subsidence of the soil will increase the relative sea level rise, putting a greater pressure at the coastal defence system of Groningen.

While the sandstone layers containing the natural gas compact gradually most of the times, sometimes it can happen abruptly. These abrupt movements, occurring mostly along fault lines in the subsoil, can cause minor earthquakes (van der Voort & Vanclay 2015). In 1986 the first earthquake believed to be directly caused by the extraction of natural gas was registered by the *KNMI* (Royal Dutch Weather Institute). From 1986 until 2015 the KNMI measured around 1200 natural gas induced earthquakes in the province of Groningen. Around 115 of them had a magnitude of 2.0 on the scale of Richter or higher (KNMI 2016). Earthquakes with a magnitude lower than 2.0 are usually not noticed by people (KNMI 2013). It is likely that in the future, more earthquakes and heavier earthquakes are more prone to occur (Ibid). The occurrence of these earthquakes has several impacts on Groningen and its inhabitants, ranging from damage to buildings and declining house prices, to anxiety and feelings of insecurity (Correljé & Verbong 2004).

Negative consequences are not only connected to the extraction of natural gas, but also to the use of natural gas as a fuel source. Currently, the production of natural gas in the Netherlands exceeds the national demand (Figure 2). Natural gas is however a non-renewable fossil fuel source and with the production rate of 2010, most of the natural gas reserves of the Netherlands will be depleted by 2025 (van Rossum & Swertz 2010). Although new technological advancements and production limiting policies extend the lifetime of the natural gas reserves (NAM 1999), it is a fact that natural gas is a fossil fuel with a non-existing regeneration speed on the human time scale (Hubbert 1976). With a continued extraction, depletion will be inevitable. If natural gas will continue to be a dominant energy source for the domestic energy consumption, the Netherlands will become more dependent on other countries for its energy supply.

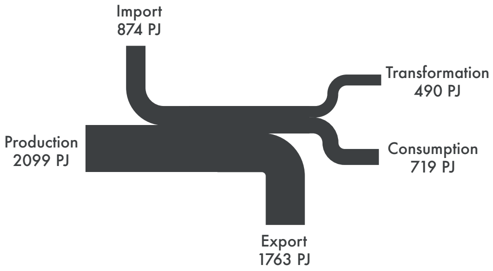


Figure 2: Sankey diagram of the annual flow of natural gas in the Netherlands in petajoules. Based on CBS (2016)

The use of fossil fuels like natural gas also causes emission of greenhouse gasses. Continued emission of greenhouse gasses will enhance the greenhouse effect and will consequently have severe irreversible impacts for the people on earth and earth's ecosystems (Garnaut 2008). Limiting greenhouse gas emissions, and climate adaption, is needed to limit climate change risks (IPPC 2013).

1.2 PROBLEM STATEMENT

Both the local problems caused by the natural gas production, like earthquakes and soil subsidence, and the global scale problem of climate change associated with the use of natural gas plea for a transition towards more sustainable energy sources. The reliance on a depleting fossil fuel also makes a change inevitable. This change will be reflected in the landscape, as the provision of renewable energy is expected to occupy a substantial part of the physical environment (Stremke & van den Dobbelsteen 2012). An extra complication regarding this transition is that landscape changes often provoke controversy (Selman 2010).

The use of energy has a direct relation with the landscape (Sijmons 2014). This relation is not a contemporary phenomenon, as anthropogenic energy extraction and consumption have shaped the landscape throughout history (Selman 2010). An energy transition occurs when dominant energy sources supersede each other (Mourik & Burger 2003). More often than not, these transitions are accompanied by profound technical, social and spatial changes (Sijmons 2014). Energy transitions have often been linear developments, ending in disrupted landscapes that became abandoned and forgotten (Pasqualetti 2015).

The province of Groningen hosts more than half of the natural gas infrastructure. Additionally, the province of Groningen also experiences the most earthquakes and the largest amount of soil subsidence. This makes the province of Groningen a valid choice as the subject of study in this research. As a large part of the above ground infrastructure is located here, the most abandoned space will be formed here when the natural gas production facilities will become obsolete. It is therefore important to think of how to deal with the current natural gas energy landscape, while accommodating a transition towards a sustainable energy landscape. If we were to think of the natural gas production landscape as an entity with a life-cycle, we can see the need for recycling instead of abandoning. This because "we recycle things that are subject to a lifecycle" (Viganò 2012, p.7). As space is scarce in the Netherlands, the need for recycling is even greater.

1.3 CONCEPTUAL FRAMEWORK

The relations between different concepts used in this research can be seen in Figure 3. The landscape is understood as being a combination of the physical, political and social landscape, related to the concept of matter- power- and mind-scapes as described by Jacobs (2004). The cultural landscape is seen as a subset of landscape. Cultural landscapes, as defined by the UNESCO World Heritage Centre (2013, p19.), are "cultural properties and represent the combined works of nature and of man. They are illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal".

As energy provision has a direct link with the landscape (Sijmons 2014), natural gas production influences the landscape. Sustainable energy can be seen as a trend, also having an effect on the landscape. By designing and recycling the natural gas production, incorporating the sustainable energy development these impacts will result in a (more) sustainable energy landscape. Sustainable energy landscapes, as defined by Stremke & van den Dobbelsteen (2012, p4.), are "physical environments that can evolve on the basis of locally available renewable energy sources without compromising landscape quality, biodiversity, food production and other life-supporting ecosystem services"

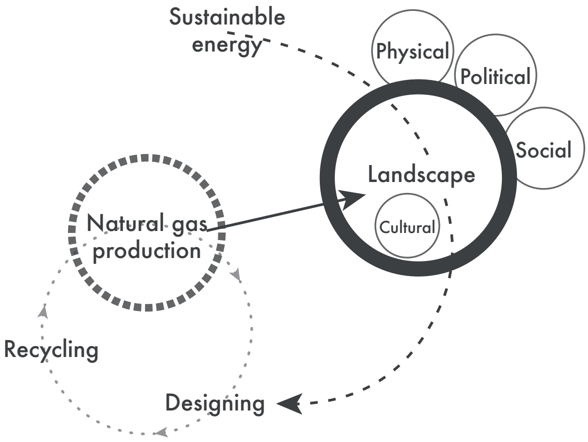


Figure 3: Relations between different concepts

Looking at the current natural gas dominated energy landscape as an entity with a life-cycle can provide us with a framework for analysis (Prosser 1995). A popular life-cycle model is the model described by Butler (1980), visible in Figure 4. This model of the life-cycle, originating in tourism research, is a conceptual tool that has appealed to researches from various disciplines and has been applied in a range of studies (Douglas 1997). Butlers model divides the life-cycle of an area into six different stages from exploration to decline. This process is similar to the emergence of natural gas as an energy source in the Netherlands. Prosser's (1995) review states that the life-cycle model can provide a framework for analysis. In this research the life-cycle model will function more as a metaphor, as using a model as a metaphor can be a source of inspiration and theoretical and explanatory advance (Wimmer 2005). By using this as a mean to analyse the current energy landscape we can put elements forth into a new life-cycle of sustainable energy. This is made visible in Figure 4.

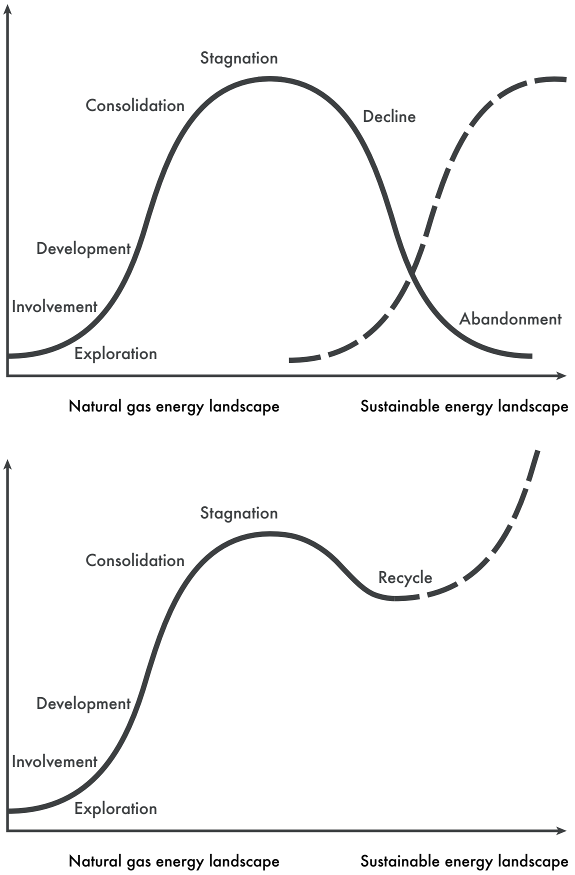


Figure 4: Conceptual image of the development of the sustainable energy landscape. Instead of treating the current energy landscape and the to be developed sustainable energy landscape as separate entities (top), recycling the current and putting forth a new life-cycle (bottom).

1.4 KNOWLEDGE GAP

This thesis addresses two knowledge gaps. First, this thesis will add to the body of knowledge on the designing of energy landscapes. Although many scholars study the topic of energy landscapes, little has been written about the design, planning, and development of these types of landscapes (Stremke & van den Dobbelsteen 2012). There is no approach that is universally applicable when it comes to designing sustainable energy landscapes. Every site demands its own approach, based on its characteristics.

Second, if we see the concept of recycling energy landscapes as a subset of the discourse on energy landscapes it becomes evident that even less has been written about the recycling of energy landscapes. Renewable energy landscapes do however show potential in being a suitable alternative for abandonment of the current energy landscape (Pasqualetti 2015). Also the establishment of a new energy system is perceived to be less interfering in a landscape that is already industrially affected, opposed to a pristine untouched landscape (Zoellner et al. 2008).

1.5 RESEARCH QUESTIONS

The central phenomenon of interest in this research is the recycling of the natural gas production energy landscape in the province of Groningen. The central overarching question posed in this research is therefore:

Central Question

How can the current natural gas production dominated energy landscape be recycled when production of natural gas diminishes in the near future?

This central question is a broad, overarching question that will be used to explore the case of Groningen. The sub-questions elaborate on the central question and are more specific. The sub-questions are linked to different scales, as the research is structured to work in increasingly smaller scale levels. This is visible in Figure 5.

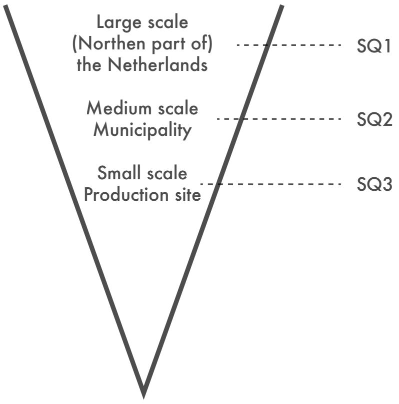


Figure 5: Research structure

SQ1 Research question

How did the natural gas production landscape evolve over time in a physical, political and social way?

Even more specific sub-questions that can be answered here are:

- *What is the public opinion on the extraction of natural gas and how did it change over time?*
- *What was the physical impact of the natural gas production on the landscape over time?*

SQ2 Knowledge question

What kind of future landscape can be expected?

Even more specific sub-questions that can be answered here are:

- *How will the landscape change in the near future?*
- *What kind of long-term developments can be expected?*

SQ3 Design question

How can this future be realised incorporating the recycling of the natural gas production landscape?

An overview of these questions, the methodologies used to answer them, and a more detailed research structure, can be seen in chapter 3.

1.6 RELEVANCE

The extraction of natural gas has been the topic of heated debate (van der Voort & Vanclay 2015). The risk people in Groningen experience have made this debate emotion-charged (Correljé & Verbong 2004). Politically it also remains a precarious subject because the extraction of natural gas provides the Dutch state with large revenues (Mourik & Burger 2003). This thesis can further the discussion on the situation in Groningen, that is now being dominated by the consequences of the natural gas production by depicting a possible future without the use of natural gas. Therefore, this thesis has social relevance, as it can provide a way to think forward in this debate.

In order to prevent the abandoned landscapes it is necessary to think of a solution for the end of the natural gas lifecycle. The concept of recycling can help the professional field of landscape architecture with this. The designs in this thesis project can help illustrate how to recycle energy landscapes.

Scientifically the results from this thesis project add to the research on energy transitions. As stated before, the recycling of energy landscapes is a topic that hasn't been studied extensively. Therefore, this research can function as a starting point for further research on this topic.

1.7 STRUCTURE OF REPORT

This report is structured in 7 chapters. In the first chapter an introduction to the research is given. This gives a clear notion about the problem statement, research objectives, research question and methods used during the working process.

The theoretical framework is described in chapter 2. Existing knowledge about the concepts of sustainability, waste space, and recycling is presented here.

In chapter 3, the methods used to answer the research questions are explained in more detail.

The context for the design is explored in chapter 4. The content analysis, combined with a physical analysis, provides insight in how the physical, political, and social components of the natural gas extraction landscape have changed over time.

In chapter 5 an analysis on the scale of the municipality leads to future landscapes, based on landscape types identified.

The recycling of a natural gas extraction site is shown in chapter 6. Implications from the previous chapters inform this design.

Discussion and conclusions are shown in chapter 7. Most important findings of the research are described and discussed. Furthermore, a conclusion to the research questions is formulated.

1.8 GLOSSARY

BROWNFIELD

Can be defined as "sites that have been affected by the former uses of the site and surrounding land; are derelict and underused; may have real or perceived contamination problems; are mainly in developed urban areas; and require intervention to bring them back to beneficial use" (Oliver et al. 2005, p1.)

NATURAL GAS:

Natural gas is a naturally occurring complex mixture of carbohydrates and non-carbohydrates, that at room temperature and normal atmospheric pressure is in a completely gaseous state (Nederlandse Gasunie 1980). It is formed when layers of organic material are heavily compacted under the pressure of the surface of the Earth over the course of millions of years.

POST-INDUSTRIAL LANDSCAPE

Term typically associated with the abandonned sites of the industrial past (Southworth 2001), but can also be associated with the poor or marginalised communities that were once connected to the industrial activities that took place there (Sandberg 2014).

RECYCLING:

Concept of reutilisation that goes beyond the physical reuse of obsolete objects and materials (Bocchi & Marini 2015). Recycling is entailed with the reinvention of meaning and cultural identity (Corner 1999). This way it can contribute to the socio-cultural dimensions of sustainable transformations.

RENEWABLE ENERGY:

Renewable energy can be defined as energy that is being obtained from "any energy storage reservoir which is being 'refilled' at rates comparable to that of extraction"(Sorensen 2010, p.19).

SUSTAINABLE ENERGY TRANSITION:

This can be defined as the "transition from fossil fuels to self-sufficient energy systems based entirely on renewable-energy sources" (Stremke 2010). In order for this transition to be sustainable it has to suffice with the criteria of sustainability.

WASTE SPACE

Waste spaces are created by an obsolescence or a loss of function and have lost value for human purpose. They come in many forms and are formed by many different possible drivers. The formation of waste space has always been part of human society, and is not contemporary phenomena (Treib 2008).

2

THEORETICAL FRAMEWORK

2.1 INTRODUCTION

In order to design for a sustainable energy landscape, a basic knowledge of the topics related to sustainability and energy landscapes must be gained. Furthermore, the concept of waste space is investigated, as this thesis operates under the postulation that the natural gas infrastructure in the Netherlands will become obsolete. The objects of the natural gas infrastructure will therefore fall out of their regulatory system as they lose their function. Without intervention the natural gas facilities will become obsolete areas, or waste spaces. The concept of recycling is therefore also investigated.

2.2 ENERGY TRANSITION AND SUSTAINABLE ENERGY LANDSCAPES

Both the local, and global scale problems associated with the use and production of natural gas production plea for a transition towards a more sustainable energy landscape. For realizing a transition like this the principles of the *Trias Energetica* concept can be considered key strategies (de Waal & Stremke 2014). According to the *Trias Energetica* concept, energy efficiency should be addressed first, then renewables should replace fossil fuels, and if fossil fuels remain to be used, this should be done in the most environmental-friendly way (Lysen 1996). This is visible in Figure 6.

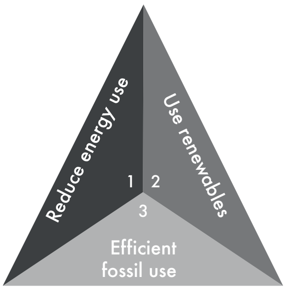


Figure 6: Trias Energetica concept, after Lysen (1996)

Reduction of energy use is an evident method for reaching a more sustainable society. The use of renewable energy is more complicated, as renewable energy sources are not necessarily sustainable. The sustainable energy transition requires changes which go beyond the installation of wind turbines and Photovoltaic (PV) cells. Renewable energy provision has to contribute to sustainable development (Lund 2007). Many definitions for sustainability and sustainable development exist but a definition commonly used is the definition that was introduced in 1987 by the *World Commission on Environment and Development* (WCED), more commonly known as the Brundtland commission (Soini & Birkeland 2014). In their report, 'Our Common Future', the WCED specifies sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p.41). The Brundtland definition broadly refers to the equal distribution of welfare, utilities and resources between generations. Since this report, the concept of sustainability has been used frequently in research and policy (Soini & Birkeland 2014).

Sustainable development is often considered to consist of three 'pillars', the ecological, economic, and social dimensions (Connelly 2007), visible in Figure 7. There has been growing interest in policy and among scholars to consider culture as an aspect of sustainable development. Culture has been mentioned as part of social sustainability and even as a fourth pillar (Soini & Birkeland 2014).

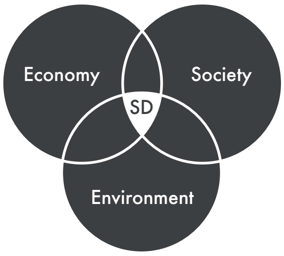


Figure 7: Three 'pillars' of sustainable development, after International Centre for Local Environmental Initiatives (1997)

Stremke (2015) poses a conceptual framework for sustainable energy landscapes consisting of four dimensions: sustainable technical, environmental, economic, and socio-cultural. In addition to this there are also some minimum technical criteria that always apply, and are therefore located in the centre of the diagram. Three of the sustainability dimensions are similar to the three pillars of sustainable development, and the cultural component of sustainability is explicitly linked to the social component in this framework. The sustainable technical criteria dimension is more specific for sustainable energy development.

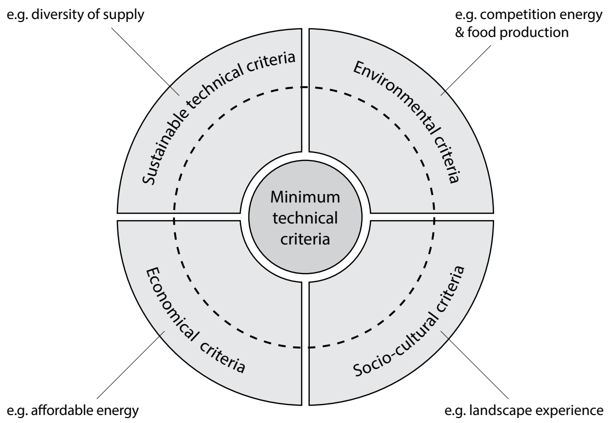


Figure 8: Schematic representation of the relations between the four sustainability domains, from Stremke (2015)

It is widely acknowledged that, in order for a transition towards a sustainable energy future to be successful, changes to the energy production need to be on a massive scale. Subsequently, changes to the existing landscape will be almost inevitable (Selman 2010). Landscape change often provokes controversy, as it is the current landscape that is cherished and people have become familiar with. A disruption to the landscape by renewable energy technologies can thus be deemed unsustainable on the basis of socio-cultural criteria (de Waal & Stremke 2011). Selman (2010) raises the possibility that by emphasizing the narrative of ingenuity in rising to the challenge of sustainable development, people can develop an *acquired aesthetic* taste for these renewable energy landscapes. He suggests that "our heads accept the need for these landscape changes; our hearts need to learn to love them" (p.169).

2.3 WASTE SPACE

The predominant perception of waste is still based on the understanding that waste is something worthless. It is something that has ceased to have value for human purpose. The word waste comes from the Latin *vastus*, meaning unoccupied or desolate (Gutberlet 2011). In his work *Wasting Away*, Kevin Lynch mentions waste can "refer to any used thing: garbage, trash, litter, junk, impurity and dirt. There are waste things, waste lands, waste time and wasted lives" (1990a, p.146).

2.3.1 Definition of waste space

When talking about waste landscapes it is important to note that it is the landscape itself that is considered waste, not that it is a landscape for waste (e.g. a landfill). Waste spaces are spaces created by an obsolescence or a loss of function. They seem inherent to human society as the waste of land is associated with landscape changes through the evolution of the economy and society (Wood & Handley 2001). Progress implies that other things will become obsolete. Waste spaces come in many forms and are formed by many different possible drivers; whether it is energy transitions that cause abandoned landscapes (Pasqualetti 2015), or globalisation and deindustrialization that cause industrial ruins (Ruelle et al. 2013). The processes of construction and decay, of use and abandonment, have always been part of human societies and are not contemporary phenomena (Treib 2008).

With industrialism, and the successive deindustrialization, new excesses of waste landscape arose. The rapid deindustrialization process of the last century, that created derelict and abandoned industrial landscapes across the USA and Europe, is perhaps the most visible creation of waste spaces in modern history (Loures & Panagopoulos 2007; Berger 2007). This rapid deindustrialization resulted in the creation of a *post-industrial landscape*. In a broader sense the post-industrial landscape can be associated with the poor or marginalised communities that were once connected to the industrial activities that took place there (Sandberg 2014), but it is typically the old factories, harbours, steel mills, and train yards, that are associated with the post-industrial landscape (Southworth 2001). Sites like these are popularly called brownfields. Many definitions exist for brownfield, differing from country to country. The European Commission funded expert network on brownfield regeneration, *Concerted Action on Brownfield and Economic Regeneration* (CABERNET), defines brownfields as "sites that have been affected by the former uses of the site and surrounding land; are derelict and underused; may have real or perceived contamination problems; are mainly in developed urban areas; and require intervention to bring them back to beneficial use" (Oliver et al. 2005, p1.).

In the field of landscape architecture many terms have been coined to capture the essence of these sites. Elizabeth Meyer (2007) chooses to use the term *disturbed site* to describe a broad category of polluted or contaminated sites previously used for industrial purpose, as the term *disturbed* "…captures the effect as well as the character of these sites" (p.58). Kirkwood (2004) uses the term *manufactured sites* to describe both the wasted sites that are the result of industrial or manufacturing processes, and the interdisciplinary approach to reclaiming these sites. Berger (2007) argues that the use of the term 'post-industrial' narrowly isolates and objectifies the landscape as being the result of very specific processes that no longer operate upon a given site. As deindustrialization isn't the only driver of waste, he poses the term *drosscape* to signify any wasted site, frozen fragment of land, expelled from the metabolism of the city. His definition of waste space is concerned with the car infrastructure dominated horizontal urban sprawl as a driver of waste (Southworth 2001).

Figure 9: Coaking plant at the Zollverein Coal Mine Industrial Complex. An example of a site typically associated with the post-industrial landscape. Photograph by Christiaan Smits

2.3.2 *Problems of waste space*

Dealing with waste landscapes is necessary in order to reach a more sustainable society (Southworth 2001). As it is often far easier to throw away something than to find a new use for it, there has to be an incentive for dealing with waste. Maskit (2007) argues it is better to actively do something with waste space as the abandonment is prone to spreading into its surroundings and can cause a quick disintegration of the community. Furthermore, wasted sites are often contaminated, threatening watersheds, human and animal population. In addition to this, wasted sites form desolated 'holes' in the landscape fabric. They must be circumnavigated, and can be perceived as eyesores (ibid). Furthermore, an increasing public discontent with waste landscapes also urges for waste landscape recycling (Loures 2015).

Currently, the benefits of redeveloping wasted landscapes are being understood more and more. Wasted landscapes are not only perceived as contamination problems that have to be dealt with, they are viewed as opportunities for saving resources and delivering sustainable development (Franz et al. 2006). In densely populated areas, wasted sites are often recognized as valuable resources as the amount of available land for future developments is limited in these areas. As a result, there is a need to maximise the potential of previously developed waste landscapes (Oliver et al. 2005; Franz et al. 2006). There are also benefits in developing wasted sites at the urban fringe where greenfield is more available for development. There is a broad range of benefits, depending on the type of land use, program and functions proposed in each project (Loures 2015). These benefits can range from environmental, to social and economic benefits. Oliver et al. (2005) identify that the population density is an important factor for the purpose of redevelopment. Densely populated places tend to focus more on the regeneration of brownfield as opposed to greenfield, while in less densely populated areas the focus is largely concerned with the remediation of risks to human health and the environment associated with contamination.

2.3.3 *Dealing with waste space*

Dealing with waste space has happened throughout history. For example, in the urban setting, the reuse of one generation's materials and forms into alternative resources and forms has been common practice for centuries (Way 2013). But the vast scale and pace at which deindustrialization processes have created waste spaces in the past century is unprecedented in history. As a result, wasted sites are spread across the landscape and initially these excesses were buried, relocated or disregarded, as they seemed only to suggest the worst of progress and civilization. From the end of the 20th century, a paradigm shift occurred when waste started to be considered part of our landscape, instead of something to be made invisible (Way 2013). Landscapes started to be seen as embodied history, and the post-industrial landscape as not only holding artefacts of previous times. New philosophies for reimagining the landscape have resulted in the conservation of structures of previous use (Raines 2011). Thinking of a site as a *palimpsest*, an idea that emerged in the 1980 in the works of Peter Eisenman, allows designers to utilize the sites layers to reveal aspects of the history of the site (Krinke 2001). Redevelopments that incorporated the site's previous use are now often considered distinct heritage (Selman 2010). The power of heritage is not restricted to exhibiting a wasted site as a museum piece. Bangstad (2011) argues that heritage allows, through representation, for someone or something to retroactively gain access into recognized "Culture with a capital C" (2011, p.3).

2.3.4 *Precedents*

Some of the most prominent landscape architecture projects of the last decades are recycled waste landscapes. Arguably one of the first contemporary examples, and therefore influential, is the design of the *Gas Works Park* by *Richard Haag Associates* (Way 2013). Haag's unique approach involved convincing the public to keep a part of the industrial apparatus on site. Although historic and cultural values were important in the design process, the main design principle behind the design has a more environmental character. By treating contaminated soil on site instead of disposing it, Haag created an important precedent for future reclamation projects. Twenty years after the creation of Gas Works Park, Peter Latz created Lanscape park Duisburg-North following some of the same principles (Donadieu 2012). Latz deals with the derelict industrial area by accepting its physical qualities, destroyed nature and topography. His vision is not one of recultivation, as that would negate the qualities that the site currently possesses and would destroy them for a second time (Krinke 2001). Examples like this show how historical preservation and remediation technologies can be joined to establish our cultural connection to our nineteenth-century industrial heritage (Krinke & Winterbottom 2001).

More than with Gas Works Park, cultural and historic values formed the basis of the design strategy for Duisburg-North (Loures et al. 2006). A more recent example of a landscape architecture project with an environmental reclamation character is Freshkills Park, designed by James Corner Field Operations. Freshkills parks was the world's largest waste landfill, currently being transformed into 890 hectares of public parkland. Environmental and ecological factors are emphasised during this large scale landscape transformation, recovering the health and biodiversity of ecosystems across the site (Corner 2005). The design consists of the life-cycles of performative systems, based on the succession of flora and fauna, over the 40-year duration required to remediate the soil (Shane 2007). The generation of renewable energy is also part of the programming of Freshkills Park, as for example the largest PV array of New York City (with the potential to generate 10MW of power) will be constructed in the park (City of New York 2013). What is consistent the designs for Freshkills Park, Gas Works Park, and Duisburg-North is that in all three projects the genius loci can be seen as the spiritual base of the design, as they all valorise the past (Loures et al. 2006).

2.3.5 *Aesthetic of waste*

Recycled waste landscapes have a certain appeal to people. Post-industrial sites, in particular those with iconic remnants, are often conceptualised as ruins of a flourishing past. Industrial ruins often pack qualities linked to their scale, material, function, and power of industry, producing quintessential sublime experiences (Chan 2009). The sublime is understood here as being part of the traditional aesthetic trichotomy of *the beautiful*, *the sublime* and *the picturesque*, where the sublime offers a more violent painful form of pleasure. Emotionally impressive, being both attractive and at the same time repellent (Maskit 2007).

Sublime ruins and wilderness have long played a central role in the field of landscape architecture. The eighteenth and nineteenth century are characterized by the picturesque and sublime traditions, when stately homes and large parks were designed with classical ruins, frozen in the perfect state of decay (Edensor 2005). Langhorst (2014) argues that these traditions still form a continuous inspiration for the design of post-industrial sites, as notable examples like Gas Works Park and the High Line in New York are framed as perfect ruins. He argues that the over-maintained plant species on the High Line, that have little to do with the original pioneer vegetation, are an aestheticized version of urban nature, thereby providing a distinct nod to the picturesque. Maskit poses the term *the interesting* to capture the emotional response post-industrial sites can provoke, as the traditional aesthetic categories of the beautiful and the sublime seem inadequate to capture this. He argues that is the aesthetic appreciation of certain post-industrial elements that lead us to think otherwise, hence the term *the interesting*.

2.4 RECYCLING

Recycling refers to the activity of placing a material, object, or site "back into circulation after a period of relative stagnation to be subsequently reprocessed" (Fabian 2014). The concept of recycling is closely related to the concepts of reducing and reusing (Formato & Russo 2014). Reduce, reuse, recycle (3R) is a formulation of a waste hierarchy is in common use worldwide (Sakai et al. 2011), but can also be expanded to a 6 tier hierarchy as described by Hansen et al. (2002) visible in Figure 10. The waste hierarchy is commonly described as "a priority order for waste management options, based on assumed environmental impacts" (Van Ewijk & Stegemann 2014, p.2).

Materials, objects, or sites can be viewed as representing a stock of energy. This stock, often called the embodied energy, is the result of the sum of energies used to create the material composition plus the energy that would be required for the elimination or demolition of the object or site (Fabian 2014). Looking at the waste hierarchy in Figure 10, the option of recycling is preferred over disposal. The concept of recycling thus starts with the notion that the physical, embodied energy can be preserved.

