XXL MIX

An explorative design study into an alternative way of placing and designing XXL warehousing in the Netherlands

Joran Lammers

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All images are made by the author, unless otherwise indicated.

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Reading guide

This report is designed to be readable in two ways. If you prefer a comprehensive story line, all parts are relevant to read. If you prefer a quick overview in 35 pages, the spreads marked with a dark blue edge are relevant to read. This contains pages 27, 47-51, 64-66, 90-111 and 126-129.

Abstract

This thesis is focused on XXL warehousing in the Netherlands; the spatial result of a changing and growing consumption economy. XXL warehouses grow in number and scale in such a speed that the current spatial planning is lacking the instruments to adequately integrate them in the landscape. This results in large-scaled fragmentation of the landscape along large-scale infrastructure: the so-called 'verdozing van het landschap' (boxing of the landscape). With its ability to find synergetic solutions for complex spatial challenges, landscape architectural design research can help to avoid large-scaled landscape fragmentation and improve the integration of XXL warehouses in the Dutch landscape.

In this thesis, new guidelines for placement and design of XXL warehouses are developed. To do so, a design hypothesis was explored, referred to as the 'XXL MIX park'. This design hypothesis states that combining the ideas of 1. clustering of XXL warehousing 2. integrating a renewable energy function and 3. meaningful landscape design, can lead to improved integration of XXL warehouses in the landscape of the Netherlands.

To test to what extent the design hypothesis 'XXL MIX park' could lead to new guidelines for placing and designing XXL warehousing, explorative research through design was conducted in three different phases of research. In phase 1, theoretically underpinned design- and placing- principles were developed to further outline the XXL MIX park from industrial, energy and landscape perspective. In phase 2, on the base of these principles, 24 spatial datasets were collected, combined and analyzed to develop a placement strategy for the XXL MIX park and to select a case study area. Phase 1 and 2 informed phase 3; a design synthesis. In multiple design iterations, an optimal integration of the design principles of the XXL MIX park was explored in the landscape of Dodewaard. Phase 3 eventually led to a final design. Lastly, this final design and the placement strategy were evaluated, and generally applicable guidelines for placement and design of XXL warehousing in the Netherlands were proposed. These guidelines can provide authorities, logistics companies, landscape architects, and spatial planners with practical tools for improving the integration of XXL warehousing in the landscape of the Netherlands.

Keywords: XXL warehousing, XXL warehouse, XXL distribution, verdozing, landscape fragmentation, clustering, energy transition, energy storage, high-voltage station, meaningful landscape, design synthesis, design guidelines, placement guidelines

Figure 1: excursion through the logistic corridors of the Netherlands.

Preface

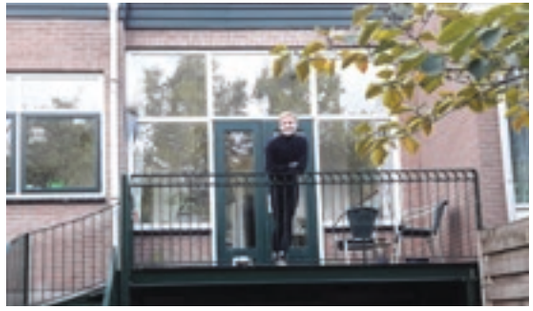


Figure 2: balcony in the backyard of my parents.

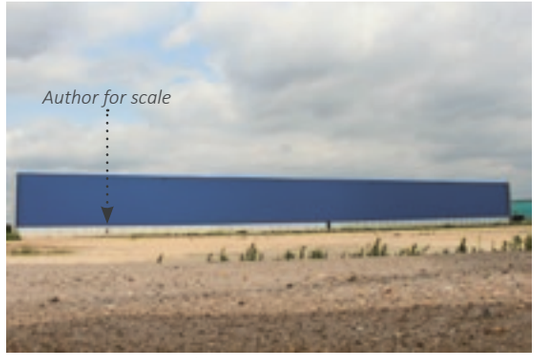


Figure 3: XXL warehouse in Venray.

Last year, in the backyard of my parents' house, a balcony of 8 square meters was placed (figure 2). Before construction, the municipal committee of spatial quality had requirements for the use of materials, the color, the architecture and the construction of the balcony. I found the regulation near to excessive, but on the other hand, I was happy with a municipality taking care of their architectural heritage.

Not a bigger contrast can be found when regarding the contemporary building of XXL warehouses (40 000 – 100 000 m^2!) in the Netherlands (figure 3). At the edge of cities and villages these 'giants' pop up at an unprecedented speed, and general regulations regarding the material, the color, the construction, and the architecture seem to be much more flexible than with my parents' balcony.

Since I am concerned with the Dutch landscape, the spatial threat this development possesses was the reason to write my master thesis about XXL warehousing. After a year of working with dedication and enthusiasm on this topic (figure 1), I am happy to see the research finished in a booklet in front of me.

For their supervision throughout the research process, I want to thank Adriaan Geuze, Joao Cortesao, Maarten van Riet and Rudi van Etteger. Furthermore, I want to thank the College of Rijksadviseurs for inviting me to their expert meeting, and Kees Verweij and Emil Goosen for sharing time and information during the interviews. Finally, I want to thank my father for his substantive help, Solve for sharing his language skills, Brecht for revising the report, Ben and Erna for their graphical check, and my girlfriend, sister, housemates, and friends for their love and support.

Figure 4: container ship in the harbor of Rotterdam.

Content

Figure 1.1: a 125-meter wide wall of an XXL warehouse, with the author for scale.

1. Introduction

1.1 Problem description

Large-scale industrial elements in the Dutch Landscape

God created the earth; the Dutch created the Netherlands. This common saying shows that the Netherlands exists of man-made landscapes. By ingeniously keeping their river-delta livable and accessible, the Dutch provide themselves with an optimal position in the global economy, shown by the fact that the Netherlands is the 5th largest export country in the world (CIA world factbook, 2018). Because of a lasting desire for a growing economy and retaining economic competitiveness, the Dutch landscape must accommodate spatial elements of a growing economy. These elements are growing in scale because of the current economic prosperity and economies of scale. Accommodating these industrial elements without conflicting other essential landscape functions is a growing challenge in the landscape of the Netherlands.

Unfortunately, industries and governments often lack a holistic and long term perspective when introducing new elements in the landscape (Alkemade, Strootman, & Zandbelt, 2018).

This results in large-scale industrial elements being implemented in the landscape in inefficient and short-term based ways. As landscape architect Adriaan Geuze mentions in Nieuwsuur: the Dutch cultural landscape is barely visible anymore, in some parts of the Netherlands, it is disappearing in an unimaginable speed because of XXL warehousing, greenhouses, windmills, billboards, etc. (Nieuwsuur, 2019).
To maintain and preserve valuable landscapes, the accommodation of large-scale industrial elements should to a large extent consider a holistic and long-term perspective. As mentioned by the Rijksadviseurs in Panorama Nederland: we have to be aware that a perceived urgency can never be an argument to settle for an inferior spatial and social quality (Alkemade et al., 2018, p. 10).

Figure 1.2 shows Venlo and its surroundings. A remarkable example of a landscape where big scaled industrial elements like XXL warehouses and greenhouses have a big impact on the landscape.

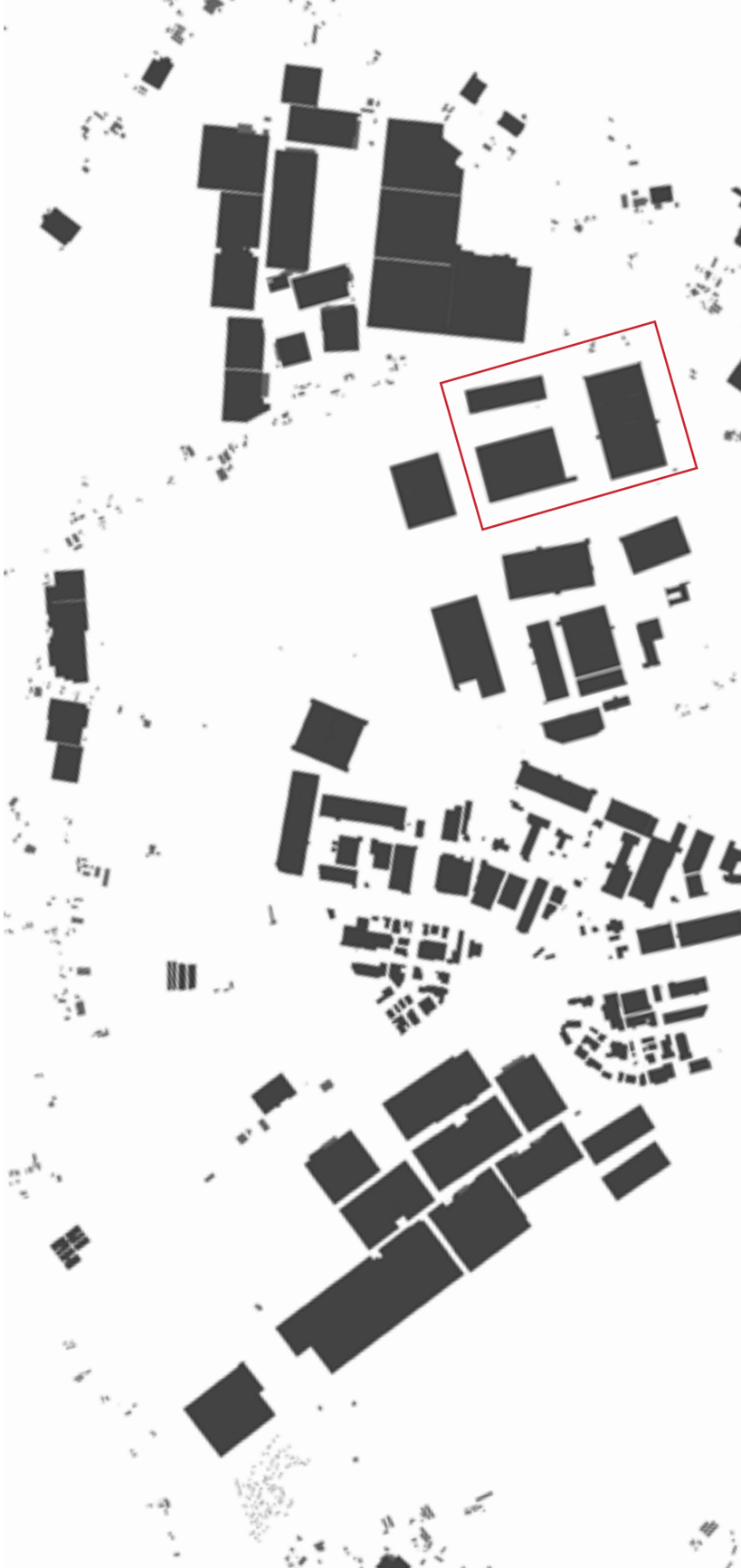


Figure 1.2: map that shows buildings in Venlo and its surroundings. A more detailed comparision between the areas indicated in the red boxes is given in figure 1.3 and 1.4 on the next page.

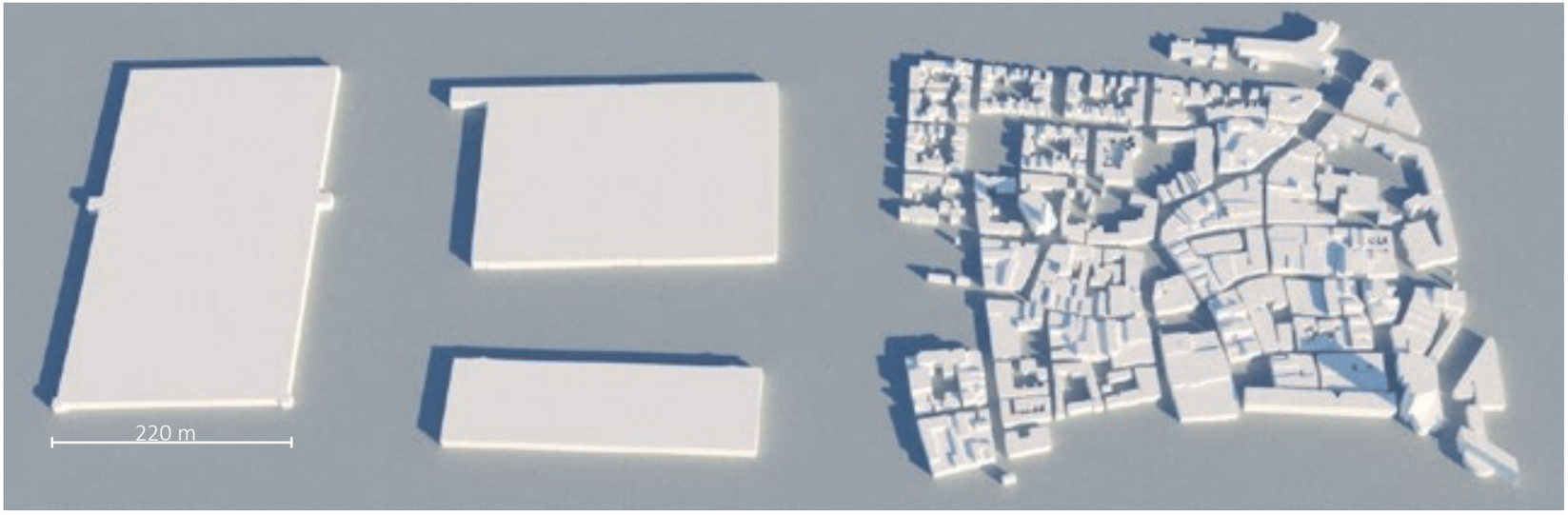


Figure 1.3: scale study: comparison of 3 recently built XXL warehouses in Venlo (developed in 1 year), next to the center of Venlo (developed in 500 years). For interpretation of the white line, see figure 1.4.

Figure 1.4: a 220-meter long side of a XXL warehouse in Venlo, please note the truck for a imagination of scale.

The rise of XXL warehousing

This thesis focuses on XXL warehouses, a striking example of a big scaled industrial element that threatens the quality of the Dutch landscape. XXL warehouses are storage locations of on-line shops, chain stores, brands, and logistics companies, with a surface bigger than 40 000 m². Figure 1.3 gives an indication of how the scale of XXL warehouses relates to the scale and footprint of the city center of Venlo. Driven by economic welfare, which is boosting purchasing power, and e-commerce, that changes the supply chain, the logistics industry is growing and changing rapidly (Stec, 2018a). Measured in m² of warehousing, the growth was 1,4 million m² in 2015, 1,8 million m² in 2016 and 2,5 million m² in 2017 (Logistiek.nl, 2018). At the start of 2017, there was an amount of 1760 XXL warehouses in the Netherlands with a total surface of 28 million m² (Schoorl, 2018) (figure 1.5). This process of expanding and scaling up is expected to continue. Prognoses for the Netherlands differ from 4 million m² (Stec groep, 2018a) to 10 million m² in the coming five years (Verweij, personal communication, October 1st, 2018a).
The rise of B2C (business to consumer) companies cause a big part of the growth in the number and scale of XXL warehouses, since these companies make products pass through two warehouses instead of one before reaching the consumer (figure 1.6). Furthermore, economies of scale and risk management cause the warehouses to grow bigger. Subsequently, the real estate market of XXL warehousing is currently a lucrative business and therefore stimulates the rise of the industry even more (Eringfeld, personal communication, October 10th, 2018).
Logistic companies base the positioning of their XXL warehouses on the availability of (cheap) land, proximity to main infrastructure like highways, railways or waterways, a strategic position in between sea harbor and hinterland, availability of workers, and/or a lenient local policy (Verweij, 2018). The industry is mainly concentrated in the southern part of the Netherlands, because it meets many of these requirements, but a scarcity of available land and employers currently results in a shift to the north (Stec groep, 2018b).

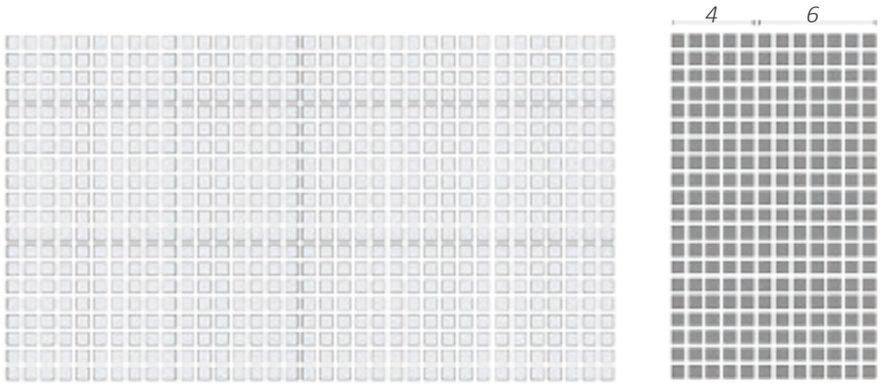


Figure 1.5: left: 28 000 000 m² warehousing in 2017 expressed in blocks of 40 000 m². Right: future growth expectations, differ from 4- 10 million m² in the coming 5 years.

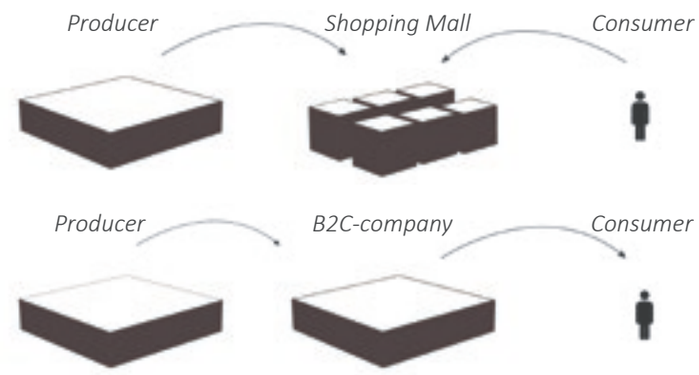


Figure 1.6: schematic representation of traditional supply chain and the emerging B2C supply chain.

Spatial planning of XXL warehousing

Spatial planning of XXL warehousing is part of business park planning, and is often organized on a municipal level. Since the eighties, industrial and living functions have been spatially separated in the Netherlands. Logistics and manufacturing industries were clustered into business parks outside villages and cities. It resulted in better production conditions for companies, and better living circumstances in neighborhoods. But besides these positive effects, currently, the planning of business parks is causing serious problems in the edges of cities and villages.
In the period 2000-2006 there was a lot of debate about the lack of spatial quality of business parks. Many publications were written about insufficient planning and lack of spatial quality. As mentioned in the book Planning van Bedrijventerreinen: the planning of industrial parks should change. A lack of cooperation between competing municipalities has led to a wide range of cheap construction ground. It forms a threat to the open landscape and obstructs the restructuring task of brownfields (Louw, Needham, Olden, & Pen, 2009). The debate led to more awareness in politics about the spatial quality of industrial parks, but in practice the problem remains. The (especially municipal) estimates of required space for industrial areas are still too high, causing an ongoing allocation of mainly agricultural land into industrial parks. A paradoxical consequence is that the development of new industrial parks causes accelerated aging of existing ones (Louw & Olden, 2016) (figure 1.7). Moreover, the process of expansion goes rather quick, since the average depreciation of warehouses is 20 years (Verweij, personal communication, October 1st, 2018a).

The result is a great surface of outdated industrial area. IBIS, the national database of industrial areas, shows that 33% percent of the total surface of existing industrial parks is qualified as being 'outdated', which means investments are needed to bring the spatial quality and functionality of the park to an acceptable level (van der Krabben, Pen, & de Feijter, 2015). With their unprecedented and growing scale, XXL warehouses are literally amplifying these problems in business park planning.

The consequences of this problem are becoming visible on the national map. The unprecedented growth makes municipal clusters of industrial areas slowly grow together, reaching the point of a visible ribbon development (lintbebouwing) (figure 1.8, 1.9).

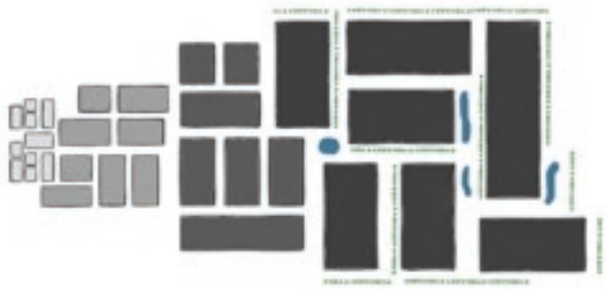


Figure 1.7: schematic representations of an expanding municipal industrial area. The development of new industrial areas cause accelerated aging of existing ones.

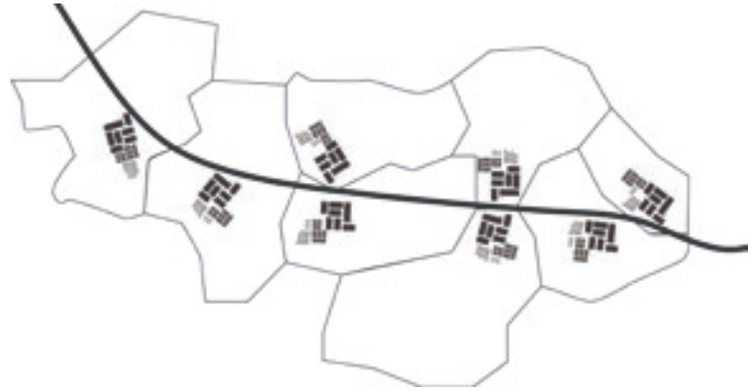


Figure 1.8: schematic representation of competing municipalities, resulting in ribbon development along logistic infrastructure.

Figure 1.9: Map of the Netherlands, showing industrial areas up to 2015 (black) and new or planned industrial areas since 2015 (red). Along highways especially (white lines), ribbon development starts to occur (CBS, 2015; IBIS, 2018).

Concerns about XXL warehousing

The fast growth of XXL warehousing and its poor planning gain attention in the media, since landscape experts as well as logistics experts are increasingly concerned about this problematic development.

In the Volkskrant, landscape architect Adriaan Geuze introduced the term 'verdozing' (boxing) of the landscape. He states: we shouldn't limitless fill our polders with XXL boxes. It seems like municipalities are enchanted for having new industrial areas (Schoorl, 2018).

Chief Government Architect Floris Alkemade mentions in Trouw that beautiful views are under pressure because of XXL warehousing. He adds that the development is a threat for the Dutch landscape, especially because in most cases there is no coordination before placing the warehouses (Velzen, 2019).

Government advisor of urban planning Daan Zandbelt states that it is strange that we do our utmost best to preserve landscape qualities by building as many homes as possible within built-up areas and at the same time this effort is lost by the development of XXL warehousing (Zandbelt, personal communication, 3th of october, 2018).

René Buck of Buck Consultants mentions in the Volkskrant: the warehouses are very large and pop up everywhere in the country. It is unprecedented for a country such as the Netherlands and causes a shortage of space and labor. We are getting full (Schoorl, 2018).

Wim Eringfeld, director of Stec mentions in a meeting that too many locally-driven logistics hotspots are developed. He adds that there is quite some financial space in the industry, that could open possibilities for improved integration in the landscape, but he adds that without a clear policy framework, companies will not start to invest themselves (Eringfeld, personal communication, 3th of October, 2018).

Besides the attention for the problematic aspects of XXL warehousing, a lot of news concerning XXL warehousing is rather positive. As shown in figure 1.10, new industrial parks are proudly presented. Often, the naming of the industrial parks reflects the municipal ambitions (figure 1.11). Figure 1.12 and 1.13 show examples of contemporary landscape integration of XXL warehousing.