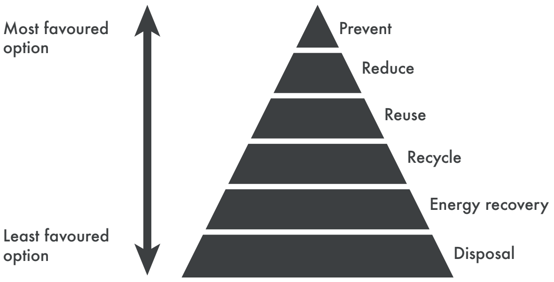


Figure 10: The six tier waste hierarchy, after Hansen et al. (2002)

Viewing territory as a deposit of energy makes it easy to view it as a resource. If we accept this idea, and that it can be recycled in parts or as a whole, territories can be seen as renewable resources (Viganò 2012). Focussing on the embodied energy puts an emphasis on the physical component, but the concept of recycling does not stop here. It has to consider the cultural component, of all the symbolic values and individual and collective memories attached to a place (Giannotti 2012). Therefore, the concept of recycling is not a mere technical operation of the reuse of obsolete objects or materials, but more broadly as a reinvention of a meaning, as the start of new life cycles (Bocchi & Marini 2015). Recycling is more than site redevelopment, as this fails to capture the larger local and regional opportunities. Recycling entails that trough design, allusions to regional and cultural identity are imbued in the landscape (Corner 1999). Thus, by recycling waste landscapes we can contribute to the socio-cultural dimension of sustainability.

Closely related to the concept of recycling is the concept of upcycling. Upcycling is often considered as a process in which waste is converted into something of higher value and/or quality in its second life. Upcycling is therefore considered by some as to be preferred over recycling, as upcycling explicitly adds quality to the newly formed object. Value and quality, despite being common in almost every definition of upcycling, may sound ambiguous. This is because value can be assessed differently by individuals (Sung 2015). It is therefore sometimes impossible to asses if an object has been truly upcycled. To avoid ambiguity, the term recycling is used in this report to signify any form of reutilisation, whether it increases or decreases the 'value' of the new object.

2.5 CONCLUSION

It is important for the transition towards renewable energy sources to happen in a sustainable way. Developments for an energy transition must fulfil the criteria of socio-cultural, economic, environmental, and sustainable technical criteria in order to be considered sustainable. Paradoxically, the disruption of the landscape by renewable energy technologies is often considered not sustainable based on the socio-cultural consequences. Emphasizing the narrative of coping with the challenges of energy provision could provide a way to increase acceptance of renewable energy technologies.

Waste space is a phenomenon that has been an integral part of development and progress. There is a need for the redevelopment of waste space, and the advantages of waste space redevelopment are understood more and more. The recycling of post-industrial sites provides examples of successful waste space redevelopment, as some of the most prominent landscape architecture project of the recent decades can be considered recycled waste space. Design strategies that are often employed when designing for abandonment are strategies that emphasise the cultural and historical character, or strategies that reinforce the naturalist and environmental character. Independent of the chosen strategy, the genius loci is often used as the theoretical base for landscape recycling.

When landscapes are viewed as representing a stock of energy, a need for recycling waste landscapes can be seen. The concept of recycling is entailed with more than the physical. It is also the cultural component that has to be considered, the symbolic values and the collective memories. Recycling can be seen as the start of a new life cycle. The concept of recycling thus can function as a way to imbue the narrative of the history and the future of a site into its design.

3

METHODOLOGICAL FRAMEWORK

In order to answer the main research question “How can the current natural gas production energy landscape be recycled when production of natural gas diminishes in the near future?” multiple methods will be used. Methods are linked to the scale level of analysis and to the sub-research questions and are therefore addressed in consequent order.

3.1 LARGE SCALE

The first sub-question “how did the natural gas production evolve over time in a physical, political and social way?” focusses on the larger scale of (the Northern part of) the Netherlands. The aim of the first sub-question is to analyse the life-cycle of the natural gas production based energy landscape. As the idea of recycling makes an explicit reference to the succession of different lifecycles (Viganò 2012), the lifecycle of the current energy landscape must be understood. The physical aspect of the research question will be answered trough a landscape analysis. The analysis includes a classification of landscape typology. This classification will be based on a combinations of features, including, but not limited to, geology, topography, vegetation, historical land use and settlement pattern, as described by van Eetvelde & Antrop (2009). In order to give an answer to the social and political aspect of the sub-question an inductive content analysis of Dutch newspapers will be conducted. An overview of this can be seen in Table 1.

Table 1: Techniques used, materials used, and deliverables

Methods/ Techniques	*Materials to be used*	*Results / deliverables*
Physical; Landscape analysis (Van Eetvelde & Antrop 2009)	(Historic) maps, field research, expert opinion	Narrative plus visual timeline explaining the relation between the physical, social and political impacts of the natural gas production
Social-Political; Inductive content analysis (Elo & Kyngäs 2007)	Dutch news/ opinion papers (1946- present) Policy documents	

3.1.1 Content analysis

The social- and political impacts of the extraction of natural gas will be explored through a content analysis. A content analysis is a research method for describing and quantifying phenomena in a systematic and objective way (Krippendorff 1980). It can be used to systematically identify characteristics of either qualitative or quantitative data (Holsti 1969). Categorizing is an important part of the content analysis. Weber defines a category as “… a group of words with similar meaning or connotations” (Weber 1990, p.37). The categorization is often called coding. One of the basic rules of coding is that you have to define all categories in such way that they are mutually exclusive and exhaustive (U.S. Government Accountability Office 1996). Mutually exclusive categories exist when no unit falls between two coding categories. The requirement of exhaustive categories is met when all data units are covered by a code, with no exception.

Two types of content analysis are typically distinguished, based on the methodological difference in defining the codes. Stemler (2001) defines these approaches as having an *emergent* versus an *a priori* approach. This is similar to the *inductive* and *deductive* approach Elo & Kyngäs (2007) distinguish. With an *emergent*, or *inductive* approach the codes are established following some preliminary examination of the content. With an *a priori*, or *deductive* approach the codes are established prior to the research based upon theory or previous studies.

Content analysis allows a researcher to explore and examine through large datasets with relative ease (U.S. Government Accountability Office 1996). It is a useful technique to identify and describe the focus of individual, or social attention (Weber 1990). Furthermore, it is a useful tool for monitoring shifts in public opinion on an empirical basis (ibid). It is therefore a useful tool to evaluate how the natural gas production landscape evolved over time from a social and political perspective.

Elo & Kyngäs (2007) provide a framework for conducting a content analysis (Figure 11), which will be used in this analysis. Despite this framework there are no systematic rules for analysing the data when conducting a conducting a content analysis (ibid). According to Weber (1990), the key aspect of conducting a content analysis is that classification of the large content into smaller content categories.

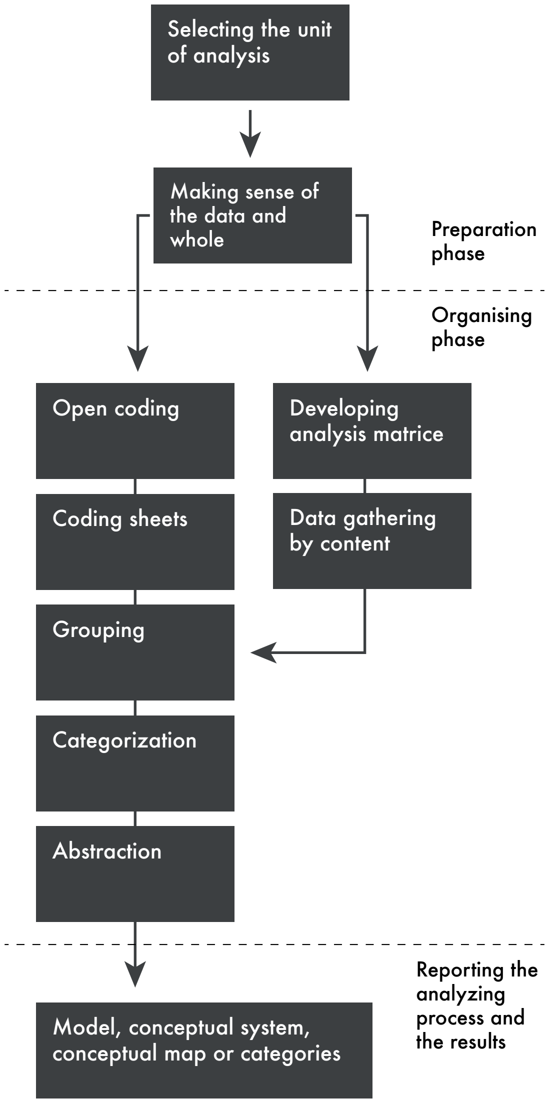


Figure 11: Preparation, organizing and resulting phases in the content analysis process, after Elo & Kyngäs (2007).

The unit of analysis that will be used is Dutch newspaper and opinion magazine articles. The primary sources of newspaper and opinion magazine articles are *LexisNexis* and *Delpher*. LexisNexis is an online U.S based commercial system that has become the media archive of choice for many academic studies across Europe and the United States (Deacon 2007). Delpher is a Dutch online text archive system developed by the *Koninklijke Bibliotheek (*Royal library). Both Delpher and LexisNexis have Dutch newspapers categorized in their archives. As they cover different sources and timespans these two services are complementary to each other. LexisNexis' Dutch newspaper database, although different for each source, ranges from 1990 till present. Delpher offers a range from 1618 to 1995. Both sources services offer Boolean search options to search through their database. LexisNexis allows for a systematic download of the found sources. Delpher does not offer any mass download options, requiring the user to process search results manual. The different characteristics of the two systems called for a different approach for each system. LexisNexis' search and download system allowed for the creation of a data set that can be analysed with relative ease. LexisNexis will therefore be used to gain a comprehensive volume of material. This data will then be analysed in order to find reoccurring themes in the reporting about the natural gas extraction. These themes will then be used to conduct more specific search actions on the Delpher database. As each search action in the Delpher database required manual processing, material will be gathered through snowball sampling. Saturation will be reached when eventually no more new themes emerge.

Search queries will consist of Dutch equivalents of terms like *natural gas, gas tap* and *gas extraction.* Geographical search terms, like *Groningen, Slochteren* and *Coevoorden,* will be added to the query in order to limit the results to the Dutch situation. Furthermore, newspaper articles have to consist of at least 500 words, this in order to limit the presence of generic news statements in the search results. Lastly search terms have to be present in the article multiple times, this in order to generate more accurate search results.

For the LexisNexis search queries the Dutch opinion magazine and the Dutch national newspapers databases will be used. Furthermore, the regional newspaper Dagblad van het Noorden will be added to include a more local perspective. An overview of the dataset used can be seen in Appendix I.

3.1.2 *RESULTS*

The analysis on a large scale reconstructs and shows the processes that have shaped the current energy landscape. From the analysis of the media reports an understanding of the trends in social attention and shifts in public opinion will be developed. Combined with an analysis of governmental documents, and a spatial analysis of the development of the natural gas energy landscape, this will evolve into a narrative of the life-cycle of the natural gas production. This narrative will be made visible through a timeline combined with maps. The timeline shows multiple sources of information at the same time, thereby making a correlation between events visible. The results, also determined the location for the next phase of research on a smaller scale. The results are in chapter 4.

3.2 MEDIUM SCALE

The second sub-question "What kind of future landscape can be expected? " is entailed with the creation of a desirable future with the incorporation of renewable energy. In this phase, the municipality chosen in the previous phase will be analysed more in-depth. Its history, and its landscape types will be studied, revealing the spatial characteristics of the municipality. Subsequently the current energy system of the municipality will be analysed which will provided the base for a future energy-usage prospect. Furthermore, the potentials for renewable energy sources will be mapped in this stage.

As the transition to a sustainable energy landscape is a process that will require decennia, it is important to deal with uncertainties by considering external trends and forces (Stremke 2012). Therefore, policy documents will be evaluated in order to identify trends and spatial developments. An overview of this can be seen in Table 2.

Table 2: Techniques used, materials used, and deliverables

Methods/ Techniques	*Materials to be used*	*Results / deliverables*
Landscape analysis (Van Eetvelde & Antrop 2009)	(Historic) maps, field research, Photographs	A desirable future visualised in collages and drawings
Identifying trends and near-future developments (Stremke et al. 2012)	Policy documents such as: Ontwerp-omgevingsvisie Groningen (2015); Planmer buitengebied Menterwolde (2013)	
Renewable energy potential study	Data analysis from Sijmons (2014), from van den Dobbelsteen et al. (2012), and from the POP Groningen (van den Dobbelsteen et al., 2007)	

Both the results of the large scale analysis and the analysis on a medium scale will contribute to the envisioning of desirable, futures for the municipality. This will be visualised in drawings and collages. The results of this phase are in chapter 5.

3.3 SMALL SCALE

The third sub-question will focus on an even smaller scale, the scale of the natural gas production site. The results from the previous phases will be used as a base for a research through design process in order to answer the third sub-question; "How can this future be realised incorporating the recycling of the natural gas production landscape?".

For this phase it is important to stress that when recycling, thus starting from the existing, it doesn't mean that we are convicted to keep everything (Giannotti 2012). This research trough design process is about what is to be modified, what is to be kept and what is to be discarded. After this design process, the results on this scale level can be extrapolated to the higher scale levels, resulting in the answering of the central research question. An overview of the whole research and design process can be seen in Figure 12.

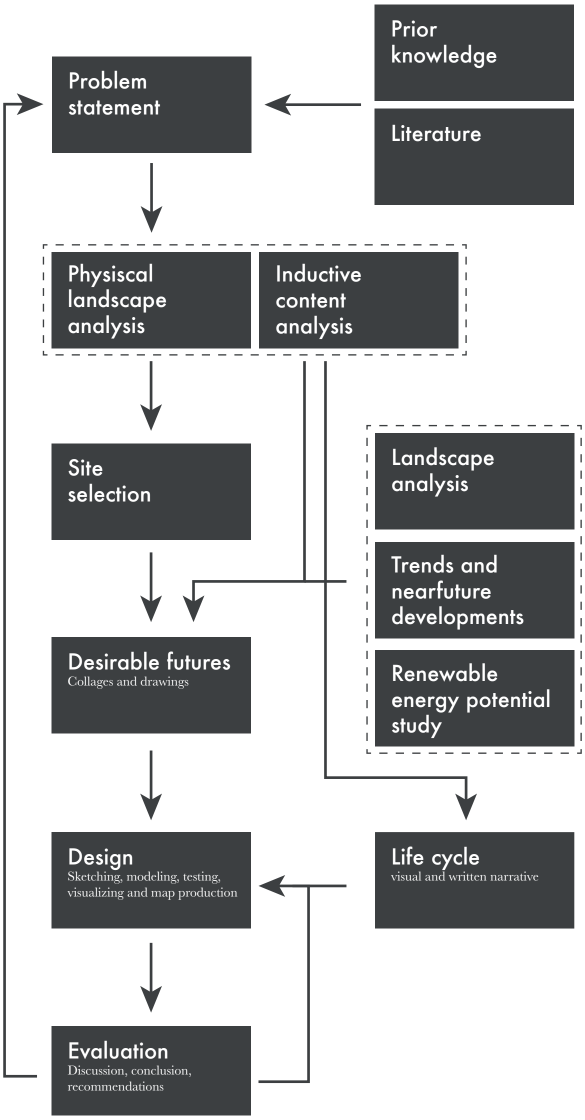


Figure 12: Research structure

4

LARGE SCALE

4.1 INTRODUCTION

In this chapter the results of the physical analysis and of the content analysis are described. In paragraph 4.2 an analysis of the physical natural gas extraction landscape is presented on the large scale level. This will provide a location for a more in-depth analysis in the next chapter. Paragraph 4.3 combines the results of the content analysis and the physical analysis in a written narrative about the life cycle of the natural gas extraction. This is also visualized. In paragraph 4.4 the conclusions are formulated.

4.2 PHYSICAL ANALYSIS

The physical analysis can be split up into three sections. First the physical landscape is analysed through its geological and cultural history, and categorized into different landscape types. Second, the current footprint of the natural gas extraction will be explored. Lastly, the physical impact of the natural gas extraction is investigated.

4.2.1 Geological history

The formation of the north of the Netherlands is the result of a complex combination of different geological processes. Over the course of thousands of years, land-ice glaciers, floods, and erosion caused by sea level rise have shaped the landscape (Meijles 2015). Around 9000 BC, the then dry North Sea starts to fill with water again under the influence of climate change. By 5500 BC the sea level has risen to a level that the northern part of what is now the Netherlands is back under the influence of the sea (Figure 13a). The rising sea levels cause a groundwater rise in the adjoining areas, causing the formation of peat. The heavy influence of the sea and its dynamic process of erosion and sedimentation of clay and sand causes continuous change in the salty marshes (Figure 13b). Around 1500 BC the sea level rise starts to slow down, making floods less common. This makes the area habitable for people (Figure 13c). Quickly after the first people start inhabiting the area, they start to raise the now characteristic dwelling mounds to increase the living security. Around 2000 years ago human interference started to have a larger influence on the landscape as peat extracting started taking place at the edges of the peat systems, and humans start diking in areas for increased living security (Figure 13d).

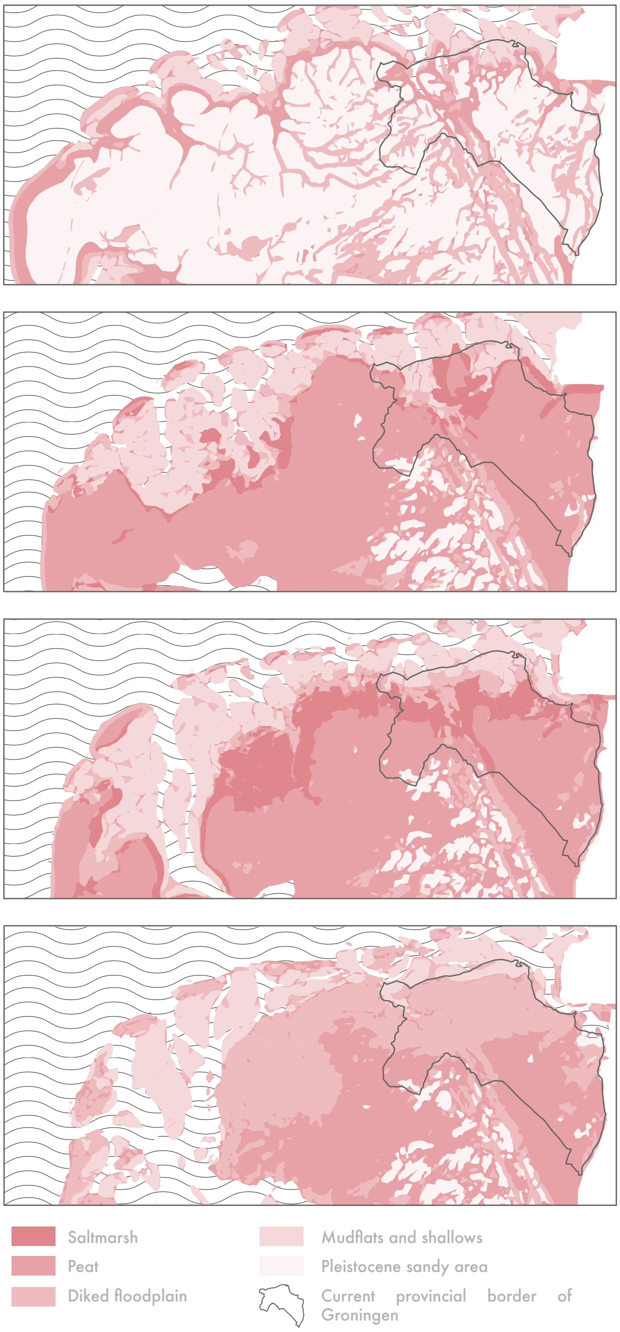


Figure 13: Development of the landscape of the North of the Netherlands, adapted from Vos & de Vries (2013). From top (a) to bottom (d): (a) approximately 5500 BC, (b) approximately 1500 BC, (c) approximately 100 AD, (d) approximately 1500 AD.

4.2.2 Anthropogenic landscape change

The combination of large natural shaping processes and the increased human influence on the landscape have resulted in a province with a variety of landscapes. The current landscapes in the province of Groningen can be divided into six different landscape types, based on their physical and cultural historical characteristics. Characteristics are often considered core values of the landscape that should be preserved and, where possible, strengthened. An overview of the landscape types is visible in Figure 14. All landscape types have an explanatory diagram (Figure 15 to Figure 20).

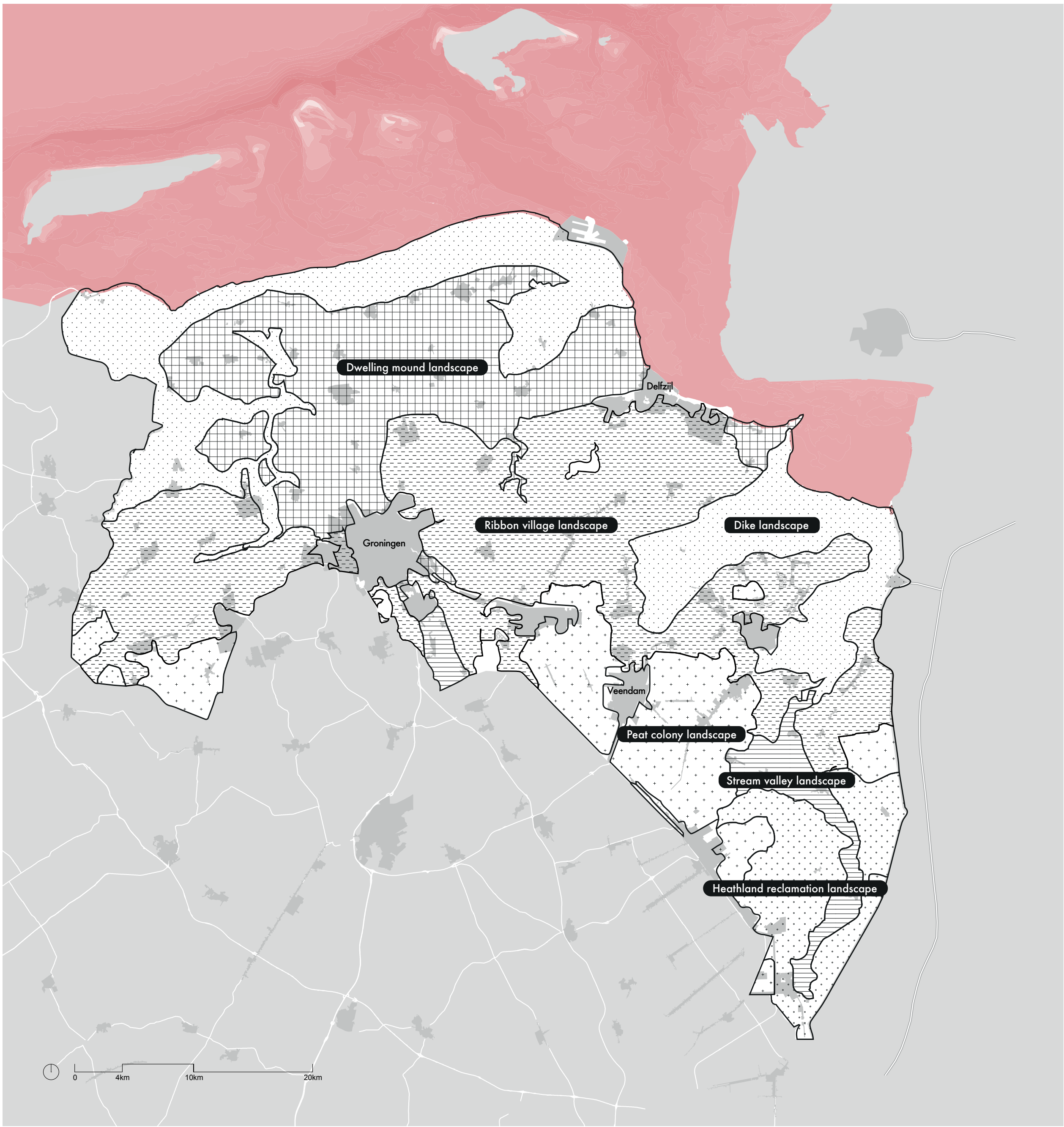


Figure 14: Landscape types based on natural shaping processes and cultural historic characteristics, based on Provincie Groningen (2009).

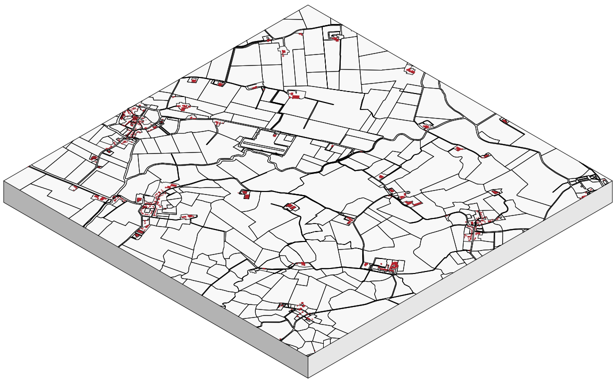


Figure 15: Dwellingmound landscape
The main structure of this landscape exist of raised dwelling mounds, often alongside natural waterways. Fossil meanders break the patterns of the irregular block parcelling.

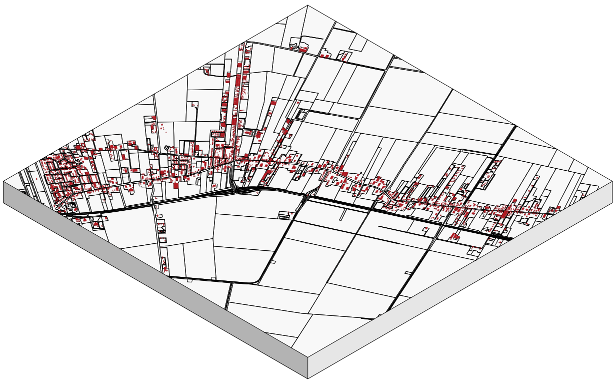


Figure 16: Ribbon village landscape
Typical are the ribbon villages, constructed on the slightly elevated natural sand ridges in the landscape. Often accompanied by linear green structures.

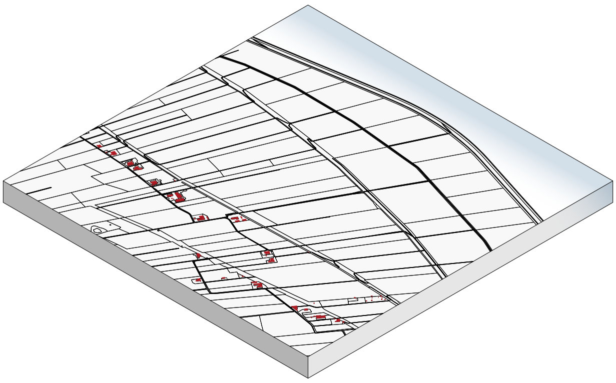


Figure 17: Dike landscape
Most areas got diked in the 18th and 19th century. Series of farmhouses are alongside the parallel sleeper dikes. Parcelling is straight and rational, which results in a large open landscape.

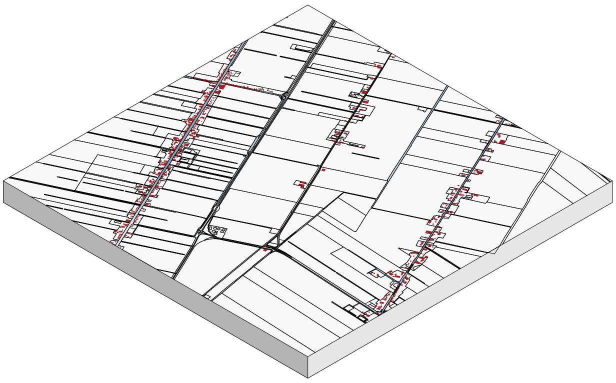


Figure 18: Peat colony landscape
Cultivation started from the 17th century, until the first half of the 20th century. Typical are the villages alongside canals and the elongated parcelling.

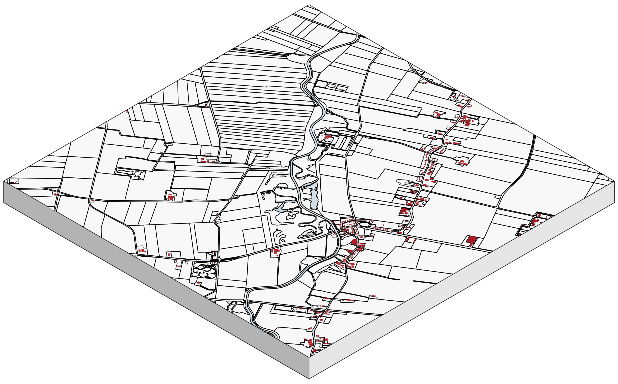


Figure 19: Stream valley landscape
Villages constructed on the hill of a stream valley. Typically, the agricultural fields are above the villages and the meadows are below the villages near the river.

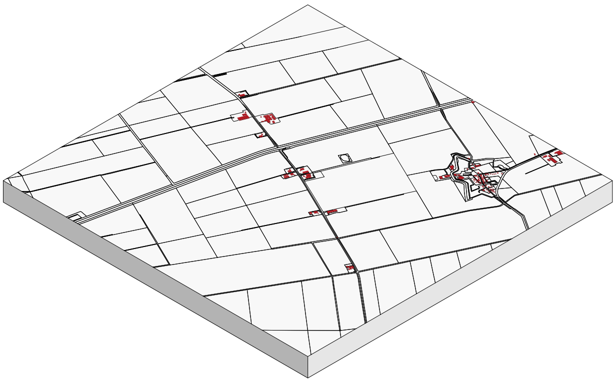


Figure 20: Heathland reclamation landscape
Cultivated mostly in the 19th century. The rational and systematic cultivation resulted in an open landscape with block parcelling. Farmhouses are scattered alongside the roads. Distinctive are the strongholds and fortifications that are present in this landscape.

4.2.3 Spatial footprint

The primary industrial footprint

The primary industrial footprint consists of the locations at the core of the natural gas business; the wells, refineries, storage units, and pipelines among others. They are highly functional in design and often inaccessible for the public. An example of some of these facilities can be seen in chapter 6. All on-shore primary facilities are mapped in Figure 21. As can be seen here is that the primary facilities needed for the production and distribution of natural gas are present in several provinces in the Netherlands, but a strong concentration can be seen in the northern three provinces; Drenthe, Friesland, and Groningen. If we look not only at the number of facilities but also at their direct footprint, we can see that the primary industrial footprint of the natural gas extraction is the largest in Groningen (Table 3).

Table 3: Number of facilities, direct footprint and the percentage of the direct footprint per province.

Province	Facilities	Direct footprint in hectares	Percentage
Drenthe	67	175,5	20%
Friesland	69	108,9	13%
Groningen	87	457,9	52%
Noord-Brabant	6	9,0	1%
Noord-Holland	15	38,2	4%
Overijssel	25	35,2	4%
Zuid-Holland	18	49,6	6%
Sum	*287*	*874,4*	*100%*

Not surprisingly, the industrial footprint is largely connected to the presence of natural gas. In de Dutch subsoil over 450 natural gas fields have been discovered to date. Around 250 of these are currently in production (NLOG.NL 2015). By far the largest field is the *Groningen field*, commonly referred to as the *Slochteren field*. All other fields are collectively referred to as the *small fields*. The discovery of natural gas fields over time is mapped and visible on the timeline on page 040.

A more detailed view of the industrial footprint in the province of Groningen is provided in Figure 23. Most facilities are located east of the city of Groningen, as that is where the slochteren field is located. The facilities have no direct visible relation with the landscape, as the processes that have created the natural gas reserves are in no way related to the processes that have shaped the current landscape (Meijles 2015). Also visible in Figure 23 are the national and regional distribution pipelines. Sometimes irregular landscape patterns and signage give away the presence of natural gas pipelines (Figure 22), but the vast majority of the network is invisible. Safety distances, that have to be taken in consideration with both the extraction facilities as with the pipelines, do however put a claim on the landscape. Land use in the near vicinity of extraction facilities and pipelines is limited by regulations. By calculating the safety distances, based on VROM (1986), the total amount of pre-occupied space amounts to 76km^2, which equates to 3,2% of the total surface area of the province. In comparison, the amount of land dedicated to transportation is 67 km^2, or 2,7% (Provincie Groningen 2008).

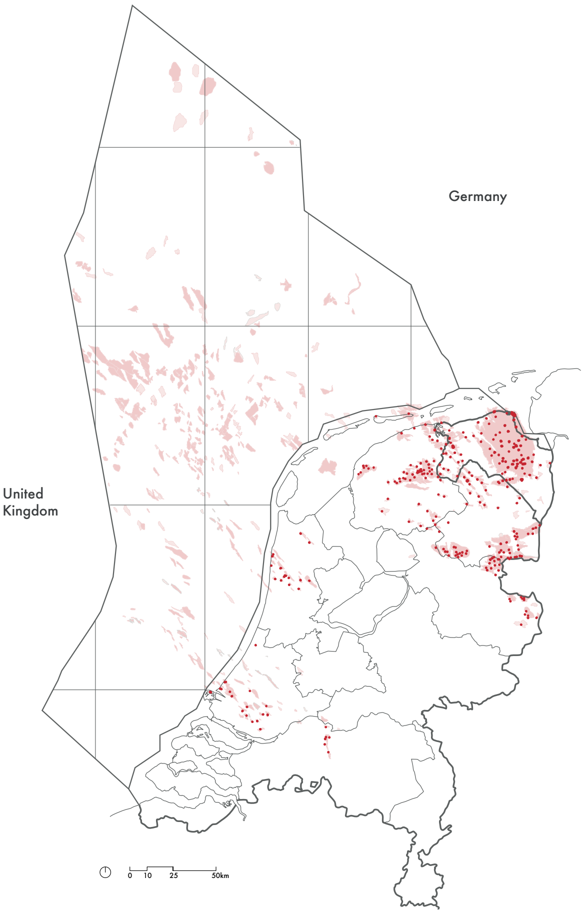


Figure 21: All known Dutch natural gas reserves and on-shore primary natural gas facilities, based on NLOG.NL (2015)

Figure 22: Underground pipeline is visible through a cleared patch of land and signage.

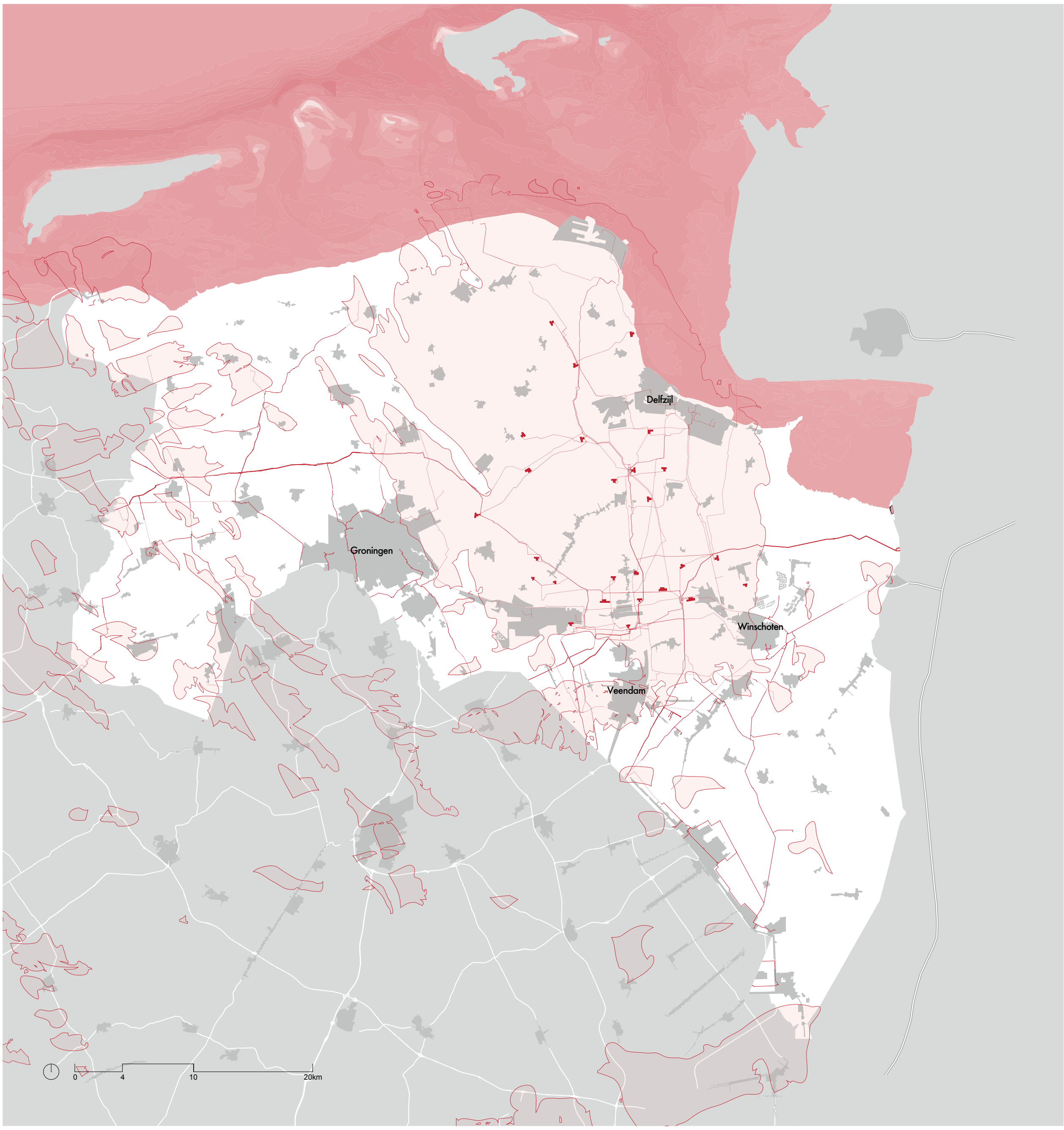


Figure 23: Natural gas fields, distribution pipelines and the primary industrial footprint of the natural gas extraction in Groningen. Based on NLOG.NL (2016) and NAM (2016).

The ancillary footprint

The ancillary footprint consists of all company build facilities like housing, leisure, and educational facilities as well as company investments into public infrastructure of various types. Headquarters, research facilities and other office buildings can also be counted to the ancillary footprint. The ancillary footprint is much smaller than the primary industrial footprint and harder to determine exactly. Furthermore, it is not specific for the natural gas extraction, as every energy source would require some ancillary structures. Ancillary structures do play a role in the public imaginary, as buildings as headquarters are often in prestigious locations (Hein 2016). An examples of an ancillary building is the NAM headquarters building in Assen (Figure 24). Another example is leisure centre *de Boô* (Figure 25), which was constructed especially for NAM employees living in the nearby NAM village.

Figure 24: NAM Headquarters in Assen. Photograph by Remko de Waal/ANP.

Figure 25: Leisure centre de Boô (www.provincialemonumentendrenthe.nl)

4.2.4 Physical impact

Soil subsidence

Depressurization of a natural gas field allows the porous sandstone layer in which the natural gas is contained to compact. This compaction leads to soil subsidence. The spatial development of subsidence is dependent on the production rate, the physical properties of the sandstone layer, and on the properties of the overlying subsurface layers (Ketelaar 2009). The compaction of the subsoil is the strongest in the northern part of the Slochteren field, near the village Loppersum. This is made visible in Figure 26, which depicts the projected situation in the year 2070. By then, the soil subsidence is expected to reach 47cm (NAM 2010).

Soil subsidence has multiple consequences. First, agricultural productivity will decrease because of soil increased soil wetness (Pöttgens & Brouwer 1991). Compensating for this by lowering the groundwater table can cause even more soil subsidence through oxidation of the soil (Deltares 2011). Second, the soil subsidence in the coastal area can decrease the protective capacity of dunes and dikes. Dunes will become more prone to erosion and relative to the subsiding land sea level rise will be higher. Protection against water may require reinforcement of dikes and levees, as well as the installation of additional water pumping stations (Doornhof et al. 2006). Third, ecological damage can occur in the Waddenzee due to a shift in currents and the associated sand transport (Pöttgens & Brouwer 1991).

Next to the extraction of gas, soil subsidence can result from several other factors in Groningen. Natural compaction of unconsolidated Holocene, Pleistocene or Tertiary sediments can occur. Furthermore, the mass of buildings or infrastructure can cause subsidence, depending on the soil. As mentioned, changes in hydrological regimes can also result in soil subsidence. It is difficult to separate the influences of these factors and as a result it is problematic to pinpoint the cause of soil subsidence. It is therefore difficult to compensate for damage due to natural gas extraction (Pöttgens & Brouwer 1991).

Earthquakes

Because of soil subsidence, friction can cause the build-up of tension alongside fault lines in the subsoil. This tension can release abruptly, causing minor earthquakes (van der Voort & Vanclay 2015). In 1986 the first earthquake believed to be directly caused by the natural gas exploitation was registered by the KNMI (Royal Dutch Weather Institute). From 1986 until 2015 the KNMI measured around 1200 natural gas induced seismic events in the province of Groningen. Around 115 of them had a magnitude of 2.0 on the scale of Richter or higher (KNMI 2016). Induced events have different characteristics than natural seismic events. Even though magnitudes of the seismic events are not as high as in naturally tectonically active areas, intensities are quite high because of the relatively shallow depth at which they occur and the soft soils in the area. This leads to damaged houses and infrastructure, even with relatively low magnitudes (van Thienen-Visser & Breunese 2015). Epicentres of all induced seismic events with a magnitude of 2.0 or larger are mapped in Figure 26. As strong concentration of earthquakes can be seen in the municipality of Loppersum, but other municipalities are also affected by the occurrence of earthquakes. There appears to be a correlation between the

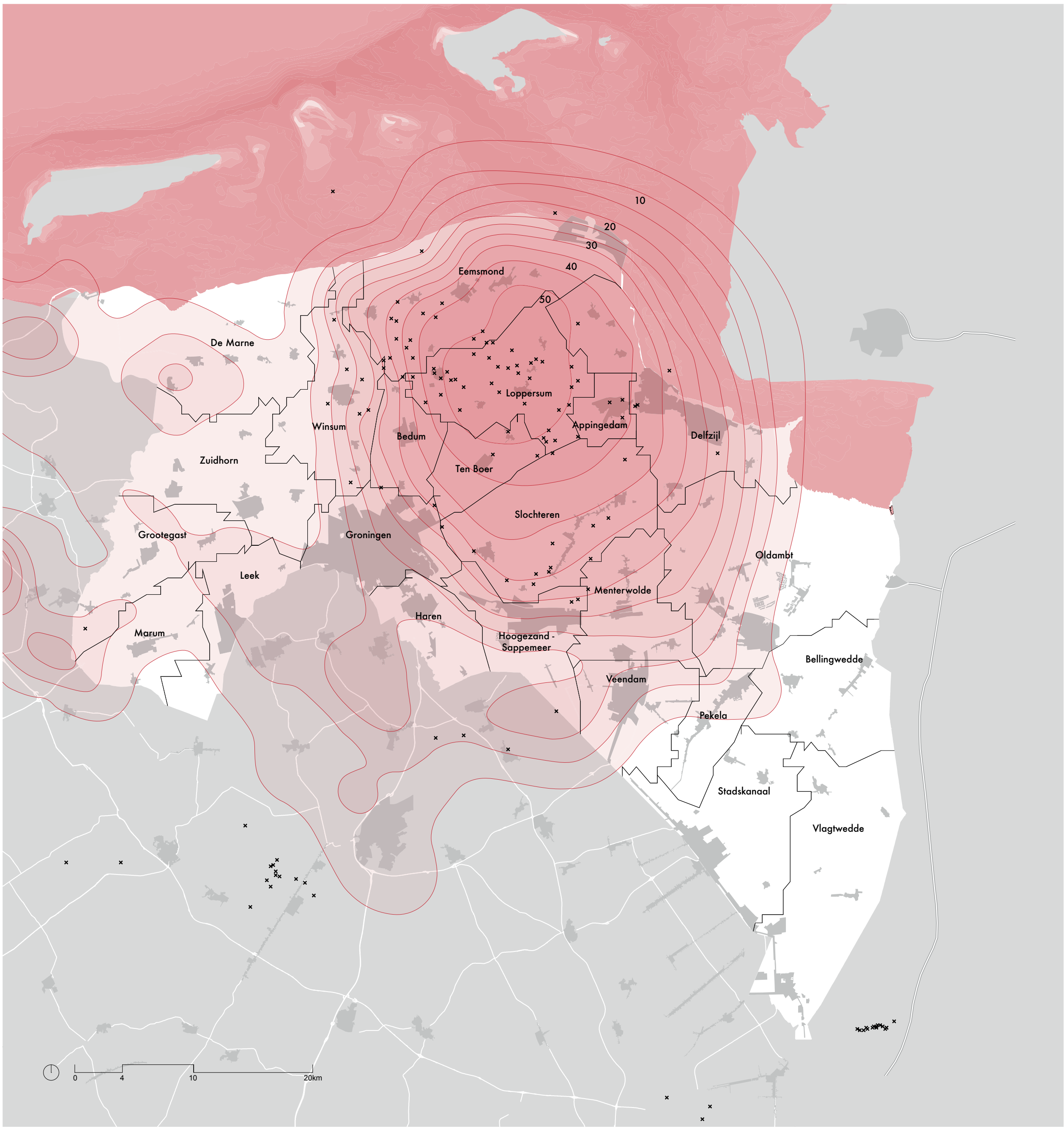


Figure 26: Expected soil subsidence in 2070 in centimeters and epicentres of extraction induced earthquakes with a magnitute greater than 2.0 on the Richter scale. Based on NAM (2015) and KNMI (2016)

increase in the number of seismic events and the increase in the production of the Groningen field (Dost & Kraaijpoel 2013). If natural gas production is not limited, it is likely that in the future, more earthquakes and heavier earthquakes are more prone to occur (KNMI 2016). The relation between seismic events and production rate is made visible on page 040.

4.3 SOCIAL- AND POLITICAL ANALYSIS

4.3.1 Introduction

Newspaper articles and policy documents were analysed as described in paragraph 3.1.1. From the analysis of the media reports an understanding of the trends in social attention and shifts in public opinion was developed. Running the search queries through the LexisNexis database resulted in a dataset consisting of 1210 newspaper articles, of which 821 where deemed relevant after quick inspection. From the Delpher database 72 newspaper articles where extracted. Combined with an analysis of governmental documents, and a spatial analysis of the development of the natural gas energy landscape, this evolved into a narrative of the life-cycle of the natural gas production. This narrative can be read in the next paragraph and is visualised on page 040. In order to improve readability, in-text citattions of newspaper articles are in superscript and are in a separate reference list in Appendix II.

4.3.2 The life cycle of natural gas extraction

19th century - Before natural gas

Before natural gas was commonplace as an energy source a different gas was used in the Netherlands. Through the gasification of coal in gas factories, coal-gas was made. In the first half of the 19th century private companies started with the exploitation of gas factories. In a later stage, municipalities started to operate these factories, and the supply infrastructure, as a public utility. This infrastructure became an important factor in the development of the natural gas based energy regime as we know it now (Correljé & Verbong 2004).

1930 - Exploration

In the 1930s the *Bataafse Petroleum Maatschappij* (BPM) a subsidiary of *Royal Dutch Shell* (Shell) acquired the exclusive rights to explore oil and gas in the north-eastern part of the Netherlands[1]. Oil was expected to be present in the soil in these areas. In 1937 the seismic exploration of the Dutch subsoil started. When seismologic experts deemed the changes of oil in the subsoil high enough, test drilling started[2]. It was during the Second Wold War when the BPM discovered the first Dutch oilfield in Schoonebeek, near Coevorden. The extraction of crude oil was however problematic. The Second World War caused a shortage of proper technical equipment to extract the crude oil from the soil. That is why, in 1947, the BPM established a joint venture with an American company: the *Standard Oil Company of New Jersey*, under the name of *Esso* (now part of *ExxonMobil*). In this joint venture, called the *Nederlandse Aardolie Maatschappij* (NAM), the American partner could provide the necessary drilling equipment that was lacking in the post-war Dutch economy[3]. The NAM acquired a drilling permit and started producing oil from the field discovered in Schoonebeek with the so called *ja-knikkers (*pump jacks). Stimulated by this success the NAM continued exploring the Dutch sub-soil for other oil fields[4].

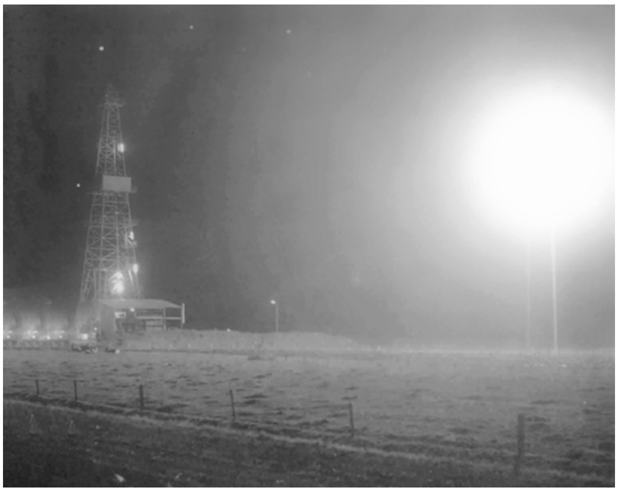


Figure 27: Flaring of natural gas at one of the first natural gas wells in the Slochteren field. Adapted from Borghuis (1988)

1948 - Involvement

Over the 1950s, a number of moderately sized deposits of natural gas and oil were discovered. The natural gas fields did not have a priority with the NAM, as the extraction of natural gas was not deemed profitable at the quantities it was found. Oil was considered more important[5]. Therefore, the discovery of the first Dutch natural gas field near Coevorden, in July 1948, was met with mixed feelings[6]. In order to get rid of the cumbersome by-product of the oil extraction, the natural gas was either burned or sold to nearby municipalities[7]. This is why, in 1951, the city of Coevorden was the first city in the Netherlands to switch from coal-gas to natural gas[8]. This transition was largely driven by the pioneering work of the owner of the Coevorden coal-gas factory, who saw the potential of his gas distribution network[9][10].

With the discovery of more natural gas field the Dutch state saw the need to regulate the market for natural gas. In 1954, the state pressed for an agreement between the NAM and the newly founded 'Staatsgasbedrijf' (SGB). The agreement entailed that the NAM was forced to sell all the natural gas they produced to the SGB. The SGB, in turn, distributed the natural gas[11]. Although the Dutch state had hoped that the SGB could form a nationwide distribution network, attempts at creating such a network failed[12]. The sudden discovery of large amounts of natural gas near Slochteren, however, provided unexpected opportunities to the Dutch gas industry.

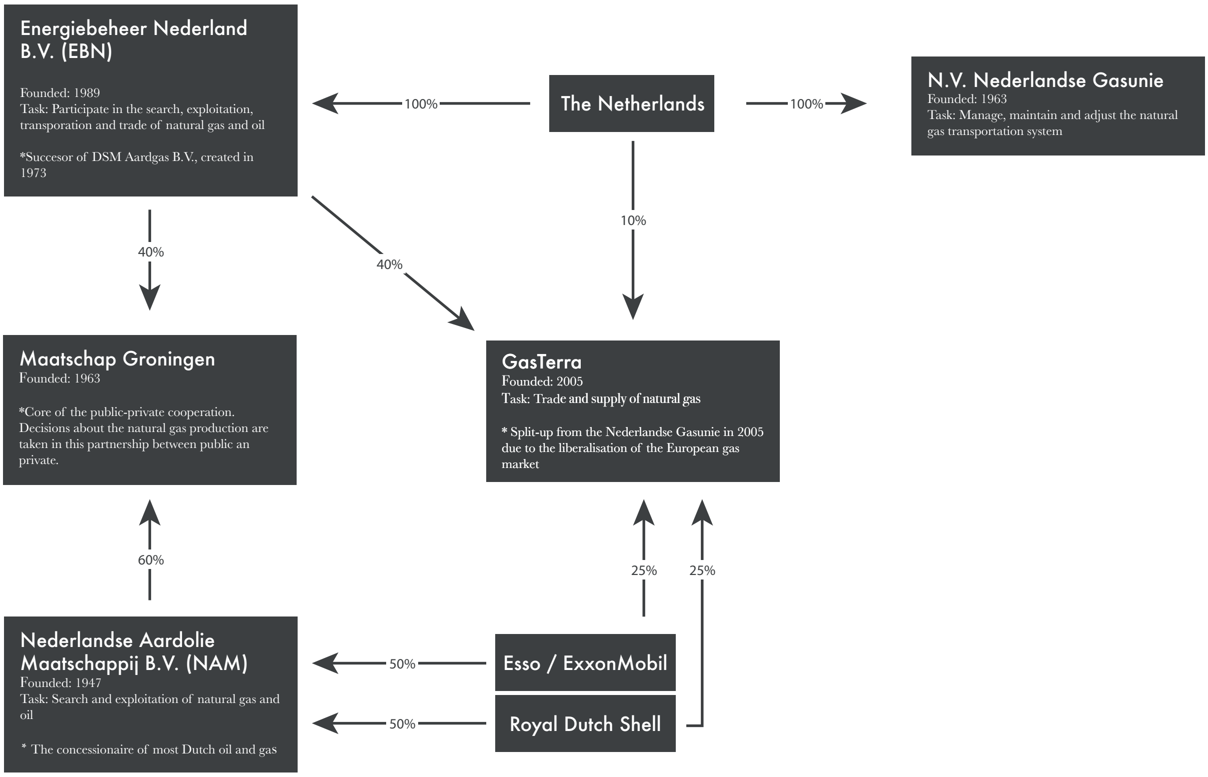


Figure 28: Institutional framework of the natural gas extraction. Adapted from de Onderzoeksraad voor de Veiligheid (2015)

1959 - Discovery

Despite the NAM's lack of interest in natural gas a large gas deposit was discovered near Slochteren in July 1959. The pressure of the new found gas field was high, but NAM director Stheeman downplayed the importance of the find as "the pressure of a gas field does not tell anything about its size"[13]. News coverage of the discovery was therefore limited. Only after Belgian senator Leemans mentioned that a large natural gas field was found in the Netherlands it was picked up by different newspapers in 1960[13]–[15]. This started speculations about the size of the Slochteren field ranging from 60 billion m^3 to 300 billion m^3 [16]. The exact size of the discovered gas field was initially unknown. Out of strategic considerations, the NAM kept as much details about the Slochteren field a secret[17]. In 1960, the NAM and the Dutch minister of economic affairs, De Pous, started negotiations about the extraction of natural gas from the Slochteren field[18]. Both parties saw the need for a renewed framework for the exploitation as the prevailing institutional framework, where the NAM was forced to sell to the SGB, was not deemed adequate for a gas field of this size (Correljé & Verbong 2004). Negotiations lasted till 1962 and resulted in the creation of a white paper, *Nota inzake het Aardgas*. The white paper effectuated the signing of a cooperation agreement between the two partners of the NAM and the Dutch government[19]. The institutional framework of the public-private cooperation that was formulated in the cooperation agreement is known as *het Gasgebouw*. This institutional framework has changed slightly over the years, mainly through liberalisation of the gas market[20]. An overview of the current institutional framework, with shareholder connections, can be seen in Figure 28.

Figure 29: Municipal promotion of natural gas, the sign reads: 'Natural gas is here tomorrow'. From Warner (2009)

1963 - Development

With the institutional framework complete, production from the Slochteren field could start. In July 1963 the first production well was spudded and in December of the same year the first natural gas was supplied to the newly founded Gasunie[21]. In order to commercialize the natural gas, Esso mooted the idea to focus on households and their heating, after a similar experience Esso had in the United States. This way the consumption of gas could increase dramatically. This was needed in order for the entire natural gas endeavour to become profitable[19][22]. An infrastructure network for the transportation of natural gas was built quickly, in order to get a quick return on the large investments. Planning for the gas distribution network started in 1962. Despite the large scale of the project, the network was constructed rapidly[23]. Local coal-gas networks were often incorporated into the new infrastructure, changing the role of the production factories to mere distribution points[24]. Techniques learned from the pioneering city of Coevorden were applied to accommodate a smooth transition. In 1968 the last Dutch municipality was connected to the distribution network[25]. In this short timespan nearly 1600 km of high-pressure pipelines was build, and the regional distribution networks doubled in size to 5000 km.

Figure 30: Construction of a pipeline to offshore gas extraction facilities, near Callantsoog. From Borghuis (1988)

Natural gas quickly became a popular energy source for domestic use. The convenience of natural gas, and the lower price made gas the preferred energy source for household heating and cooking[22]. Also the reimbursement of the cost of the adaptions to the household gas appliances by municipalities greatly added to a quick adaption of natural gas[26]. Public opinion was positive at this time as natural gas was perceived a clean energy source. Furthermore a healthy competition between natural gas and electricity was deemed positive[27]. The impact on the landscape was hardly considered problematic. When the large Groningen field was discovered beneath his agricultural fields, farmer Boon reacted laconically on the news; “I heard that I had to allow it [the drilling], so I agreed to temporarily give away a few hectares to the NAM”[28].

Exploration for natural gas field did however cause social unrest when it concerned nature areas, like the Waddenzee. Exploration of the Waddenzee started in 1962 and when the first natural gas fields were discovered a discussion started[29]. Nature conservation groups started questioning the necessity of natural gas extraction in such fragile nature areas[30]. Furthermore, inhabitants of the Wadden-islands feared that the production facilities would irreparably damage their landscape, and disrupt the peace of living[31]. Future drilling operations, and the possibility of spills, were also seen as a thread for the mussel cultivation[32]. Objections filed by nature conservation groups accomplished to severely stall the exploration process.

Figure 31: Queen Beatrix visiting a Slochteren production site. From Borghuis (1988)

1974 - Regime change

The shock of the first oil crisis lead to a more conscious energy policy. In 1974 the first *energienota* (energy white paper) was created by the Dutch government[33]. It described, among others, the policy of how to deal with problems in energy supply, new energy sources and their effects on the environment and problems connected to scarcity of energy sources. The first *energienota* also had an impact on the natural gas production in the Netherlands. In 1974, the share of natural gas in the total energy consumption was around 50%. This large amount was seen as problematic, as production of the current know gas reserves would lead to a depletion of all the reserves in the year 2000 (Ministerie van Economische zaken 1974). Initial plans to produce the Slochteren field as quickly as possible, instigated by the promise of the abundant availability of nuclear energy[34], were revisited. The new aim was at stretching the availability of natural gas for the future by reducing the demand of natural gas trough pricing and allocation policy and increasing the supply[35]. This increased supply was to be achieved by exploiting several smaller natural gas fields. This even though the notion that exploiting these fields could become problematic due to the objections from nature, environment and planning perspectives. This policy was later named the *kleineveldenbeleid* (small fields policy). In this small field policy, the large Slochteren field would function as providing swing-production capacity in times of extreme cold[36]. Furthermore, the gas from the Slochteren field could be used to balance the differences in the calorific value of the natural gas of the smaller fields, ensuring a stable product.

In 1980 the Dutch government allowed for the extraction of natural gas from the subsoil beneath the Waddenzee[37]. NGOs such as *Waddenvereniging* and Greenpeace organised several protest actions and collected signatures, disagreeing with the course of action[38][39]. After heavy protest the Dutch government and the gas companies agreed on a moratorium on further gas production in this area. This moratorium was installed in 1984, and would last for 10 years[40].

1986 - Earthquakes

In December 1986 the city of Assen was surprised by earth shocks that lasted over 50 seconds. The KNMI concluded that the earthquake had a magnitude of 3.0 on the scale of Richter[41]. Geographer van der Sluis was the first to make a connection between this earthquake and the natural gas extraction[42]. He argued for an independent investigation. The NAM responded to this by stating that a relation between earthquakes and natural gas production is pure fiction[42]. The KNMI also did not see any evidence for the theory gas extraction induced earthquakes[43]. In the next few years, several more earthquakes occur and the extraction of natural gas is beginning to be questioned more[44]. This urges the minister of economic affairs to considers a multidisciplinary investigation into the earthquakes occurring in the northern part of the Netherlands[45]. It is only in 1992 that the first preliminary results of this study acknowledge a connection between natural gas extraction and earthquakes[46].

1995 - Maturity/Stagnation

By now the Dutch subsoil has been charted intensively with different and increasingly modern techniques. Until now the amount of new natural gas that was being discovered had been stable, adding on average 30 billion m^3 of gas per year to the total known reserves. By the mid 90s, a stagnation occurred in the discovery of new gas reserves. The prospect portfolio changed over time as less attractive prospects were discovered and more small or high-risk prospect became part of the portfolio[47]. The chances of locating significant amounts of natural gas became more limited, the natural gas industry reached a mature phase. Oil and gas companies active in the Netherlands started reducing their exploration activities and budget significantly (Geluk 2012).

In order to compensate the declining production rates of the small fields the Slochteren field started to structurally increase production again from 2000[48].

Towards the end of the moratorium on drilling in the Waddenzee protest flared up again, as nature conservation groups feared new drillings in the area[49][50]. Despite heavy protest the Dutch government allowed new exploration drilling activities in 1994, as the natural gas in the Waddenzee would be a substantial addition to the known gas reserves[51]. This decision was further motivated by the fact that earlier drillings did not have any adverse effects on the Waddenzee ecosystem[52]. In 1999 the government reversed this decision, after heavy emotional pressure from parliament. Further drillings were prohibited from this point[53]. This decision was reversed again in 2004, allowing companies to drill in the Waddenzee. A fear of damage claims for the loss of revenue by drilling companies possibly played a role in this decision[54].

Just like with the Waddenzee drillings, the plans for a gas storage facility near Langelo, a village in Drenthe, were met with great resistance. Not the underground storage was feared but the impact of the above ground facility. The noise, smell, and visual pollution were seen as a threat[55]. An industrial area like a gas storage facility was considered harmful to the stream valley landscape by inhabitants and nature conservation groups[56]. Despite protests, the gas storage facility was eventually built, but with a clear architectural concept[57].