Retrieved from: pzc.nl/tholen

Retrieved from: rijnmond.nl/nieuws

Retrieved from: www.logistiek.nl/warehousing

Figure 1.10: examples of municipalities presenting their bussiness park as national or regional hotspot.

Figure 1.11: the naming of industrial areas in ‘s Heerenberg reflects the municipal ambition. From a reference to a local landscape ‘het Goor’ (1988), to a reference to a whole nation ‘DocksNLD’ (2015) to attract logistic companies (map retrieved from Google maps).


Figure 1.12: example of current landscape integration of XXL warehouses; the use of ground walls.


Figure 1.13: example of current landscape integration of XXL warehouses; the use of single tree lanes.

Knowledge gap

As indicated, landscape and logistics experts acknowledge the problems concerning XXL warehousing. They propose several ideas and research directions that are needed to fill the current knowledge gap regarding placement and design of XXL warehousing.
Landscape architect Adriaan Geuze pleads for control by the national government. He suggests policy that obliges solar fields on the roofs, and prevents building on good agricultural soils (Schoorl, 2018). The College van Rijksadviseurs pleads for design-based research concerning spatial distribution (clustering <-> spreading), multifunctionality (energy, agriculture, etc.), landscape integration, and policy instruments (Strootman, Zandbelt & Alkemade, 2018). Director of Stec, Wim Eringfeld, calls for more governmental control too. He states that XXL warehousing could be helped by new planning and design policies. He proposes a more regional based spatial planning. Furthermore, he suggests clustering of XXL warehouses, multi-modal accessibility and integration of an energy function (Eringfeld, personal communication, 3th of October, 2018). Kees Verweij of Buck Consultants states that the expression of XXL warehousing will gain importance in the future and suggest research into architectural expression and landscape integration. Furthermore, he pleads for a demand-oriented, regional spatial planning policy (Verweij, personal communication, 10th of October, 2018a).

Because XXL warehousing is a relatively recent phenomenon, the problem has only recently started to get attention of spatial planners and designers. The research directions as proposed by the experts are comprehensible, but still broad and multi oriented. In this 'starting phase', the focus should be on explorative research. Although research in placement and design of XXL warehousing is new, inspiration can be taken from existing researches about related topics. Research has been done into characteristics and design principles of Dutch business parks (van der Gaag, 2004), into ways of designing business parks according to eco-efficiency principles (Grant, 1997), (Côté & Cohen-Rosenthal, 1998) and into systems for a more sustainable supply chain, for example, the physical internet system (Montreuil, 2011).

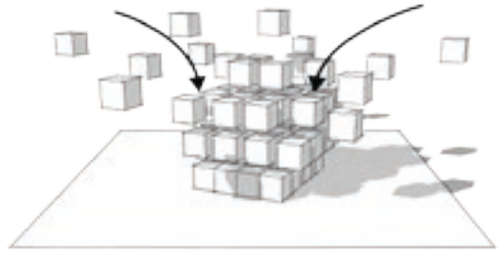
Relevance

Landscape architectural research through design can be of significant relevance in an explorative research phase since it can explore the 'new' and 'unknown' and generate new 'insights or constructs' (Lenzholzer, Duchhart, & Koh, 2013). Furthermore, as mentioned in the publication Integrating design thinking with sustainability science: "by using a holistic perspective, and by expanding the framing of the problem, research through design methods can create integrated concepts where components work in harmony with each other and their context" (Maher, Maher, Mann, & Mcalpine, 2018, p. 1568). Therefore, landscape architectural research through design is suited to explore solutions for the placement as well as the design of XXL warehousing in the Netherlands.

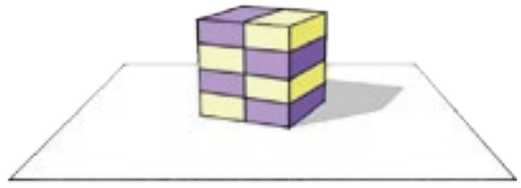
1.2 Conceptual framework

To be able to state a specific research objective within the broad and multi-oriented research field of XXL warehousing, this conceptual framework outlines a specified design hypothesis. To do so, 3 working assumptions are combined that build up this hypothesis (figure 1.14).

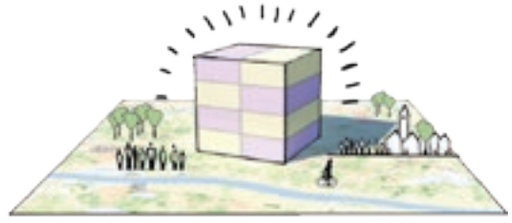
The assumptions are based on research directions as proposed by landscape experts, logistics experts and energy experts. By combining the assumptions from different perspectives, a holistic approach towards placing and design of XXL warehouses is pursued.



1. Cluster XXL warehousing



2. Integrate a renewable energy function



3. Meaningful landscape design

Figure 1.14: three working assumptions build up the design hypothesis.

1. Cluster XXL warehousing

Landscape experts as well as logistics experts mention clustering of XXL warehousing as possible solution for the current problems. From a landscape preservation point of view, clustering can avoid landscape fragmentation, since strategic and suitable places can be selected to enhance a cluster of XXL warehouses, while other landscapes remain unharmed. From an industrial perspective, clustering, or campus formation can increase efficiency of the logistics supply chain. By putting together different activities, transport costs for example, can be minimized.
The current planning of business parks is already based on clustering. But as shown in the problem description, this planning system lacks a regional- or even national planning perspective and is not suited for the contemporary scale of XXL warehousing. By exploring clustering from a national perspective, guidelines for placing and designing XXL warehouses can be developed apart from this current, problematic municipal business park planning (figure 1.15).

Therefore, the first working assumption states that clustering of XXL warehouses from a national planning perspective can improve the placement and design of XXL warehousing.

2. Integrate a renewable energy function

"One of the main future spatial developments will be caused by the energy transition" (Stremke & Dobbelsteen, 2013, p. 10). As a result, space demand of energy functions will highly increase (figure 1.16). Therefore, function combination with energy is frequently mentioned concerning new ways of placing and designing XXL warehouses. Often, the possibility for solar fields on the large roofs is appointed (figure 1.17). As Alkemade puts in Trouw: how is it possible that solar panels are not installed as standard on the roofs of XXL warehouses, while they are now being placed in meadows? (Velzen, 2019) (figure 1.17). But the potency and need of combining industrial activities and renewable energy appliances goes beyond utilizing big roof surfaces, as the following points will shortly describe:

- The energy use of the industrial sector is 40% of the total amount (3150 PJ) of energy used in the Netherlands (CBS, 2018). In terms of electric energy, this percentage is even higher: 70% (van Riet, personal communication, 19th of September 2018). This means an important part of the energy transition must be conducted in the industrial sector.
- Because climate change and energy transition are gaining priority in society, for industries the integrating of renewable energy techniques is of growing interest. For some industries, producing, or deploying energy losses can become a substantial part of their business model (van Riet, personal communication, 19th of September, 2018).
- The Dutch climate agreement states that innovation, pilots and demonstrations of renewable energy systems are of great importance in achieving the goal of reducing industrial emissions with 50% in 2030 (Dutch government, 2019). Since the fast growth of the logistics sector is currently transforming big parts of landscape, these landscapes might be suitable to offer space for large-scaled innovation of renewable energy systems as well.

By developing clusters of XXL warehouses not only from an industrial motive but by exploiting the potential of integrating renewable energy functions, future-oriented and multifunctional industrial parks could occur.

Therefore, the second working assumption states that integrating a renewable energy function can improve the placement and design of XXL warehousing.

Figure 1.15: schematic representation of removing XXL warehousing from municipal business park planning.

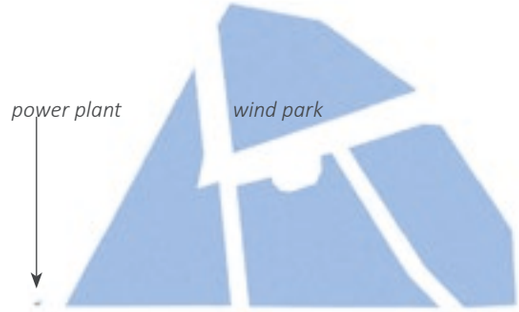


Figure 1.16: scale study: coal power plant Eemshaven and future wind park Borssele; both have a power capacity of 1500 MW.

Figure 1.17: solar roof of an XXL warehouse, still a rare phenomenon (retrieved from: logistiek.nl)

3. Meaningful landscape design

Clustering and integration of a renewable energy function are promising ideas that can improve the placement and design of XXL warehousing. Nonetheless, these concepts can never offer a complete solution for the described problem, since they mainly tackle the symptoms and do not directly relate to spatial quality.
The problem in placing and design of XXL warehousing starts with its gigantic scale and its fast expansion. The core of that development starts with mass consumption. In the end, XXL warehouses are a direct result of our own consumption behavior, reflected in the landscape. So where-ever and how-ever placed, XXL warehouses will remain to have a big spatial impact as long as our consuming behavior does not change (figure 1.18, 1.19).
This thesis will not try to 'force' societal change by directly aiming for landscapes that contain less or smaller XXL warehouses than currently demanded.
To give a truthful alternative to the current way of placing and designing XXL warehouses, this research will work within the current reality and future growth expectations. But to do more than finding ways to optimize a problematic development, this thesis will aim for creating societal awareness regarding consumption behavior by creating societal awareness through landscape design.
In a manifest, Meyer relates to the role landscape design can play in creating awareness: "What is needed are designed landscapes that provoke those who experience them to become more aware of how their actions affect the environment, and to care enough to make changes".
"Sustainable development requires more than designed landscapes that are created using sustainable technologies".
"Sustainable landscape design should be form-full, evident and palpable"(Meyer, 2008, p. 6, 15 and 17).
When projecting Meyers statements to the case of XXL warehousing, creating palpability might become challenging, since because of their enormous scale, XXL warehouses are very difficult to relate to. They can be considered as 'footloose' landscape elements, having an inconvenient connection with their environment. To add meaning to the landscape design nonetheless, connecting the 'footloose' XXL warehouses to human-scaled experiences in the landscape will form a main goal of this thesis.
If the large and small scale can be interconnected in the landscape design, people could be provoked while experiencing the XXL warehouses, and become aware of how their consumption behavior affects the environment, and maybe even be altered to change this behavior.

Therefore, the third working assumption is that meaningful landscape design can improve the placement and design of XXL warehouses, and might even help to change consumption behavior.

Figure 1.18: inconvenient contradiction; societal concern and energy use.

Figure 1.19: inconvenient contradiction; societal concern and consumption behavior.

Design hypothesis: XXL MIX park

Summarizing, the hypothesis of this thesis states that the ideas of 1. clustering of XXL warehouses from a national planning perspective, 2. integration of a renewable energy function and 3. meaningful landscape design, can improve the placement and design of XXL warehousing.

A research through design is needed to find out to what extent this combination indeed leads to improved placement and design. To be able to easily relate to this combination of assumptions, from now on, it will be referred to as a design proposal, named the '**XXL MIX park**' (figure 1.20).

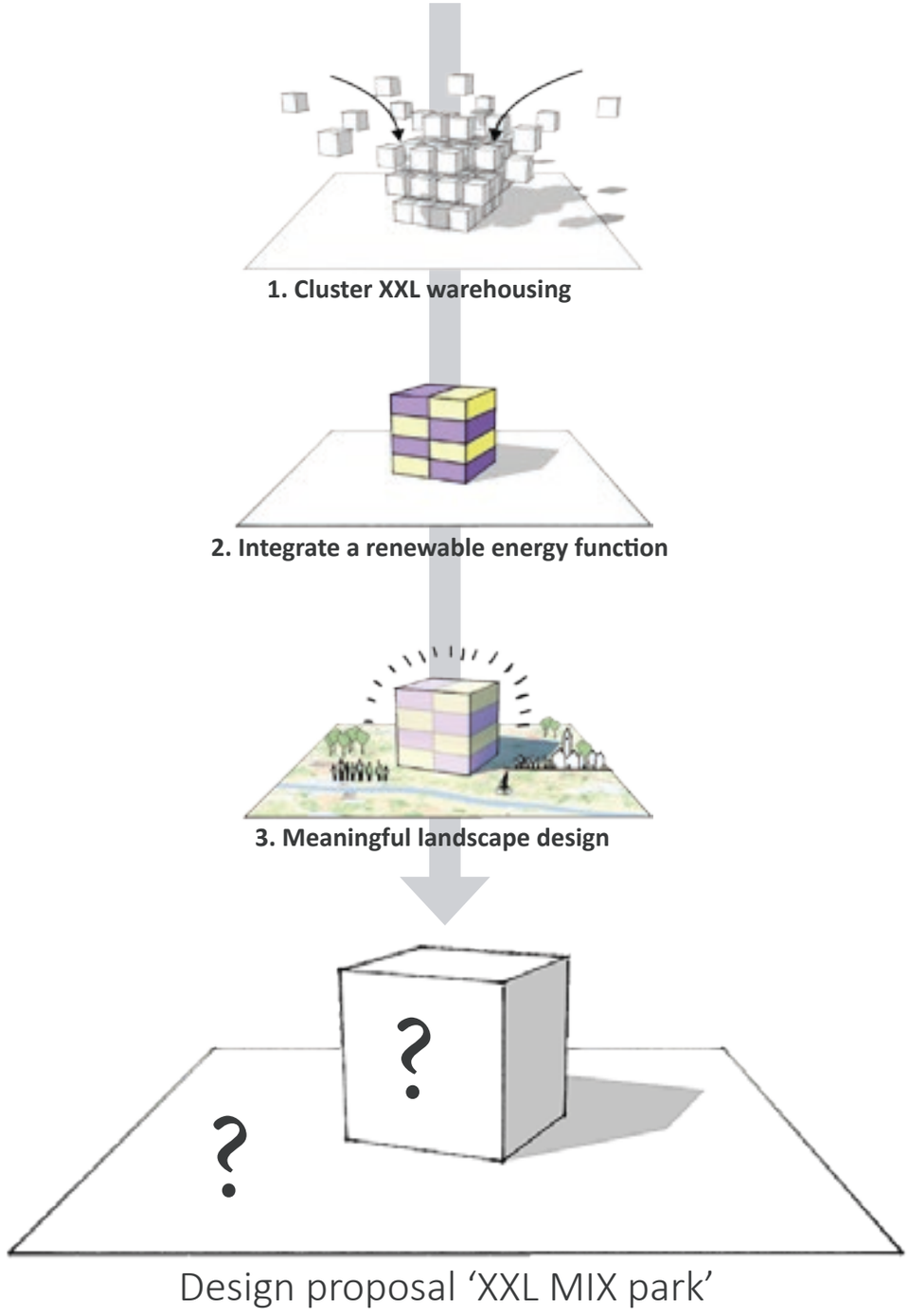


Figure 1.20: the construction of the design proposal 'XXL MIX park'.

1.3 Research questions

Thesis statement

XXL warehousing, with its unprecedented scale, is perishing the suburban landscape. A regional or even national perspective is missing, resulting in inappropriate placement and design of warehouses spread around the landscape. To stop this development, and avoid the landscape being further scattered, research is needed to find new guidelines for placement and design of XXL warehousing in the Netherlands.

It is assumed that combining the ideas of, 1. clustering of XXL warehouses from a national planning perspective, 2. integration of a renewable energy function and 3. meaningful landscape design can result in improved guidelines for XXL warehousing. This combination of ideas is related to as 'XXL MIX park'.

Prescribed argumentation leads to the following thesis statement:

By exploring where and how the design proposal 'XXL MIX park' can be applied, this thesis aims to develop new guidelines for placement and design of XXL warehousing in the landscape of the Netherlands.

Research questions

Main research question:

What guidelines can improve the placement and design of XXL warehouses in the Netherlands?

Sub-research questions:

1. What are the principles for placement and design of the XXL MIX park?

2. Which locations in the Netherlands can be suitable for placing the XXL MIX park according to the placement principles?

3. How can an XXL MIX park function, and be integrated and expressed in the landscape according to the design principles?

2. Methods

Figure 2.1: container ship in the harbor of Rotterdam.

The aim of developing the 'XXL MIX park' is to generate new insights and constructs for the placement and design of XXL warehousing in the Netherlands. This aim fits in a constructivist knowledge claim, since research in this claim is about exploring and generating the new and unknown, and focuses on generating new insights and constructs rather than quantitatively testing them.(Lenzholzer et al., 2013). Because the assignment asks for alternatives based on sustainable development, a research through design process is conducted that contains: broad problem framing, maximize synergy, integrating diverse perspectives, thinking visually and multiple feedback loops (Maher et al., 2018).

To answer the research questions in this constructivist research through design process, 3 research phases are conducted. Each phase relates to one of the sub research questions. **In phase 1,** design and placing principles are developed, to specify the design proposal XXL MIX park (chapter 3.1). The principles are based on concepts, theories and ideas from literature and from conducting interviews with experts. The gained information is used as input for phase 2 and 3 of the research process. Research **phase 2** consists of a placing analysis (chapter 3.2). Based on the placing principles, spatial datasets are collected and analyzed to develop a placement strategy for the XXL MIX park and to select a case study area for research phase 3.

Phase 1 and 2 inform **phase 3**; the design synthesis (chapter 3.3). To find a synthesis of industrial functionality and meaningful design, two activities are simultaneously executed; landscape design and element development. In three design iterations, integration of the design principles (from phase 1) in the case area (from phase 2) is gradually explored, eventually leading to an optimized final landscape design.
To answer the main research question, in a final evaluation, guidelines for placement and design of XXL warehouses are extracted from the main products of this thesis: the final design and the placement strategy. For an overview of the research process, see figure 2.2.

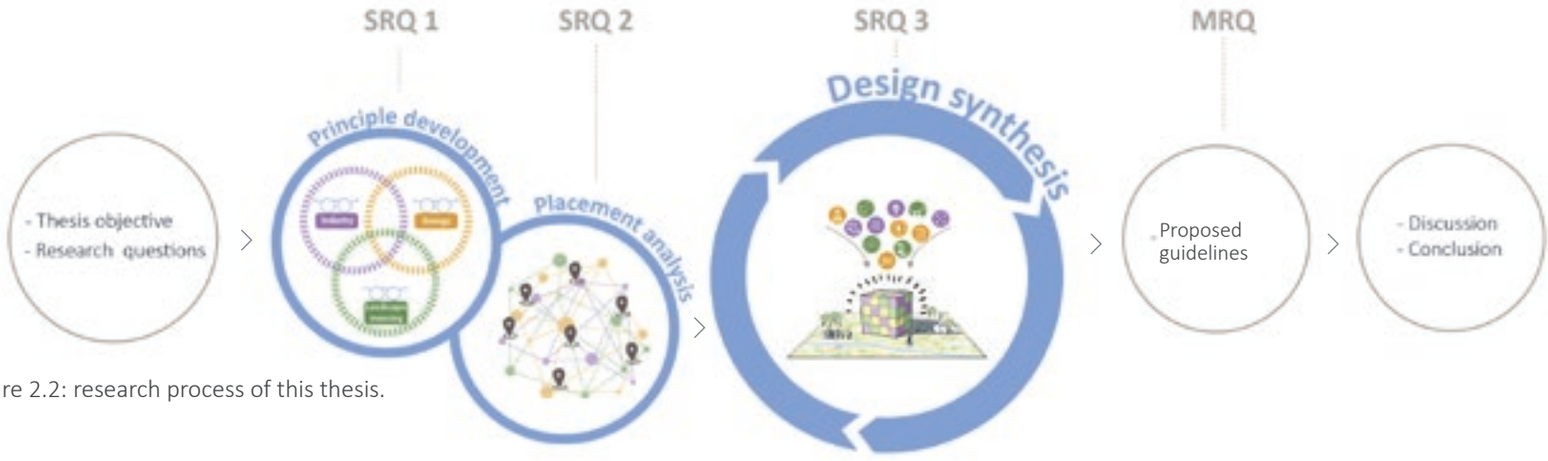


Figure 2.2: research process of this thesis.

Principle development (see chapter 3.1)

SRQ 1. What are the principles for placement and design of the XXL MIX park?

Since the theoretical framework of this thesis is strongly anchored in the exploration process of the XXL MIX park, it is referred to as principle development, and is part of the research process. To be able to explore and evaluate the XXL MIX park more specifically, principles for the XXL MIX park are developed based on literature and expert interviews. Firstly, scientific literature is scanned for approaches or theories concerning industrial park design, energy conscious planning and design, and meaningful landscape design. Secondly, since the XXL MIX park will be placed in a Dutch context and in a specific time frame, contextual literature is scanned for contemporary concepts, theories and ideas. Thirdly, to further specify and evaluate the design proposal XXL MIX park, expert interviews are conducted with Maarten van Riet, energy consultant at Alliander, and Kees Verweij, partner of Buck Consultants. The next step of the principle development consists of relating the gained information to the design proposal XXL MIX park. Based on this, the gained knowledge is subdivided into placing principles and design principles for the XXL MIX park. Lastly, to make the principles insightful, they were categorized into an industrial, an energy and a landscape category and comprehensibly visualized. An overview of the research process of the principle development is shown in figure 2.3.

The developed placement principles inform phase 2 of the research: the placement analysis. The design principles inform phase 3 of the research: the design synthesis.

Figure 2.3: process of research phase 1: the principle development .

Placement analysis (see chapter 3.2)

SRQ 2. Which locations in the Netherlands can be suitable for placing the XXL MIX park according to the placement principles?

To answer sub research question 2, a placement strategy for the XXL MIX park is developed in the context of the Netherlands. To develop the placement strategy, spatial datasets are extracted, mapped out, and analyzed. According to the placing principles from industrial, energy and landscape perspective, datasets are selected and retrieved from open GIS sources. The datasets are extracted and combined using QGIS and Adobe Illustrator. Subsequently, based on explorative argumentation, the datasets are combined and analyzed, to find ideas for for placing the XXL MIX park in the Netherlands. Thereafter, all locations from the most promising idea are qualitatively assessed on a relative scale according to the placing principles. This is done in a scoring table as shown in figure 2.4. The most suitable locations for placement of the XXL MIX park form the final placement strategy. One location from this placement strategy is selected as case area and forms the spatial context of the design synthesis. Figure 2.5 gives an overview of the research process of the placement analysis.
The placement strategy is used in the final evaluation, to be able to discuss to what extent findings from the final design could lead to guidelines for placement of XXL warehousing in the Netherlands.

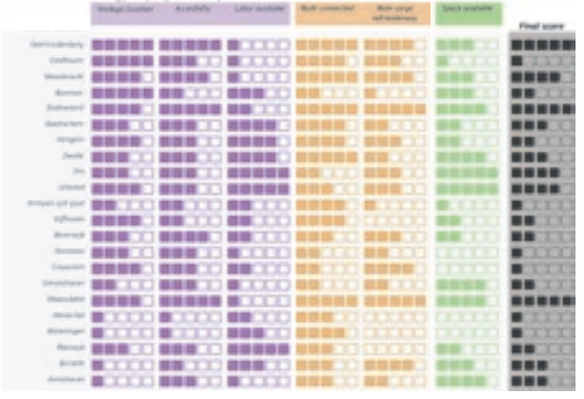


Figure 2.4: scoring table based on the placing principles

Figure 2.5: process of research phase 2: the placement analysis.

Design synthesis (see chapter 3.3)

SRQ 3. How can an XXL MIX park function, and be integrated and expressed in the landscape according to the design principles?