Figure 32: Natural gas storage facility near Langelo, designed by HOSPER landscape architects. (www.arquitectes.cat)

In 1996 the NAM terminated oil production from its Schoonebeek field. The field, that triggered the search for oil and gas in the Netherlands, had produced some 40 million m^3 of oil after nearly 50 years of production[58]. The oil field was considered so important for the village of Schoonebeek that one of the pumpjacks was preserved in the village centre as a monument of historic importance. Other remnants were removed in a large clean-up operation[59][60].

Figure 33: Iconic pumpjack near Schoonebeek. From Borghuis (1988)

2010 - Decline

The realisation that most conventional underground gas deposits have been discovered at this point sparked an interest in other sources of natural gas. Around 2010 first media attention was given to the exploration of these so called unconventional gas sources (Geluk 2012). In the Netherlands the name shale gas is most commonly being used to describe unconventional gas. Unconventional gas occurs in different reservoirs than conventional gas. The consequence of this is that the production methods of unconventional gas differ greatly from those of conventional gas. Development of unconventional gas requires a very large numbers of wells, and is often accompanied by injections of large quantities of water, mixed with chemical components, a process called *fracking* (ibid). The extraction of unconventional gas was seen as an opportunity to rejuvenate the natural gas market in the Netherlands, as new gas reserves could be exploited (Metze 2014). However, the uncertainty about the negative environmental impacts of fracking quickly made fracking a controversial issue (ibid). Plans for unconventional gas developments have been met with great opposition throughout the country[61][62] (Figure 34). Currently no unconventional gas production wells are active in the Netherlands.

In 2012, the earthquake in Huizinge (municipality of Loppersum), refuelled the debate on earthquake risks. The tremor, with a magnitude of 3,6 on the Richter scale, is the largest natural gas induced earthquake registered to date (KNMI 2016). People living near the epicentre later described the tremor as “different than before” and described the ground as “wavy, like the sea”[63]. People living above the natural gas fields start to fear the tremors more and more[64]. More and more building damage reports reach the NAM, but inhabitants do not have confidence in a swift an adequate settlement procedure[65]. The amount of earthquakes increased through the years. From 1986, when seismic monitoring started, 152 earthquakes with a magnitude equal or greater than 2.0 were recorded (KNMI 2016). An increase in the number of earthquakes can be seen from 2002, two years after the production of the Slochteren field started to increase again (visible on page 040).

Figure 34: Protest against shalegas winning. (www.milieudefensie.nl)

2014 – Current situation

The earthquake in Huizinge renewed the debate about the negative consequences of the natural gas extraction[66][67]. A decrease in the production is generally seen as the only option to reduce the amount of earthquakes (Geluk 2012), something that was urged for by several advocacy organizations and political organisations[68]–[70]. This led to the decision to limit the production of the Slochteren field to 39,4 billion m^3 in 2014[71]. Under pressure of the province of Groningen, the affected municipalities, and the *Raad van State* (Council of State), the production was even limited further in 2015. Minister Kamp decided on a production cap of 30 billion m^3 for 2015, and a cap of 27 billion m^3 for 2016[72]. Next to a production limit, minister Kamp also reserved money for the structural strengthening of buildings in the affected areas[73].

4.4 CONCLUSIONS

The life cycle of the natural gas production in the Netherlands has reached a state of decline. Attempts at rejuvenation of the natural gas market through unconventional natural gas sources have failed and are likely to be met with great public resistance in the future. The physical consequences of the natural gas extraction, soil subsidence and especially earthquakes, have caused a shift in the public perception. The energy source that was once viewed as a welcome, clean fuel is now seen as problematic.

After several heavy earthquakes feelings of insecurity and a dissatisfaction in the mitigation and compensation measures resulted in anger and distrust towards the extraction of natural gas. Key turning points in this were the earthquakes in 1986 and in 2012. As there is a large opposition against natural gas, especially amongst inhabitants of the gas extraction area, now is the time to move away from natural gas as an energy source and move forward towards renewable alternatives.

Figure 36: Occupation of a natural gas extraction facility. The sign reads: 'Occupied! Claimed by and for the people of Groningen'. Photograph by Anjo de Haan/ANP.

In the early years of natural gas extraction there was no opposition against the physical presence of natural gas extraction facilities. After a decade, the first protest against planned extraction facilities started. The industrial looking complexes were seen as unwanted when they were planned in or near fragile nature areas. Protests against new facilities were often dominated by concerns about the ecological consequences, and not so much the impact on the human experience[32]. In a few cases the visual impact, or other sensory experiences like noise or smell, were mentioned as arguments against expansion of the natural gas infrastructure[30][31]. A clear architectural concept helped the natural gas storage facility in Langelo to be more accepted. The starting notion of the design by landscape architecture firm *HOSPER* was that an industrial complex can form a positive addition to the landscape as something that is attractive to look at. In more recent years the natural gas extraction facilities have become the target of protest groups.

Some of the remnants of the oil extraction from the Schoonebeek field are preserved and function now as a testament to the oil extraction. A pumpjack is conserved in the village centre of Schoonebeek. This shows that remnants like this prove to have cultural value.

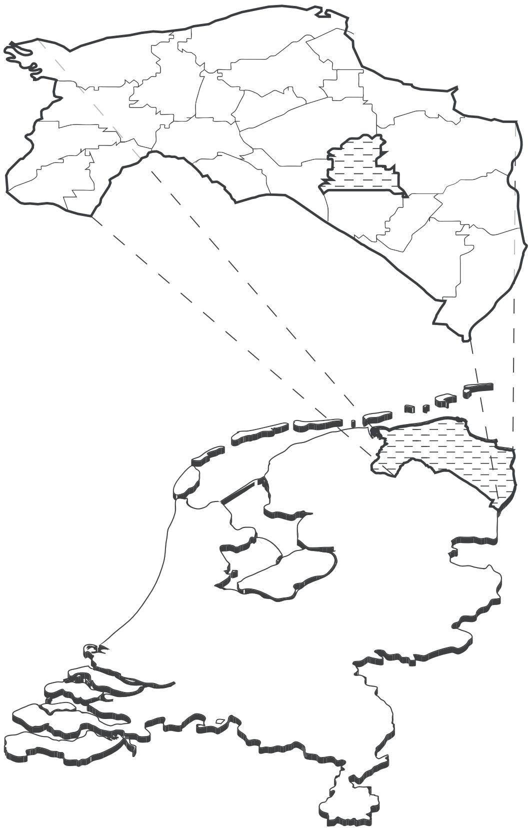
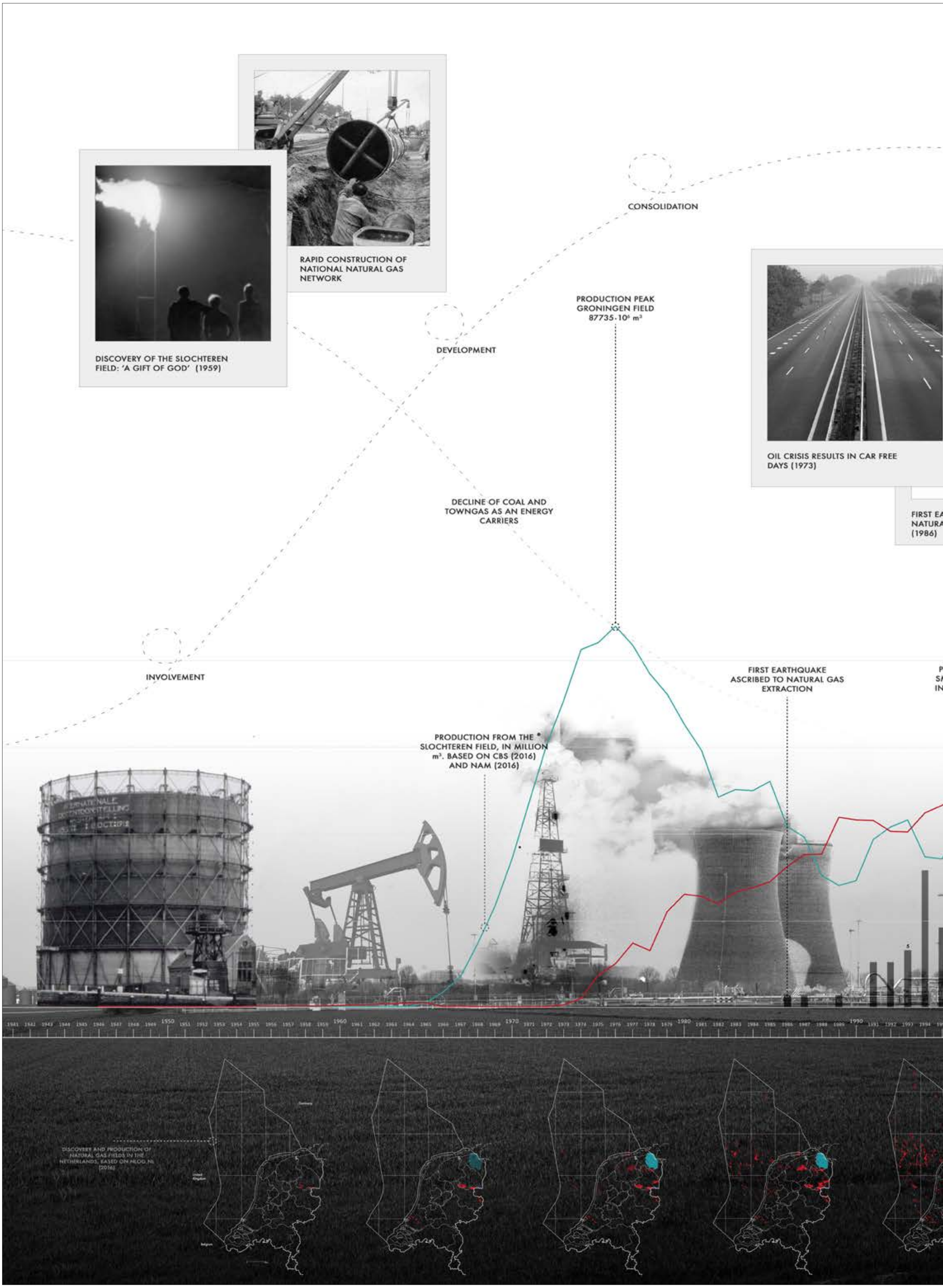


Figure 35: Location of the municipality of Menterwolde, relative to the province of Groningen and to the Netherlands.

Based on the physical analysis the municipality of Menterwolde was chosen as the location for further analysis and design. Menterwolde is a municipality in the eastern part of Groningen (Figure 35), and one of the municipalities that is affected by soil subsidence and earthquakes. Furthermore, Menterwolde hosts several facilities connected to the extraction of natural gas, both above ground and beneath the surface. Lastly, Menterwolde is a municipality with a variety of landscape types, as three of the described landscape types are present in the municipality. This makes the design on the municipal scale more varied and increases the research value as multiple design options have to be explored.



DISCOVERY OF THE SLOCHTEREN FIELD: 'A GIFT OF GOD' (1959)

RAPID CONSTRUCTION OF NATIONAL NATURAL GAS NETWORK

OIL CRISIS RESULTS IN CAR FREE DAYS (1973)

CONSOLIDATION

DEVELOPMENT

INVOLVEMENT

PRODUCTION PEAK GRONINGEN FIELD 87735·10⁶ m³

DECLINE OF COAL AND TOWNGAS AS AN ENERGY CARRIERS

FIRST EARTHQUAKE ASCRIBED TO NATURAL GAS EXTRACTION

PRODUCTION FROM THE SLOCHTEREN FIELD, IN MILLION m³. BASED ON CBS (2016) AND NAM (2016)

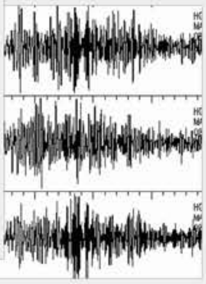
DISCOVERY AND PRODUCTION OF NATURAL GAS FIELDS IN THE NETHERLANDS, BASED ON NLOG.NL (2016)

STAGNATION

DECLINE

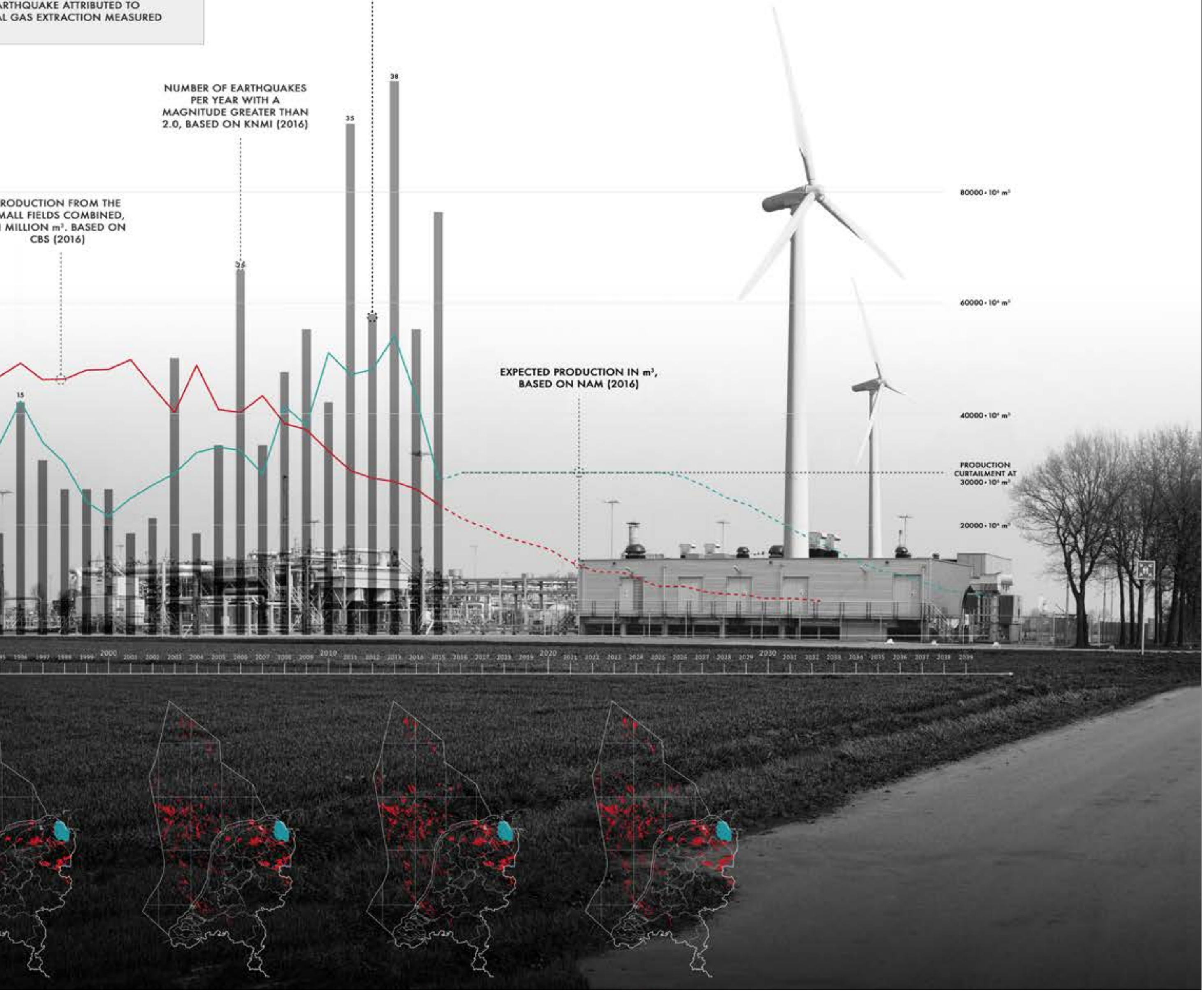
HEAVY PROTESTS CAUSE THE INSTALMENT OF A PRODUCTION CURTAILMENT (2014)

INHABITANTS FEEL FORSAKEN WHEN DEALING WITH EARTHQUAKE DAMAGE



ARTHQUAKE ATTRIBUTED TO
AL GAS EXTRACTION MEASURED

HEAVY EARTHQUAKE (3,6 ON THE RICHTER SCALE) REFUELS THE DEBATE ON NATURAL GAS EXTRACTION



NUMBER OF EARTHQUAKES PER YEAR WITH A MAGNITUDE GREATER THAN 2.0, BASED ON KNMI (2016)

RODUCTION FROM THE
MALL FIELDS COMBINED,
MILLION m³. BASED ON
CBS (2016)

EXPECTED PRODUCTION IN m³, BASED ON NAM (2016)

5

MEDIUM SCALE

5.1 INTRODUCTION

The following paragraphs will form the base for an energy landscape design for the municipality of Menterwolde. Therefore the following research question was posed:

What kind of future landscape can be expected?

In order to answer this question several characteristics of the municipality were studied. A more in depth landscape analysis reveals the spatial characteristics of the municipality in paragraph 5.2. In paragraph 5.3 the present energy system is analysed. This will serve as a baseline for the energy prospect given in paragraph 5.4 In paragraph 5.5 the expected spatial developments for the near future are depicted, which will form the starting point for the medium scale design. In paragraph 5.6 the potentials for renewable energy are mapped. This will result in a desing principles in paragraph 5.8, followed by designs in paragraph 5.8. The energy balance of the depicted future situation is visible in paragraph 5.99.

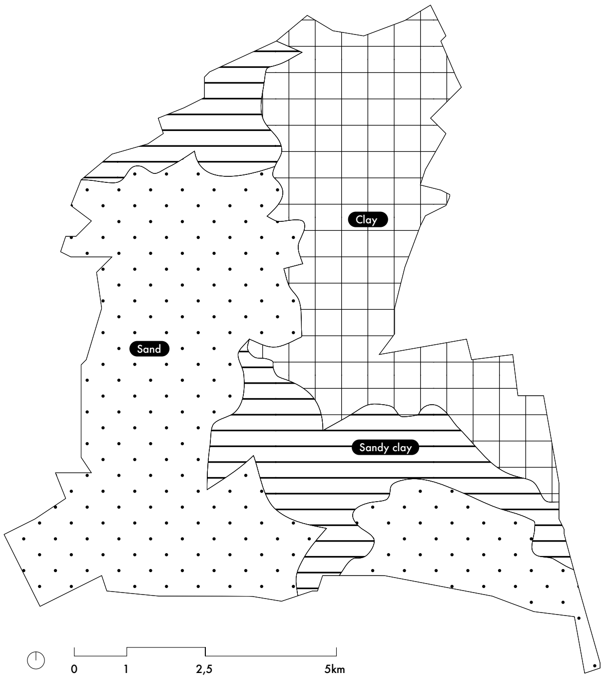


Figure 37: Soil types in Menterwolde, based on Alterra (2006)

5.2 LANDSCAPE CHARACTERISTICS AND LAND USE

The landscape in Menterwolde has a strong connection with the subsoil, but also has a strong anthropogenic character. The municipality is located on the transition between the clay soils in the east of the province, and the sandy soils in the south and west of the province (Figure 37). Ribbon villages like Noordbroek and Meeden are constructed at the transition between these two soil types, where sand ridges provided a slight elevation above the rest of the landscape. The agricultural landscape on the clay soils is characterized by its large openness, where in the sand soils more historic parcelling has remained. The differences in soil type have had a large influence on the process of human cultivation of the landscape and has resulted in the origination of three distinct landscape types in Menterwolde, that stretch further than the municipal border (Figure 38).

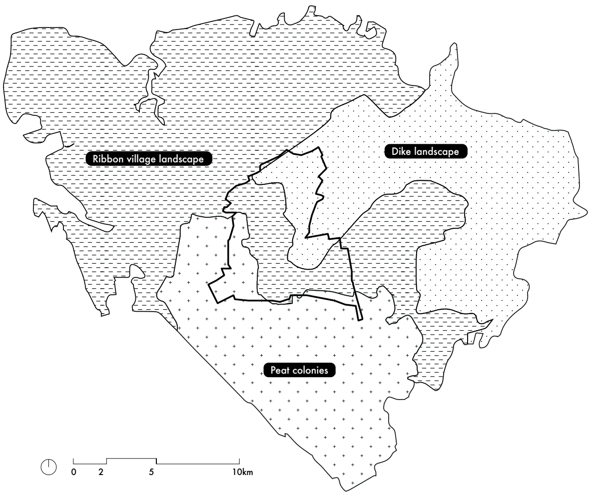


Figure 38: Landscape types in Menterwolde, after Provincie Groningen (2013)

On the south side of the municipality there are parts of the *Groninger Veenkoloniën* (peat colonies), a landscape type that has arisen from the cultivation of the peat bogs. The process of cultivation started from the 17th century and continued to the first half of the 20th century. In a similar fashion to that of the colonization of new land (hence the name),. The prefix *Groninger* doesn't refer to the province but to the city of Groningen, who was in charge of the colonisation process. Jacobus Sibrandi Mancadan vividly illustrated the roughness of the peatlands before the cultivation (Figure 39). The roughness is in sharp contrast with the rationality of the cultivated landscape, characterized by a long and narrow parcelling. Canals played an important role for transportation in the cultivation process and are now still visible in the landscape. Villages are constructed alongside canals and consist of a mixture between agricultural, residential and sometimes industrial buildings. Farmhouses of the Oldambster type are typical (Figure 40).

years, visible in Figure 41. This resulted in a landscape with large parcels, heavy sea clay soil, and old dikes. It is characterized by its large openness, as view obstructing objects are scarce. The openness can be considered one of the core landscape value of this landscape. Van Holten captured this vast open landscape strikingly in his abstract acryl painting (Figure 42). The rich clay soils make the land well suited for agriculture. Farmhouses of the Oldambster type are also common in this landscape.

Figure 39: 'Hoogveenontginning waarschijnlijk in de omgeving van Wildervank' by Jacobus Sibrandi Mancadan (1650). (https://commons.wikimedia.org)

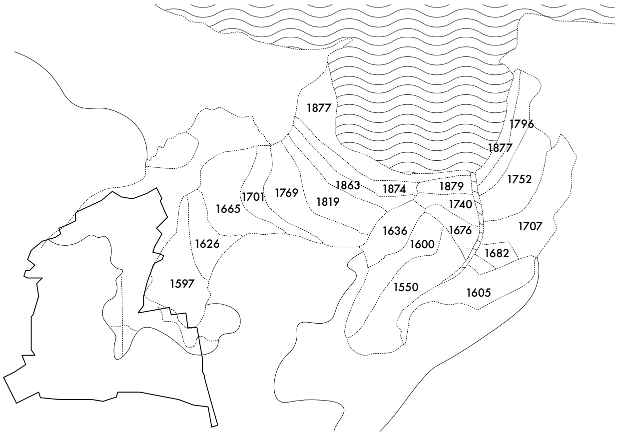


Figure 41: Land reclamation of the Dollard through time, after (http://irs.ub.rug.nl/ppn/16050354X)

Figure 40: Photograph of a ribbon village next to a canal. The farmhouse on the left is of the Oldambster type

Figure 42: 'Oldambt vier' Marten van Holten (n.d.). (www.martenvanholten.nl)

The eastern part of the municipality can be classified as being part of the *Dijkenlandschap* (dike landscape). The Dollard, the sea-arm connecting the Ems river with the North Sea, once reached close to Muntendam. Much of the land east of Menterwolde has been reclaimed on the Dollard over the course of hundreds of

The third landscape type that can be identified is the *Wegdorpenlandschap* (ribbon village landscape). This landscape type is smaller in scale and the parcelling has a more irregular character. The ribbon villages are iconic for this landscape type. They are located on the slightly higher sand ridges. The surrounding landscape permeates into the ribbon villages, as it is clearly discernible from the main road of the ribbon villages (Figure 43). The ribbon villages consist of a concatenation of large and smaller farmhouses, houses, and trees. Road accompanying planting is also frequently present.

Figure 43: Photograph taken from the main road of a ribbon village. The surrounding landscape is visible between the farm houses.

The municipality of Menterwolde is a relative small municipality, with a suface area of 81,6 km^2. Agriculture is the most dominant land use in the municipality, as it constitutes of more than 80% of the total land use. In Menterwolde there are five natural gas extraction sites located, of which two are currently suspended from production. Furthermore, several smaller facilitative locations are present. Beneath the surface many national and regional distribution pipelines are present. The safety zones for the natural gas pipelines, in which land use is restricted, put a claim on 3,5km2. This is visible in Figure 49.

Historically, Menterwolde has been dominated by agricultural land use. What is the most notable change in the last century is the difference in parcelling size (Figure 44). Land consolidation programs have caused a great increase in the average parcel size. The amount of small ditches has also been reduced drastically. Infrastructure has also changed in the last century. One railroad connection has been removed. A canal to Veendam was constructed. Both the A7 and the N33 were newly constructed, and connected with each other through a cloverleaf interchange. Growth occurred mostly in Muntendam and Zuidbroek, near the canals. Most ribbon villages still have their traditional character. Business parks and greenhouses have arisen in the vicinity of the A7.

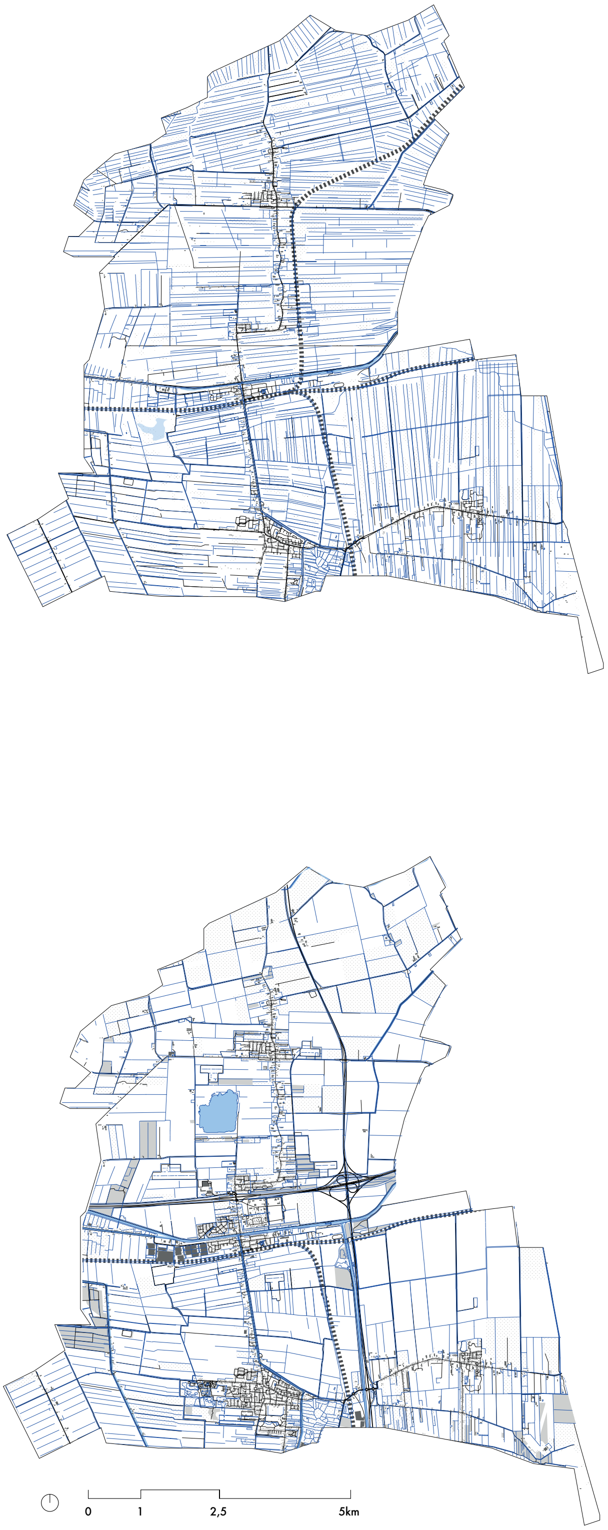


Figure 44: Land use in 1904 (top), based on Wieberdink (1989), and current landuse (bottom).

Figure 45: Road accompanying linear tree structures in the ribbon village Zuidbroek

Figure 46: Irregular parcelling with road accompanying tree structures in the outer areas of the ribbon village landscape

Figure 47: Canal with accompanying linear tree structure, typical for the peat colony landscape.

Figure 48: Large open agricultural landscape next to the N33, typical for the dike landscape.

Figure 49: Municipality of Menterwolde, current landuse (81,6 km² total)

5.3 PRESENT ENERGY SYSTEM

The current energy balance of the municipality of Menterwolde is based on quantitative data gathered from *Klimaatmonitor* (2016) and the *Central Bureau of Statistics* (CBS 2016) (Table 4). Klimaatmonitor gathers data from mulitiple sources and makes assumptions based on a distribution model for unknown figures. Klimaatmonitor divides the energy consumption in different sectors. Most data is over 2014, except for data about mobility, which is over the year 2013. Data about energy production and natural resource extraction activities are classified for Menterwolde, and are therefore not included. Moreover, they would skew the energy consumption greatly because of the high amount of natural gas extraction facilities in the municipality. In order to make different energy sources comparable, all data is shown in Terajoule (TJ).

Table 4: Energy use of Menterwolde in TJ, after Ministerie van Infrastructuur en Milieu (2016)

Sector	*Sub-sector*	*TJ*
Build environment	Housing	389
	Commercial services	58
	Public services	55
Mobility (excl. rail traffic)	Road traffic	495
	Mobile equipment	71
	Inland ship transport	9
	Ship transport	0
Industry, energy, waste, and water	Industry	13
	Construction industry	6
	Waste and (waste) water	1
Agriculture	Agriculture, forestry, and fisheries	159
Renewable	Heat	38
Total		***1294***

Comparing the energy balance to the average of the province of Groningen shows three interesting points. First, the energy consumption of the mobility sector is far above the provincial average. This can probably be contributed to the low population density in Menterwolde while extensive infrastructure is present in the municipality. Second, the energy consumption in the industry sector is a lot lower than the provincial average. This is due to an absence of large, energy intensive, industry in the municipality. Lastly, the energy consumption of the agricultural sector is higher than the provincial average. This can be contributed to the relatively large presence of agricultural businesses in the municipality.

Currently, Menterwolde relies largely on fossil fuels. Only 5,8% of the energy is being generated from renewable sources (Ministerie van Infrastructuur en Milieu 2016). This number is however a top-down interpolation based on a national distribution model and could therefore be inaccurate. The amount of renewable energy generated is often not monitored (ibid). Determining the amount of renewable energy in Menterwolde is therefore troublesome. A bottom up indication, based on for example the amount of installed capacity, is not available at this time. Therefore, the top-down data will be used with its limitations in mind.

The current energy consumption in Menterwolde can be divided into three categories:

- *Heat/cold demand*
- *Electric energy demand*
- *Mobility energy demand*

Calculations on the attribution of energy consumption towards the different categories are visible in Appendix III. Referencing the energy consumption data per category with the energy consumption data per neighbourhood, provided by the CBS (2016), generates a spatial view of the energy consumption in the Municipality. This is made visible in Figure 50. This information can be useful as bringing energy sources and energy sinks close together can be a good strategy to minimize energy losses through transportation (de Waal & Stremke 2011).

The energy system in Menterwolde is visible in the landscape in some places. The natural gas extraction facilities that are located in the municipality are often highly visible. Furthermore, high voltage powerlines and an electrical substation are present in the municipality. Both are indicated in Figure 49.

5.4 FUTURE ENERGY DEMAND

In order to design a future energy landscape consisting of renewable energy sources it is important to make estimations on the amount of energy consumed in the future. This implies many uncertainties. Assumptions will therefore be a part of this prospect. These assumptions will be reasoned and explained, in order to be as realistic as possible. The future energy consumption will be based on the current energy consumption patterns. A timeframe of ten years is taken as a starting point.

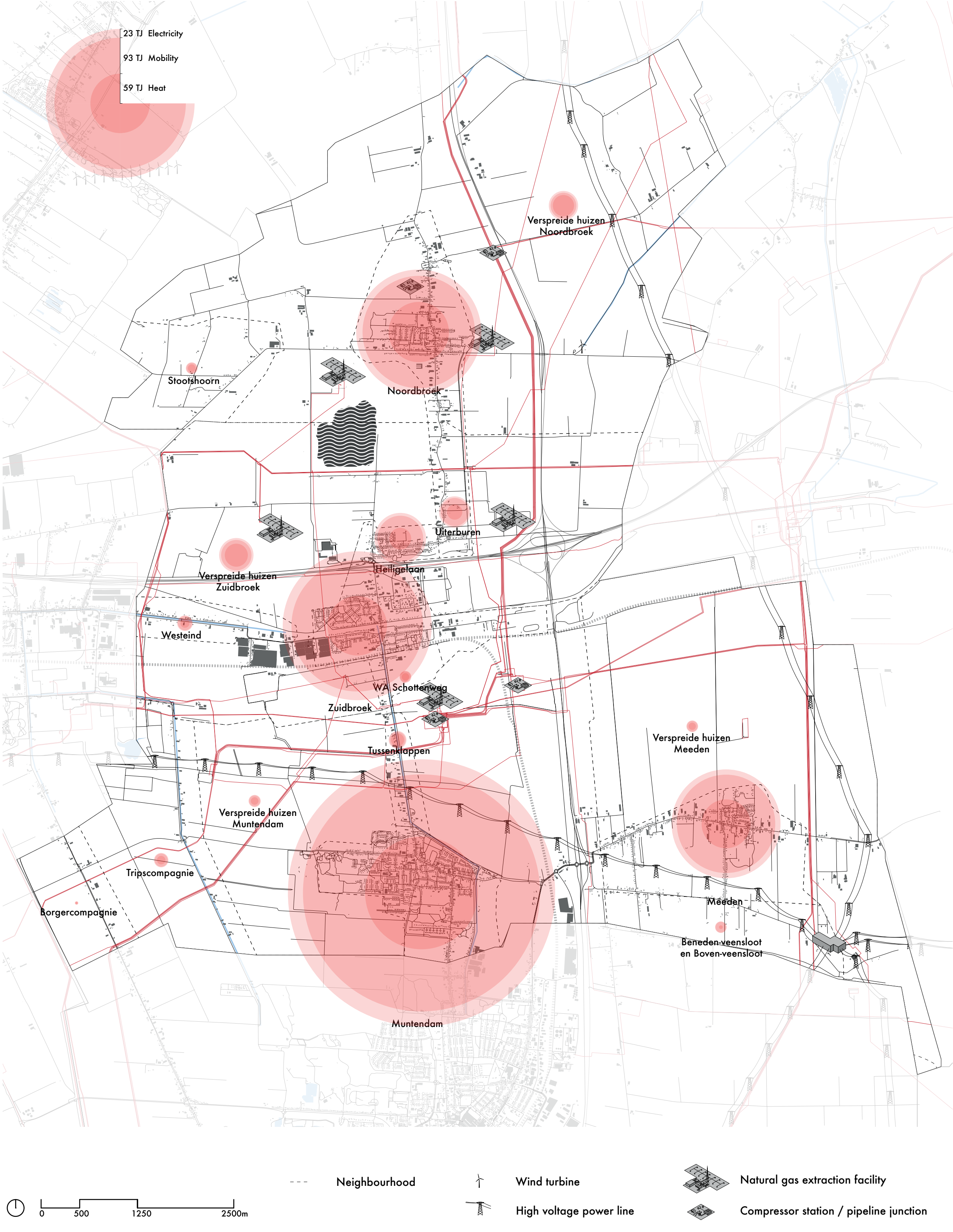


Figure 50: Current energy system and energy use per neighbourhood

In order to be able to compare different energy types, is it common to use the Joule as the unit of energy. This is problematic in a way as it does not differentiate between ‘useful’ energy or ‘less useful’ energy. When dealing with energy it is important to understand the concepts of thermodynamics. The process that we call consuming energy is actually decreasing the energy quality (i.e. exergy) and increasing disorder (i.e. entropy), as energy cannot be created or destroyed (Stremke & Koh 2011). The quality of energy, the exergy, can be defined as the amount of work that can be obtained when the energy comes into equilibrium with the surrounding environment (Rosen & Dincer 2001). Different sources of energy can have a different exergy, and are thus more or less useful to us (ibid). This is why at some points in this report we do make a differentiation between thermal (J_{th}), electrical (J_e), and chemical (J_{ch}) energy, while still using the same unit of energy.

5.4.1 *Heat/cold demand*

Space heating is the best known form of heat demand, but industrial processes also have a large demand for heat. The demand for heat is with 38% the largest share of the primary energy use in the Netherlands. No data about the demand for heat is available on the level of the municipality. However, the heat demand can be estimated based on the natural gas consumption. Broersma et al. (2012) use a conversion rate of 10:9 for the household heat demand and a conversion rate of 20:9 for industrial heat demand. They base these numbers on the efficiency of household room heating installations.

The average natural gas use per household is showing a steady decline for over 10 years. This can largely be contributed to better insulated buildings and more efficient central heating (ECN 2014). Extrapolating this trend of declining natural gas demand shows a decrease in the demand of almost 30% in 2025, visible in Figure 51. Using these figures to calculate the future heat demand results in a demand of 278 TJ_{th}. This calculation is visible in Appendix IV.

Cold demand can be distinguished into two categories, comfort cooling with air-conditioning and climate-control systems, and product cooling with for example refrigerators. In the Netherlands the demand for cold is responsible for 2,4% of the primary energy consumption, most of this demand is from the industry and service sector. For households the cold demand is largely for product cooling (e.g. refrigerators). Comfort cooling is not common place in the Netherlands (Agentschap NL 2013). Exact data about the cold demand are scarce and incomplete, especially on the level of a municipality. As the energy demand in Menterwolde is largely household based, the comfort cooling energy demand is expected to be negligible. For the cooling demand no data is available, but the energy consumption for cooling is in the electricity demand. Therefore, the cold demand will not be taken into account as a separate item in the energy balance.

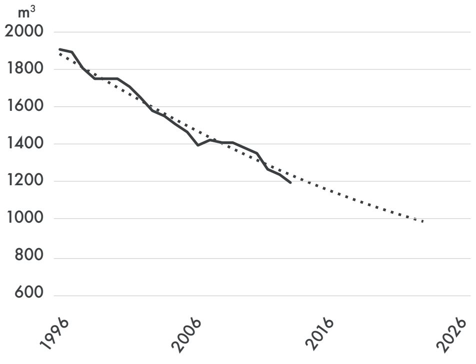


Figure 51: Natural gas use in m^3 per household in the Netherlands (exponential extrapolation), Based on CBS (2016)

5.4.2 *Mobility*

The most recent figures for the energy demand for road traffic is 495 TJ_{ch}/a (Ministerie van Infrastructuur en Milieu 2016). This demand is met almost exclusively by fossil fuels like petrol, diesel or LPG (ibid). Many technologies are being developed in order to replace the now dominant fossil fuels. What kind of technologies will eventually replace the now dominant oil based fuels is uncertain but electricity is expected to play a large role in the near future, either in hybrid vehicles or fully electric vehicles (Van Mierlo et al. 2006). In order to be able to take mobility energy demand into the equation the assumptoin is made that all road transportation will be electric. Calculations about the mobility energy consumption can be seen in Appendix V. The total mobility energy demand is expected to be 131 TJ_{el}.

5.4.3 *Electricity*

In contrast to the steady decline in the natural gas consumption per household, the average electricity consumption per household does not show a clear trend. Electricity demand peaked in 2005 but was inconstant after that (ECN). While an increase in the number of electronic devices can be seen (ibid), an increase in efficiency compensates for this increase. It is therefore assumed that electricity demand will stay roughly the same, except for the addition of electric vehicles. The total electricity demand that will therefore be used is 125 TJ_{el} + 131 TJ_{el} = 256 TJ_{el}.

5.5 NEAR FUTURE DEVELOPMENTS

In order to be able to design for a transition that will take several decades it is important to consider future developments (Stremke et al. 2012). Near-future developments influence long-term spatial developments of a region and are therefore important to map. Illustrating near-future developments in a map gives us a base-map for further design activities. For the municipality of Menterwolde, near-future developments were mapped, based mostly on available governmental planning documents. Near-future developments were also predicted based on trends identified.

The trend of scale enlargement in the agricultural sector will have a spatial impact in Menterwolde. Agricultural building blocks are expected to grow in size, while the absolute number of farms will decrease, resulting in fewer but larger farms (CAB 2011). Furthermore, an increase in dairy animals is predicted. This will result in an increase in the amount of pastures, decreasing the amount of arable fields (CBS 2016).

A second trend that can be identified is a demographic trend. The north of the Netherlands is faced with shrinkage and an ageing population. This is not any different for the municipality of Menterwolde. The total number of people living in the municipality will shrink, but the number of households will slightly increase (CBS 2016). As the population ages more people will live alone, keeping the number of households almost at the same level. As a result of this the housing stock will remain relatively stable. The number of new houses balances with the number of houses withdrawn from the housing stock. Two housing development projects have currently been identified. Old farmhouses where agricultural production is discontinued trough the intensification can also be converted to residential housing (Menterwolde 2008).

As a strategy to cope with shrinkage of the population the province of Groningen invests in the connectivity between the more rural areas of the province and the urban centres. This has recently resulted in the broadening of the provincial road N33, south of the A7 (Provincie Groningen 2015b). A broadening, from 1x1 to 2x2 lanes, of the N33 above the A7 will complete the connection to Delfzijl and can therefore be expected (Provincie Groningen & Ministerie van Infrastructuur en Milieu 2015). Another infrastructural connection that has been given attention is the South-East railroad connection. The creation of this railroad-arc will result in the possibility of a direct connection between Winschoten and Veendam. The project is however currently on hold (Buro Vijn 2013).

Other smaller spatial developments that have been identified are the continued development of the business area in Zuidbroek and the discontinuation of sand mining at *Botjes Zandgat*, a flooded sand pit (Buro Vijn 2013).

All Dutch provinces reached an agreement with the state on a target number of 6000 MW wind energy to be realised on land in 2020. For the province of Groningen the target is 855,5 MW (Provincie Groningen 2015a). An area next to the N33 has been designated as a search area for the realisation of a wind farm. After several public consultations, a preferred variant has emerged. In this variant 27 wind turbines are placed in, or on the border of, Menterwolde. This wind farm will have a total capacity of 90-95 MW (de Sain 2015). The future base-map resulting from all these future developments is in Figure 52.

5.6 RENEWABLE ENERGY POTENTIALS

A multitude of techniques exist to generate renewable energy. In the Netherlands, wind energy, solar energy, and biomass energy are generally considered as promising renewable energy sources (Verbong et al. 2008). Hydropower and geothermal energy are also considered potentials for the land-based generation of renewable energy (Turner et al. 1999). While not necessary renewable, residual heat sources can also be a source of energy (ibid). The potentials for the municipality of Menterwolde are explored here, focussing on proven technologies rather than counting on technological breakthroughs. This in order to maintain a sense of realism. Additionally, it is not the goal to find a single renewable source that can replace the current energy consumption, because the production of energy from renewable sources is often fluctuating. In order for the future energy system to be resilient, a diversification of sources and technologies is important in order to be able to cope with periodic shortfalls (Lund & Münster 2003).

5.6.1 *WIND*

Wind energy can be harvested by wind turbines. The spatial footprint of wind turbines is small, but placement options for wind turbines are limited. Shadow flickering of rotating blades, blade glint, noise pollution, and aesthetic concerns are all reasons for wind turbines to be at a distance from sensitive objects like housing (Devine-Wright 2005). In the Netherlands the noise production of wind turbines is generally the limiting factor for construction near housing. A distance of four to five times the axis height of a wind turbine is therefore generally considered necessary for housing (Koers & Rietveld 2014). Large wind turbines generally have a higher energy yield (Crawford 2009), but also require a larger distance from housing.

Figure 52: Future base map of Menterwolde

The proposed windfarm in the area next to the N33 would constitute of wind turbines 100m to 140m in height (de Sain 2015). Figure 53 shows the potential locations for the placement of wind turbines with an axis height of 120, and a buffer distance to buildings of 5 times the axis height.

Figure 53: Potential locations for the placement of 120m wind turbines based on a 600m buffer with housing

5.6.2 SOLAR

Two types of systems are common in the Netherlands to harvest the energy provided by the sun, photovoltaic and thermal systems. Photovoltaic solar panels operate by converting the solar energy directly into electricity. By exposing a semiconductor to light, they capture photons to release electrical energy. Solar hot water panels are an example of thermal solar systems in use in the Netherlands. Large scale *Concentrated Solar Power* (CSP) are also part of this family but are currently not used in the Netherlands.

The potential of solar energy can be quantified by multiplying the suitable acreage by the efficiency of the to be installed photovoltaic or thermal system. Solar systems can be installed on buildings and on the ground. In general, solar systems are more profitable when placed on roofs or other left over space, but the revenue of some solar systems can compete with the revenue of agricultural production (Spruijt 2015). When placed on agricultural fields, the energy production will be at the expense of food production. Around 29% of the available roof area is suitable for the placement of solar energy systems (Broersma et al. 2012). In Menterwolde this would result in 39ha of suitable roof surfaces. Using the full potential would result in either 200 TJ_{el}/a or 470 TJ_{th}/a. These calculations are visible in Appendix VI.

5.6.3 BIOMASS

To produce energy from biomass a wide range of conversion technologies is available, and under continuous development. Combustion, gasification, and the conversion into biofuels are the most common options for biomass conversion (Sims et al. 2006). Biomass can either be dedicatedly grown or constitute of a residue from other activities like food processing or agricultural practice. Dedicated energy crops offer a higher energy yield than residual biomass, but dedicated energy crops will almost always compete directly for agricultural land with food production (Ranney & Mann 1994). Dedicated energy crops generally either woody crops such as willow or poplar, herbaceous plants such as Miscanthus, or whole-crops such as maize or wheat (Pöschl et al. 2010).

As a highly agricultural municipality, Menterwolde has several options for the use of biomass as a renewable energy source. First, some agricultural lands that are now dedicated to food production can switch to the production of dedicated energy crops. Furthermore, Menterwolde has a relative high amount of dairy animals and consequently a large manure surplus. The expected increase in dairy animals will only increase this surplus. Through anaerobic digestion, animal manure can be used for the creation of biogas and digestate. In order to enhance the biogas production a co-substrate is often added to the manure (Bekkering et al. 2010). In Figure 54, the potential farm expansion sites are mapped, together with the suitable arable fields and pastures.

Sewage sludge can also be used to create biogas and digestate trough anaerobic digestion. Currently there is no sewage treatment plant in the municipality of Menterwolde. There is therefore no easy option to implement the extraction of energy from sewage waste water, hence it will not be included as an energy potential.

5.6.4 HYDROPOWER

Hydropower installations derive power from falling or fast running water. The technical potential for hydropower in the Netherlands is small. Also, hydropower technology is fully mature, and little cost reductions and efficiency improvements are to be expected (Junginger et al. 2004). No potentials for hydropower have been identified in Menterwolde.

Figure 54: Potential farm expansion sites, suitable arable fields and pastures.

5.6.5 *Soil energy systems*

The soil can be harnessed to extract and store thermal energy. Different systems exist but they can be classified into two categories: open and closed systems. Closed systems are typically storage systems that store excess heat in summer, and extract this in colder periods. These type of systems can be used to enhance the efficiency of energy use.

Open systems extract heat from aquifers in the subsoil. These systems can operate at different depths, where an increase in depth is generally an increase in extraction temperature. For household application of the heat a depth between 1000 and 3000 meters is often required, depending on the availability of aquifers (TNO 2013). In order to know the amount of thermal energy that can be extracted sustainable, the total amount of extractable energy has to be divided by the regeneration time. A standard geothermal doublet has a regeneration time of approximately 300 years (Broersma et al. 2012). The possibilities for geothermal heat extraction depend on the presence of aquifers in the subsoil. Compared to the rest of the Netherlands, Menterwolde shows a relative high potential for geothermal energy extraction. Furthermore, there is a possibility that the boreholes of the natural gas extraction can be reused for the extraction of geothermal heat (van den Dobbelsteen et al. 2007). The potential for geothermal energy in Menterwolde are visualized in Figure 55.

5.6.6 *Residual heat sources.*

Potential sources of residual heat are power plants, waste incinerators, or large industries like cardboard industry or food processing industry. No large sources of residual heat have been identified in Menterwolde.

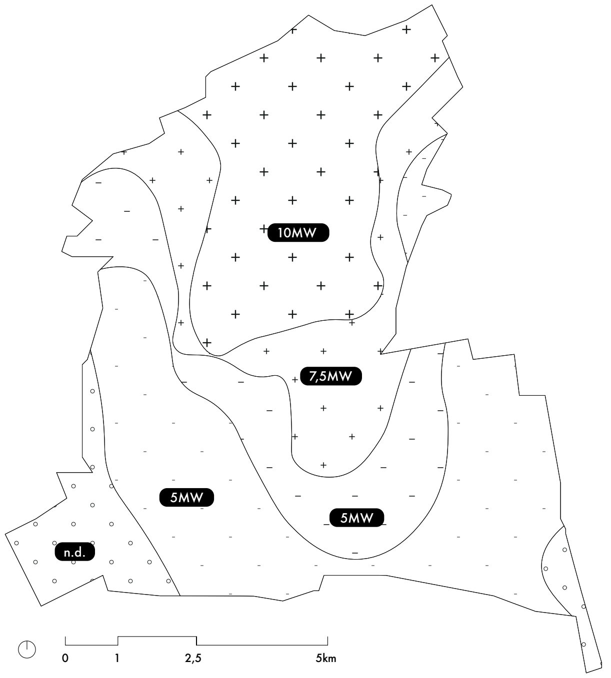


Figure 55: Indication of the geothermal potential and the producible power of a standard geothermal doublet. Based on TNO (2016)

5.7 DESIGN PRINCIPLES

From the analysis multiple design principles were formulated:

In order for the transition to be sustainable it should fulfil the criteria of sustainability; Environmental, economical, sustainable technical, and socio-cultural.

A multitude of renewable energy technologies should be used in order to create a robust system.

At least enough renewable energy should be generated in order to fulfil future demand.

As the extraction of natural gas was a process that was kept out of sight, renewable energy generation should be perceivable. Interventions should preserve or enhance the defining spatial characteristics of the landscape.

Figure 56: Collage of the future for the Veenkoloniën landscape, explained in Figure 57

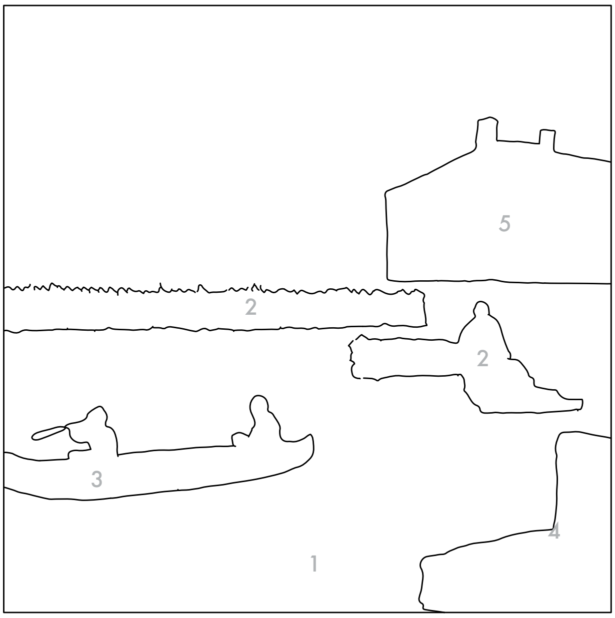


Figure 57: Collage of the desirable future for the Veenkoloniën landscape

1) Extra water retention should keep agriculture viable

2) New agricultural opportunities

3) Increased water recreational posibilities

4) Less productive arable field can be transformed to pastures

5) Ribbon villages with iconic farm houses are preserved

5.8 DESIRABLE FUTURES

The design on the medium scale will show how the future energy demand of Menterwolde can be met locally by renewable energy. The designing of sustainable energy landscapes is more than the placement of renewable energy sources. The design will feature a conscious reorganization of the current landscape, and will thus be strongly based on the different landscape types identified. This is because "spatial organization of the physical environment not only determines where renewable energy is assimilated and consumed, but also influences how much energy is assimilated at which quality and at what time" (Stremke 2010, p93.).

5.8.1 *VEENKOLONIËN*

Currently, the canals and ditches that characterize the Currently, the canals and ditches that characterize the Veenkoloniën can provide an adequate water supply for the agricultural demand. In summer, the system is being flushed with freshwater from the Ijsselmeer. This is needed as the sand and peat soils of the Veenkoloniën are susceptible to drought (Waterschap Hunze en Aa's 2008). Water from the Ijsselmeer comes from the north via the Winschoterdiep and from the south via the Hoogeveenschevaart. In times of surplus the water system can provide a rapid discharge of excess water. The water system of the Veenkoloniën, as it is now, has few problems. In the future, climate change will have an impact on the availability of fresh water as well as on the agricultural demand for fresh water. The availability of the Ijsselmeer water is also uncertain in the future and it is therefore important to look for a sustainable water supply in order to limit agricultural yield loss (EO Wijers-stichting 2011). An increase in water retention areas is seen as an option to cope with the future water demand in summer. A transformation of 6% to 13% of the current land area into water retention is need in order to cope with the increasing water demand, depending on the climate change scenario (Querner et al. 2011). Also a change in land use can limit the need for water retention capacity.

In order to be able to continue practicing agriculture on a competitive level in the future it is necessary to increase the water retention capacity. In order to transform the water system to accommodate the needed amount of water retention the current landscape form was used as a basis. The internal structure of the Veenkoloniën offered several leads for this. Three models were developed, visible in figure, based on the historic cultivation patterns. Model A concentrates the retention areas. Advantage of this model is that the evaporation of water is lower when the body of water is larger. A concentrated retention system can therefore be smaller than a distributed model. A drawback of this model is that it has a large impact on the landscape. Furthermore, distribution of the fresh water into the veins of the water system is more complicated. In model B the extra retention capacity is generated by the broadening of all the waterways in the system. Advantage is that it conserves the current appearance of the landscape the best. Furthermore, it enhances the peak discharge capacity. A drawback is that the effects on the retention capacity of this increase in surface water are limited. Model C is based on the excavation of parcels, distributed across the landscape. The advantage of this model is that with this system the retention water can be accurately and swiftly distributed into the veins of the water system. Another advantage is that the least productive parcels can be taken out of production. A drawback of this model is that it is costlier in development.

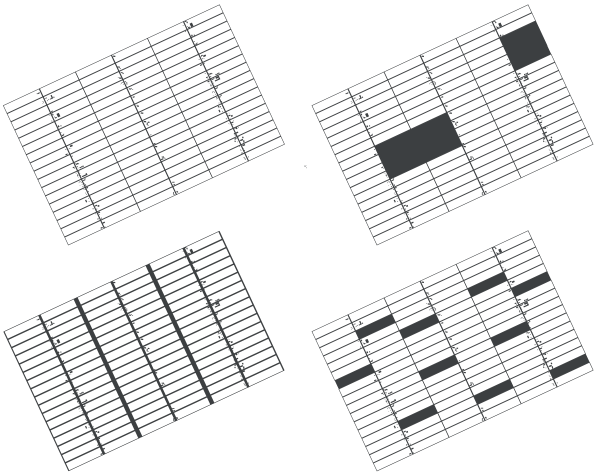


Figure 58: From top left to bottom right: current situation, model A, model B, model C.

Based on this, a combination of models B and C was chosen. A broadening of some waterways, combined with the distributed parcel size retention ponds of model C combines the advantages of both models. The distributed water retention system also can be used as a responsive tool to the expected population shrinkage, as the least productive fields can be taken out of production. Furthermore, it creates a base for a broader form of agriculture. The renewed retention and discharge system forms the base for a new landscape form.

By combining water retention with different renewable energy producing technologies land-use can be multifunctional. By using reed, and water tolerant willow as short rotation coppice, energy production can also be combined with water retention interventions. By also integrating PV-panels in the water retention system, PV-parks can be integrated in the traditional landscape.

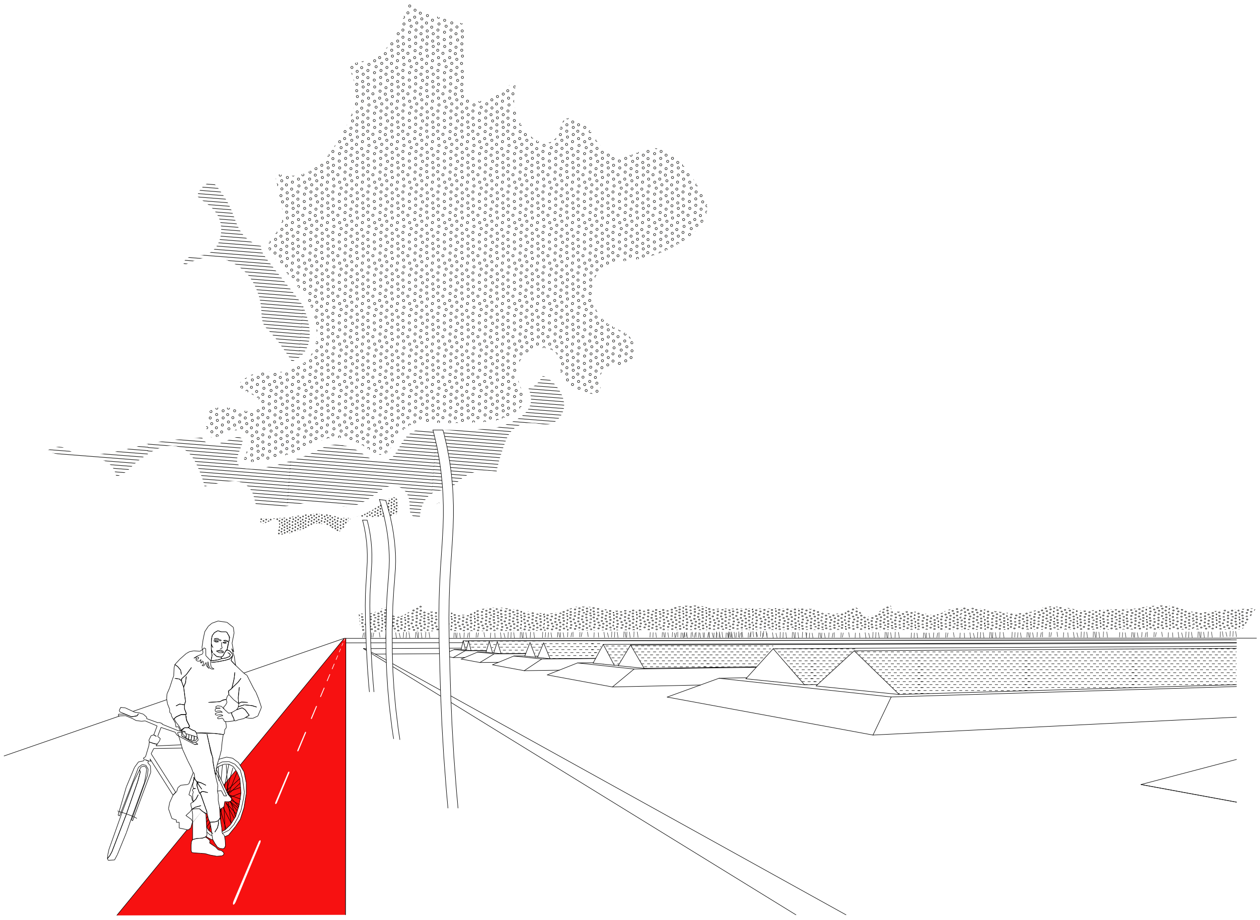


Figure 59: PV panels combined with water retention. The heat grid can provide the opportunity for an heated (ice-free) bicycle path and provides a visual clue for the presence of renewable energy technology

The production of different sources of biomass creates a broadening of agricultural practice. As agricultural scale enlargement conflicts with the cultural values of the protected ribbon villages a broadening of agricultural practice is preferred over intensification. Interventions create new opportunities for entrepreneurship. The highest quality reed can be selected as resource for thatched roofs, where the lesser quality can serve as energy crop. Furthermore, reeds function as a natural water filter, decreasing nitrate and phosphate runoff (de Haan et al. 2011). The extra water retention can also provide potential for water recreation in the form of canoes or small boats, increasing touristic value. With a more diverse agricultural practice, an increase in biodiversity can be expected as short rotation coppices provide new habitats.

Ribbon villages will be connected to the municipal wide heat grid. Locally produced biomass can be transformed into energy in small booster stations that keep the heat grid on the right temperature over larger distances. The booster stations will be located on plots that will become free because of shrinkage. The booster stations can be designed multifunctional, functioning also as a community centre and a touristic hot spot.

The soil that is being excavated from the water retention plots is being used in the same plots to construct natural hills in the optimal angle for solar PV panels. This way there is no need for additional stands to position the PV panels in the optimal position. Furthermore it creates an aesthetically calmer image, and it ensures the ground balance is closed Figure 60.

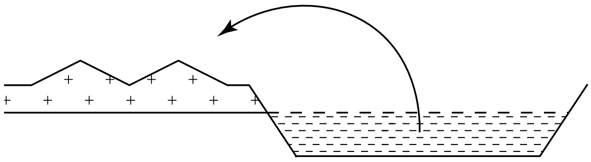


Figure 60: Excavated soil is used to create mounts for the PV panels

Figure 61: Landscape plan of the new Veenkoloniën. A distributed water retention system combined with energy generation follows the pattern of cultivation.