To answer the third sub research question, a design synthesis is conducted in the selected case area from research phase 2. The design principles formed the conceptual framework for this design synthesis. To ensure an optimal combination of landscape quality and industrial functionality, the design synthesis consists of two simultaneously conducted activities: landscape design and element development. These activities are repeated three times in an iterative process, containing analysis, design, organization and evaluation.
In the landscape design process, ways to integrate and express the elements of the XXL MIX park in the landscape of Dodewaard are explored. This process starts with a landscape analysis. Thereafter, it contains design activities and evaluation of the preliminary design products.
In the element development process, industrial elements that could be placed in the landscape design are explored by doing literature review and by conducting an interview with Emil Goosen, COO of AquaBattery. Thereafter, it contains scaling, modeling and evaluation sessions. For an overview of the research process of the design synthesis, see figure 2.6.

To aim for maximal synergy of the design principles of the XXL MIX park, the design process contained design techniques as intended for constructivist research through design. Many of the classical 'creative' reflection-in action techniques

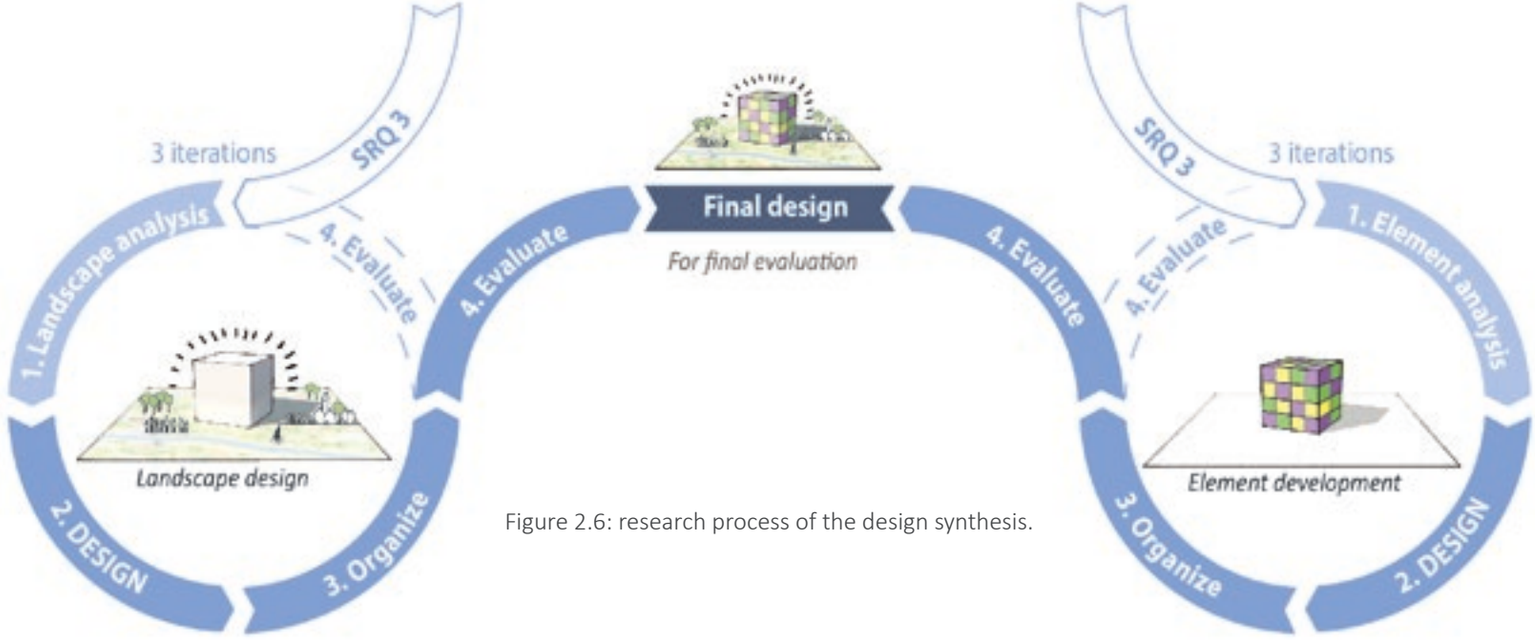


Figure 2.6: research process of the design synthesis.

of the repertoire of the landscape architect are undertaken, such as drawing (physical and computer drawing), crafting, building scale models and ideation techniques such as 'stepping out of the box' and 'doodling' (Lenzholzer et al., 2013) (figure 2.7). By applying the design principles of the XXL MIX park in different sequences, in each design iteration the integration of the XXL MIX park was explored in an alternative way (figure 2.8).

The three design iterations led to three preliminary designs. In the evaluation sessions, these designs are judged by experts. Landscape architect Adriaan Geuze judged the preliminary products from a landscape perspective. Maarten van Riet, Energy consultant at Alliander judged the products from an energy perspective. This evaluation sessions are summarized into qualitative scoring tables as shown in figure 2.9.

As last step of the design synthesis, the third preliminary design was elaborated into a final design: '**XXL MIX park Dodewaard**'. This design is visualized and explained, containing, maps, sections and visualizations. The final design is used as input for the final evaluation, to find out to what extend the outcomes could lead to guidelines for the design of XXL warehouses in the Netherlands.

Figure 2.7: sketching during the design synthesis. XXL warehouses are very big, so a 1:2000 design map is big as well.

Figure 2.8: scheme showing the sequence in which design principles were applied in one of the iteration processes.

Figure 2.9: qualitative table showing to what extend a design principle is successfully integrated in the preliminary design.

Proposing guidelines

Main research question:
What guidelines can improve the placement and design of XXL warehouses in the Netherlands?

The design proposal 'XXL MIX park' is extensively explored by answering the three sub research questions in respectively the principle development, the placement study, and the design synthesis. The main products of this exploration are a placement strategy for the Netherlands and a landscape design in Dodewaard.
In a final evaluation of these products, guidelines are extracted. First, the final design was analyzed for outcomes that could be generalized into design guidelines for the design of XXL warehousing in the Netherlands. Secondly, according to the outcomes of the final design, the placement strategy is further assessed and translated into placement guidelines for XXL warehousing in the Netherlands (chapter 4).

In the discussion (chapter 5), the research approach and the validity and relevance of the guidelines are discussed. In the conclusion (chapter 6), all results are summarized and the research questions are answered.

Research scope

To frame the context of the research process, choices and assumptions are made in advance.

The physical context is the Netherlands, since the problem is framed within its physical and social environment. The physical context is further specified in the placement analysis. The time frame of this thesis is determined by expectations from two main functions of the XXL MIX park, its industrial function, and its energy function. Since both the developments in XXL warehousing as well as the energy transition are expected to have a big spatial impact in the coming decades, +\- 2030 is the focal point of this research.

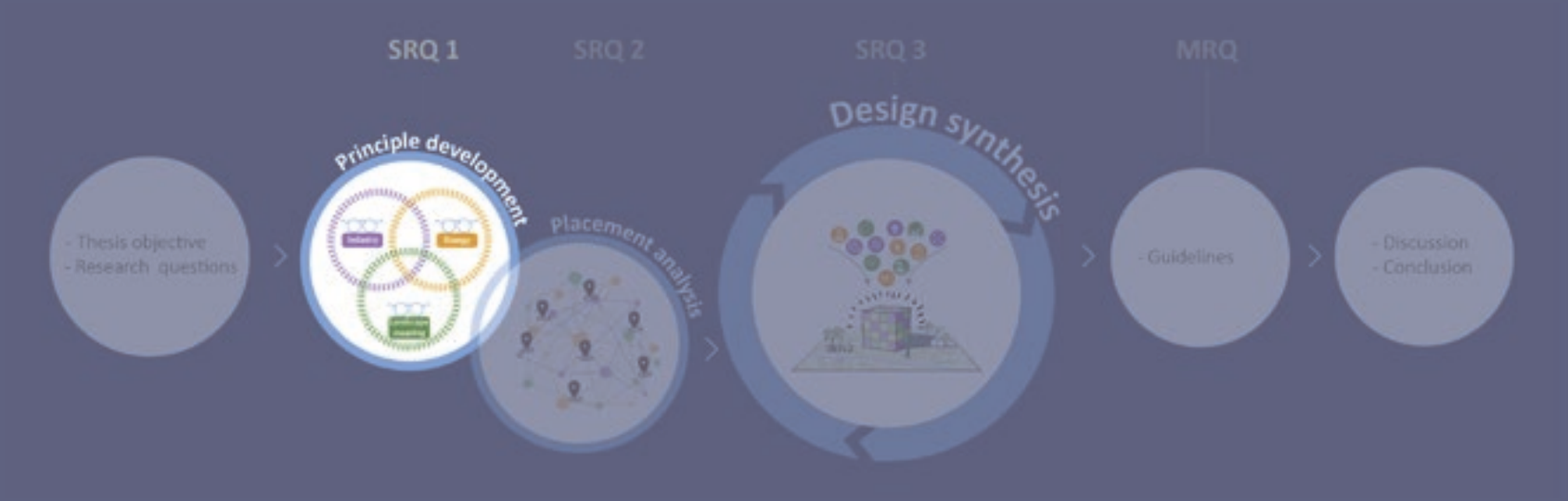
Other assumptions in this thesis consider the continuations of trends in both XXL warehousing and energy transition. It is assumed that XXL warehousing will grow with another 4 to 10 million m^2 in the coming 5 years (Stec, 2018a; Verweij, personal communication, 10th of October, 2018). Furthermore, it is assumed that the climate agreement as stated by the Dutch government will be complied with, resulting in a shift from a fossil-based energy system towards a renewable-based energy system in the coming decades (Ducth government, 2019).

3. Results

Figure 3.1: XXL warehouses and high-voltage lines in Venlo.

Principle development

chapter 3.1



Principle development

Answering sub research question 1:
What are the principles for placement and design of the XXL MIX park?

In this sub chapter, firstly, the concepts, theories, and ideas from literature that were used to create the principles are shortly described. Also, the way these publications are related to the XXL MIX park is elaborated. The publications are subdivided into a scientific category, and a contextual category.
Subsequently, the expert interviews that helped to further specify the idea of the XXL MIX park are described. The conversations with Maarten van Riet, energy consultant at Alliander, and Kees Verweij, partner of Buck Consultants are summarized into a few statements.

Lastly, the result of research phase 1 is presented; **the placement and design principles for the XXL MIX park**. The 8 placement principles inform phase 2 of the research: the placement study. The 12 design principles inform phase 3 of the research: the design synthesis.

Content of this sub chapter:

3.1.1 Scientific concepts, theories and ideas

Eco-efficiency in industrial landscapes

In a publication of Grant, an alternative approach towards the planning and design of industrial landscapes is suggested, based on ecosystem principles. In this approach, the common relationship between industrial areas and their underlying landscapes is reversed:
"Instead of engineering options to try to control natural processes (e.g. drainage), the manager operating by ecosystem principles seeks to design the site to work with those processes"... "Putting a high priority on conserving local landscapes need not increase business costs. In many cases, working with ecosystems can save money for business whilst simultaneously providing benefits for employees and for indigenous wildlife" (Grant, 1997, p. 76).

Relating this to the XXL MIX park, the existing landscape should be the source of inspiration for the landscape design. Therefore, landscape structures should be the general guidance in finding solutions for the placement of industrial elements, water regulation, infrastructure, and vegetation. This will be difficult because the elements have a surface of > 40 000 m^2. Nevertheless, the successfulness of implementing this approach can tell a lot about the suitability of the XXL MIX park itself.

Ecological concepts for industrial parks

In a publication of Cote & Cohen-Rosenthal, ecological concepts are applied to the development and maintenance of industrial parks. They state that businesses may realize significant savings through site- and building-design when applying ecosystem principles. In the publication, 11 steps are defined to develop and maintain an eco-industrial park. The following 4 steps could be related to the XXL MIX park:

1. Define the community of interests and involve that community in the design of the park.
2. Continuously improve the environmental performance by the individual businesses and the community as a whole.
3. Orient it's marketing to attract companies that fill niches and complement other businesses.
4. Maximize energy efficiency through facility design and construction, co-generation, and cascading. (Côté & Cohen-Rosenthal, 1998, p. 188)

Relating this to the XXL MIX park, the philosophy of the park should be expressed into its functional design. The XXL MIX park should be more than a random collection of companies but should express an overarching meaning as a whole.

Trias energetica

The theory of the Trias Energetica is a three-step strategy to make energy-efficient urban designs developed by Kees Duijvestein in 1976. The widely known theory is mainly applied to the architecture of buildings but can be used to larger systems as well. Thinking in the scope of a renewable-based energy future, the Trias Energetica has been altered by van den Dobbelsteen into the following four steps:

1. Reduce energy consumption
2. Reuse waste energy streams
3. Use renewable energy sources
4. Supply the remaining demand cleanly and efficiently, as long as fossil fuels are needed (Vandevyvere & Stremke, 2012, p. 1314).

Relating this theory to the XXL MIX park, the altered Trias Energetica can be applied by 1. Reducing energy consumption by clustering and concentrate industrial activities in the XXL MIX park 2. Utilizing energy losses of industries for heating purposes 3. Utilize all available roof surface for solar panels, and 4. As long as fossil fuels are needed, use them in the most efficient way available, for example by prefer placing of warehouses along waterways and railways over highways.

Energy conscious spatial planning and design

Stremke and Koh state that "ecological concepts and strategies have the capacity to expand the frame of reference in planning and design of the physical environment" (Stremke & Koh, 2010, p. 530). Some of these concepts and strategies are related to the XXL MIX parks and used for the development of the principles.

Sources and sinks

The concept of sources and sinks relates to the flow of energy, material, and information between system components. In a source area, the rate of `production' exceeds local `consumption'. Sinks consume more energy and resources than is provided locally; they depend on either storage or the import of resources. Increasing the connectivity of corridors and the spatial proximity of sources and sinks can optimize energy flows (Stremke & Koh, 2010, p. 524).

Based on this concept, XXL MIX parks (sinks), should be placed close to renewable energy sources or storage systems, or/and be closely connected to the energy grid. The same concept could be integrated within the park itself, where energy-demanding companies could be connected to renewable energy production or storage systems.

Differentiation of niches

Energy flow refers to the transfer of energy between systems or system parts. Within these energy flows, the differentiation of niches is a strategy in natural ecosystems for optimizing energy utilization. Highly differentiated ecosystems are able to sustain a higher population density and species diversity compared with other, less differentiated, ecosystems. More differentiated use of energy according to the concept of differentiation in niches, have great potential (Stremke & Koh, 2010, p. 527).
Relating to the XXL MIX parks, elements that demand high-valued energy should be directly connected to renewable energy production systems, while elements that demand low-valued energy (for example for heating purposes), should use low-valued energy sources, for example by utilizing the waste streams of the high demanding elements. Therefore, in the XXL MIX park different types of companies with different demands for energy should be integrated and combined.

Biorhythm and periodicity

"One of the challenges in designing sustainable environments is to synchronize energy supply and demand in time. Energy demand can be reduced by technological innovation, the adaptive behavior of consumers, and, as we advocate, advanced spatial planning. Increasing energy production and storage capacity in the physical environment can help to synchronize the system from a supply perspective. Energy storage systems can buffer periodic fluctuations in energy supply and demand" (Stremke & Koh, 2010, p. 528).

Based on this, the XXL MIX parks should contain renewable energy production and storage techniques to be able to synchronize energy supply and demand in time. When renewable storage systems are implemented in the same scale as the XXL warehouses, their function in maintaining grid balance could enhance more than balancing the 'biorhythm' of the park, and can maybe be expanded to the 'biorhythm' of the surrounding region.

Sustaining beauty, the performance of appearance

Meyer mentions in her manifest: “Sustainable development requires more than designed landscapes that are created using sustainable technologies” (Meyer, 2008, p. 15). From this perspective, the article mentiones ideas and aspects that helped to frame principles for adding meaning to the landscape design of the XXL MIX park: “Sustainable landscape design should be form-full, evident and palpable so that it draws the attention of an urban audience distracted by daily concerns of work and family, or the over-stimulation of the digital world. This requires a keen understanding of the medium of landscape, and the deployment of design tactics such as exaggeration, amplification, distillation, condensation, juxtaposition, or transposition/ displacement” (Meyer, 2008, p. 17).

Relating this to the XXL MIX park, the landscape design of the XXL MIX park should consider:

- ‘Form-fullness’ to reflect the multi functionality of the XXL MIX park in its appearance
- ‘Evidence’ in size and functionality, making the expression of the park more than a symbolic act.
- ‘Palpability’ to provoke people to become more aware of how their consuming behavior and energy use affect the environment.

3.1.2 Contextual concepts, theories and ideas

Regional logistics ecosystem (2017)

In a publication of Buck consultants, the concept of a 'regional logistics ecosystem' is elaborated. It describes how logistics activities could be ideally implemented as 'circular logistics business park'. For the industrial functionality of the XXL MIX park, relevant parts of this concept are used to find principles for placement and design of the XXL MIX park:

- Close connection to highways
- Close connection to rail-terminal
- Close connection to an inland shipping terminal
- Efficient use of space
- Focus on companies using multi-modal transport
- Companies with lean & green certificate
- Focus on chain approach
- Mutual collaboration between companies
  (Bleumink, 2017)

Relating this to the XXL MIX park, its placement should be based on logistics accessibility, closely placed to highway exits, inland shipping harbors or rail-terminals. The design of the XXL warehouses should consider a 'focus on chain approach' and 'mutual collaboration between companies'.

Design strategy FABRICations (2018)

The design company Fabrications developed a design strategy towards designing energy landscapes in the Netherlands. Parts of their strategy can inform the design of the XXL MIX park. As mentioned by the design company Fabrications: "the spatial impact that the energy transition will have in a densely populated country like the Netherlands should be approached as a cultural act rather than a technical one, this requires input from designers, architects, and landscape architects (FABRICations, 2018).

Landscape design should contain:

- a combination of different renewable energy sources,
- a combination of energy infrastructure with other functions wherever possible
- energy systems should be embraced by the people that experience them in their daily lives.
  (Fabrications, 2018)

Relating this to the XXL MIX park, the different types of renewable energy sources should all be expressed and linked to the existing landscape in their own way. The energy function should be combined with the function of XXL warehousing. Furthermore, the landscape should be designed as a place that is embraced by the people that experience it in their daily life.

Klimaatakkoord (2019)

The climate deal of the Dutch government is a document stating agreements that will be or should be taken in the Netherlands to achieve the goals as stated in the climate agreement of Paris. This document contains ideas that could be applied to the XXL MIX park:
The ambitions (to achieve the goals of the Paris agreement) are feasible if the following preconditions will be met:

- By searching for locations for renewable energy production, the availability, the construction and the costs of grid-capacity will be considered.
- At places were a big grid-capacity is available, projects can be quickly executed.
- The space needed for electric infrastructure is part of the spatial plan.

In the regional energy strategy (RES), the following four spatial principles should be considered.

- Aim for multi functional and economical use of space
- Bring supply and demand of renewable energy together as much as possible.
- Combine challenges and if needed, consider exchange and reallocation of areas.
- Consider and utilize the spatial qualities of the existing landscape
  (Dutch government, 2019)

Relating this to the XXL MIX park, for placing of the XXL mix parks, locations close to the electricity grid should be considered to a large extent. In the design of the XXL MIX park, multifunctional use of space should be an important focus, and the existing landscape should be used to find motives to do so.

3.1.3 Expert interviews

Interview Maarten van Riet

Energy expert Maarten van Riet is energy consultant at Alliander. In the interview he mentioned:

- All needed techniques for the energy transition are there, but they are not commonly implemented because they don't fit in business cases and planning processes.
- Saving of energy can be done by combining complementing industrial activities and the use of thermal exchange.
- Storing of energy can be done by a growing amount of energy-storing techniques, some techniques can be even integrated into industrial activities
- Cooling houses and data centers can play an important role in future grid balance. Therefore, these functions should be closely connected with the energy grid, and regulated according to energy availability.
- Producing energy can be done by utilizing the roofed surface of industrial parks for solar fields, or by smartly integrating windmills in designs of large-scale industrial areas.

(van Riet, personal communication, 19th of September, 2018)

Interview Kees Verweij

Kees Verweij is partner at Buck consultants, a that advices companies in the logistic sector. In the interview he mentioned:

- Architecture should play a larger role in XXL warehousing. There is a challenge for architects to improve the visual quality.
- Placement requirements for XXL warehouses differ per company. For example, companies with a national sales market (like grocery stores) are mainly concentrated in the middle of the country, while companies with a European sales market are concentrated in the south-east of the Netherlands.
- When generally spoken, the positioning of XXL warehouses is based on availability of (cheap) land, a close distance to main infrastructure like highways, railways and/or waterways, labor availability, and a lenient local policy.
- To avoid the impairment of the Dutch market, actions regarding regulations of XXL warehousing should be part of European wide policies.

(Verweij, personal communication, 1st of October, 2018a)

3.1.4 Principles for the XXL MIX park

By combining the scientific, the contextual and the expert information, placement and design principles could be developed. It resulted in 8 placing principles and 12 design principles that outline what placement and design of an XXL MIX park should contain.

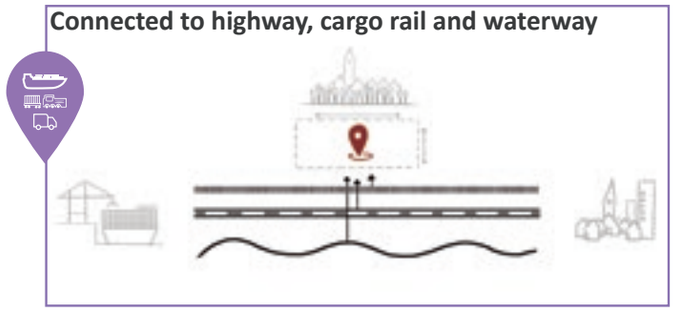
Firstly, the placing principles are presented, organized in an industrial, an energy and a landscape category. Secondly, the design principles are presented, also organized in an industrial, an energy and a landscape category.

In the following research phases, the principles will be referred to by using the symbols as shown in the explanation.

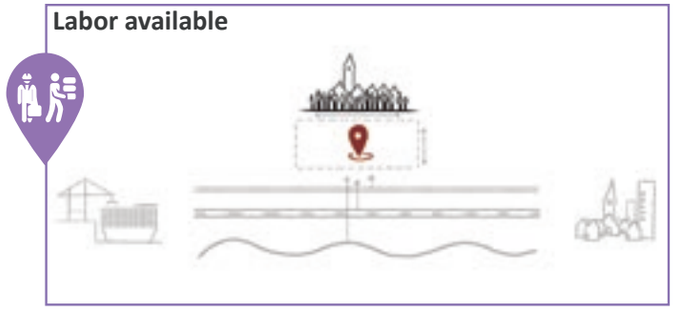
Placing principles, industrial perspective

XXL MIX parks should be placed on strategic locations in between sea harbors (Rotterdam, Antwerp, Amsterdam) and hinterland.

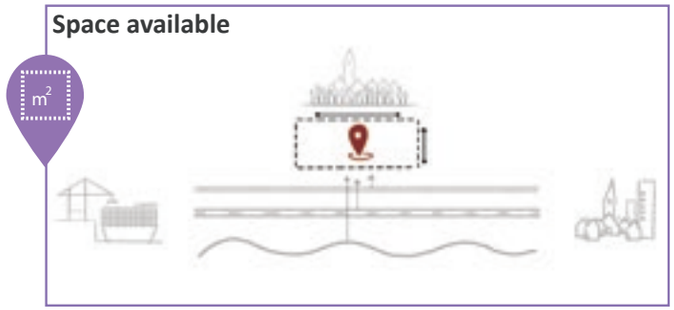
XXL MIX parks should be placed on locations closely connected to logistic infrastructure like highways, cargo rails and main waterways.