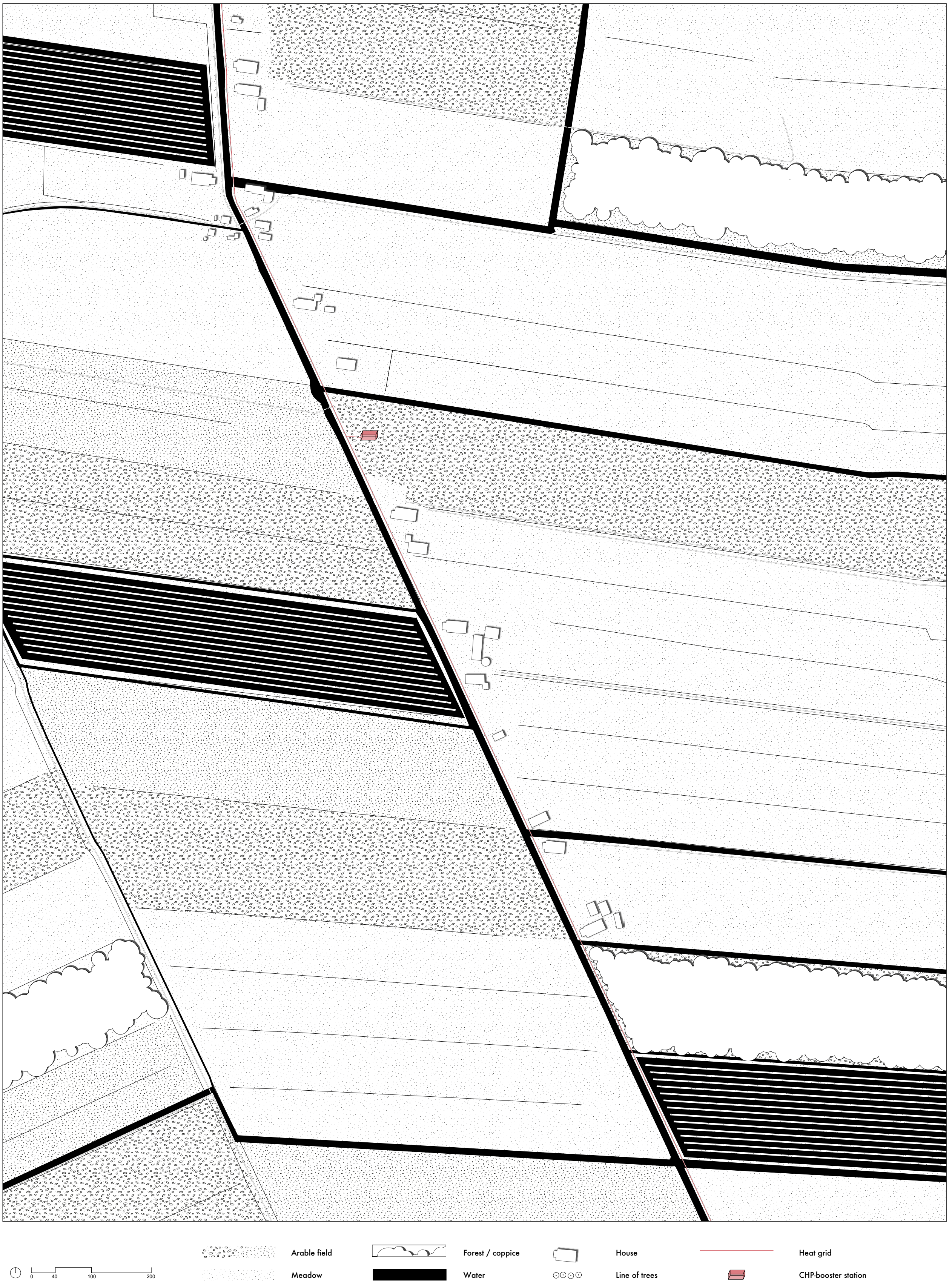
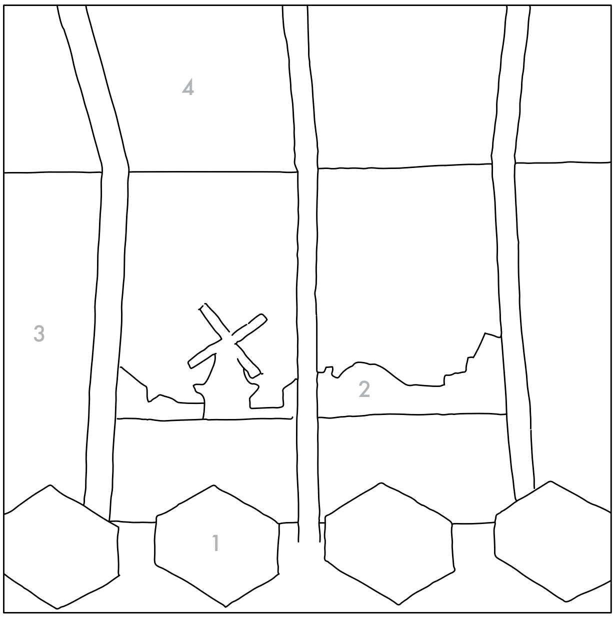


Figure 62: Detail of the landscape plan. Water retention, biomass production and the CHP-booster station all in one ribbon village.

Figure 63: Perspective drawing. Recreational possibilities next to the wetering gives the opportunity to enjoy the pastoral landscape on the and the highly technical landscape on the right

Figure 64: Collage of the desirable future for the Wegdorpen landscape, explained in Figure 65



1) Greenhouses provide agricultural specialization

2) Ribbon villages with iconic farm houses are preserved

3) Biomass production protects viewsheds

4) Energy generation and agricultural production combined

Figure 65: Collage of the desirable future for the Wegdorpen landscape

5.8.2 *Wegdorpen landscape*

The ribbon villages give character to the Wegdorpen landscape. In the future situation, their character will therefore be preserved and enhanced when possible. The production of energy should be assimilated into the landscape in such a way as to not damage the appearance of the ribbon villages. The ribbon villages are visible from the outer areas as they are slightly elevated above the rest of the landscape. This makes interventions here extra discernible and making interventions should be done carefully.

Where the new agricultural practice in the Veenkoloniën is based on diversification, in the wegdorpen landscape competitiveness is attained through specialization. In this future prospect, specialization is realised through the conscious design of greenhouses. By creating a cluster of greenhouses, a competitive greenhouse hub can be realised. Clustering greenhouses will increase the economy of scale; A shared logistic centre can decrease operational costs. The geographic location of the greenhouse hub provides competitive advantages for entering the Scandinavian and German market (Elzerman 2006). Furthermore, a greenhouse cluster can provide synergies for energy production.

Greenhouses are traditionally designed as being large solar collectors in order to enhance the growth of plants inside the greenhouse. Theoretically greenhouses collect enough energy to heat the greenhouse year-round, while excess heat and/or electricity can be supplied to its surrounding (de Zwart et al. 2011). However, currently greenhouses are net consumers of energy. It is expected that in the future technological innovations make an energy producing greenhouse realistic. Electricity can be generated by using flexible PV-Cells in shading mechanisms, or by using translucent PV-Cells that use parts of the light spectrum that are not used by plants in their photosynthetic processes (Figure 66). Through heat exchange, excess heat generated can be made available for storage and use in winter.

Central to the greenhouse cluster is an energy-hub. Combining a CHP-plant, a geothermal doublet, and the logistics hub all in one location provides the opportunity of an efficient energy system. The energy hub will be constructed centred, with three main axes going outwards that connect the hub to the surrounding villages. The axes all have a heat grid pipeline and are recognizable in the landscape by their linear tree structures. Greenhouses are located alongside the axes. Heat will be cascaded to the greenhouses with a higher heat demand first, and to the villages with a lower heat demand second. This concept is shown in Figure 67.

CO2 that is being produced in the CHP-plants can be fed back to the greenhouses through old natural gas pipelines. An increased CO2 level inside the greenhouse will often increase plant quality and growth rate (Mortensen 1987). Organic waste from the greenhouses can be digested in the CHP plant.

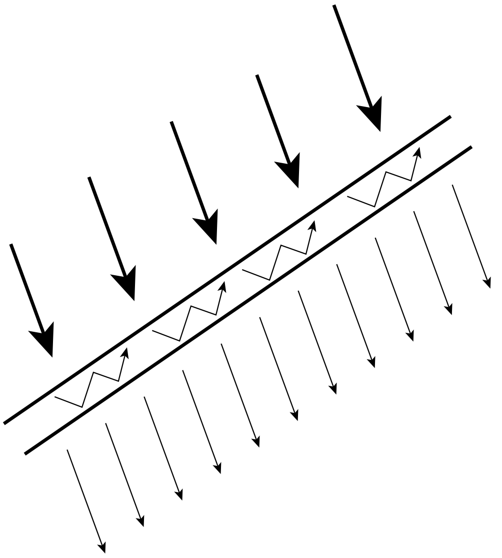


Figure 66: PV-panel integrated in the glass roof of a greenhouse, using parts of the light spectrum not used by plants for photosynthesis

By combining the logistic centre with the energy hub, trucks can be charged with energy generated directly from the CHP plant. Moreover, biomass can be easily gathered and stored in the hub. This makes it easier to adjust supply and demand of energy.

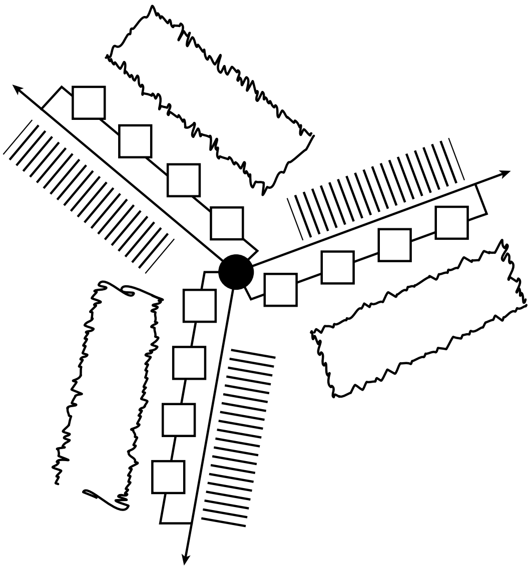


Figure 67: Conceptual drawing of the spatial organisation of the energy cluster

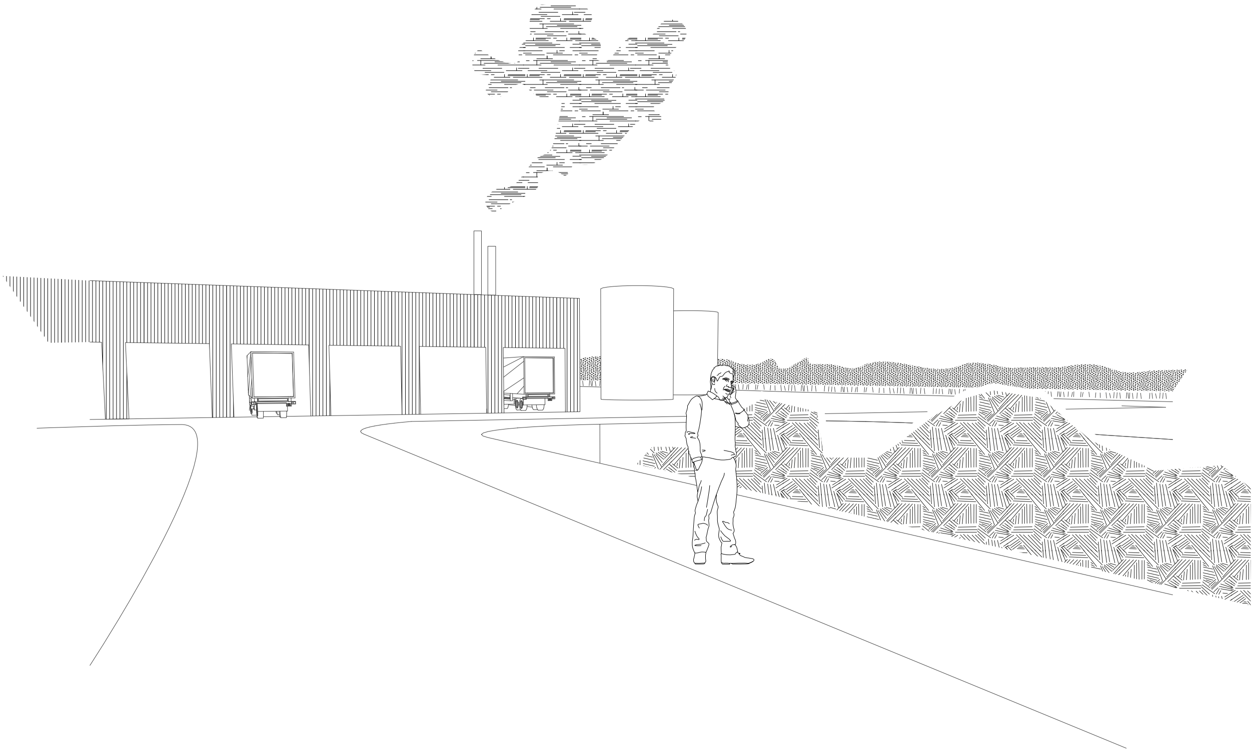


Figure 68: Perspective drawing of the combined energy and logistics hub. Biomass is stored in the storage pits (front-right)

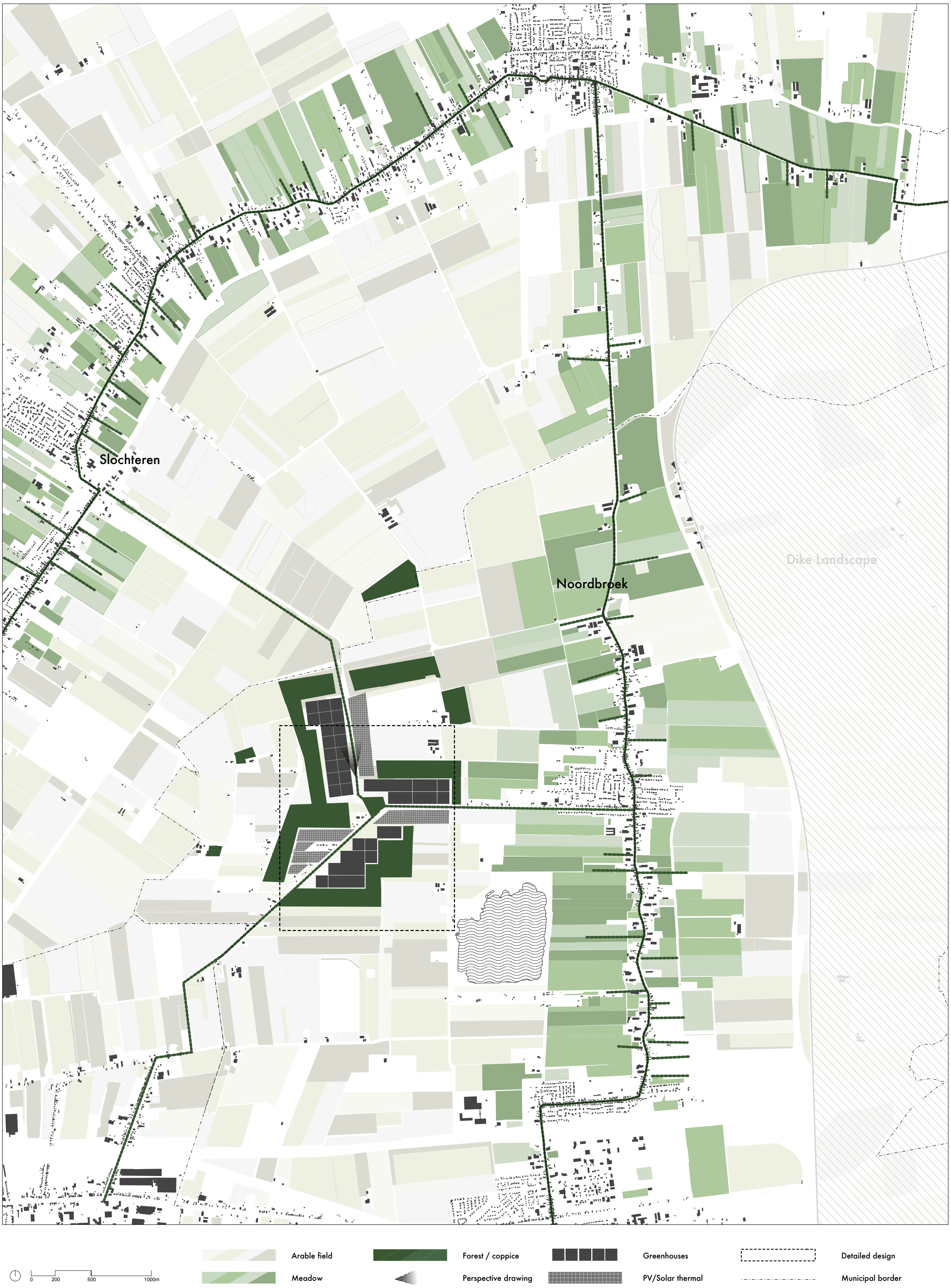


Figure 69: Landscape plan of the wegdorpen landscape. An energy hub is located in the lower parts of this landscape type. The character of the ribbon villages is accentuated by traditional hedgerows

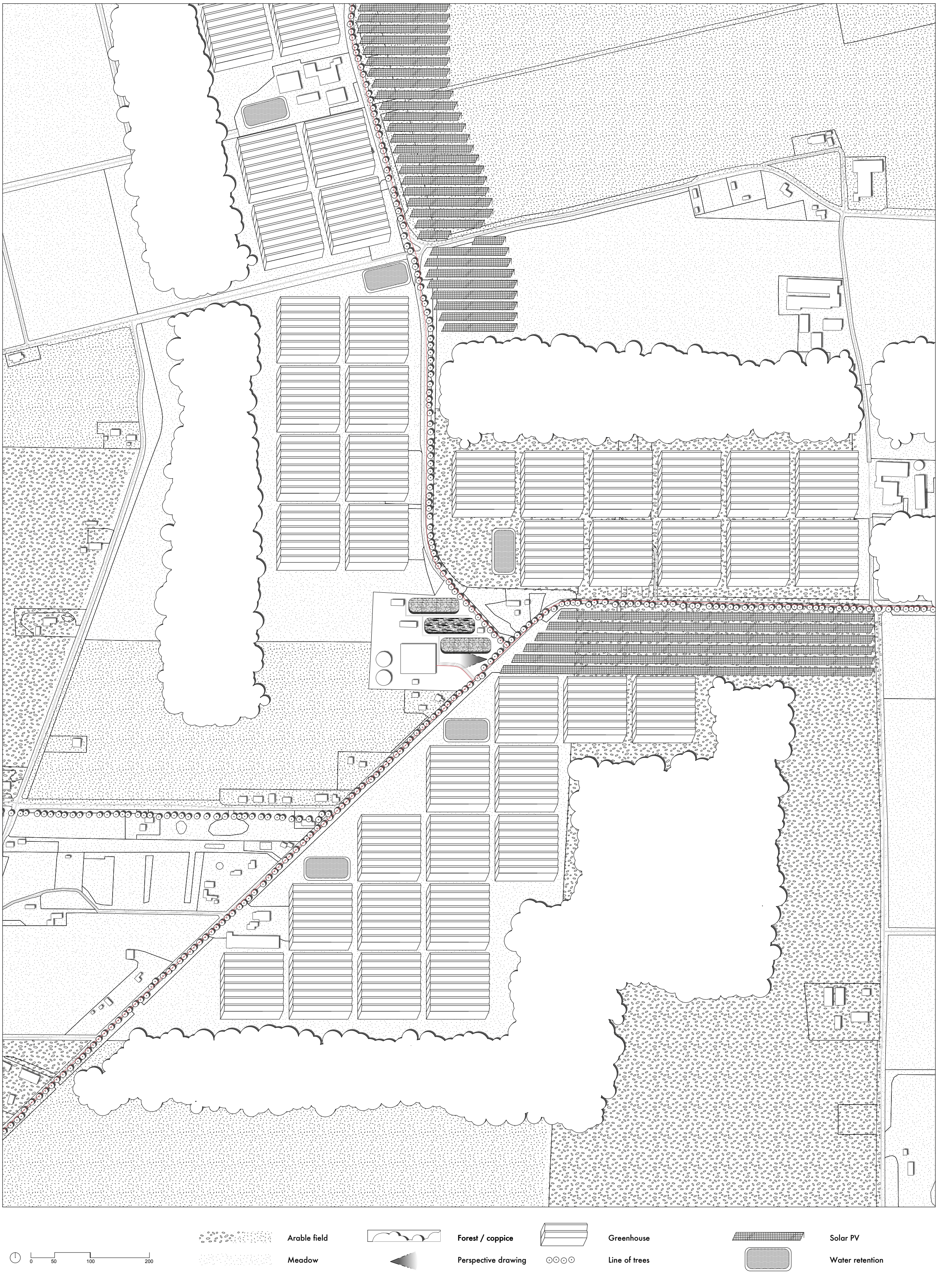


Figure 70: Detail of the landscape plan. The energy hub is in the centre of the design, a heat cascade is formed by the greenhouses.

Figure 71: Perspective drawing. Translucent PV panels appear red as they filter parts of the light spectrum not used for photosynthesis. Landscape maintenance on trees and roadside provides biomass.

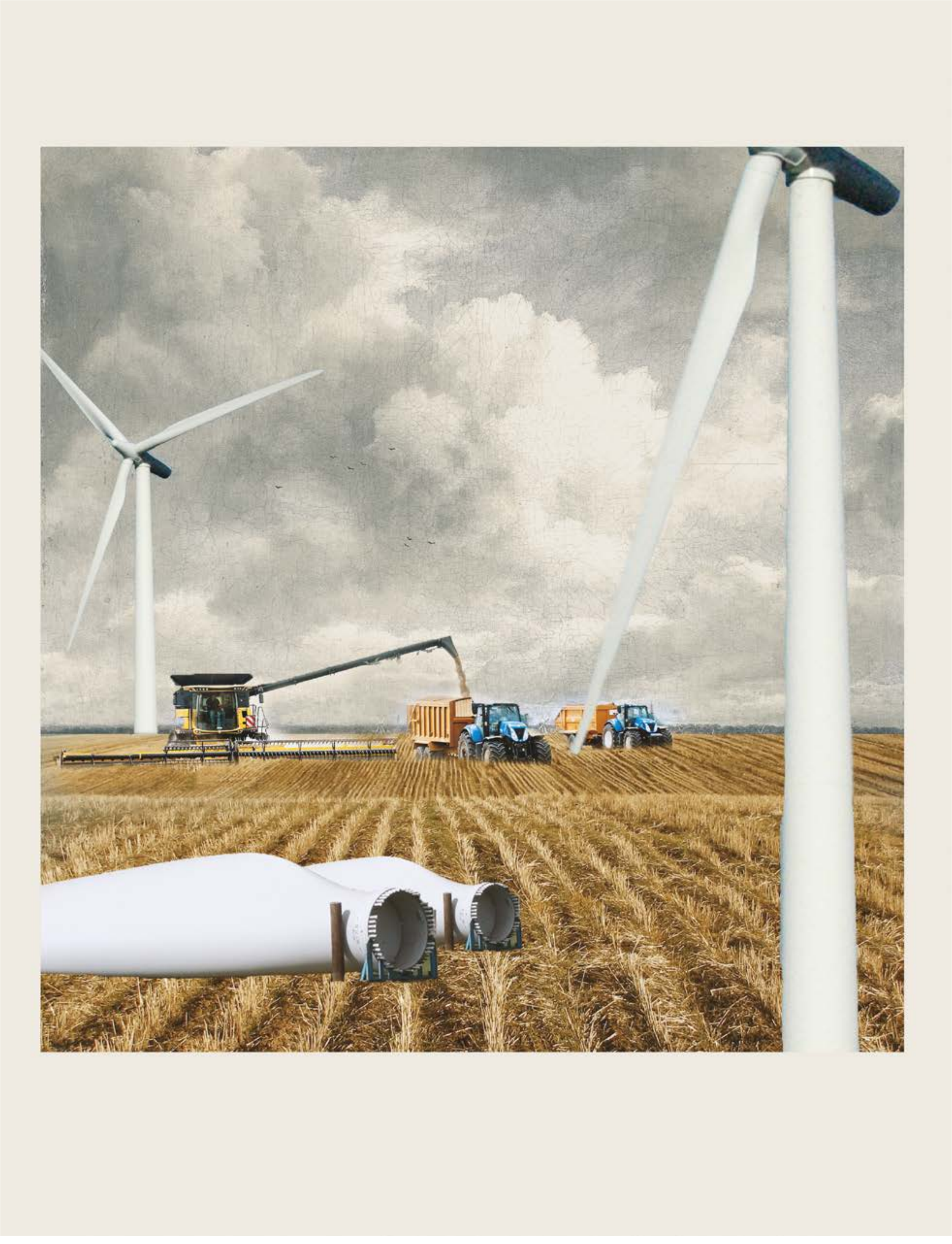


Figure 72: Collage of the desirable future for the Dijken landscape, explained in Figure 73

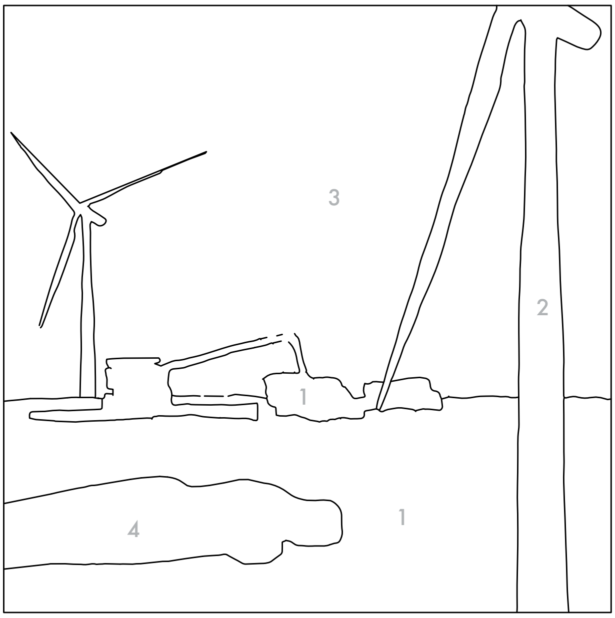


Figure 73: Collage of the desirable future for the Dijken landscape

1) Scale enlargement produces agricultural intesification

2) Large scale energy production in a large scale landscape

3) Large open landscape is preserved and enhanced

4) Large scale wind turbine installation can create jobs

5.8.3 *DIJKEN LANDSCAPE*

The sea clay polders of the dijken landscape are characterized by their large openness. This characteristic is key to the experience of the landscape and is a core quality that should be preserved. View obstructing elements are scarce. The polders of the Dollard are well suited for scale enlargement, as the landscape is already large of scale. Scale enlargement can make agricultural practice intensify, creating an even more rational landscape pattern.

The dikes that were created to conquer the land back from the sea are important landscape elements. The process of land reclamation is a process that has been going on for centuries. Not all dikes are still visible in the current landscape. The dikes can function as counterbalance to the straight and rational parcelling of the polders. Especially the older dikes in the area around Menterwolde have a meandering characteristic. They could provide a slow recreational route, guiding the visitor from the oldest polders towards the sea. This is visible in Figure 75.

As the polder landscape is so flat and open, wind turbines can create a strong visual image. By placing large scale wind turbines, the horizontality of the landscape is emphasised by the verticality of the wind turbines (Figure 76). The contrast between the old dike corridor that crosses the straight landscape dominated by large wind turbines can form a sublime experience.

Figure 74: Landscape plan of the Dijken landscape. Wind turbines accentuate the pattern of the parcels under influence of scale enlargement. The old dike is meandering through this rational landscape

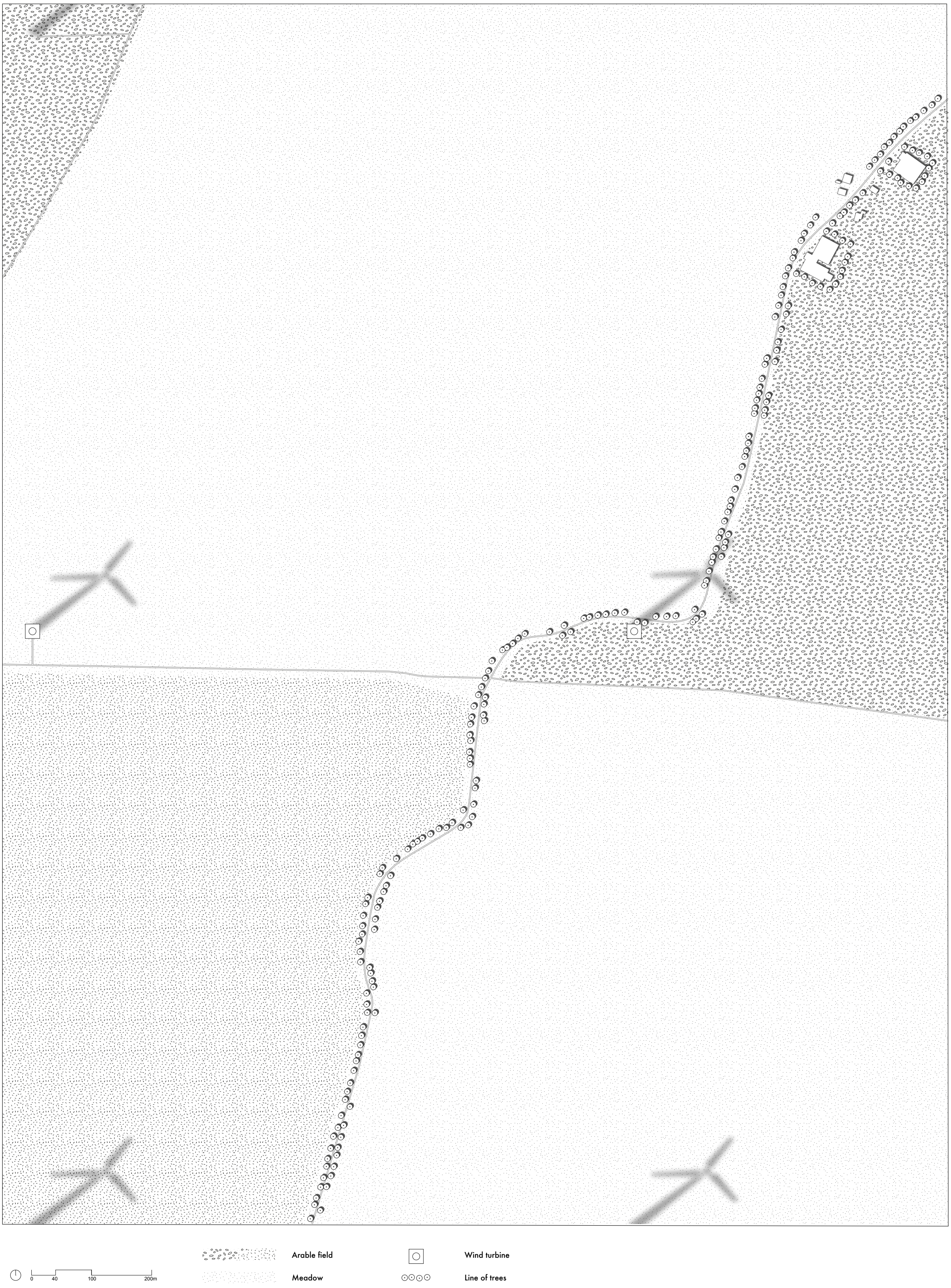


Figure 75: Detail of the Dike landscape. The dominance of the large wind turbines in the horizontal landscape creates an imposing experience

Figure 76: Visualization of the sublime experience the 120m heigh wind turbines can offer

5.9 ENERGY BALANCE

This paragraph shows how the designed energy system can contribute toward energy neutrality for Menterwolde. The expected yields of the designed interventions are added up and compared with the expected future energy demand. The newly designed energy system is schematically visible in Figure 77.