XXL MIX parks should be placed in areas with sufficient labor availability.

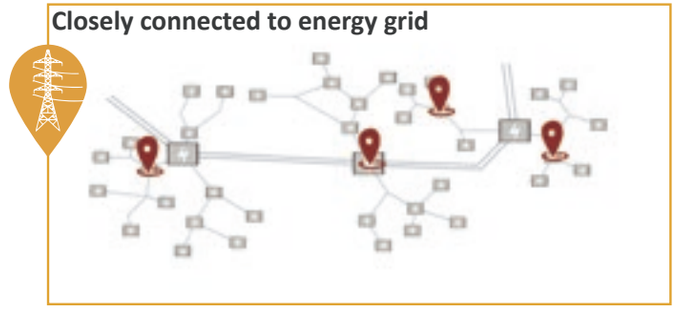


XXL MIX parks should be placed on locations with sufficient space available for the integration of a cluster of XXL warehouses.

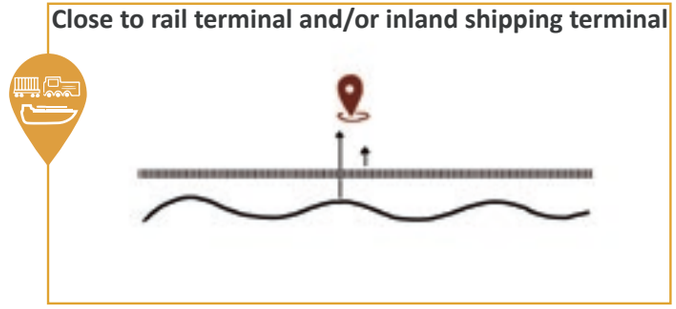


Placing principles, energy perspective

XXL MIX parks should be placed on locations that are closely connected to the energy grid.

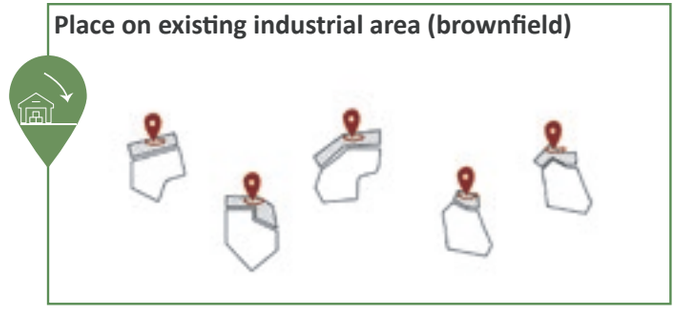


XXL MIX parks should be placed on locations that are closely connected to rail terminals or inland shipping terminals.

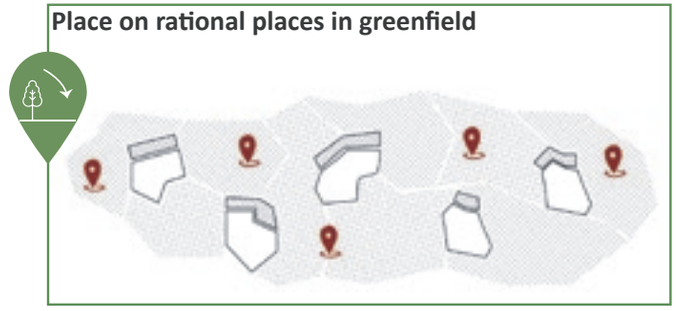


Placing principles, landscape perspective

XXL MIX parks should preferably be placed in existing industrial areas (brownfield).



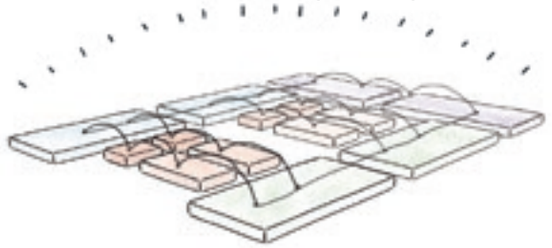
If placement in existing industrial areas is not possible, XXL MIX parks should be placed on rationally chosen locations in greenfield.



Design principles, industrial perspective

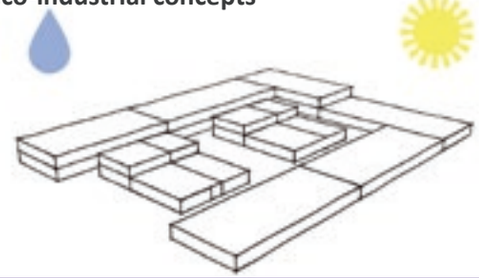
In XXL MIX parks, different logistic activities should be combined for an efficient supply chain. The XXL MIX park should be more than a random collection of companies but should express an overarching meaning as a whole.

Combine activities for efficiency and expression



In XXL MIX parks, eco-industrial concepts should be applied to save money for business whilst simultaneously providing benefits for employees.

Apply eco-industrial concepts



XXL MIX parks should be easily accessible for workers, preferably by bike or public transport. To attract workers, the park should have an appealing expression.

Easily accessible and appealing workplace

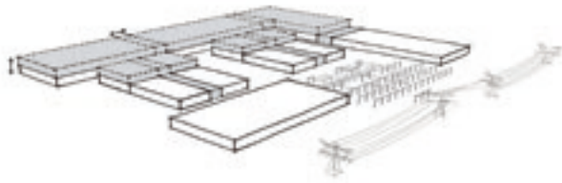
XXL MIX parks should be functionally designed, containing a efficient road system for trucks, sufficient docking space for loading and unloading of goods, and standard sizes of warehouses.

Functional design for logistic transport

Design principles, energy perspective

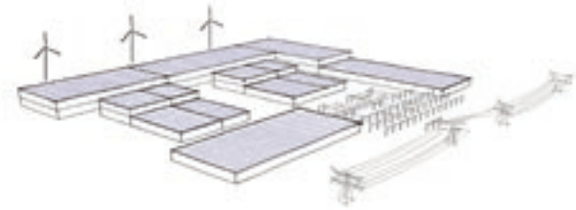
To save energy in XXL MIX parks, there should be aimed for connecting and stacking of buildings, and combining complementing industrial activities.

Saving energy by connecting and stacking of buildings



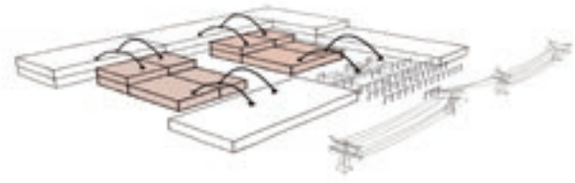
To produce renewable energy in XXL MIX parks, all roof surfaces should be utilized for solar fields. Depending on the location, wind turbines should be considered as well.

Utilizing all roof surface for solar panels



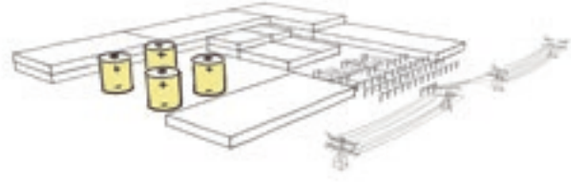
To make efficient use of energy, energy losses should be utilized in the XXL MIX park. Refrigerated warehouses can play an important role to do so, and can have a role for preserving energy grid balance as well.

Utilizing energy losses



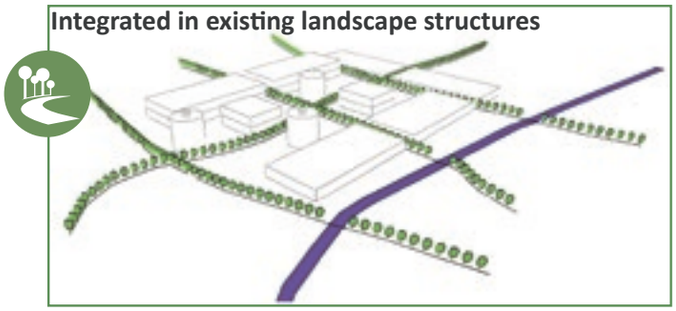
To be able to synchronize energy supply and demand in time for the park itself, and possibly even for the region, large-scale energy storage systems should be integrated in the design of XXL MIX parks.

Include large-scaled storage systems

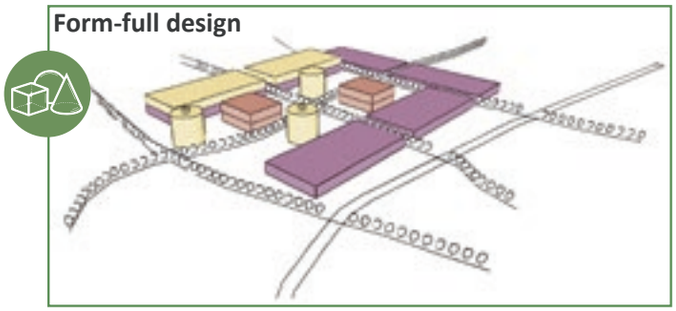


Design principles, landscape perspective

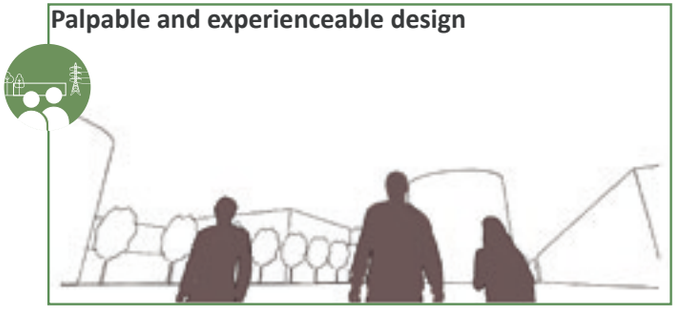
The existing landscape should be the source of inspiration for the XXL MIX park. Therefore, existing landscape structures should be the general guidance in finding solutions for the placement of industrial elements, water regulation, infrastructure, and vegetation.



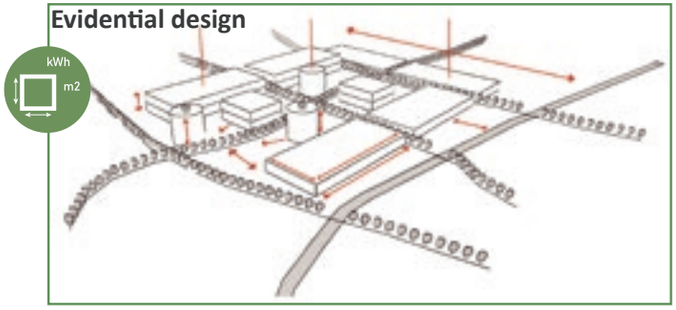
The landscape design of the XXL MIX park should be form-full, to clearly reflect the multi functionality in its appearance, and to create an interesting landscape experience.



The landscape design of the XXL MIX park should be palpable, to provoke people to become more aware of how their consuming behavior relates to the contemporary scale of industrial elements in the landscape.

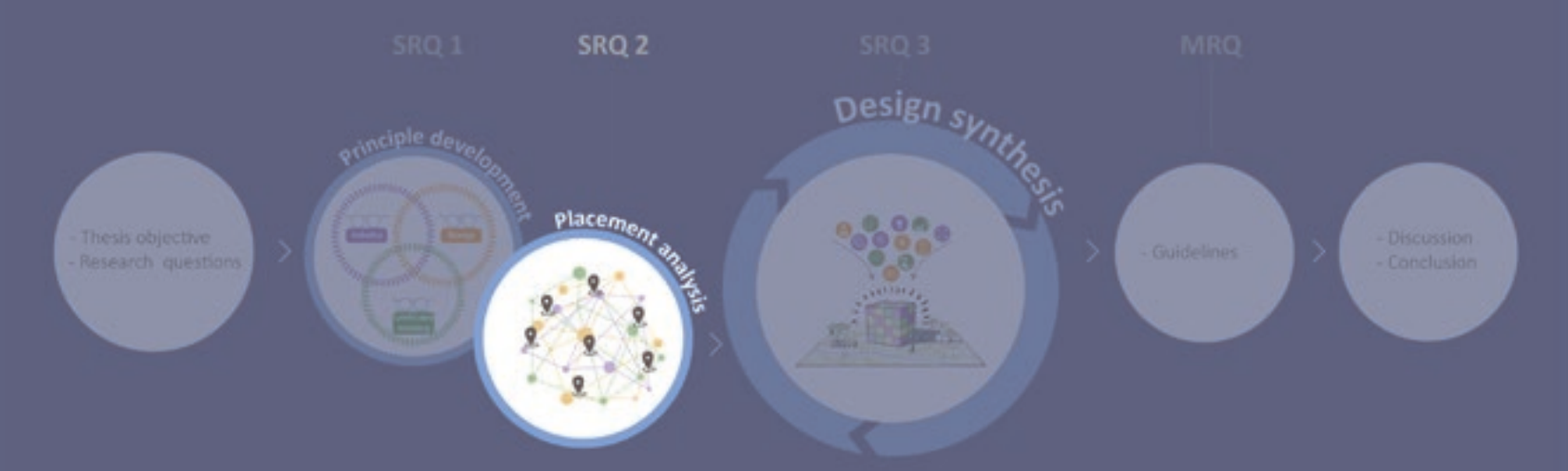


The landscape design of the XXL MIX park should have an evidential value, making the expression of the park more than a symbolic act.



Placement analysis

chapter 3.2



Placement analysis

Answering sub research question 2:
Which locations in the Netherlands can be suitable for placing the 'XXL MIX park' according to the placement principles?

In this sub-chapter, firstly, the 24 spatial datasets are presented. Secondly, the analysis of the datasets and the explorative argumentation that led to the placement strategy is elaborated in 4 different steps. Thirdly, the result of research phase 2 is presented: the **placement strategy.** Lastly, the selected case area from this strategy is explained.

Content of this subchapter:

3.2.1 Spatial datasets

On the base of the placement principles, spatial datasets within the context of the Netherlands were selected. Datasets were retrieved from open GIS sources and then mapped out and combined using QGIS and Adobe Illustrator. Figure 3.2 shows the combination of all datasets. On the next two pages, each dataset is separately presented.

Figure 3.2: combination of all 24 spatial datasets.

1. 380-KV high-voltage stations
(HoogspanningsNet, 2019)

2. 150/110-KV high-voltage stations
(HoogspanningsNet, 2019)

3. National 380 KV power lines
(HoogspanningsNet, 2019)

4. Regional 150/110 KV power lines
(Hoogspanningsnet, 2019)

5. Estimate of data cables
(Ruimtelijke strategie datacenters, 2019)

6. Logistics hotspots 2018
(logistiek.nl, 2019)

7. Inland container terminals
(kim mobiliteitsbeeld, 2019)

8. Highways/logistic corridors
(openstreetmaps, 2019)

9. Populated areas
(openstreetmap, 2019)

10. Industrial area until 2018
(IBIS, 2018)

11. Industrial area 2015
(CBS, 2015)

12. Deprecated industrial area
(IBIS, 2018)

13. Current production sites >300 MW
(Seebregts & Volkers, 2005)
(Wikipedia, 2019)

14. Current and future wind parks
(Sijmons et al., 2017)

15. Refrigerated warehouses
(Fikiin et al., 2017)

16. Data centers
(Ruimtelijke strategie datacenters, 2019)

17. Highway exits
(openstreetmaps, 2019)

18. Rail/ main cargo-rails
(openstreetmaps, 2019)

19. (Main) waterways
(CBS, 2009)

20. Labor availability logistics
(Arbeidsmarktrapportage, 2016)

21. Not fully built industrial area
(IBIS, 2018)

22. Natura 2000 area
(PDOK, 2019)

23. Former EHS area
(PDOK, 2019)

24. Outlines of the Netherlands
(openstreetmaps, 2019)

3.2.2 Placement analysis

Step 1: placement in energy network

To start exploring outside the current course of events regarding the placing of XXL warehouses, the placement analysis started from an energy perspective.

The current development from fossil to renewable energy resources will affect the function of the electricity grid. Two main developments can be distinguished: Firstly, unlike fossil power plants, wind turbines and solar panels are distributed widely and diffuse and can be owned by everyone. Therefore, households, companies, etc. will increasingly become energy users and energy source at the same time. Because of this, the future energy grid will have to be more flexible and incorporate an energy flow in two directions. Secondly, with a guaranteed supply of fossil resources, big powerplants can be regulated relatively easily compared to renewable resources, which availability depends on natural circumstances. This difference makes grid balance a big challenge in the future energy grid. Energy storage systems and other grid-balancing appliences will therefore gain importance in the future.

In this changing electric infrastructure, high-voltage stations are the main nodes. On these stations, energy is distributed, and/or changed over to other voltages.

There are different types of high-voltage stations that can be roughly divided into two categories or scales:
380 KV high-voltage stations can be compared with highway junctions. These stations are the nodes within the 380 KV network, in which large amounts of power are transported. In this network, electric power produced in the Netherlands or abroad is distributed to the regional networks. The 380 KV network connects provinces and even countries. Because of the high voltage, 380 KV high-voltage stations are located outside of living environments, and often in rural area. In the Netherlands, the stations are interconnected in a ring, to ensure power supply at all times (HoogspanningsNet, 2019).
Regional (150 KV/110KV) high-voltage stations can be compared with regional road junctions. These stations are the nodes within the regional electric grid (150 or 110 KV). The function of this network is to distribute energy from the 380 KV network towards cities and industrial areas. The regional stations are often located at the edge of living or industrial areas.

Because of prescribed changes in the electricity grid, the function of high-voltage stations might also change. From being a node, where energy is distributed only, they could become places where energy is stored, and energy flows are balanced as well. Therefore, within the aim of integrating a renewable energy function in the XXL MIX park, placement around high-voltage stations could be a promising starting point for finding functional symbiosis.
Furthermore, even though high-voltage stations represent a main societal function, their appearance is little known and/or appreciated by the greater public. In that sense they can be compared to XXL warehouses. Since one of the aims of the XXL MIX park is the development of a meaningful landscape design that makes people aware of the contemporary scale of consumption, the surrounding of high-voltage stations could deliver interesting opportunities from this perspective as well. Awareness about large-scaled consumption and energy use could be combined.
Concluding, high-voltage stations can be promising places to develop the XXL MIX parks because of their main function in the energy infrastructure, their changing function because of the energy transition, and their little visible societal importance. Therefore, high-voltage stations were chosen as first frame in the placement strategy. Figure 3.3 and 3.4 show how the role of high-voltage stations could change.

100 km

Coal power plant >300 MW

Gas power plant >300 MW

Gas power plant >300 MW

Existing wind park

380 KV high-voltage station

220/150/110 KV high-voltage station

Future wind park

Solar roofs

high-voltage line

380 KV

220 KV

150 KV

110 KV

50 KV

Figure 3.3: current role of the energy grid; transferring of energy from fossil powerplants towards households and industries.

Figure 3.4: future role of the energy grid; transferring energy from anywhere to anywhere. High-voltage stations could develop into storage/regulation hubs for grid balance.

Step 2: placement in existing industrial areas

By choosing for placement around high-voltage stations, the energy perspective of the XXL MIX park was guaranteed. Therefore, the second step of the placement analysis was to find places around high voltage stations that could also meet the demands from an industrial and landscape perspective.
The exploration started in existing industrial areas, because from a landscape perspective, XXL MIX parks should ideally be placed in brownfields (existing business parks). To do so, there was searched for locations around 150/110 KV high-voltage stations, since these stations are mostly located in existing industrial areas. Furthermore, the data of industrial areas of the Netherlands was used. Within the dataset of IBIS, outdated industrial areas could be mapped out. Since these outdated areas require restructuring anyway, this dataset was used to find places for the XXL MIX park in existing industrial areas.
By combining the data of the 150/110 KV high-voltage stations, the data of outdated industrial areas, and the data of logistics hotspots and corridors, potential locations for the XXL MIX park within existing industrial areas could be retrieved. 24 of the 150/110 KV high-voltage stations met the requirements (see figure 3.5).

However, concerning the current growth expectations of XXL warehousing (4-10 million m² in the coming 10 years), finding enough space for clusters of > 40 000 m² warehouses within existing industrial areas appeared to be difficult. Next to the complex restructuring task these locations possess, many of them would be simply too small. Still, some of the locations are certainly worth further consideration, especially in Venlo, Roosendaal and Bergen op zoom. Combining 1. transformation of 150/110 KV high-voltage stations into energy storage/balancing nodes with 2. the smart integration of energy-demanding industrial activities, could offer great possibilities for these industrial cities. However, since objective of this thesis concerns large-scale clustering of warehouses of 40 000 m² and bigger, I continued to search for places around high-voltage stations outside of built (industrial) areas.

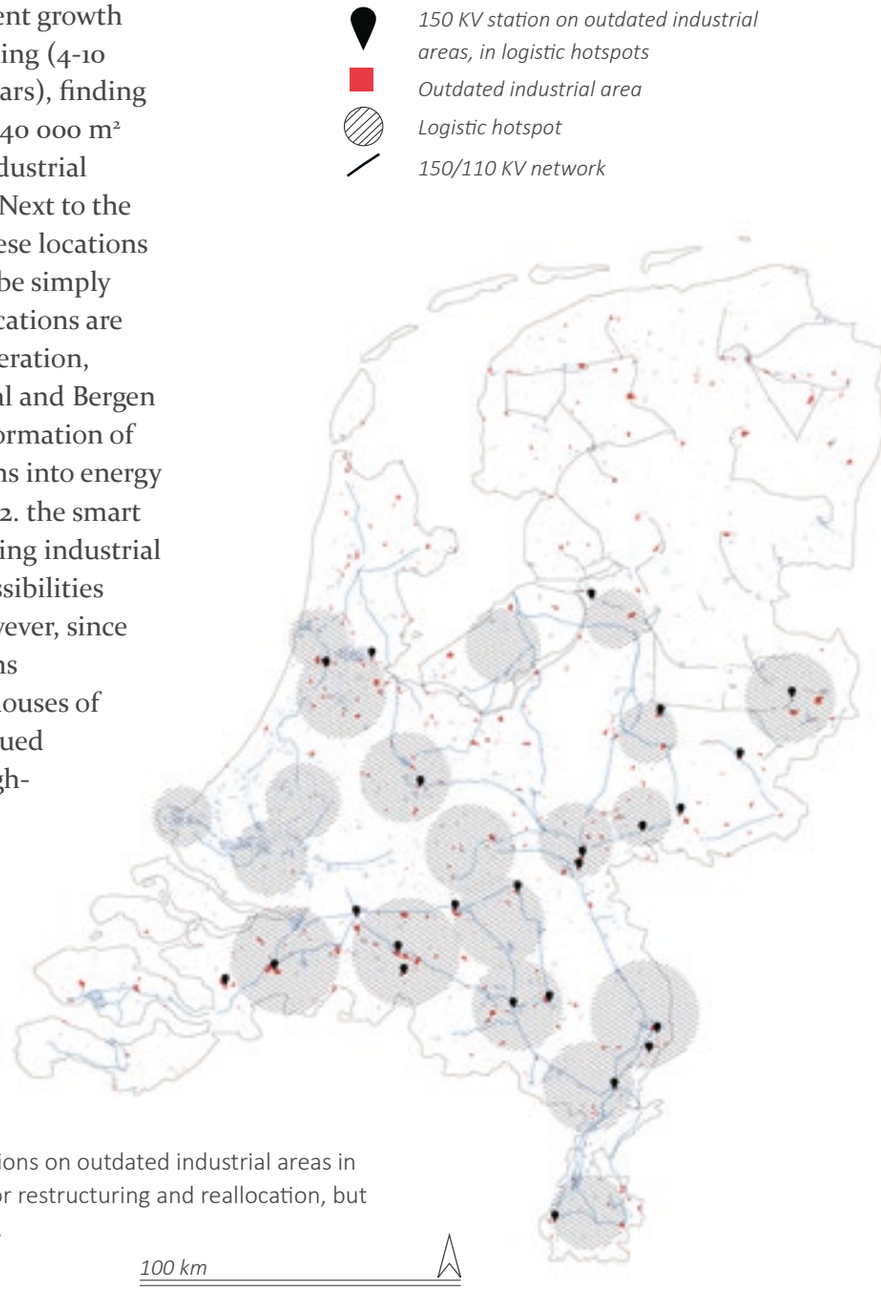


Figure 3.5: 150 KV high-voltage stations on outdated industrial areas in logistic hotspots; promising areas for restructuring and reallocation, but to small to contain an XXL MIX park.

Step 3: placement in greenfield

Because 380 KV high-voltage stations are mostly located outside of built areas, they were explored to find suitable places for the XXL MIX parks in greenfield. By combining the data of 380 KV high-voltage stations, the data of existing powerplants, and the data of the energy network, it became clear that 380 KV high-voltage stations are often located close to (former) fossil power plants and from there, act as main hubs in the high voltage grid. Regarding the energy transition, many of the powerplants will be closed, and therefore the function of these places will change.
By adding the datasets of the logistics infrastructure and the data of the logistics hotspots, it became clear that many of the 380 KV high-voltage stations were situated at interesting locations from a logistics perspective as well (figure 3.6). A convenient but not unexpected outcome, since the big infrastructure is often bundled (highways, railroads, high-voltage lines, etc.) and fossil powerplants need big waterways for cooling purposes.
Another promising characteristic of the landscapes around 380 KV high-voltage stations is their big and industrial appearance. The stations have surfaces of +/- 80 000 m² and contain elements of 30-meter-high. The high-voltage lines, that approach from every direction, contain high-voltage towers of 30 up till 100 meters high. Therefore, the appearance of these landscapes is already big-scaled, and potentially suitable for integrating XXL warehouses as well.

Concluding, the 380 KV high-voltage stations are promising locations for the XXL MIX park. They offer landscapes that are already big scaled, will be transformed due to changing energy resources and are often located close to main waterways. Challenging for these locations is the integration of new elements in the 'web' of high voltage lines. Because of the promising location characteristics, 380 KV high-voltage stations were chosen as preferred locations for the XXL MIX parks and were further elaborated.

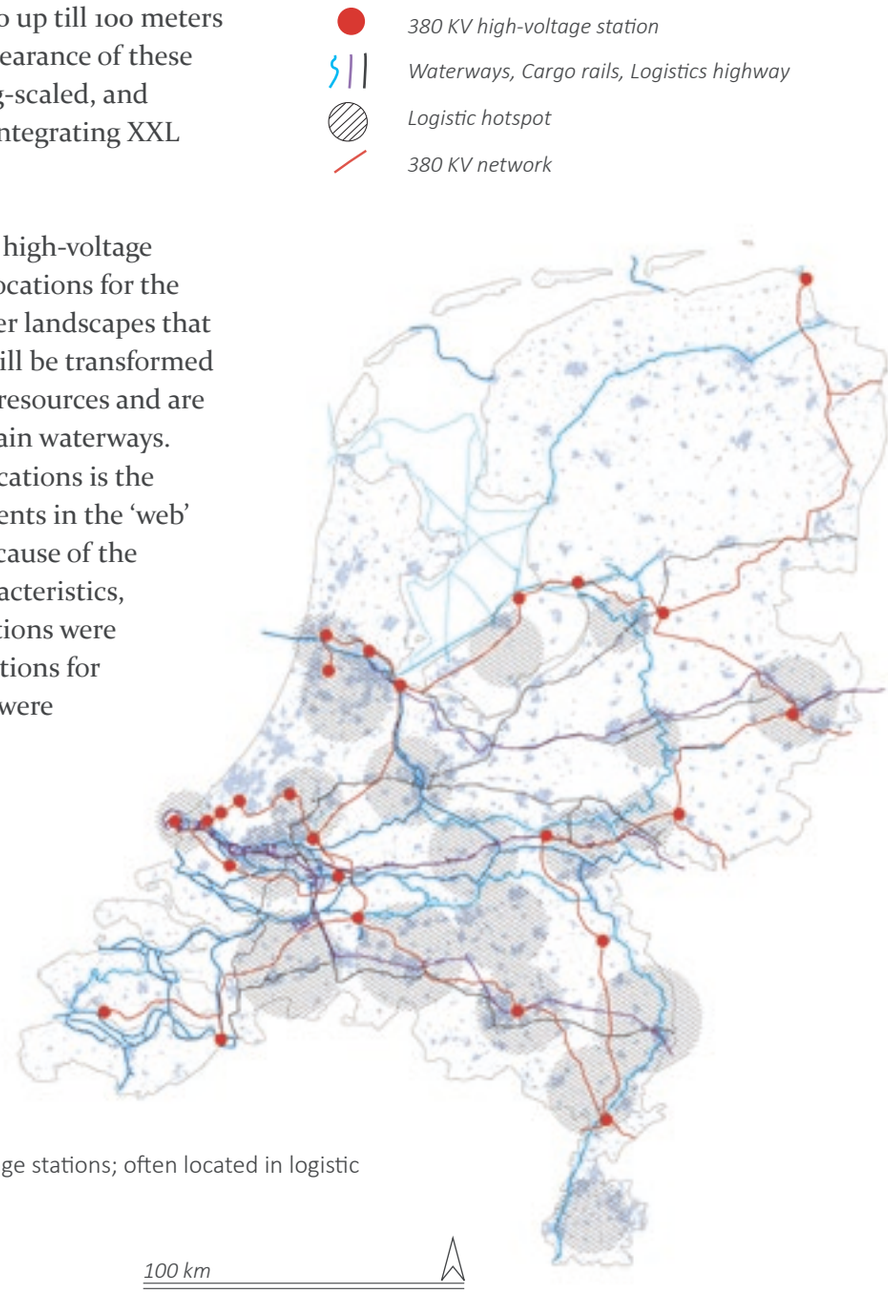


Figure 3.6: 380 KV high-voltage stations; often located in logistic corridors and hotspots.

Step 4: placement around 380 KV high-voltage stations

To explore which 380 KV high-voltage stations would be suited to serve the function of the XXL MIX park, all 23 stations in the Netherlands were assessed and scored according to an assessment form (figure 3.7). For this assessment form, the placing principles were specified for the context of 380 KV high-voltage stations. All stations were scored 1 up to 5 points, where 1 stands for the lowest score, and 5 for the highest. The scores were given on the base of a semi-quantitative assessment and scored according to the specified principles as prescribed on the right. Figure 3.8 shows the combination of datasets that were used to rate the locations.

To determine the final score, the sub-scores were added up. Some categories weighted more heavily than others. For example, the category 'space available' counted heavily, since without space, no XXL MIX park can be developed. Out of this final assessment, 10 areas around 380 KV high-voltage stations were framed as potential for the integration of an XXL MIX park.

Strategic location: a high score when in logistics hotspots or along logistics corridors

Accessibility: a high score when connected to waterways, cargo rails and highways

Labor availability: a high scoreregions with high supply of logistics labor

Multi-connected to energy grid: a high score when connected to 7 or more high-voltage lines

Cargo rail or waterway connection: a high score when close to inland harbors and train terminals

Space available:
a high score for stations surrounded by space that is:
- >500 hectares
- no nature area
- no living area

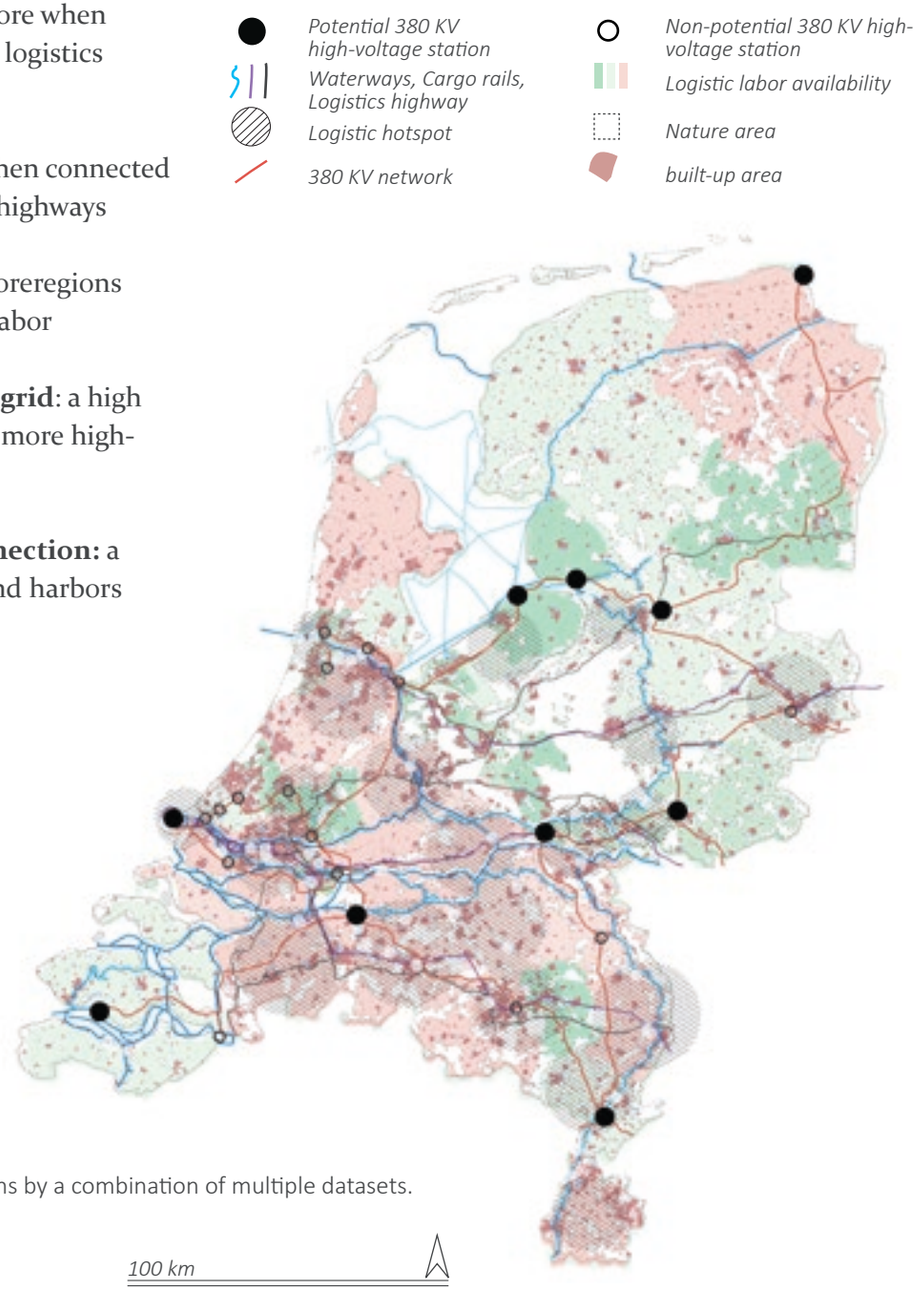


Figure 3.8: assessing 380 KV-stations by a combination of multiple datasets.

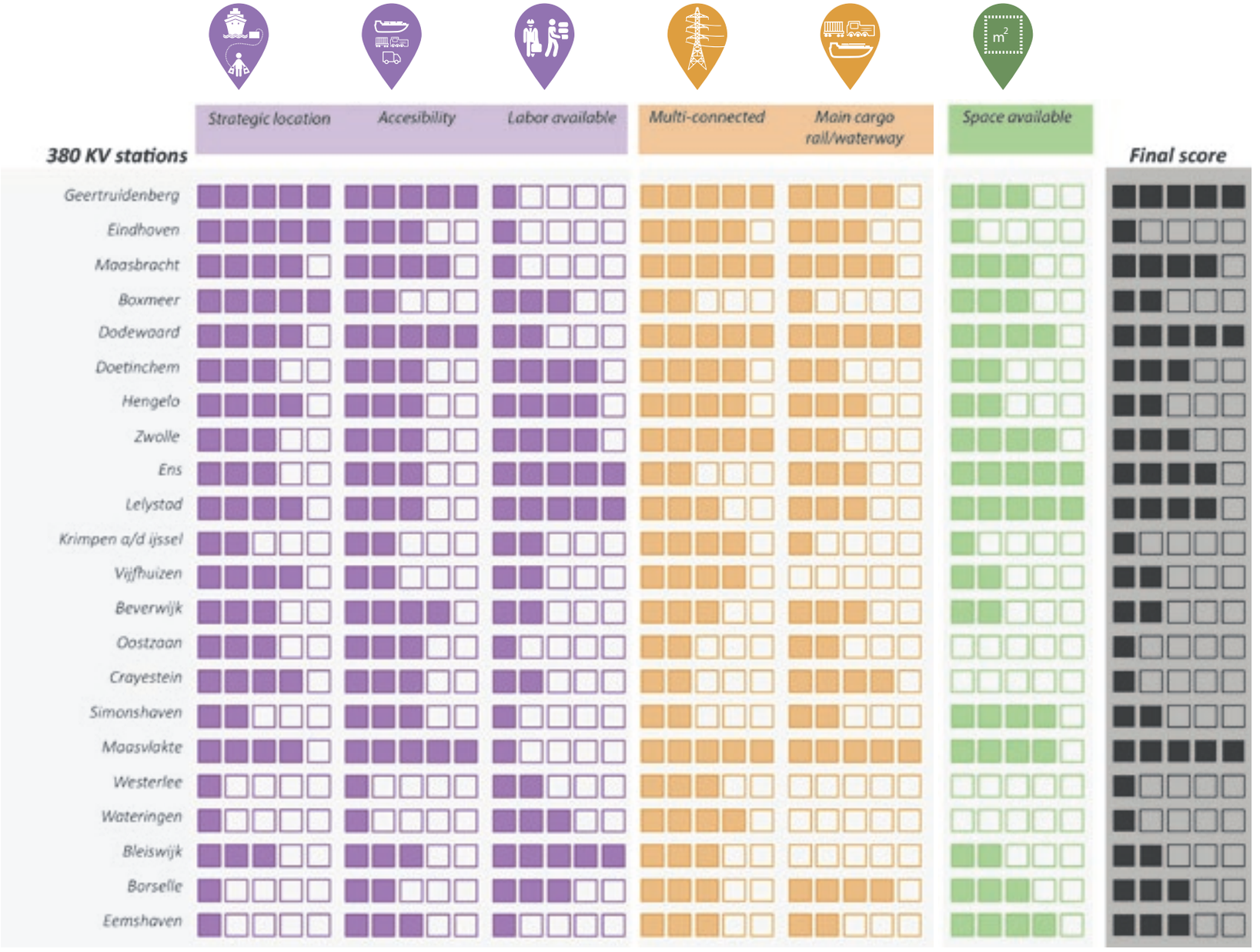


Figure 3.7: all 380 KV-stations in the Netherlands according scored according to the placement principles.

3.2.3 Placement strategy for the XXL MIX park

In conclusion, a placement strategy for the XXL MIX park could be developed by using multiple datasets and explorative argumentation. The strategy states that XXL MIX parks can be best placed in landscapes around 380 KV high-voltage stations, on strategic places in the logistic infrastructure (preferably close to rail and waterways), and with enough space available. In this strategy, 10 locations for the XXL MIX park could be selected (figure 3.9, 3.10) Dodewaard was selected as case area for the design synthesis (figure 3.9a).

Potential 380 KV high-voltage stations for the XXL MIX park:

- **Dodewaard**
- **Geertruidenberg**
- **Maasbracht**
- **Tweede Maasvlakte**
- **Lelystad**
- **Ens**
- **Doetinchem**
- **Zwolle**
- **Eemshaven**
- **Borssele**

Figure 3.9a: case area Dodewaard: Location of 380 KV-station and possible area for the XXL MIX park.

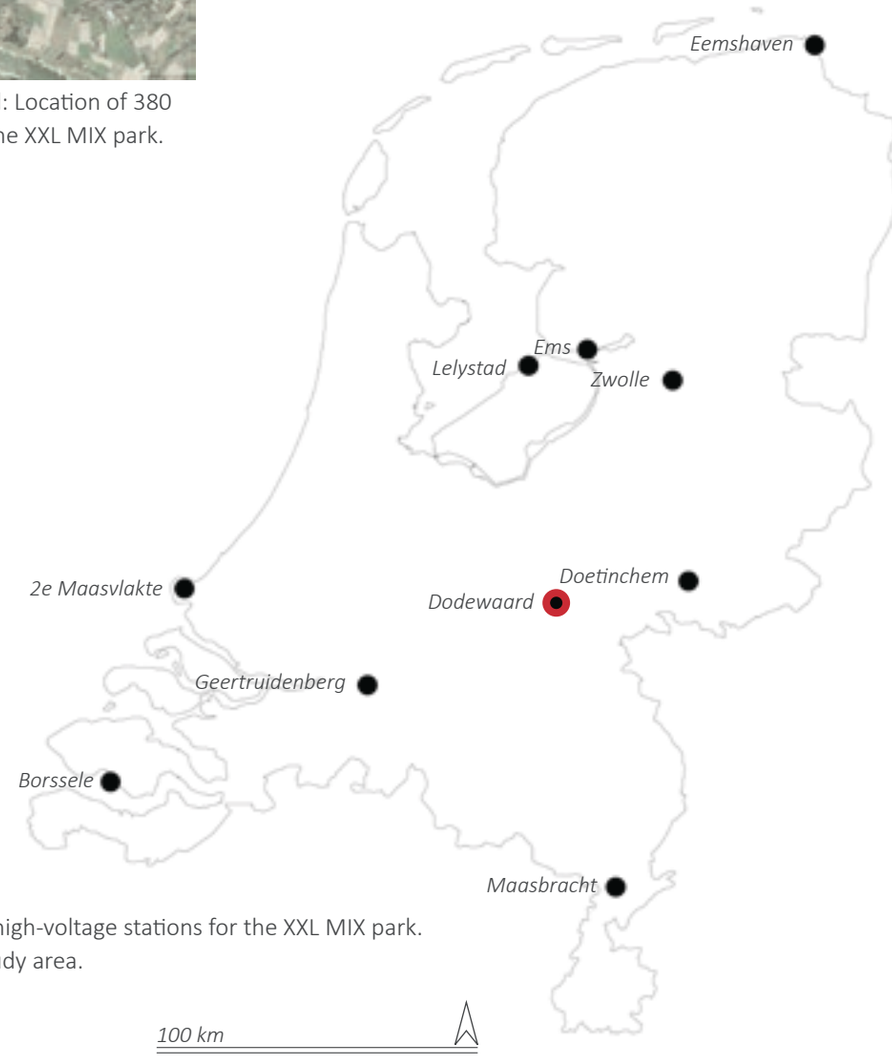
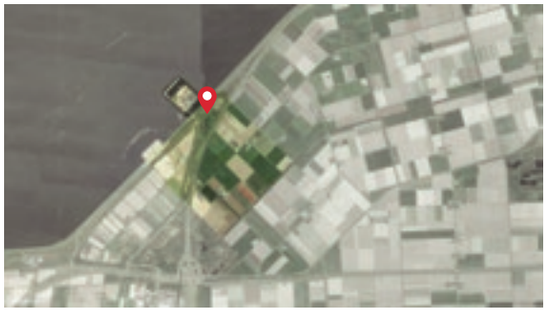


Figure 3.10: the selected 380 KV high-voltage stations for the XXL MIX park. Dodewaard is selected as case study area.


Geertruidenberg


Maasbracht


Tweede maasvlakte


Lelystad


Ems


Doetinchem


Zwolle


Borssele


Eemshaven

5 km

Figure 3.9: Locations of 380 KV-station (location symbol) and possible areas for the XXL MIX park (highlighted areas) (map data from Google Earth).

3.2.4 Case area selection: Dodewaard

One out of the 10 potential locations is chosen for further elaboration in the design synthesis: the 380 KV high-voltage station of Dodewaard (figure 3.12).

Dodewaard was chosen because of the following reasons:

- Dodewaard is situated in the Betuwe, a region with a highly valued cultural landscape. It makes the area challenging for finding symbioses of industrial, energy and landscape functions
- Dodewaard is a main node in the energy grid. The high voltage station is connected to 7 high-voltage lines.
- Dodewaard is famous because of its former nuclear power plant (figure 3.11).
- Dodewaard is located in the logistics A15 corridor, containing the Waal, the Betuweroute and the highway A15. It makes the area very attractive for logistic activities, and vulnerable for 'boxing' of the landscape.
- Dodewaard is close to the University of Wageningen, offering possibilities for multiple excursions

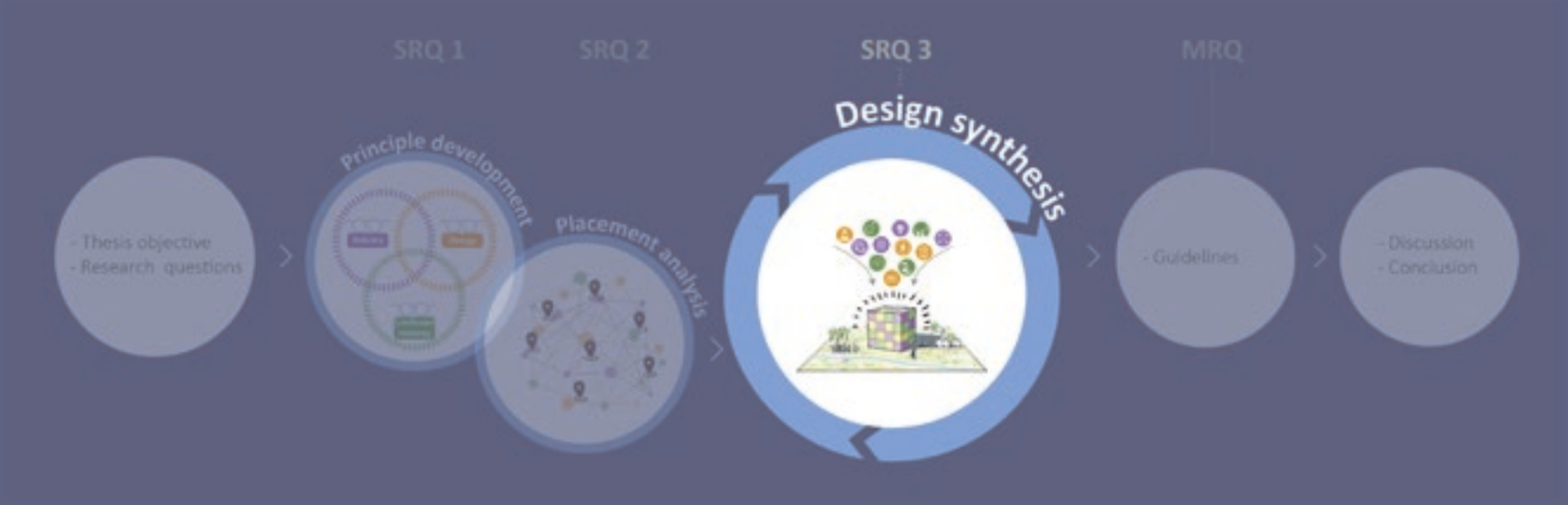
Figure 3.11: former nuclear power plant in Dodewaard.