In Appendix VIII all the implemented renewable energy technologies, and their yields are listed. As the potential for geothermal energy is relatively high in Menterwolde, this will contribute a substantial part to the total heat demand. Next to this the thermal solar parks in the Veenkoloniën and in the wegdorpen landscape have a large contribution. For electricity the PV parks in the Veenkoloniën and in the wegdorpen landscape have the highest yield. As the wind turbines are part of a larger national program, only 10% of the yield is allocated to Menterwolde. Moreover, the assumption is made that on 20% of all the suitable roof surface, PV panels will be placed.

Theoretically the designed landscapes together could provide enough renewable energy for the yearly energy demand of Menterwolde. As many renewable energy sources have an intermitted nature, a mix of different energy sources is needed in order to reach a robust energy system. For Menterwolde a mixture of many different techniques is used in order to minimize the risks of periodic energy shortfalls. A more thorough investigation is needed in order to calculate the possibility of energy shortages.

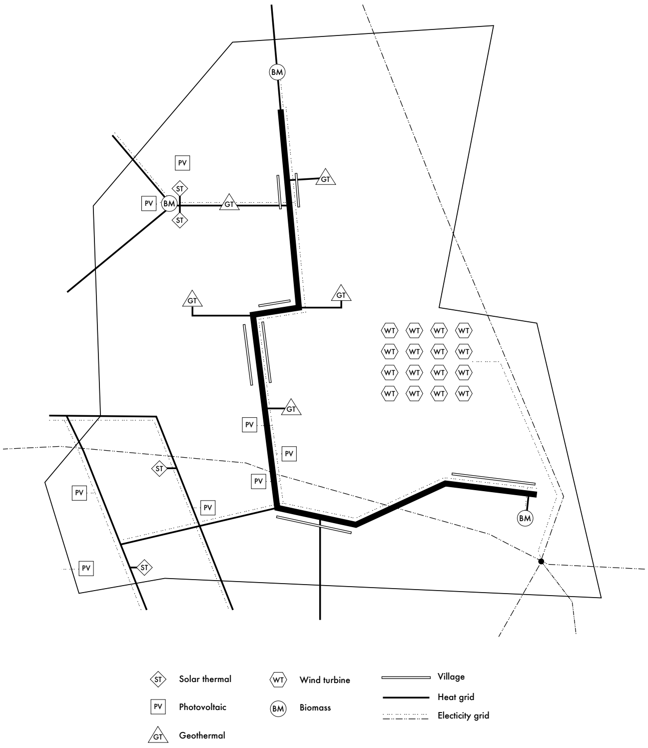


Figure 77: Schematic representation of the renewable energy system

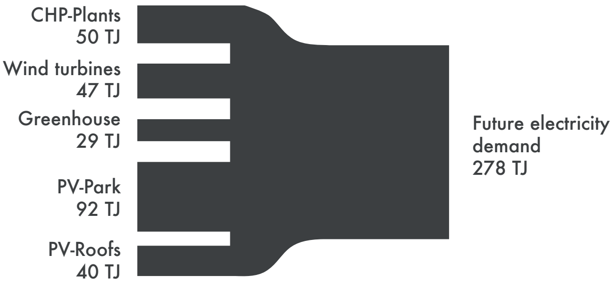


Figure 78: Sankey diagram of the electricity balance

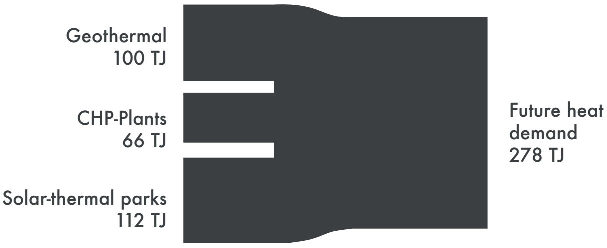


Figure 79: Sankey diagram of the heat balance

6

SMALL SCALE

6.1 ANALYSIS

The village Noordbroek is one of the linear villages of the Wegdorpen landscape. The historic structure of the village is still very much visible. A large number of buildings have a historic character, as can be seen in Figure 81. This contributes to the character of the village. Most buildings in Noordbroek are dwellings or have an agricultural function. Moreover, there are a few shops, a small supermarket, and facilities like a pharmacy. They provide for the basic needs for the inhabitants. As with most ribbon villages in the wegdorpen landscape, Noordbroek's ribbon is permeable and there is a strong connection with the surrounding landscape. As a result, the natural gas extraction plant west of Noorbroek and the sand extraction pit are visible from the main road of the village (Figure 85).

Noordbroek is well connected by car, as the N33 and the A7 are accessible within minutes. This can be beneficial for communters who live in Noorbroek but work in for example Veendam, Delfzijl or the city of Groningen. This is also beneficial for tourist from out of town. Noordbroek is also reachable by public transport. The train station of Zuidbroek is nearby and two bus lines have multiple stops in Noorbroek. Most roads in and around Noordbroek are shared between cyclist and cars. Not many dedicated cycling paths exist, but traffic is light on most roads. Several long and short distance cycling routes cross through Noordbroek (ANWB 2016).

An important feature near Noordbroek is the sand extraction pit Botjes Zandgat. Currently, swimming is tolerated in a designated area on the south side of the pit, but accessibility is poor and facilities are of low quality (Figure 86). When the extraction of sand stops in the near future the whole pit can be made accessible. The flooded pit is already popular with divers as the water is clear and visibility is high. The sand pit could have an important recreational function in the future.

The natural gas extraction site west of Noorbroek is very much visible from its surroundings. This can be seen as something negative now, but can also be a positive feature when the site will be recycled in the future (Figure 86). Its proximity to the sand extraction pit makes a connection between the two logical, as they are both sites where natural resources are extracted.

Figure 80: Location of Noordbroek and the recycled natural gas extraction facility

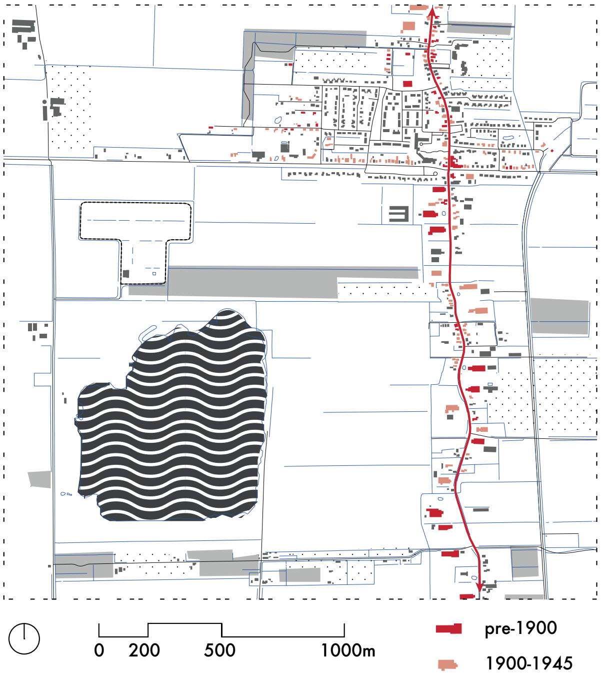


Figure 81: Historic identity of Noordbroek

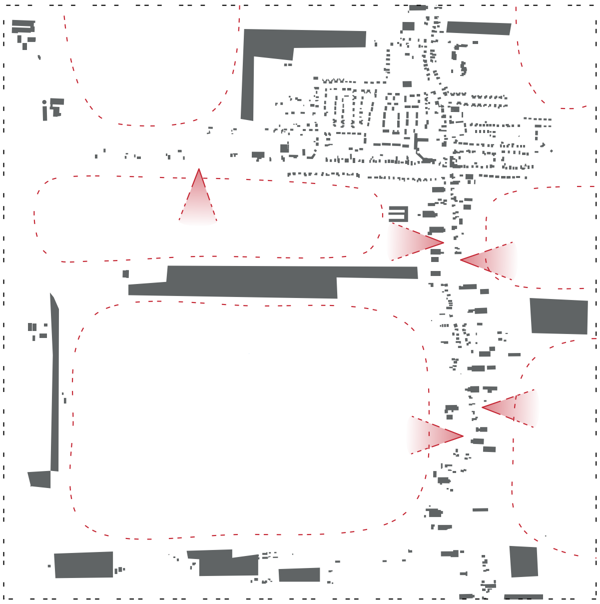


Figure 85: Mass and voids; Most places in Noordbroek offer a vista to the surrounding landscape

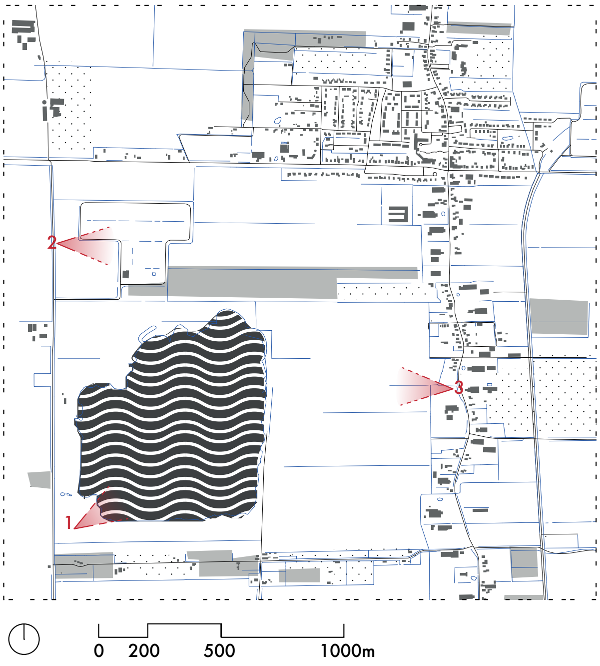


Figure 86: (1) Figure 82
(2) Figure 83
(3) Figure 84

Figure 82: Low quality recreational opportunities

Figure 83: Visibility of the natural gas extraction site

Figure 84: Visible connection between the village and the extraction site

6.2 EXTRACTION SITES

Natural gas extraction plants and other primary facilities are scattered all across the north of the Netherlands. They all have an industrial appearance and are organised in a rational efficient manner. Sites often appear similar to each other and look interchangeable to one another. This is illustrated in Figure 87, where aerial photographs of the primary installations of the natural gas extraction are rearranged into a collage of elements. Some sites look so similar they appear to merge into each other.

The industrial aesthetic of the primary facilities is further explored in Figure 88 to Figure 93. The photographs are reduced to black and white images in order to emphasize the form and shape of the objects instead of the colour. Pipelines are dominant in all photographs. Although most structural elements are composed of very basic shapes there is a large visual complexity in most of the images.

The structures were responsible for the growth and prosperity of the Netherlands and provided a cleaner alternative to coal as an energy source. But the structures are also part of the more local history of earthquakes, soil subsidence and the fear and anger that is connected to that. Some see the sites of natural gas extraction as a blemish on the province of Groningen, a vivid reminder of the disregard for the inhabitants of the area. A response could be to clear the land, to wipe away all evidence of this history. The disturbed site would then literally concealed by a pastoral landscape. But this assumes one can remove the human interference and the consequent damage like magic. This is therefore not a valid approach.

6.3 PRINCIPLES

From the content analysis, physical analysis and the design on the larger scale several design principles were formulated.

- *The natural gas extraction site and the sand extraction pit are both evidence of the extraction of natural resources. A connection between the two should be searched for, as their identities can strengthen each other.*

- *The site is well connected and can therefore provide recreational value for inhabitants as well as tourists. A characteristic like the diving conditions can provide the site with an attraction for tourist. Reinforcement of characteristics like this is desirable.*

- *The site is visible but not accessible from the village. The site should be made easily accessible for pedestrians and cyclist coming from the village.*

- *Structural elements of the site have historic value. Some elements should therefore be preserved. Their functional appearance can also have an aesthetic value that can offer sublime experiences.*

- *It should be able to experience the production of energy on site.*

- *Strategies that emphasise the cultural and historic values, and strategies that emphasise the naturalist and environmental values have been used to recycle post-industrial sites successfully (Loures et al. 2006). Employing these strategies should be considered.*

6.4 DESIGN

The site will be transformed into an energy park, offering recreational opportunities for both local inhabitants as for tourists. Furthermore, it functions as an exhibition of the energy producing technologies in the municipality, making people more accustomed to renewable energy. The natural gas extraction has always been inaccessible and at a distance from the inhabitants. This alienated the production sites from the public imagination.

The history of the site remains visible in the new design. Most shapes and forms are derived from the original shapes of the gas extraction plant. Elements like a former drilling tower are incorporated into the design and can become highly visible, iconic parts of the park. Furthermore, the drilling tower offers a vantage point over the park and its surroundings. Other elements testify to the industrial past, and as they rust they recall the decay that is a part of the process of aging. In some parts the history of the site is deliberately and explicitly revealed, where in other parts it is more open for interpretation.

The main entrance for pedestrians and cyclist is located in the east of the park. A road perpendicular to the ribbon village leads visitors along energy crop production and testing sites. At these locations different energy crops can be tested in order to advance the research on energy crops. A small greenhouse test facility is also located in this strip. The growth of the energy crops will make the greenhouse appear to sink into its environment throughout the year. The energy park is accessible by car from the west, making it possible to launch small boats into the water. A maintenance entrance is located in the north, making the PV panels accessible for technicians. One main axis lead visitors from the north of the park to the south. Another diagonal axis provides a quick access to the recreational beach, while intersecting all the different elements of the park.

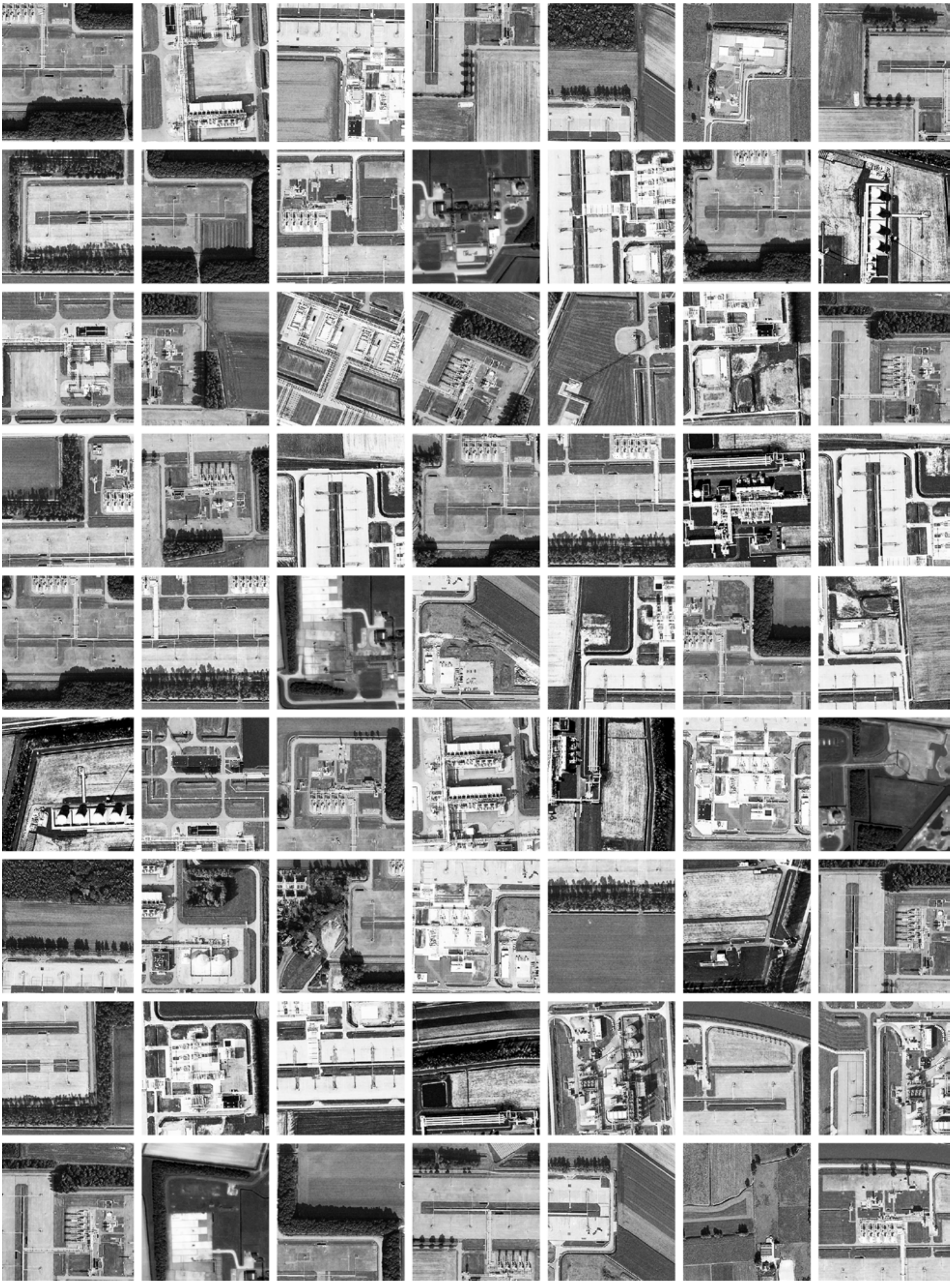


Figure 87: Collage of aerial photographs of natural gas extraction sites

Figure 88:

Figure 89:

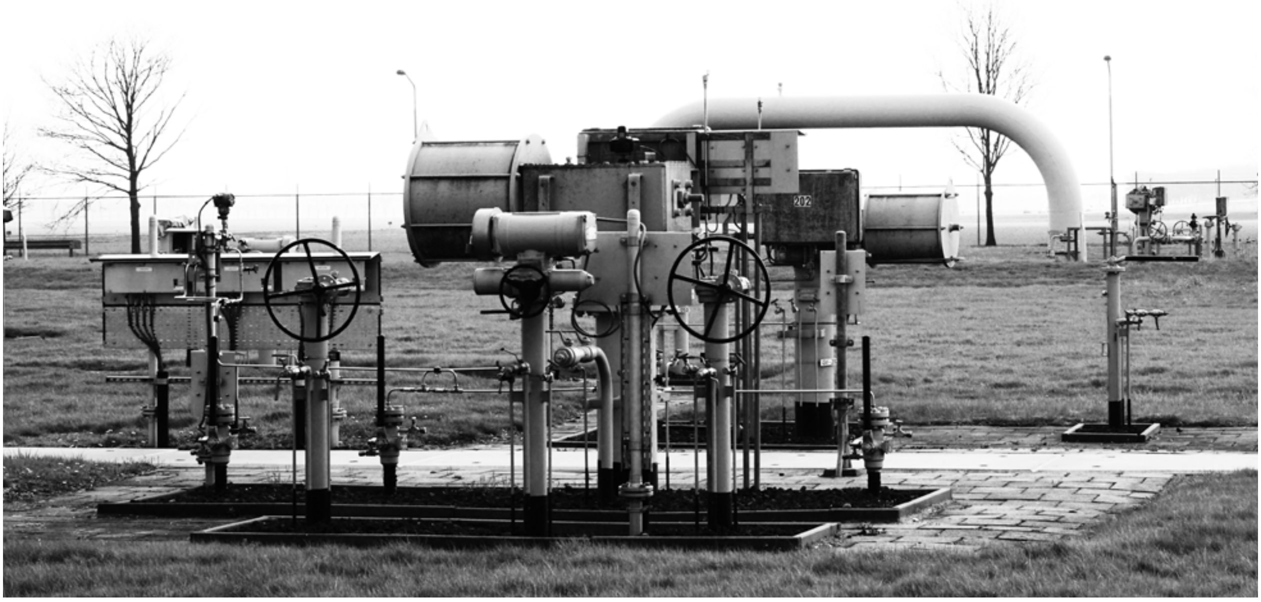


Figure 90:

Figure 91:

Figure 92:

Figure 93:

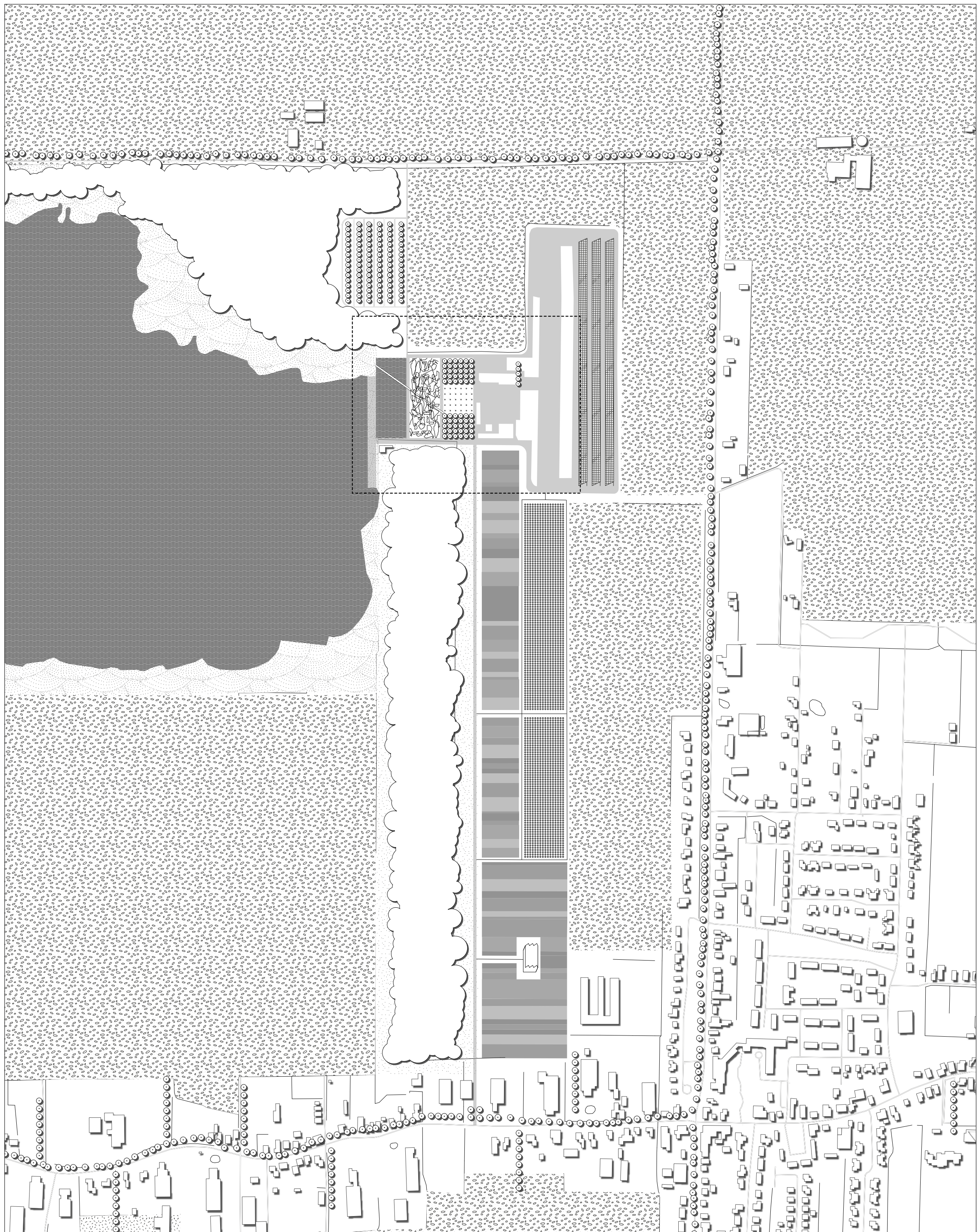


Figure 94: Masterplan of the energy park.

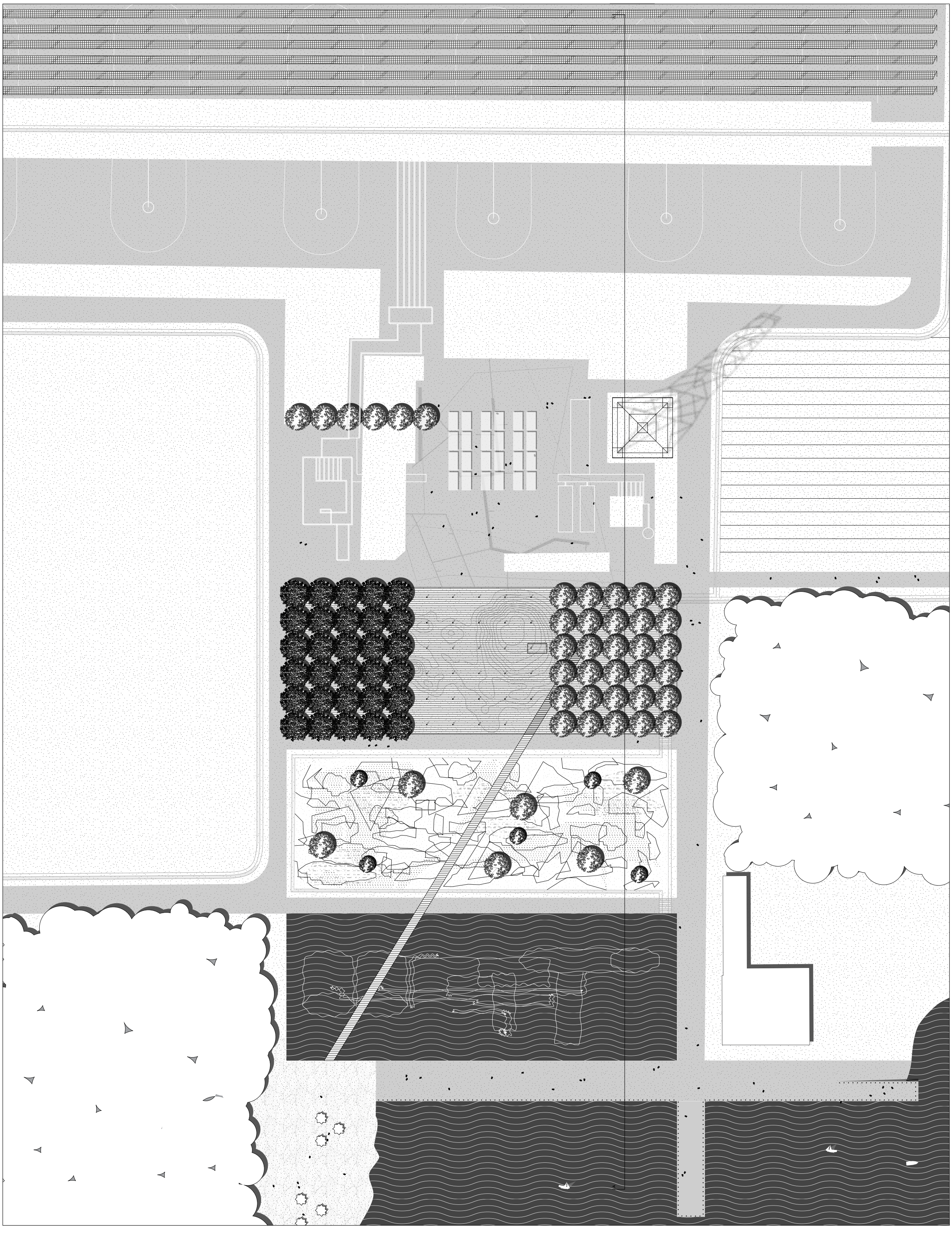


Figure 95: Plan drawing of the main areas of the energy park

Different parts of the park have different functions, this can be seen in Figure 96 and Figure 97. In the north of the park a field with PV panels is located. This field is close to most of the conserved installations, creating a clear contrast between the old and the new. This enhances the idea of different life-cycles following up on each other. The event terrain south of this is surrounded by the same conserved installations, providing a unique backdrop for a variety of events. The monotony of the large tarmac slab of the event terrain is broken by a graphic representation of the renewable energy system of the municipality.

South of the event terrain is a large plaza with a grid of trees and recycled pipelines. The trees placed in a grid symbolize the rationality of the production forests. They furthermore create a thermal comfortable place in summer, when the tarmac of the event square can heat up quickly. The vertically placed pipelines are placed out of their context, creating an estranged experience. By placing elements from the natural gas extraction out of their context, visitors are triggered to think and reflect on the extraction of natural gas. A monument to experience the soil subsidence caused by the extraction of gas is created at the plaza. Soil subsidence has caused the surface to subside by almost 50cm at its deepest point. The isolines of the soil subsidence are taken as the basis for the design. The contour lines each represent a subsidence of 10cm. By walking along the large steps it is possible to go back in time, as the highest part of the monument will be at the height of the original undisturbed landscape. The cracks in the large steps remind of the earthquakes that have afflicted Groningen.

The concept of recycling is incorporated into the design on multiple levels. The use of materials already on-site or from nearby sites can be seen both as a pragmatic cost-driven decision, and as a way to literally and metaphorically use the existing landscape in a new way. As not all extraction sites will be preserved, materials from other sites will be recycled on this site. The soil subsidence monument is constructed from debris. Furthermore, a helophyte filter is constructed on residual asphalt from other sites (Figure 99). In a combined effort, plants and water will slowly conquer the asphalt slabs and turn them into smaller pieces. This process shows the contrast between human influence and nature.

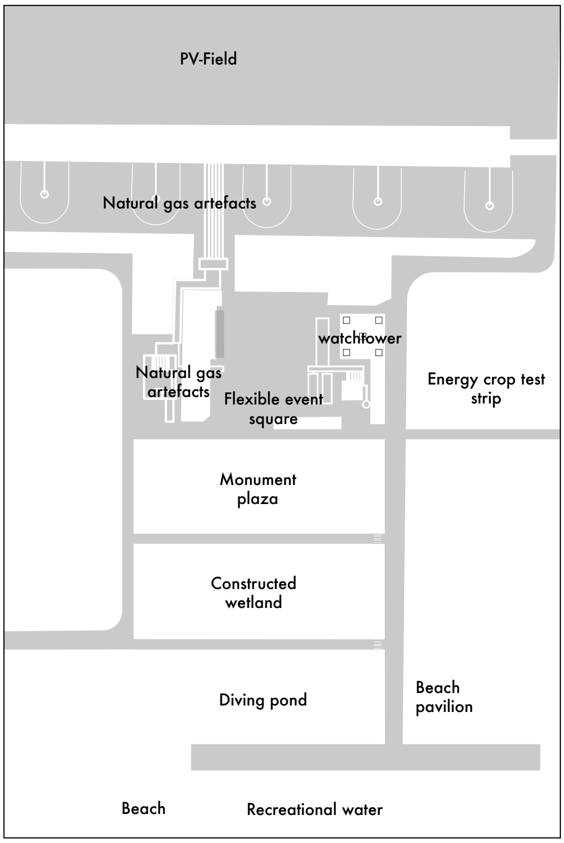


Figure 97: explanation of the different functions and programming

As the sand pit is a man-made object, few interesting underwater structures are present. By sinking some of the structural elements of one of the natural gas extraction sites in an enclosed diving pond, a spectacular and safe diving experience will be created, this is shown in Figure 102.