Figure 3.12: map of the landscape around the high-voltage station in Dodewaard.

5 km

Design synthesis

chapter 3.3



Design synthesis

Answering sub research question 3:
How can an 'XXL MIX park' function, and be integrated and expressed in the landscape according to the design principles?

To explain the way a final design was created in the design synthesis, first, the outcomes of the landscape analysis of Dodewaard and the analysis of industrial elements are elaborated. Secondly, design steps taken that led to 3 preliminary designs are outlined, to explain how the design principles were applied. The considerations and choices made during the development of these preliminary designs are illustrated by sketches, photos, and preliminary products. After each explanation, the evaluation of the preliminary design is illustrated in an assessment tabel.
Finally, the result of research phase 3 is presented: **the final design**.

Content of this subchapter:

3.3.1 Landscape analysis

A15 corridor and Betuwe

High-voltage station Dodewaard is located in the Betuwe, a region in the province of Gelderland. The landscape of the Betuwe is formed by an interplay between human and river. It is famous for its dike villages, levees (oeverwallen) with fruit and tree farming, wide and open alluvial plains (komgronden), and big scaled industrial infrastructure. Because of the rivers Nederrijn and Waal, the Betuwe is traditionally part of an important trade route connecting the West of the Netherlands with the Ruhr area in Germany. The construction of the highway A15 and a freight railway (Betuweroute) expanded this function. Besides economic prosperity, the big scaled industrial elements increasingly change the character of the landscape of the Betuwe. The traditional landscape of the Betuwe, with her identity of 'living and fighting' against the water, is now often crossed by large-scaled infrastructure, or replaced by industrial activities.
Because of the attractive transport characteristics, which will even improve due to the future extension of the A15 and the connection of the Betuweroute to a German freight rail, the logistic 'A15 corridor' is increasingly preferred above the 'Brabant route' (Roosendaal-Breda-Tilburg-Eindhoven-Venlo), that is currently the most popular logistic corridor, but is confronted with a lack of space and labor. Along the A15 corridor, rapid development of XXL warehouses can already be seen in among others Gorinchem, Geldermalsen, Tiel and Oosterhout (see figure 3.13).

Figure 3.13: map of the A15 logistic corridor, showing industrial areas and logistic infrastructure from Rotterdam to the German border. The white dotted line shows the area that is referred to as the Betuwe.

Landscape units in the landscape of Dodewaard

High-voltage station Dodewaard is located in between the Waal and the Nederrijn, river branches of the river Rhine. Both rivers originally were in a sedimentation phase in this part of their track. Therefore, the landscape of Dodewaard is highly determined by former sedimentation processes of both rivers. Nowadays, the river courses of both rivers are fixed and the rivers are accompanied by dikes. Only in the river plains (uiterwaarden), sedimentation processes are still present. In between the dikes, the landscape that emerged from the former alluvial sedimentation processes can be roughly subdivided in two categories: the sandy levees (oeverwallen), and the clayey alluvial plains (kommen). The levees are higher and contain sandy soils. The alluvial plains are lower and contain clayey soils. High-voltage station Dodewaard is located in the tightest part of the Betuwe. In this area, the Nederrijn and Waal are closest to each other. Because of this, levees and alluvial plains are smaller compared to other parts of the Betuwe. Figure 3.14 shows the rivers, the river plains, the levees and the alluvial plains in the area of Dodewaard.

Levees

The levees (L in the map) traditionally contain the most human activity. In the case area, the old village centers of Dodewaard, Hemmen, Opheusden, Zetten, Andelst, and Herveld are clearly located at the high levees, where people were protected against fluvial floods. The levees are mainly situated close to the rivers. Because of excellent agricultural properties, besides living area, the levees are traditionally used for fruit farming and tree nursery. The rich cultural history of this landscape can be experienced by some mansions and the estate of Hemmen with its castle ruin (Brons+partners, 2009).

Alluvial plains

Compared to the levees, the alluvial plains (P in the map) traditionally form an open and large-scaled landscape. Since the land consolidation (1947-1959), the lower and wet alluvial plains are characterized by long continuous lines of waterways and roads along large, regularly formed plots. Buildings are scarce and the main land use is grassland.

Dikes

Since the middle ages, dikes (thick grey lines in the map) protect the area against river floods of the Waal and Nederrijn. The 'banddijken' (the main protection dikes) are continuous lines in the landscape and fix the landscape units in their current form. Due to their height, the banddijken often form a vantage point for views on the landscape. Ever since people lived in this area, living with and fighting against the water was a main activity for survival. Besides the banddijken, this fight can be experienced in the many dike breaches with deep swirl lakes (rivier wielen), remains of old dikes, and old river gullies. In the landscape of Dodewaard, an old transversal dike is located (dotted line on the map). This 'Spanjaardsdijk' was constructed (1591) for protection against inland river floods and for protection against a Spanish invasion. Big parts of this dike are removed during the land consolidation, but some parts remained, including a few swirl lakes that occurred during inland river floods in 1600 (van Rossum, 2008) (A in the map).

River plains and inland harbors

Outside the 'banddijken' are the river plains (RP in the map). River plains in this part of the Betuwe are characterized by their openness, but some groups of poplars and willows are present. Old river runs and clay extraction pits give the area a characteristic relief. Big parts of the river plains are protected nature area. Some buildings are present on the higher grounds. They mainly have/had industrial purposes.

Figure 3.14: map showing landscape units in the landscape of Dodewaard (capitals are explained in the text).


Figure 3.15: fruit farming in the levees, (B in the map).


Figure 3.16: rational landscape in the alluvial plains, (C in the map).


Figure 3.17: view from the dike, (D in the map).

Landscape elements in the landscape of Dodewaard

Inland harbors

In the river plains of Dodewaard, two inland harbors are located along the Waal (Fig. 3.20, A on the map). One is in use for mainly steel distribution and the other for the distribution of raw material. Since the settlement of a raw material company the Beijer, a new connection road is constructed from the flood plains directly to the highway A15.

Boven-Linge

The Boven-Linge (see indication on the map) is a dug waterway that was already constructed around 1300.The Boven-Linge got its current width in 1950. Nowadays, it takes care of the water drainage of the whole Betuwe and is an important recreational element. However, at many places the Linge lacks recreational infrastructure.

Train stations

The railroad between Elst and Dordrecht was conducted in 1880. In that time, it was an important trade and traveling route which gave the Betuwe a substantial economic impulse. This former importance can still be seen in the case area by the characteristic train stations of Hemmen-Dodewaard and Zetten-Andelst (indicated by letter B). The connection and the stations still function, the railroad is a quite track.

Nuclear power plant

Because of the presence of a high-voltage station and the river Waal, a 50 MW nuclear power plant was constructed close to Dodewaard (C on the map). It was opened in 1967, after a lot of societal consternation. The power plant was closed in 1997 and is slowly dismantled since then. Some parts of the building still remain. Because of the nuclear powerplant, Dodewaard is a famous name in the Netherlands regarding energy production.

Villages and industrial parks

After the construction of the A15, the villages in the area progressively grown. Due to the construction of industrial areas along the highway, Opheusden and Dodewaard, and Zetten and Andelst are growing together.

Agricultural activity

Fruit farming and tree nursery is traditionally the main agricultural activity in the area (color in the map indicated by C). Nowadays, the growing tree nurseries are increasingly expanding into the alluvial plains, traditionally the place were cattle farms are located (see figure 3.22).

Figure 3.18: inland harbor (A* on the map).

Figure 3.19: train station Hemmen-Dodewaard (B* on the map) (image by William Moore).

	Forest		Houses
	Fruit farming/ tree nursery		Industrial building
	Grassland		Water
	Arable farming		Rivers

Figure 3.20: map showing landscape elements of the landscape of Dodewaard (capitals are explained in the text).


Figure 3.21: tree nursery in the alluvial plain (C on the map).


Figure 3.22: cattle farm in the alluvial plain (D on the map).


Figure 3.23: expanding industrial areas along the A15.

Large-scale infrastructure in the landscape of Dodewaard

A15 and Betuwelijn

The A15 is a highway that stretches out from the 2e Maasvlakte in Rotterdam to Bemmel in between Nijmegen and Arnhem. The section that crosses the case area was finished in 1976. Dodewaard and Opheusden as well as Zetten and Andelst have their own highway exit (A in the map). On the one hand, the highway forms an important quality for the area in terms of accessibility and trade. On the other hand, the highway has a big spatial impact on the landscape and divides the already narrow landscape of the Betuwe in two parts.

The Betuweroute is a cargo rail line connecting the harbor of Rotterdam with the German rail network. It was opened in 2007. A connection to a new German freight rail is planned in 2022. The Betuweroute is placed parallel to the highway A15. In contrast to the highway, it is not connected to local infrastructures and therefore does not provide the area with accessibility and trade possibilities. However, a rail terminal is planned next to the village of Valburg, that is close to the case area. Together with the A15, the Betuweroute has a negative impact on the landscape in terms of local accessibility and noise.

High-voltage stations and lines

Since 1930, the landscape of the case area contains a node in the high voltage network. Because of a constantly growing demand for energy, the high-voltage station Dodewaard developed in the following decades and is nowadays one of the main nodes in the electricity grid of the Netherlands. The node exists of two separate high-voltage stations, a 150 KV station constructed in 1955, and a 380 KV station constructed in 1970 (Börger, 2017) (figure 3.30). In this node, 8 high voltage lines come together:

380 KV connections

- Dodewaard - Maasbracht (B)
- Dodewaard - Doetinchem (C)

150 KV connections

- Dodewaard – Tiel (D)
- Dodewaard – Veenendaal (E)
- Dodewaard – Ede (F)
- Dodewaard - Nijmegen (G)
- Dodewaard – Arnhem (ground cable)

50 KV connection

- Dodewaard - Nunspeet (H)

Since grid operator Tennet plans to strengthen the high voltage connections in between the wind parks on the North Sea and their hinterlands, high-voltage station Dodewaard might be extended with another connection in the future.

Figure 3.24: highway exit Dodewaard/Opheusden (A* on the map).

Figure 3.25: Betuweroute (left) and A15 (right) (1 on the map).

Figure 3.26: public railroad Arnhem-Tiel (2 on the map).

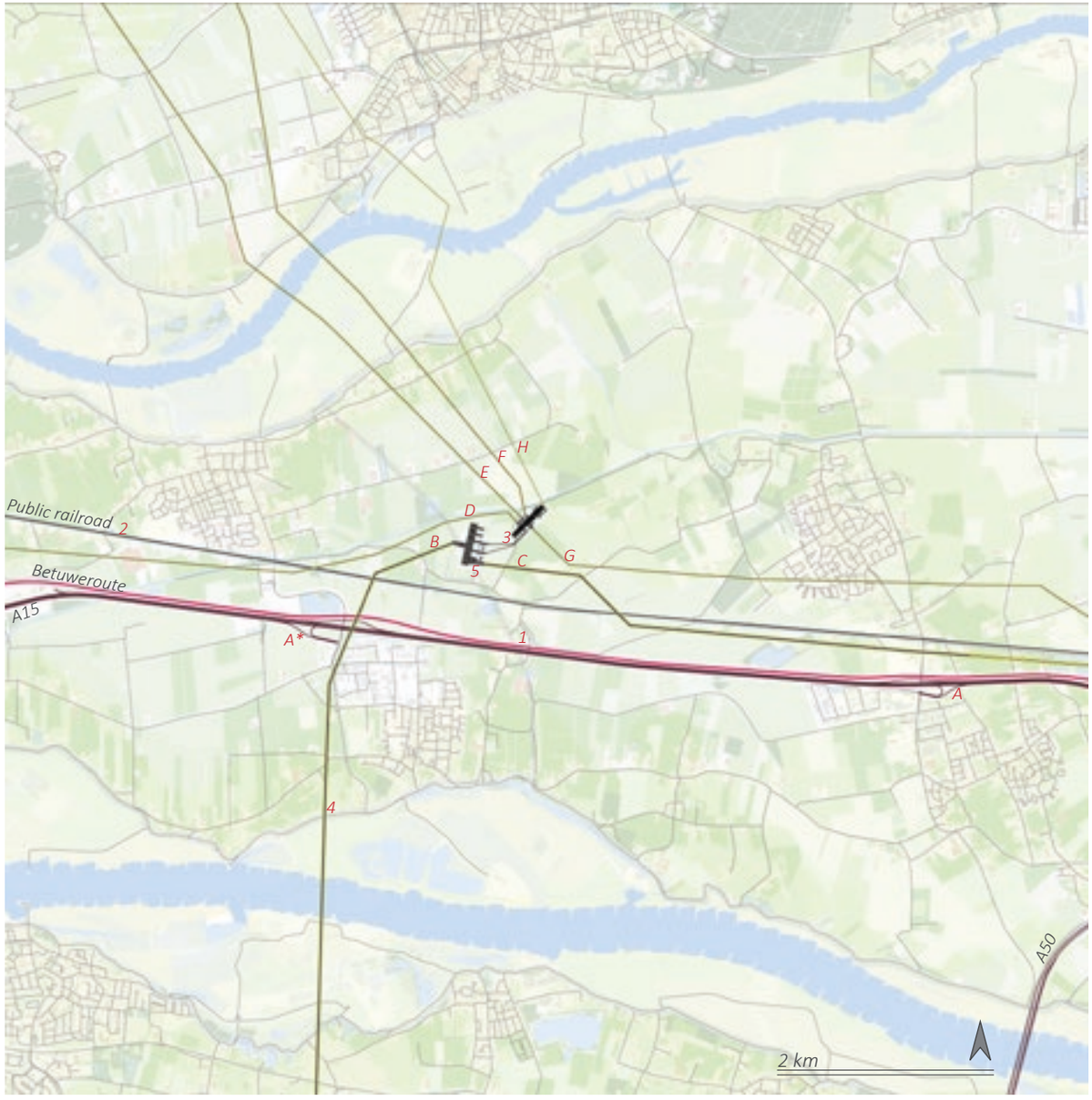


Figure 3.27: map showing the large-scale infrastructure in the landscape of Dodewaard (capitals and numbers are explained in the text).


Figure 3.28: high-voltage line at 150 KV station (3 on the map).


Figure 3.29: high-voltage tower next to house (4 on the map).


Figure 3.30: 380 KV station Dodewaard (5 on the map).

3.3.2 Element analysis

Refrigerated warehouses

Despite the opportunity for renewable energy resource integration, the possibilities of refrigerated warehouses (koel- en vrieshuizen) are often neglected (Fikiin, Stankov, et al., 2017). Refrigerated warehouses are large energy consumers (see figure 3.31), but when smartly used, they can fulfill a significant role in maintaining electricity grid balance in two ways. They can function as a 'thermal battery' and form an ideal surrounding for applying 'cryogenic energy storage systems'.

Refrigerated warehouses as a thermal battery

Van der Sluis introduced the idea of using refrigerated warehouses as thermal battery (van der Sluis, 2009). By letting refrigerators over-produce during the availability of renewable energy, they will cool down beneath their required temperature, and store thermal energy in the present products. During energy shortages, the cooling system can stop producing and relieve the energy network, while heating up towards the temperature limit again. The Netherlands contains the highest density of refrigerated warehouses in Europe. When lowering the temperature in refrigerated warehouses in the Netherlands with 1 degree celcius, it is estimeated that +/- 4500 MWh can be stored, which means 98 MWh per large-scaled refrigerated warehouse in the Netherlands (European Commision, 2008; van der Sluis, 2009; Fikiin, et al., 2017).

Ideal surrounding for cryogenic energy storage

Refrigerated food warehouses can be converted from a simple power consumer to a smart energy hub, when integrating cryogenic energy storage. (Fikiin, Stankov, et al., 2017). Cryogenic energy storage is a technique that is based on liquefying air to very low (cryogenic) temperatures. In 'charging mode', the system uses electricity from renewable energy resources or the grid to liquefy air. The liquefied air is stored in a large insulated vessel at very low (cryogenic) temperatures (around -185 Celcius). In 'discharging mode', the liquefied air is pumped and expanded to drive a generator of power which is restored to the electrical grid. Currently, cryogenic energy storage is rather limited by the efficiency due to unrecovered energy losses (Fikiin, Stankov, et al., 2017). To overcome this problem, Fikiin (2015) launched the idea to apply the system in refrigerated warehouses. The vast amount of cryogenic cold that is released in 'discharging mode', could be captured and utilized to provide a substantial part of the refrigeration capacity needed to maintain the desired low-temperatures in storage warehouses for chilled or frozen foods. Thereby, integrating cryogenic energy storage systems into refrigerated warehouses is an attractive way to store energy, as well as to improve efficiency in refrigerated warehouses.

The company Highview Power launched the first grid-scale and grid-connected cryogenic energy storage system with a power of 5 MW and a storage capacity of 15 MWh in 2018. The company states that their technology can be built up to 200 MW of power output, with a storage capacity up to 2000 MWh (Highview Power, 2019)

Figure 3.31: scale study: energy use of a large-scaled refrigerated warehouse can be compared to the energy use of a village of 3300 households.

XXL warehouses

XXL warehouses exist in many different widths, lengths, and heights. Their shape differs around the world. In for example Asia (Tokyo, Hong Kong, Singapore), many warehouses are stacked because of space efficiency (figure 3.32), the relatively small Asian trucks drive up and down to reach the different levels. In Europe these stacked warehouses are rare, mainly because of the larger trucks, but some examples can be found, for example the two leveled warehouse of Jumbo in Woerden (figure 3.33). In the past years, the XXL warehouses in the Netherlands grow in size, but in height as well. In Roosendaal, warehouses are allowed to reach heights of 17 meters. (Verweij, Overmeer, le Duc, 2018). XXL warehouses have some straightforward components. A warehouse, a mezzanine, an expedition, a dock-zone, an office and parking space (Dekker, 2018), the section in figure 3.34 shows a common XXL warehouse.

Figure 3.32: multifloored warehouse in Tokyo (retrieved from google streetview).

Figure 3.33: multifloored warehouse in the Netherlands (retrieved from sportlust46.nl).

Figure 3.34: section of an average XXL warehouse in the Netherlands.

BlueBattery storage system

The BlueBattery energy storage system, developed by the company Aquabattery is chosen as large-scale storage system in the design synthesis since it can serve landscape principles as well as energy principles. The BlueBattery system stores electricity solely using water and table salt, this makes the BlueBattery system a sustainable technique in terms of environmental impact, and offers opportunities for integrating the technique in public landscapes too. Furthermore, one of the drawbacks of the BlueBattery is the low energy density per cubic meter, causing relatively large-scaled systems compared to for example a lithium-ion battery. Nevertheless, since the scale of XXL warehouses is enormous, a large-scaled BlueBattery system and XXL warehouses could be a promising combination. The BlueBattery system is further elaborated in an interview with Emil Goosen, COO of the company Aquabattery.

Operation of the Blue Battery

The BlueBattery consists of two main components, a membrane stack, and water tanks for fresh and salt water. The energy capacity depends on the size of the water tanks and the power rating depends on the amount of membrane stacks. An advantage of the BlueBattery is that the power rating and the energy capacity can be independently scaled depending on the need. The membrane stacks are the most expensive part of the system and have the most environmental impact. In large-scaled BlueBattery systems, membrane stacks can be relatively small, because of decreasing energy demand fluctuations. Hence, the bigger the system, the better it is in terms of material use and cost-efficiency. The BlueBattery is still in a development phase. In Delft the first pilot-scale system is built (figure 3.35). The round-trip efficiency of the pilot system is around 35%. In lab, an efficiency of 65% is achieved. The company expects a future efficiency of 70-80%. The energy density in the water tanks is currently 0,5 kWh per m3 of water. In the coming years the company expects the energy density to increase to 2 kWh/m3. For the far future (2030-2040), they strive for 5 kWh/m3. The power rating of the membrane stack is 10 kW per m3 (Goosen, personal communication, 24th of January, 2019).

Prescribed information was used in the design process and a large-scaled, future BlueBattery system was drawn in Sketchup to get a sense of scale (figure 3.36).

Figure 3.35: first pilot-scale system of the BlueBattery (Aquabattery, 2018).

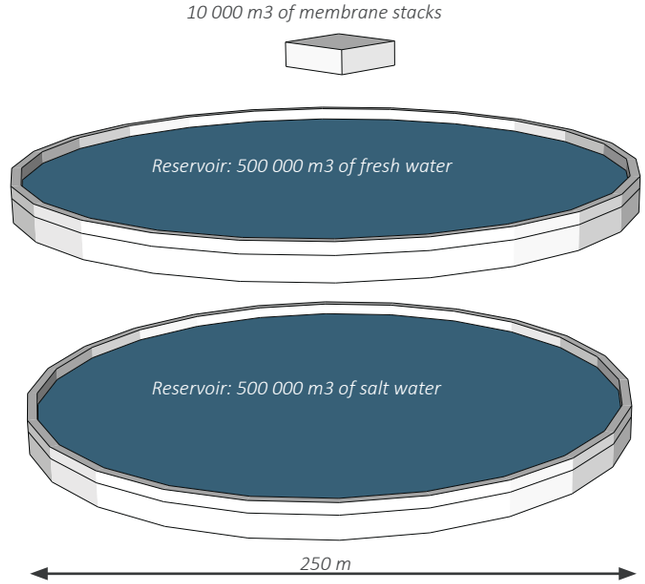


Figure 3.36: future representation of an enormous BlueBattery system. The Energy storage capacity could be 5000 MWh (for 2030-2040). The membrane stack has a power of 100 MW.

High voltage stations and high voltage towers

The aim to make the scale of energy use and consumption behavior experienceable in the XXL MIX park resulted in a search for experiential elements fitting in the XXL MIX park. Because of the many high voltage towers in the case area, this element was chosen for this purpose. High voltage towers have different heights and shapes. Their size is mainly determined by the voltage they are transferring. The high voltage towers of 380 KV connections are therefore higher (48 m) and much wider (40 m) than the ones of 150 KV and 50 KV connections. The network of high voltage stations and lines is full of extra-ordinary techniques that always ensure energy supply (van Riet, personal communication, 1st of october, 2018).

In 2008, design company Choi+Shine presented the project 'The land of Giants'. The project contained high-voltage towers in the shape of human beings and won many design awards (Choi+Shine, 2008) (figure 3.37, 3.38). It was assumed that this artpiece could help to make the large-scale industrial elements in the design palpable for the users of the XXL MIX park .Therefore, based on the idea of Choi+Shine, high-voltage giants were built in Sketchup to include them in the design process (figure 3.39).

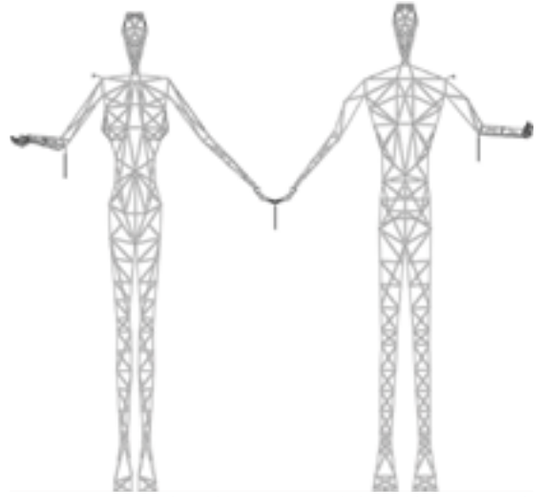


Figure 3.37: High-voltage giants (Choi+Shine, 2008).

Figure 3.38: High-voltage giants (Choi+Shine, 2008).

Figure 3.39: High-voltage giants of Choi+Shine recreated in Sketchup.

3.3.3 Design iterations

The landscape analysis and the element analysis made the design ingredients clear.

Before designing, some functional criteria were set:

- a minimum of 300 hectares of XXL warehousing, since when applied at all 10 locations of the placement strategy, this amount would form a relevant amount of 30% - 75% of the expected growth in the Netherlands.
- a minimum of 40 000 m² per warehouse, since from 40 000 m²<, men speaks of 'XXL' warehousing.
- a minimum of 4 large refrigerated warehouses.
- a minimum power of at least 100 MW, either usage or production, since Maarten van Riet stated that from this amount of power, it would be relevant to built around a 380 KV high-voltage station.
- a minimum energy storage of 2400 MWh in the blue battery, since that would roughly stand for a capacity to deliver 100 MW during a whole day, and thereby was assumed as relevant factor in retaining grid balance.

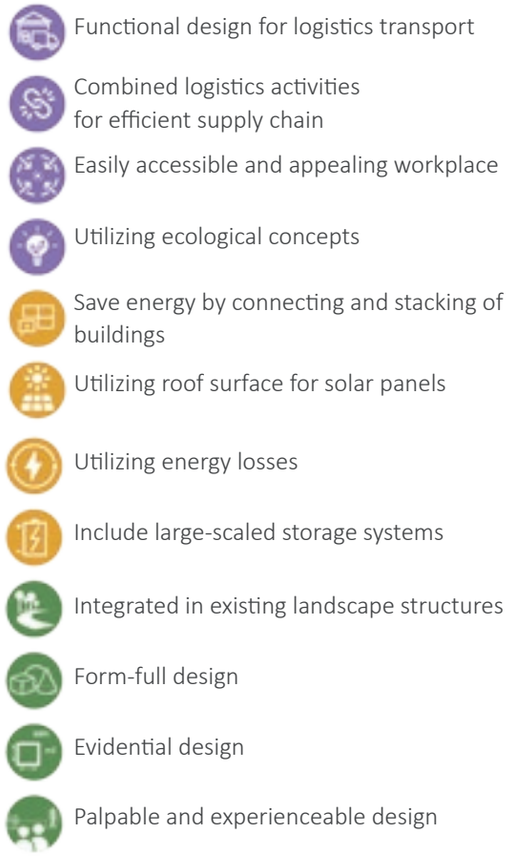


Figure 3.40: the design principles for design proposal XXL MIX park. For explanation, see chapter 3.1.

Figure 3.41: Aiming for synthesis.

Iteration 1: 'high concentration in high-voltage spiderweb'

Figure 3.42: sequence of exploration in which the design principles were applied in iteration 1

In the first iteration process, there was aimed for a concept that can be described as a fortress in the middle of a spider web, where the fortress stands for industrial elements, and the spiderweb consists of high-voltage lines (see figure 3.42, 3.43). With this concept, a high concentration of functions, enclosure of industrial activities and a recognizable landmark expressing the functions of the XXL MIX park was aimed for.

Exploration started with designing a generally applicable construction form that combined XXL warehousing, refrigerated warehousing and the BlueBattery storage system. There was aimed for a shape that could be integrated around the high-voltage stations in Dodewaard and be easily transferred to the other locations of the placement strategy as well. To find enclosure on the one hand, and industrial functionality on the other hand, different models in circle-like shapes were developed, having a large-scaled BlueBattery system in the middle (figure 3.44). Subsequently, the models were tested in the landscape around the high-voltage stations of Dodewaard (figure 3.45). It appeared to be difficult to integrate such enormous 'prefab' elements because they exceeded all existing landscape structures, were difficult to connect with existing infrastructure and were difficult to shape in appealing forms.

Therefore, this idea was left behind and the same concept was explored within existing landscape structures (figure 3.46, 3.47). By using the Linge canal and the existing road structure as a framework, many aspects of the XXL MIX park were combiend in a relatively small area (figure 3.48). However, concentrating XXL warehousing in circle- like shapes appeared to be difficult for ensuring industrial functionality. Furthermore, fitting in all functions in a relatively small area resulted in struggles to achieve an appealing expression. Regarding energy saving, the design concept seemed interesting, since by interconnecting the XXL warehouses and refrigerated warehouses, energy could be saved, and heat flows could be easily integrated. For energy storage, the concept was restrictive, since the BlueBattery storage system had to fit in a relatively small area.
When scoring this preliminary design according to the design principles, the design appeared to be a compromise of functions rather than a synthesis (figure 3.49). Nevertheless, the design also contained ideas that could be used in the second iteration.

Figure 3.43: design concept of iteration 1.

Figure 3.44: 'prefab' building complex, containing multiple warehouses.

Figure 3.45: explore ways to integrate the large-scaled 'prefab' complex in the landscape.

Figure 3.46: process of the design synthesis.

Figure 3.47: process of the design synthesis.

Figure 3.48: preliminary design 1.

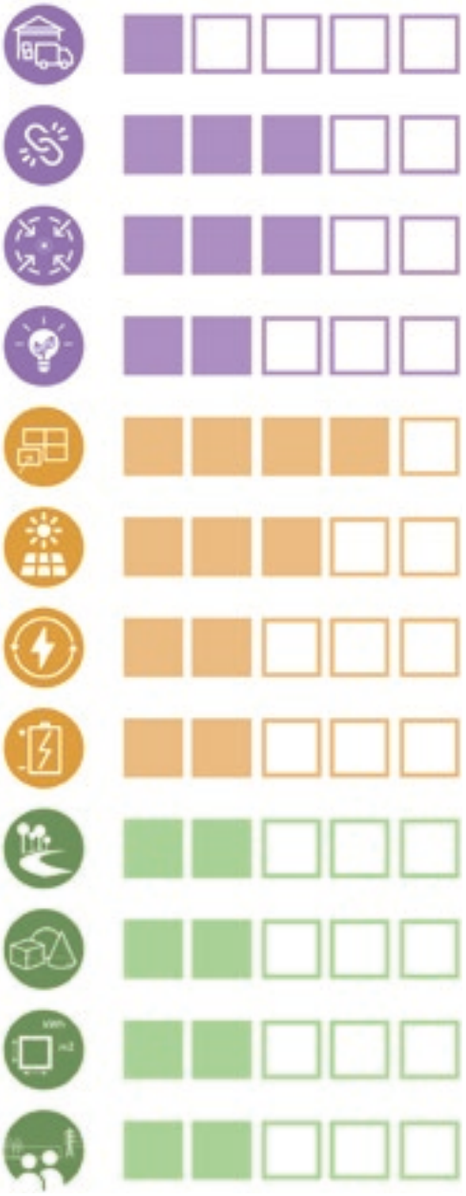


Figure 3.49: assessment table scoring preliminary design 1 according to the design principles of the XXL MIX park.

Iteration 2: 'functional freedom within a fixed area'

Figure 3.50: sequence in which the design principles were applied in iteration 2.

The highly concentrated concept of iteration 1 did not meet the requirements of the XXL MIX park so the playing field of the design area was enlarged. An area was determined in advance because there was still aimed for a high concentration of functions. Within this framework, there was more freedom to combine design ingredients and apply design principles of the XXL MIX park (figure 3.50, 3.51).

To find a different way of organizing the XXL warehouses, concepts of designing industrial parks were explored. In 'Vadecuum van bedrijventerreinen', different organizations of industrial parks are explained (van der Gaag, 2004). One of them is the 'kamstructuur'. In this organization, the road system is constructed in a comb shape, surrounded by industrial buildings. This structure looked promising because it could combine industrial functionality and landscape integration. The second step in organizing the warehouses was to depict their size. By using warehouses of +/- 120 meters in width, loading and unloading of trucks could be done at one side of the building. Therefore, the buildings themselves could function as a buffer between industrial activity and surrounding landscape (figure 3.52). With this concept in mind, the warehouses were integrated in between the highway A15 and the high-voltage stations (figure 3.53).

To find a different way of shaping the BlueBattery system, techniques to store large amounts of liquid were explored. Oil tanks such as in the harbor of Rotterdam were depicted. By taking the largest size of storage tanks as present in the harbor of Rotterdam, each pair of tanks (one for fresh, and one for salt water) could store +/- 400 000 m3 of water. Relating to the interview with Emil Goosen of Aquabattery (Goosen, 2019), a future BlueBattery system, could store +/- 2000 MWh of energy in each pair of tanks. There was assumed that water tanks would not need big fences for security reasons (as with oil tanks). Therefore, water tanks were integrated in a playful way in between the high-voltage lines, and around the Linge, where wetland nature was introduced. Together, these elements would form an impressive experience while entering the industrial park, while the wet nature area would function as a rainwater retention area as well (figure 3.54, 3.55).

The park could be connected with inland harbors in the Waal via existing infrastructure, since lately (2016), a big

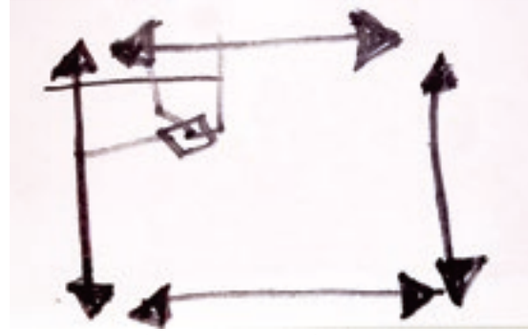


Figure 3.51: design concept of iteration 2, functional freedom within fixed area.

Figure 3.52: depicting road structure and warehouse size.

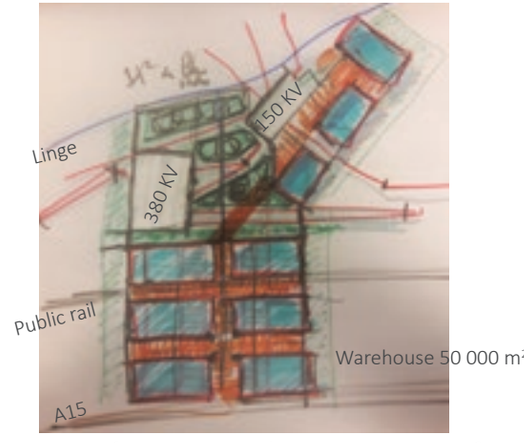


Figure 3.53: fitting XXL warehouses in existing infrastructure.

company for raw materials settled in here, and a new connection road was conducted. Second, close to the design area, a train terminal is already planned, therefore, this was not integrated in the area itself. By utilizing existing highway exits, the industrial park was connected with the A15 and thereby shortly connected with inland harbors and a train terminal (figure 3.56).

To make the park accessible for workers and inhabitants, preserving local roads and accessibility of the train station Hemmen-Dodewaard were aimed for. To integrate the elements in an existing landscape structure, the scenic landscape of estate Hemmen, with its tree lanes, forests and fruit farming, was extended into the design area. By integrating the 'high-voltage giants' in between the high-voltage stations, I tried to create an experiential park were the contemporary scale of energy use and consumption could be experienced figure 3.55, 3.57) .

When scoring preliminary design 2 according to the design principles (figure 3.58, 3.59), the design appeared to be more successful according to industrial principles, but mainly the landscape principles still scored poorly. Successful findings like the organization of the

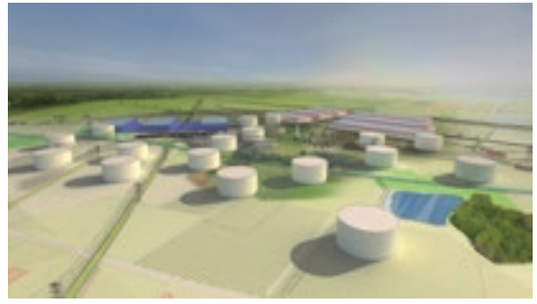


Figure 3.54: large-scaled BlueBattery water tanks.

Figure 3.55 testing the experience of the design.

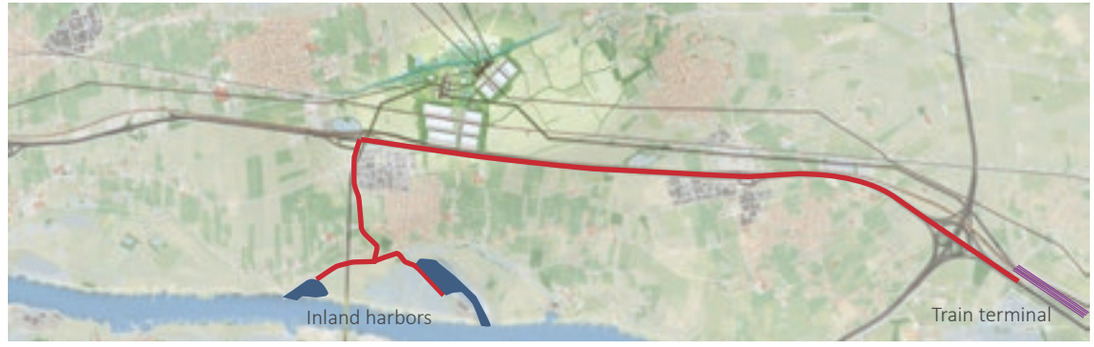


Figure 3.56: the design of iteration 2, connected with existing inland harbors and future train terminal.

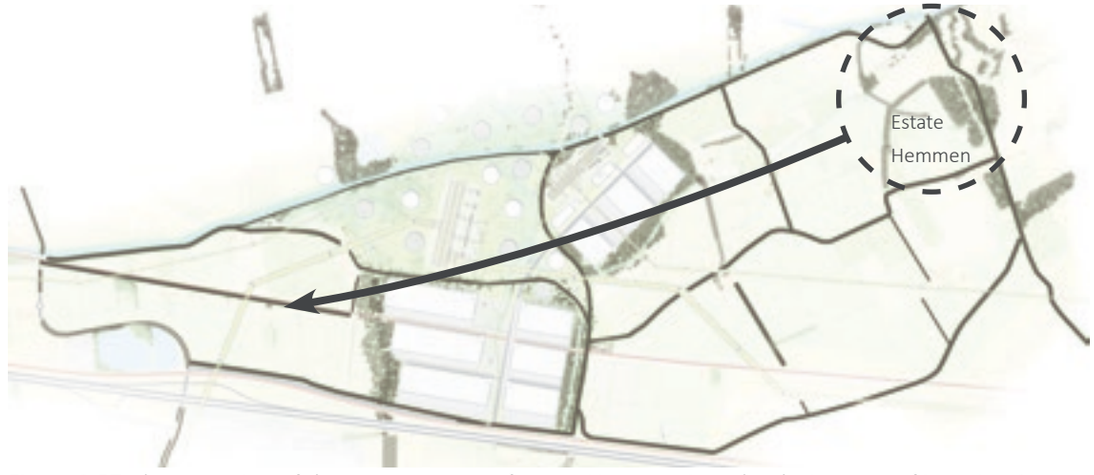


Figure 3.57: the extension of the tree structure of estate Hemmen into the design area of iteration 2.

XXL warehouses, the shape of the BlueBattery water tanks and connection to existing infrastructure were taken to the third iteration.

Positive points

- A high concentration of XXL warehousing
- BlueBattery system in the shape of Rotterdam Oil tanks fits well in combination with XXL warehouses
- Connections with existing infrastructure
- Comb concept for organizing XXL warehouses

Negative points

- The spread-out placing of BlueBattery water tanks is not functional
- Landscape integration not optimal.
  - Camouflage instead of integration
  - Estate structure not sufficient to integrate the warehouses in the landscape.
  - No experience from the highway

Figure 3.58: preliminary design 2. High concentration of functions, but lacking landscape integration.

Figure 3.59: assessment table scoring preliminary design 2 according to the design principles of the XXL MIX park.

Iteration 3 'landscape first, function second'

Figure 3.60: sequence in which the design principles were applied in iteration 3.

In iteration 3, the landscape principles formed the starting point (figure 3.60), since mainly the appliance of these principles did not meet the expectations in the foregoing iterations. Therefore, this time no area was fixed on forehand, but existing landscape structures were used to explore ways to place the large-scaled elements (figure 3.61). To be able to define small-scale and large-scale elements during designing, an enormous 1:2000 map (3,5m x 2,5m) of the area was made (figure 3.65).

Since landscape structures such as existing roads and water streams proved themselves not to be appropriate to integrate XXL warehouses, the largest natural landscape structures were used as motive for placing the elements: the levees, and the alluvial plains. With their large-scaled character, the XXL warehouses and the water tanks of the BlueBattery system were placed in the alluvial plains, and thereby 'spared' the levees, with their small-scaled character and their rich cultural heritage (figure 3.62).

Close to the high-voltage stations of Dodewaard, two alluvial plain landscapes could be found. Regarding modern building techniques, it was assumed that building in these wet areas would be possible with the right water management. The wet character of these areas, in combination with the large amounts of rainwater from the large-scaled roofs could be utilized to create interesting wetland nature. To ensure water discharge, the alluvial plains were changed into large natural wetlands. A water drainage system was developed by connecting new waterways to existing streams such as the 'Wust' and the Linge canal. For water retention, multiple shallow lakes were integrated in the water system.

To create a firm and natural landscape framework for the large-scale industrial elements, a distribution of mixed (Poplar, Willow, Ash, Alder) wetland forests as already present in the landscape of the Betuwe, was integrated in the alluvial plains. Based on existing allotment structures, a distribution of forests and open fields was explored, that would camouflage the big scaled elements, but would not totally hide them (figure 3.63). Besides being a framework for industrial activity, this landscape could also serve nature goals, since nature areas with a low dynamic and shallow waters are seen as missing link in the nature around rivers in the Netherlands (Geest, Peters, Wijers, 2014).

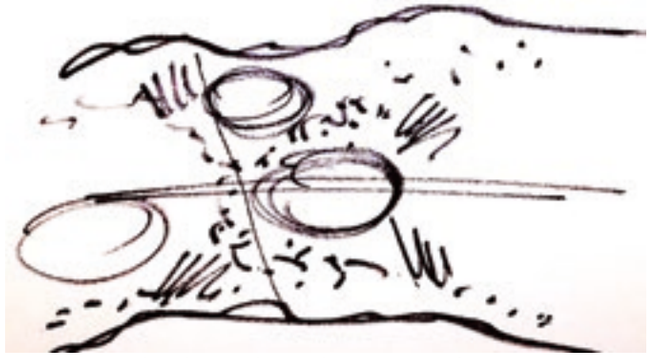


Figure 3.61: sketch visualizing the concept of iteration 3.

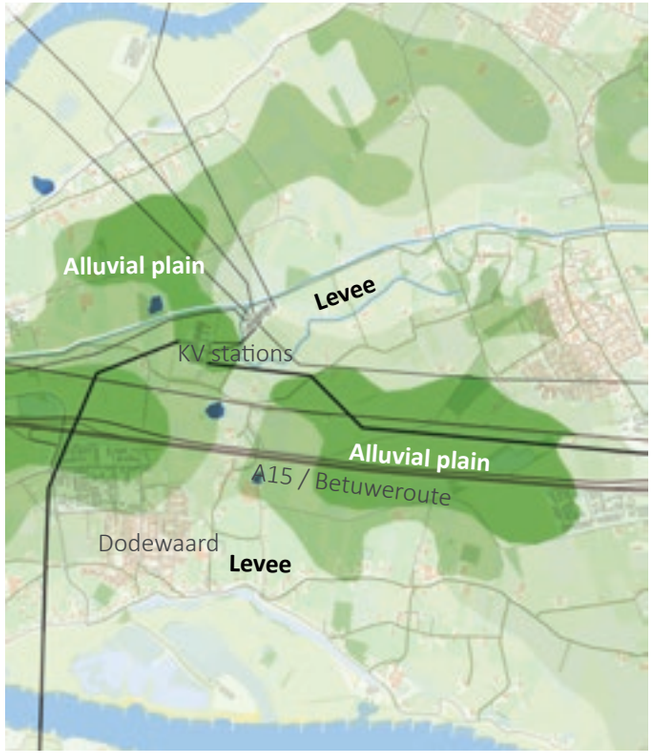


Figure 3.62: Two alluvial plains as motive for placing the large-scale industrial elements.

Figure 3.63: distributing forests in the alluvial plains.

Figure 3.64: reinforcing lane structures in the levees.

Figure 3.65: exploring ways to integrate industrial elements in the alluvial plains, 3d modeling on the big 1:2000 map.

In the levees, by adding and reinforcing missing tree lanes along the local roads, the small-scaled character of the scenic landscape (coullissen landschap) could be improved. Since the levees traditionally contain most human activity, preserving them would integrate local infrastructure and cultural heritage in a natural way, (figure 3.64). In addition, to protect the most nearby village of Zetten from visual disruption, and to create a local recreation area, the estate forests of Hemmen were enlarged, and thereby a buffer zone in between living areas and the industrial park was created.

As last step of developing a landscape framework, the almost vanished 'Spanjaardsdijk' was renewed. Renewing the dike could 1. function as a visual boundary between Dodewaard, Opheusden and the industrial activities, 2. could be a symbolic protection against contemporary scaled industrial activities, and 3. could contain an experiential path where the meaning of the XXL MIX park could be experienced. The renewal of the dike differed per section. Interventions contained a combination of adding lines of poplar trees as visual boundary, elevation of the dike, or addition of a cycling/pedestrian paths.

With this firm landscape framework developed, the industrial elements could be integrated. For functional reasons, the XXL warehouses were integrated in the southern alluvial plain along the highway, and the BlueBattery water tanks were integrated in the northern alluvial plain next to the high-voltage stations. Optimal integration of the industrial elements was explored in sketch sessions and by modeling on the big 1:2000 map (figure 3.65).

Overall, this design iteration led to a preliminary design that optimally combined the design principles of the XXL MIX park (figure 3.66), which was confirmed during evaluation sessions with the supervisors. Thereby, the design synthesis was finished, and the preliminary design was worked out into a final design as shown in the following part of this report.

Positive points

- Clearly integrated based on existing landscape characteristics
- Meaning and appearance are derived from a combination of existing, new, industrial and natural elements.
- Utilizing the alluvial plains gives more space for organizing the functional elements
- The functional grid for the BlueBattery water tanks enables more storage capacity
- The functional grid containing cryogenic storage, refrigerated warehouses, and XXL warehouses enables efficient energy usage, and offers a lot of roof space for solar fields.
- Utilizing and reinforcing existing infrastructure makes the landscape easily accessible and experienceable.
- Preserving and reinforcing the levees makes sure existing landscape qualities are maintained.

Negative points

- Functions are not as concentrated as in the first iteration processes.

Figure 3.66: assessment table scoring preliminary design 3 according to the design principles of the XXL MIX park.

3.3.4 Final design: XXL MIX park Dodewaard

Figure 3.70: the 'Lane of Giants' in XXL MIX park Dodewaard.