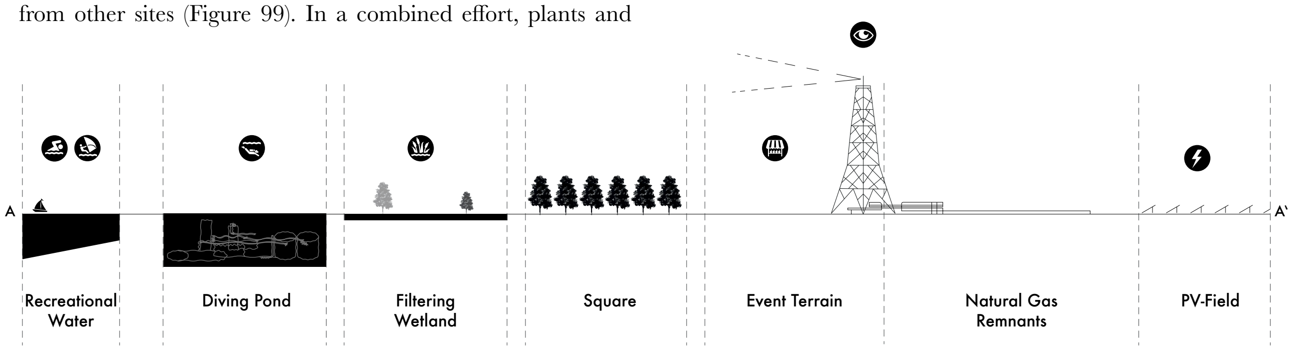


Figure 96: Section of the energy park showing different functions and programming

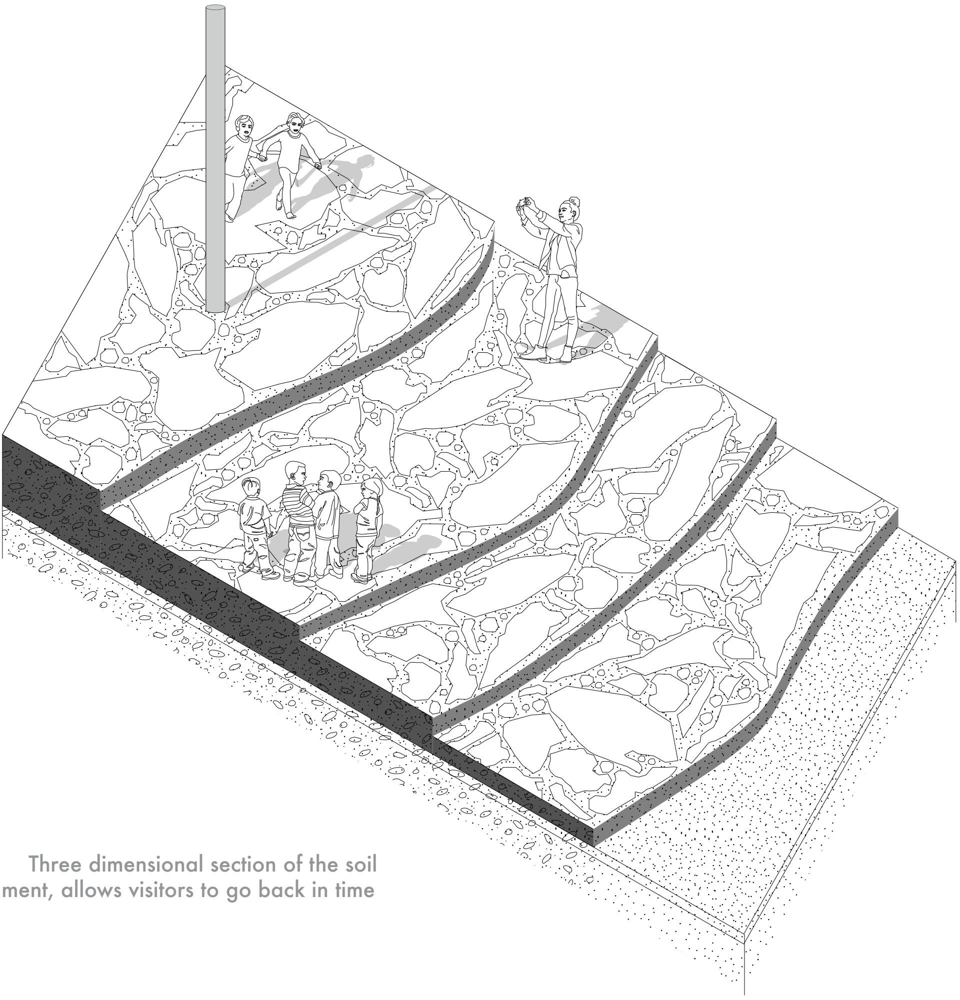


Figure 98: Three dimensional section of the soil subsidence monument, allows visitors to go back in time

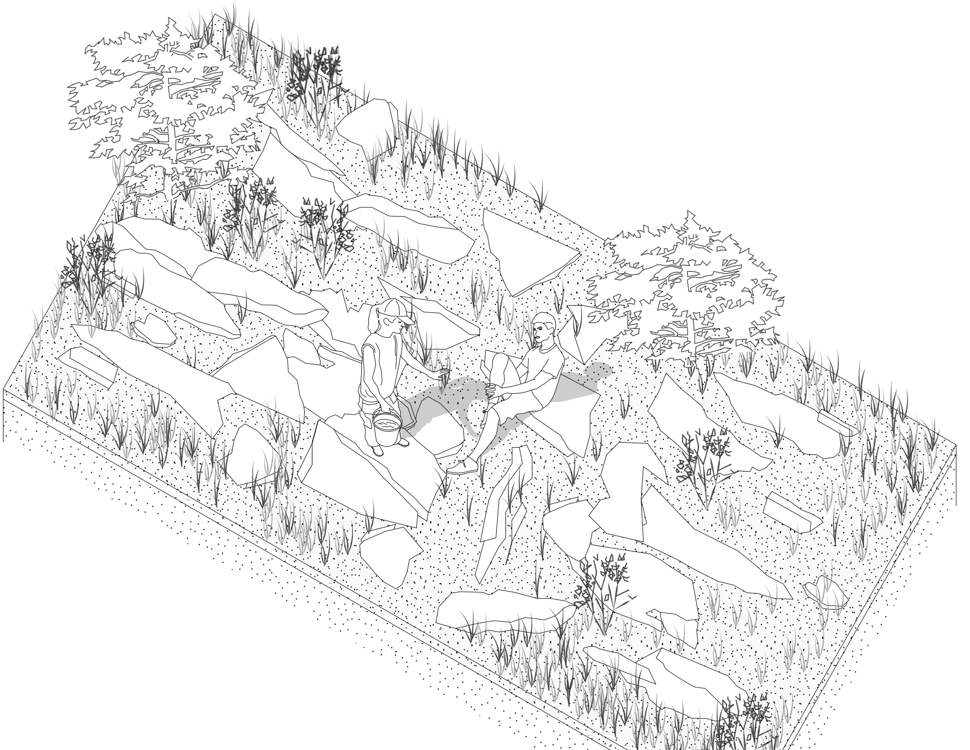


Figure 99: Three dimensional section of the helophyte filter, constructed from recycled materials

Figure 100: Perspective drawing of the flexible programmable event square with a graphical representation of the renewable energy system. The artifacts of the natural gas extraction can be explored and also provide an interesting backdrop

Figure 101: Perspective drawing of the plaza with the soil subsidence monument. The vertical pipelines offer an imposing experience.

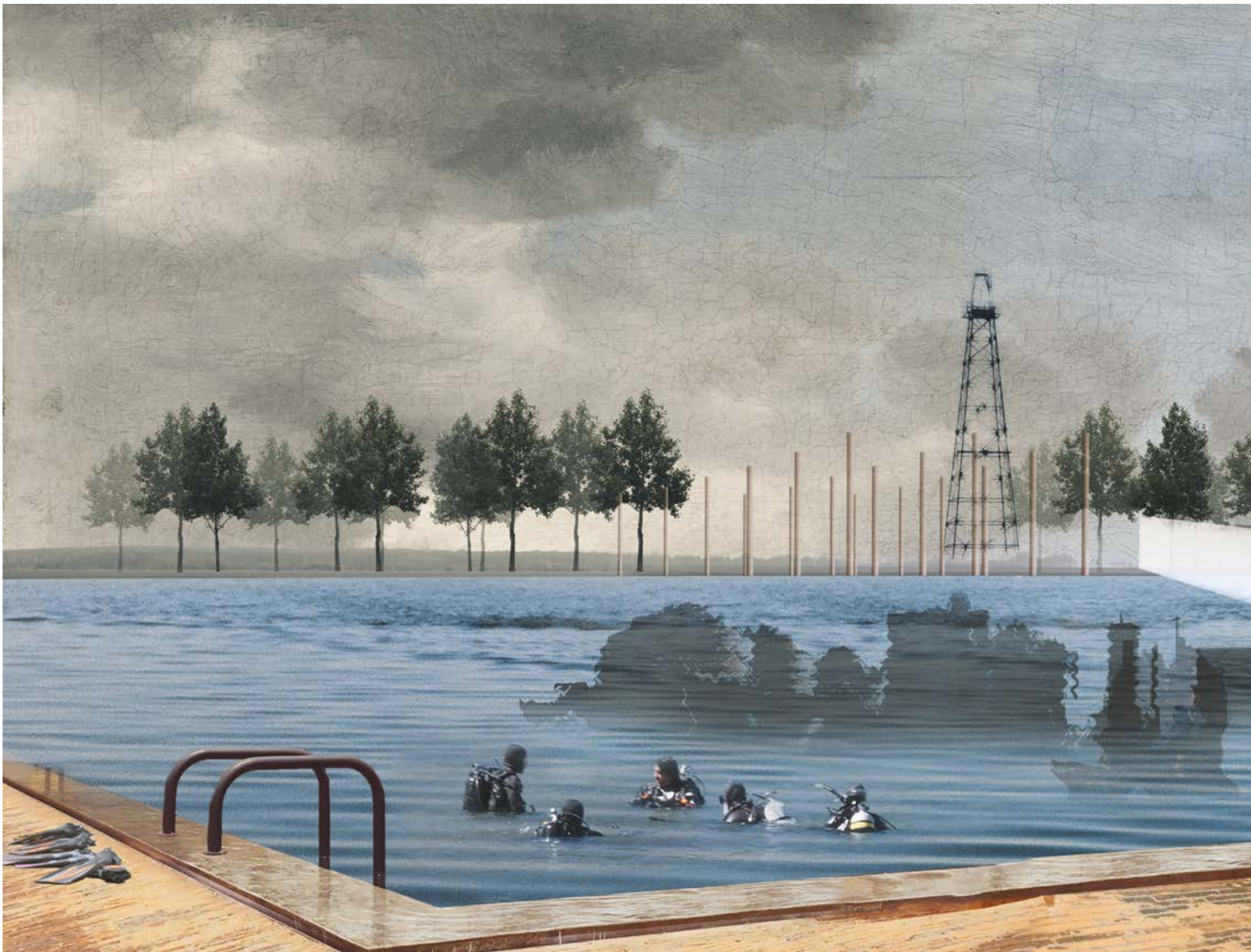
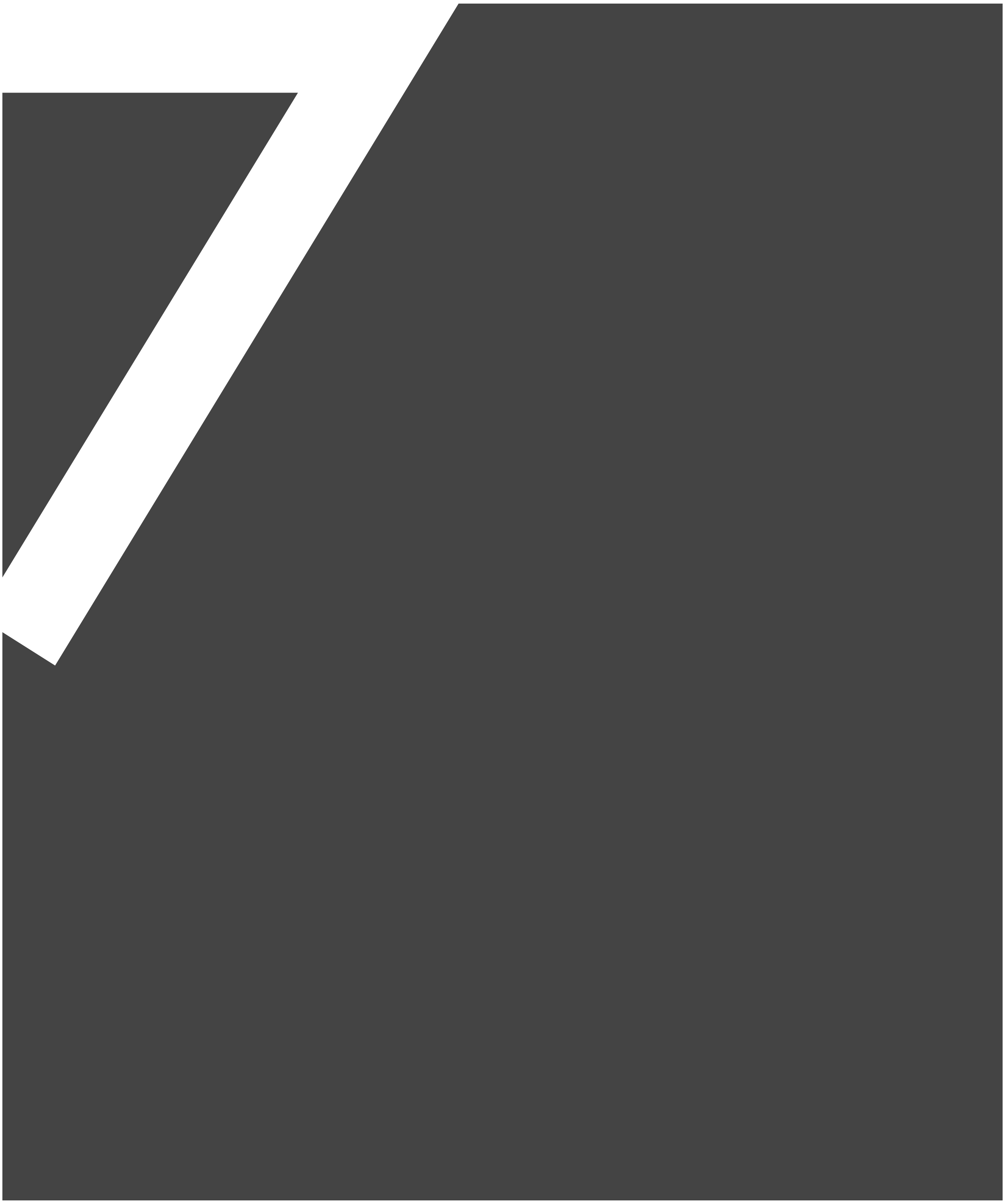


Figure 102: Perspective drawing of the diving pool. Artifacts from the natural gas extraction provide an interesting underwater experience. The diagonal axis cuts straight through all the areas and offers the quickest path to the beach.



DISCUSSION & CONCLUSION

7.1 DISCUSSION

In this section the results and methods of this thesis are being discussed.

The main premise of this thesis was that the natural gas extraction will end in the near future. While there are a lot of negative consequences connected to the extraction and use of natural gas, it is not self-evident that the natural gas extraction will end in the short-term. The international natural gas market is a complex system and the Netherlands plays a prominent role in this market, as it is the 10th largest producer of natural gas in the world. The natural gas distribution network in the Netherlands is well connected to that of its neighbouring countries, this is visible in Figure 103. This combined with a large dependency on natural gas as an energy source make stopping with the extraction of natural gas a complex decision.

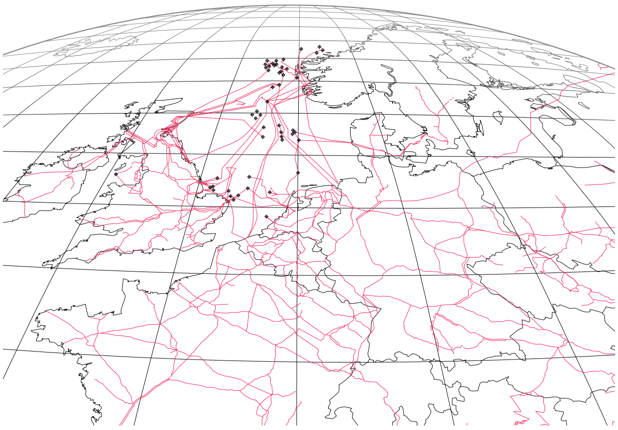


Figure 103: European high pressure natural gas network and offshore production locations, after ENTSOG (2016)

For analysing the social and political extends of the natural gas production landscape a newspaper content analysis was conducted. A clear understanding of the life-cycle of the production of natural gas in the Netherlands was gained from this. However, the physical aspects of natural gas extraction sites are not often portrayed in newspaper articles. Public perception on natural gas extraction therefore stayed on a relative abstract level. Although out of scope for this research, an understanding of people's perception on the physical presence of the natural gas extraction sites could have been an interesting research subject that could inform design. Nevertheless, the understanding of the life-cycle of natural gas did have a tacit influence on the design phase.

As the provision of renewable energy is linked to the physical environment, working with landscape types as units of analysis was a suitable approach. Landscape types do not stop at administrative municipal borders, as was the case with the landscape types identified in Menterwolde. It is therefore recommended to look for larger coherent landscape typologies instead of municipalities when dealing with the planning and designing of sustainable energy landscapes. This is however complicated, as data about energy generation and consumption is often organised at the level of a municipality.

The design for the natural gas extraction facility is strongly contextual as it is influenced heavily by the presence of the sand extraction pit. Using this design as a model for other natural gas facilities is therefore not possible. The context of the site should always be investigated. Furthermore, the design emphasises the cultural and historical values that the artefacts of the natural gas extraction contain. This approach loses value if it is being applied multiple times in close vicinity. A more environmental approach, aimed at remediation could provide an alternative for this.

7.2 CONCLUSION

In this section the conclusions from the study are formulated by answering the various questions posed. In order to answer the main question, first the three sub-questions were posed. The first sub-question was:

<u>How did the natural gas production landscape evolve over time in a physical, political and social way?</u>

The physical analysis of the natural gas production landscape showed that the presence of installations grew overtime, in accordance with the discovery of more and more natural gas deposits. The industrial footprint of natural gas extraction is the largest in the province of Groningen. Most of the infrastructure is hidden beneath the surface and therefore not visible, but indirectly it puts a large claim on land use. Extraction sites are often not embedded in the landscape; locations appear to be chosen based solely on efficiency. In general, the content analysis did not reveal a negative attitude towards the placement and presence of the natural gas extraction sites in the cultural landscape of Groningen. This was different when infrastructure threatened to disturb 'fragile nature areas'. In these cases, it was the ecological consequences that were feared the most. In some cases, landscape experience was perceived to be threatened. The construction of the natural gas storage facility near Langeloo showed that a clear architectural concept can help in these cases.

Earthquakes, and soil subsidence to some extent, changed the way natural gas was perceived. A clear increase in news coverage can be seen after the earthquakes of 1986 and 2012. Inhabitants now fear the earthquakes and want the extraction of natural gas to stop. Over time, natural gas extraction facilities have become dissonant sites. They have become the artefacts, the daily reminders, of the consequences of natural gas extraction. They remind inhabitants of the negative consequences of the natural gas extraction. Occupation of natural gas extraction facilities by protest groups is a manifestation of this.

Political decisions regarding the extraction of natural gas focussed heavily on the security of supply of natural gas. Focus has been on making extraction possible rather than limiting it. Economic motives have played a large role in this.

In the village centre of Schoonebeek, some of the pumpjacks that have been pumping oil for nearly 50 years have been preserved. They function now as a testament to the extraction of oil, a process that has influenced the village and its inhabitants. This shows that remnants like this can become iconic artefacts that prove to have cultural value.

The second sub-question was:

What kind of future landscape can be expected?

Because of the presence of natural gas infrastructure, and the presence of multiple landscape types, the municipality of Menterwolde was chosen as focus area. Three distinct landscape types were distinguished in the municipality. Several future developments and trends could be identified for Menterwolde and based on this, the future land use and energy consumption were mapped. Next to this, the potentials for renewable energy were mapped.

As the spatial organization of the physical environment determines where renewable energy is assimilated and consumed, a different future is to be expected for the three landscape types. For each landscape type, a future was envisioned where the defining characteristics of the landscape where conserved and enhanced, while incorporating renewable energy technologies. Furthermore, a basis for a strong agricultural sector was provided. The mixture of renewable energy technologies was used as a landscape shaping and organising element, creating a new cultural landscape of production. This way, the generation of energy is correlated to the landscape again, as was not the case with the production of natural gas. Synergies between energy generation, agricultural production, tourism, liveability and ecology were searched for in order to create a landscape that meets all dimensions of sustainability.

The third sub-question was:

How can this future be realised incorporating the recycling of the natural gas production landscape?

Natural gas extraction sites can be recycled into multifunctional sites that convey the narrative of energy generation and sustainability. The designed energy park shows that the potentials for these sites go beyond a technical re-use of certain elements. With the design of the energy-park a place is created that embodies both the narrative of the past and the future. The history of the site is captured through the presence of remnants, the decay of structural elements, and more implicitly through a monument that depicts the consequences of the natural gas extraction. Renewable energy generation is integrated in the site and presents a new life-cycle of energy generation that supersedes the extraction of natural gas. Recreational functions and program make it possible to enjoy the now detested site. Additionally, it is believed to help the acceptance of renewable energy technologies. As it offers no extra value to keep all extraction sites, some sites will be removed. A conscious analysis of potentials for a site is needed before the decision about removal has to be made.

The main research question that was the start for this research was:

How can the current natural gas production dominated energy landscape be recycled when production of natural gas diminishes in the near future?

A cultural and historic design strategy can be employed when recycling natural gas extraction sites, as remnant like this often prove to have cultural value. Renewable energy generation can be incorporated into designs for the old extraction facilities. By treating renewable energy as landscape shaping elements, the cultural production landscape can change into a new cultural landscape of energy generation.

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APPENDIX I

Table 5: News sources present in the LexisNexis database used.

News source	From	To	Freq
AD/Algemeen Dagblad	04-11-91	-	daily
Algemeen Nederlands Persbureau ANP	04-11-91	-	daily
Almere Vandaag	01-01-93	-	daily
BN/DeStem	23-04-07	31-05-14	daily
Boerderij	01-01-94	-	daily
Boerderij Vandaag	02-02-99	-	weekly
Brabants Dagblad	02-03-99	-	daily
Dagblad De Limburger	03-01-93	-	daily
Dagblad van het Noorden	27-06-07	-	daily
De Dordtenaar	01-01-97	-	daily
De Gelderlander	17-10-93	-	daily
De Gooi- en Eemlander	23-05-07	-	daily
De Groene Amsterdammer	01-02-94	-	weekly
De Stentor	01-06-02	-	daily
De Telegraaf	02-01-99	-	daily
De Twentsche Courant Tubantia	22-11-03	-	daily
De Volkskrant	02-01-95	-	daily
Eindhovens Dagblad	24-08-94	-	daily
Elsevier	15-05-99	-	weekly
Forum	04-10-94	-	bi-weekly
Het Financieele Dagblad	01-04-94	-	daily
Het Parool	01-07-92	-	daily
Leeuwarder Courant	01-01-97	-	daily
Nederlands Dagblad	14-06-07	-	daily
Noordhollands Dagblad	16-06-07	-	daily
NRC Handelsblad	08-01-90	-	daily
Provinciale Zeeuwse Courant	13-12-02	-	daily
Reformatorisch Dagblad	10-12-05	-	daily
Trouw	02-01-92	-	weekly
Vrij Nederland	01-01-04	-	weekly

APPENDIX II

1. Officiele mededeling exploratievergunning. Drentsch Dagblad (18/07/1944).
2. Boortorens in het Drentse land. Amigoe di Curacao; weekblad voor de Curacaosche eilanden p.2 (19/02/1946).
3. Aardgas in Drenthe. De Waarheid p.3 (18/09/1948).
4. De ontginning van aardolie. Nieuwsblad van Friesland Hepkema's courant p.4 (11/06/1948).
5. Pijpleidingen van Texas tot New York. Nieuwe Apeldoornsche courant p.2 (22/06/1950).
6. Onderzoek naar olie bij Coevorden later voortgezet. Leeuwarder courant; hoofdblad van Friesland (10/08/1949).
7. Aardgas in kanaalstreek. Nieuwsblad van het Noorden p.5 (03/03/1959).
8. Eerste aardgas in Coevorden. De Tijd (05/09/1951).
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APPENDIX III

Table 6: Energy consumption Menterwolde per Neighbourhood based on CBS (2016)

	Natural gas use in TJ				Electicity use in TJ			
Neighbourhoods	Household	Service industry	agraric	industrial	Household	Service industry	agraric	industrial
Zuidbroek	54,46	19,91	0,00	2,79	10,69	9,47	0,00	2,50
Uiterburen	9,47	2,84	7,12	0,40	1,76	1,35	0,84	0,36
Heiligelaan	21,73	5,69	0,00	0,80	3,92	2,71	0,00	0,71
Westeind	4,63	0,00	7,12	0,00	0,90	0,00	0,84	0,00
W A Schottenweg	2,55	0,00	7,12	0,00	0,52	0,00	0,84	0,00
Verspreide huizen Zuidbroek	5,30	2,84	21,36	0,40	0,94	1,35	2,53	0,36
Noordbroek	46,41	9,24	21,36	1,20	8,43	4,40	2,53	1,07
Stootshorn	2,81	0,00	7,12	0,00	0,57	0,00	0,84	0,00
Verspreide huizen Noordbroek	3,68	2,13	21,36	0,40	0,76	1,01	2,53	0,36
Meeden	40,56	7,82	14,24	0,80	7,54	3,72	1,69	0,71
Beneden-Veensloot en Boven-Veensloot	4,83	0,00	0,00	0,00	0,94	0,00	0,00	0,00
Verspreide huizen Meeden	2,27	0,00	7,12	0,00	0,33	0,00	0,84	0,00
Muntendam met Oude Verlaat	116,00	26,31	0,00	3,99	23,02	12,51	0,00	3,57
Tussenklappen	2,72	0,00	14,24	0,00	0,51	0,00	1,69	0,00
Tripscompagnie	3,88	0,00	7,12	0,00	0,73	0,00	0,84	0,00
Borgercompagnie (gedeeltelijk)	2,49	0,00	0,00	0,00	0,40	0,00	0,00	0,00
Verspreide huizen Muntendam	2,72	0,00	7,12	0,00	0,53	0,00	0,84	0,00
Totaal Menterwolde	326,5	76,8	142,4	10,8	62,5	36,5	16,9	9,6

APPENDIX IV

Table 7: Exponential extrapolation of the natural gas consumption per household. R^2=0,98053. based on CBS (2016)

YEAR	M3
1995	1900
1996	1890
1997	1800
1998	1740
1999	1750
2000	1740
2001	1700
2002	1650
2003	1580
2004	1550
2005	1500
2006	1460
2007	1400
2008	1420
2009	1410
2010	1410
2011	1380
2012	1350
2013	1270
2014	1236
2015	1202
*2016	1168
*2017	1135
*2018	1101
*2019	1067
*2020	1033
*2021	999
*2022	966
*2023	932
*2024	898
*2025	864
*2026	831
*2027	797
*2028	763
*2029	729
*2030	695

APPENDIX V

Table 8: Calculations for the mobility energy demand of Menterwolde, based on CBS (2016)

	LPG	DIESEL	PETROL	SOURCE
LITERS	464459	7931510	6076982	Klimaatmonitor
kM/L	10	18	14	based on ANWB (2016)
KILOMETERS	4644590	142767180	85077748	

Table 9: expected future mobility energy demand

	ELECTRICITY	SOURCE
KWH/KM	0,15625	based on (Mohsenian-Rad et al. 2010)
TOTAL KM	36326487	
TJ	130,78	

APPENDIX VI

Table 10: Total potential for solar energy generation on existing roofs in Menterwolde

	Total roof area	Suitable roof area (29%) (broersma et al. 2012)
ha	135,7	39,3

	Max solar energy Groningen	Source
TJ/ha/a	34,0	KNMI(2011)

	Yield solar-PV (15%)	Yield solar-thermal (35%)
TJ/ha/a	5,1	11,9

	Total potential PV on roofs	Total potential thermal on roofs
TJ/a	200,7	468,2

APPENDIX VII

Table 11: Cattle population in Menterwolde with a yearly growth of 1%, based on CBS (2016)

YEAR	AMOUNT
2012	5091
2013	5221
2014	5300
2015	5585
2016	5640
*2026	6169

Table 12: Calculation data

	MANURE PRODUCTION	SOURCE
tonne/animal/year	20	Bekkering et al. (2010)

	BIOGAS PRODUCTION	SOURCE
m^3/h	653	Hengeveld et al. (2014)

	Full load hours	Source
h/a	8766	Hengeveld et al. (2014)

APPENDIX VIII

Table 13: Future energy demand of Menterwolde

Neighbourhood	Heat demand (TJ/a)	Electricity demand (TJ/a)
Zuidbroek	41,42	47,33
Uiterburen	9,22	8,70
Heiligelaan	15,72	15,61
Westeind	5,16	3,53
W A Schottenweg	3,84	2,50
Verspreide huizen Zuidbroek	11,08	7,70
Noordbroek	39,22	34,29
Stootshorn	4,01	2,47
Verspreide huizen Noordbroek	9,83	6,20
Meeden	32,73	30,63
Beneden-Veensloot en Boven-Veensloot	3,04	3,37
Verspreide huizen Meeden	3,67	2,39
Muntendam met Oude Verlaat	82,55	81,71
Tussenklappen	6,19	3,26
Tripscompagnie	4,68	3,20
Borgercompagnie (gedeeltelijk)	1,57	0,81
Verspreide huizen Muntendam	3,95	2,60

Total	277,9	256,3

Table 14: Future energy supply of Menterwolde

Technology	Heat supply (TJ/a)	Electricity supply (TJ/a)
Geothermal	100,8	
CHP-Plants	66	50,1
Wind turbines (10%)		46,7
PV Greenhouses		28,8
PV parks		91,8
Solar thermal parks	112,7	
PV roofs housing (20%)		40,1

Total	279,6	257,5