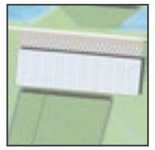
XXL MIX park Dodewaard, 2030

In the A15 corridor, the fastest connection from Rotterdam to the German Ruhr area, a national cluster of XXL warehousing is placed around the high-voltage stations in Dodewaard. In this 'XXL MIX park', XXL warehousing is combined with large-scale energy storage and comprehensibly integrated in the landscape of the alluvial plains.
In XXL MIX park Dodewaard, the natural landscape determined the framework for industrial development. Large-scaled wetland nature in the alluvial plain, containing 200 hectares of poplar-willow forests, 40 hectares of shallow lakes and 200 hectares of natural grassfields, forms a natural framework for the large-scale industrial elements. In the levees, the traditional 'coulissen' landscape with tree lanes is reinforced, and the local road system is improved.
Together, the warehouses in the XXL MIX park offer 700 000 m² of storage capacity. The park has a multi modal connectivity, being closely connected to an inland harbor at the Waal, a train terminal along the Betuwroute and the highway A15. It has a logical internal road system, and combines different logistic activities for an efficient supply chain. Furthermore, it is integrated in a natural and appealing park design, making it an attractive business location for logistic companies.
Next to an industrial function, the park is connected to 7 high-voltage lines, and functions as regional energy buffer. By storing regional surpluses of renewable energy and releasing them during shortages, the park is an important node in the renewable energy network and ensures grid balance. A BlueBattery storage system with a capacity of 25 500 MWh and a power capacity of 600 MW functions as a regional battery. In the park itself, energy is efficiently used. The solar fields on the roof have a total surface of 60 hectares and a power capacity of 48 MW. By combining cryogenic energy storage systems with refrigerated warehousing and heating purposes, the produced solar energy is used in a very efficient way.
Due to its comprehensible combination of functions, and its formfull and palpable design, XXL MIX park Dodewaard is a place that shows how industrial and energy functions can be sensibly integrated in the landscape. XXL MIX park Dodewaard is one of the 10 XXL MIX parks that can be applied in the Netherlands by the national government. With this multifunctional clustering concept, large-scaled fragmentation of the Dutch landscape can be avoided, and a natural limit for XXL warehousing in the Netherlands can be determined.

Figure 3.71: overview of the final design: XXL MIX park Dodewaard 2030.

Fold out

XXL MIX Dodewaard: an overview

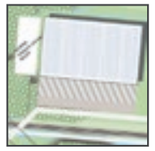


XXL warehouse of 50 000 m²

380 KV high-voltage station

Gradient showing soil type: from clayey soil (dark green) to sandy soil (light green).

Estate 'Hemmen'



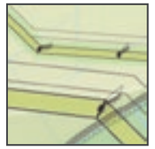
Refrigerated warehouse with integrated cryogenic energy storage system

150 KV high-voltage station

Reinforced 'coulissen' landscape in the levees

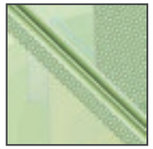
Train station Dodewaard-Hemmen, Public railroad and Bicycle highway

Solar roof



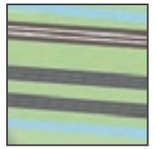
High-voltage line
Narrow: 150 KV line
Broad: 380 KV line

Wetland nature in the alluvial plains

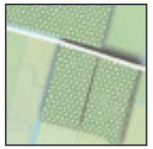


Reinforced transversal dike,
the ' Spanjaardsdijk'

Docking space for trucks, parking space and road

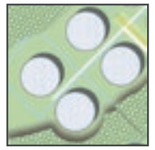


Cargo rail Betuweroute and highway A15



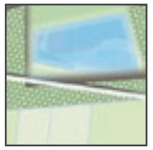
Poplar/willow forest

River dikes of the Waal and the Nederrijn



Watertanks for BlueBattery storage system

Existing industrial park



Shallow lake

Linge canal, and split-off to the Nederrijn

Buildings for membrane stacks of BlueBattery storage system

Village

River swirl lake (wiel)

Water stream the 'Wust'.

1 km

Figure 3.72: masterplan of XXL MIX park Dodewaard.


Opheusden
Zetten
Dodewaard
Andelst

Fold out

The industrial elements of XXL MIX park Dodewaard are integrated in the clayey soils of the alluvial plains, to save the levees; with premium soil quality, cultural heritage and living areas (figure 3.73).

To ensure water retention and drainage, retention lakes are integrated in the design, and the existing water system is adapted to the new functions (figure 3.74).

Around the BlueBattery water tanks and the XXL warehouses, a firm framework of poplar/willow forests is integrated in the landscape, according to old allotment structures. Figure 3.75 and 3.76 show the existing and the new forest areas in the landscape.

To make XXL MIX park Dodewaard easily accessible and experiencable, the local road system is improved. Some gaps in the network are filled, and the former transversal 'Spanjaardsdijk' is renewed (figure 3.77).

To make the XXL warehouses easily accessible for industrial purposes, a new highway exit is added. The park can be left via existing highway exits. The inland harbor along the Waal is at close distance, and can be reached by the existing road network (figure 3.78).

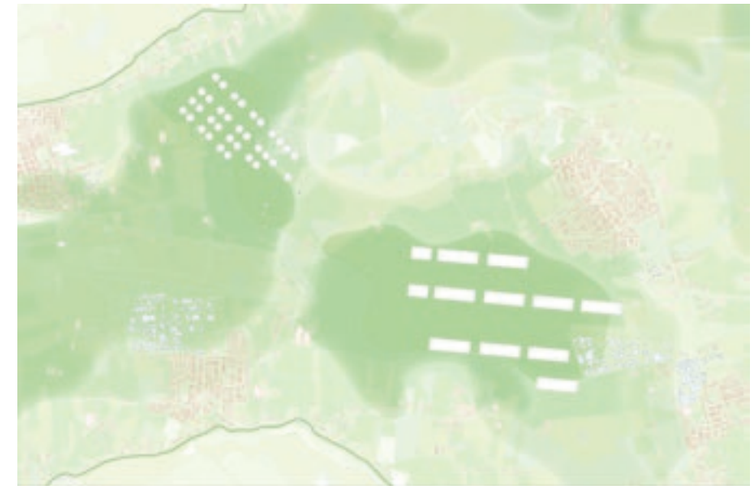


Figure 3.73: the large-scale industrial elements are integrated in the alluvial plains.

Figure 3.74: the adapted water system. Retention lakes are integrated to ensure water retention.

Figure 3.75: existing forests in the area.

Figure 3.76: existing + new forests in the area.

Figure 3.77: the red lines mark new local road connections. The Spanjaardsdijk is renewed.

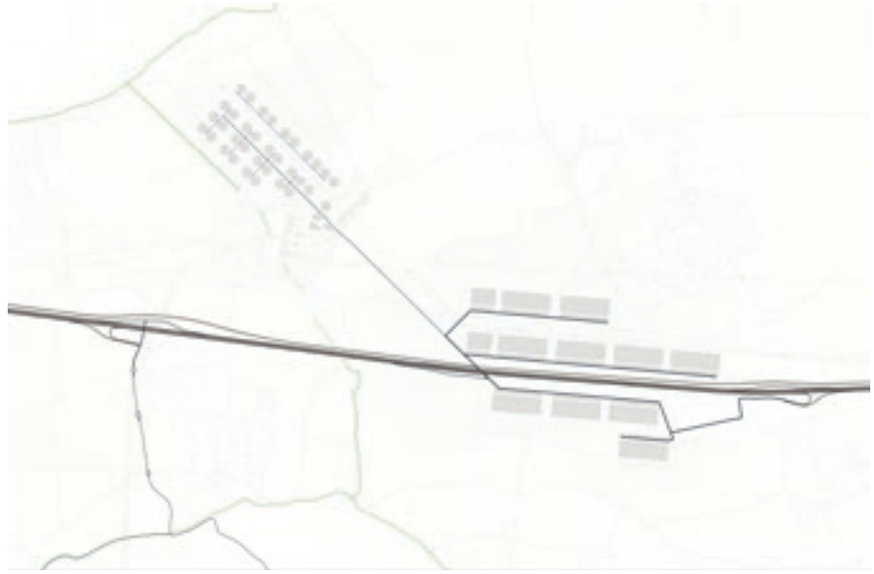


Figure 3.78: road network for trucks.

1 km

Southern part: XXL warehouses and XXL lanes

In the southern part of XXL MIX park Dodewaard (figure 3.79 and figure 3.80), XXL warehouses are integrated parallel to the existing infrastructure. Two large-scaled lanes are crossed by many infrastructures. The highway A15 and the cargo rail Betuweroute cross the southern lane. The 380 KV power line Dodewaard-Doetinchem, the public rail road Arnhem-Tiel and a new constructed 'bicycle highway' run through the northern lane. The XXL warehouses are surrounded by a large-scaled framework of poplar/willow forest, natural grassland and shallow lakes. This natural area serves nature development, carbon storage, camouflage, water retention, and landscape experience goals.

The following pages will outline components of the southern part of the design: the experiential lanes, the energy system, and the water system.

Figure 3.79: the southern part of the design is indicated in the black rectangle in the upper image. The symbols in the lower image indicate the positioning of visuals and sections on the coming pages.

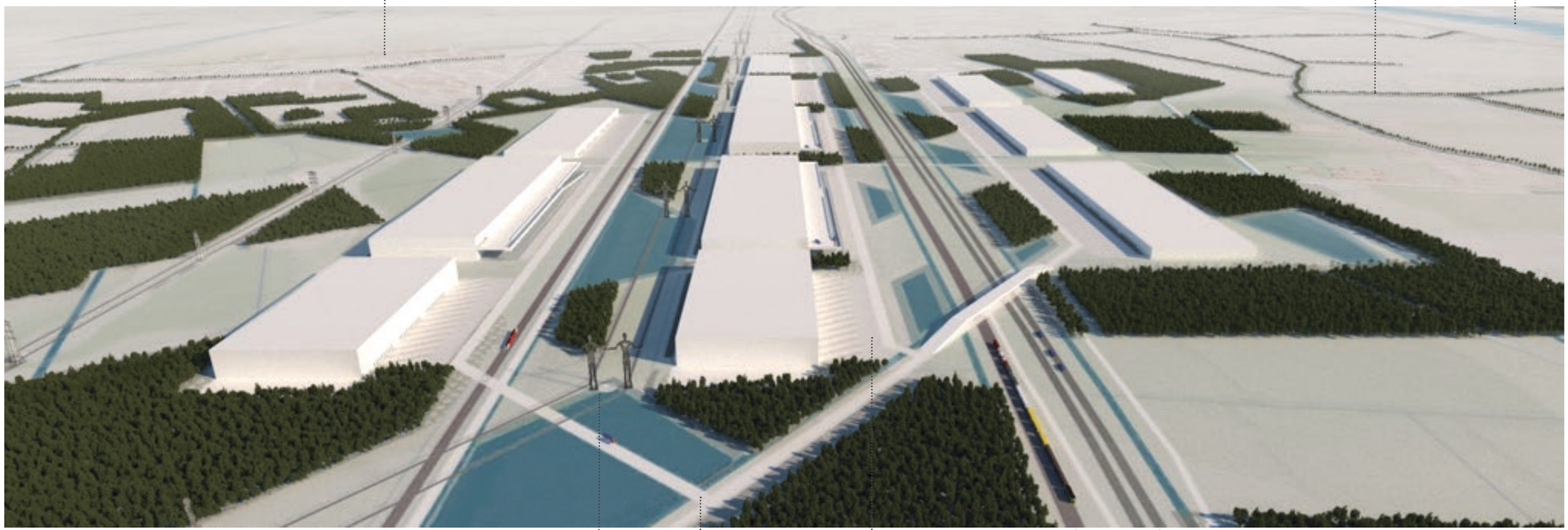


Figure 3.80: birdview of the southern part of XXL MIX park Dodewaard.

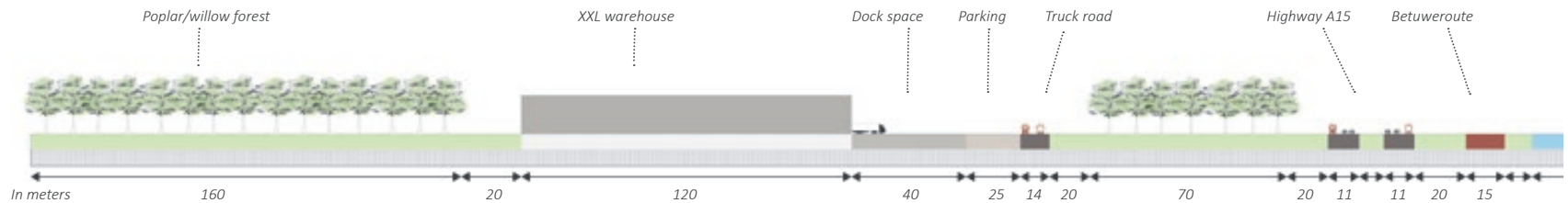


Figure 3.81: section of the southern part of the design.

Large-scaled 'lanes of giants'

In the large-scaled lanes, the contemporary scale of energy use and consumption behavior can be experienced from the public train, the bicycle highway, the A15 and from the warehouses itself. 10 pairs of high-voltage giants (Choi+Shine, 2008), that carry the cables towards the 380-KV high-voltage station, give a palpable experience of the scale of energy use. An endless wall of warehouses (2 km), gives a palpable experience of contemporary consumption behavior. An alternation of tree clusters and water bodies, which shapes are determined by following sight lines from the infrastructure, ensure varying views on the landscape (figure 82). By applying one-sided warehouses, there is a clear distinction between an industrial side, and a landscape side. The industrial side is characterized by infrastructures, like truck roads, and docking and parking space, while the landscape side has a direct interface with the wetland nature. In this way, the warehouses themselve function as a visual- and noise barrier camouflaging industrial activities and large-scale infrastructures (see figure 3.82).
For a view from the bicycle highway, see the visual at the right page (figure 3.83), for a view from the warehouses, see the visual on the next page (figure 3.84). A section of both lanes is shown in figure 3.81.

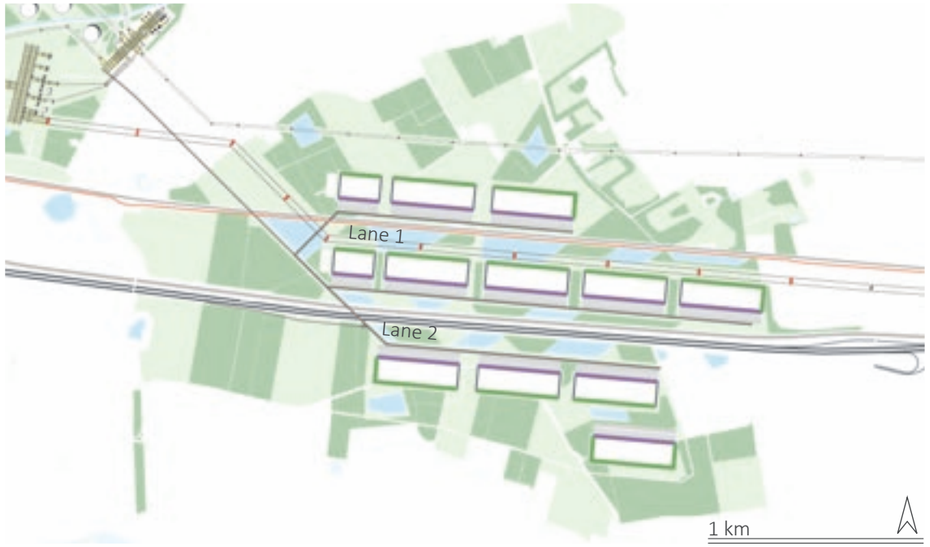


Figure 3.82: map showing the organization of the warehouses and the two large-scaled lanes.

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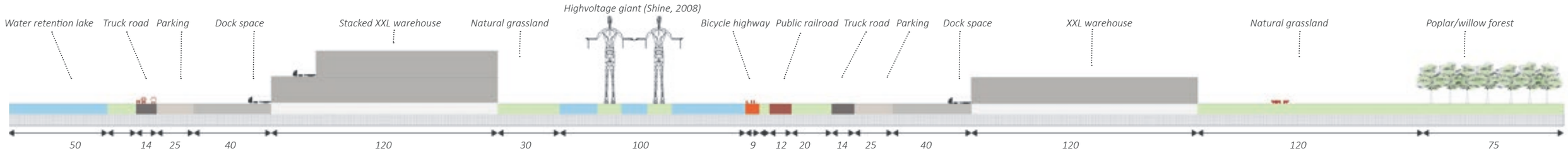

Figure 3.83: view from the bicycle highway on the 'Lane of Giants'.

Fold out

Energy and water flows

Energy is efficiently used in the industrial park. Solar fields on all roofs provide the refrigerated warehouses and the XXL warehouses with electricity. During surplusses of solar energy, a cryogenic storage installation is charged. During shortages of solar energy, the system can be discharged. The energy losses in the charging process of cryogenic energy storage systems contain cold air, which is used to cool the neighboring refrigerated warehouses. Energy losses for the cooling compartments of refrigerated warehouses contain warm air, which is used to heat the neighboring XXL warehouses. This circular system ensures an optimal use of energy (figure 3.85).

Because of the enormous roof surface, a firm water retention system is integrated in the alluvial plains in which the XXL warehouses are situated. During heavy rainfall, surplusses of water can be stored in the surrounding shallow lakes, ensuring the water to be gradually drained towards the Linge canal (figure 3.86).

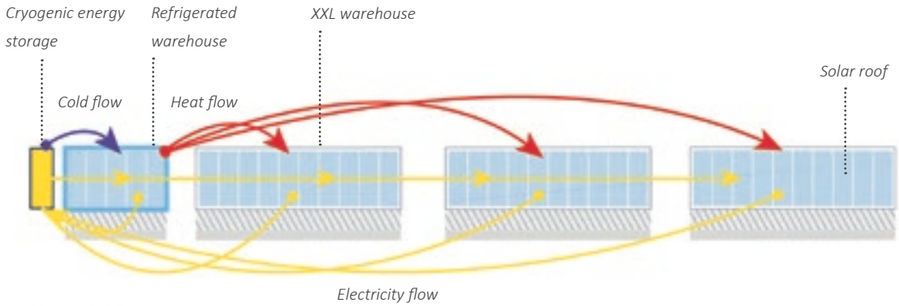

Figure 3.85: energy flows.

Figure 3.86: water system.

Figure 3.84: view from a XXL warehouse in XXL MIX park Dodewaard.

Northern part: experiential energy node in Linge wetland

The northern alluvial plain of XXL MIX park Dodewaard (figure 3.87 and 3.88) is crossed by the Linge canal, and contains a BlueBattery storage system and the high-voltage stations. 17 sets of BlueBattery water tanks are integrated in the landscape. The water tanks are sized like oil tanks in the harbor of Rotterdam, and every set of tanks contain fresh and salt water. Poplar/willow forests, that follow old allotment structures along the river dike, surround the water tanks, which are integrated in between high-voltage lines and the reinforced transversal 'Spanjaardsdijk'. The membrane stacks of the BlueBattery are closely connected to both the 380 KV and the 150 KV high-voltage stations. The high-voltage stations are integrated in structure of the poplar/willow forests. The area is crossed by the Linge canal and the Wust, a water stream that contains drainage water from the XXL warehouses. The northern alluvial plain can be experienced by a cycling and pedestrian paths along the Linge canal and on the 'Spanjaardsdijk'.

The following pages outline components of the northern part of the design: the regional energy storage system, the experiential path along the Linge canal and the 'Spanjaardsdijk'.

Figure 3.87: the northern part of the design is indicated in the black rectangle in the upper image. The symbols in the lower image indicate the positioning of visuals and sections on the coming pages.

Fold out

Figure 3.88: birdview of the northern part of XXL MIX park Dodewaard.

Fold out

A regional battery

With a storage capacity of 25 500 MWh, and a flexible power up to 600 MW, the future BlueBattery storage system in XXL MIX park Dodewaard serves as a regional energy buffer. During surpluses of solar and wind energy on the grid, the BlueBattery system can be charged. During shortages of energy on the grid, the BlueBattery system can be used to supply the region with energy (figure 3.89).

Energy storage function in the landscape

The huge BlueBattery system, with its large water tanks integrated in the wetland, can be experienced from a path along the Linge canal, or from a boat on the Linge itself. Energy storage becomes an evident and palpable part of the landscape (figure 3.90).

Figure 3.89: XXL MIX park Dodewaard serving as regional energy buffer.

Figure 3.90: walking on a path along the Linge Canal while experiencing BlueBattery water tanks.

Fold out

Spanjaardsdijk, symbolic protection against ourselves

Where the old Spanjaardsdijk from 1591 served water safety goals, the rebuilt Spanjaardsdijk 2030 serves as symbolic protection against our own consumption behavior and energy use. It 'holds' the high-voltage giants, the BlueBattery water tanks, the high-voltage stations and the XXL warehouses from 'breaking through'. However, as the case with natural dikes, it has been breached several times, the 380 KV high-voltage station for example 'breached through' in 1970. Therefore, next to the station, a symbolic river swirl lake is created. From the dike, at the edge of this swirl lake, there is a view over the 380 KV station. The station used to be hided, but now its huge scale and importance can be experienced (figure 3.93).

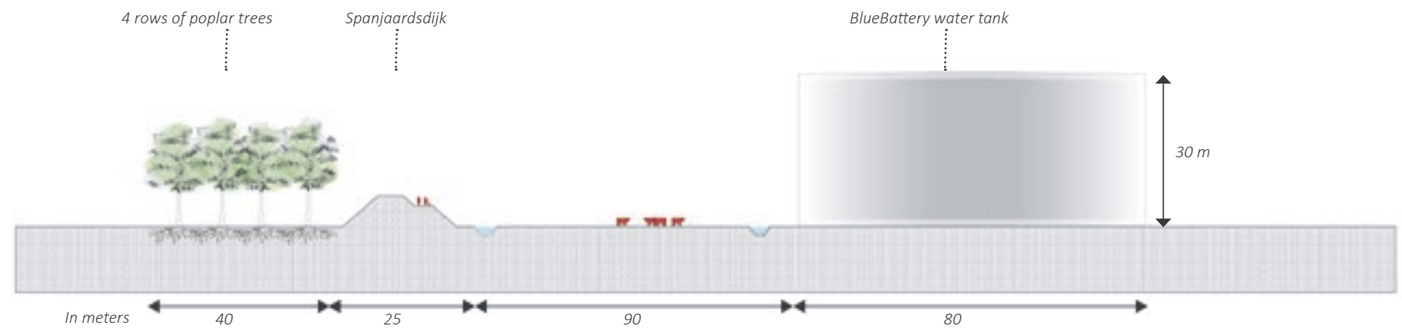

Figure 3.91: section of the renewed spanjaardsdijk and a BlueBattery water tank.


Figure 3.92: birdview showing XXL MIX park Dodewaard and its symbolic border, the renewed Spanjaardsdijk (indicated with a red line).

Figure 3.93: view from the Spanjaardsdijk on the river swirl lake symbolising the 'dike breach' of the 380 KV station

Fold out

XXL MIX park Dodewaard

With the prescribed characteristics, XXL MIX park Dodewaard avoids large-scaled fragmentation of the landscape in the A15 corridor by XXL warehousing. Furthermore, it forms an important node for maintaining regional electric grid balance.
The development of XXL MIX park Dodewaard will have a great impact on the landscape. However, by 1. following existing, large-scale landscape structures, 2. integrating the large-scale industrial elements in a firm landscape framework, and 3. creating a clear spatial structure for industrial development, the design optimally strives for giving XXL warehousing a genuine place in the landscape of Dodewaard.

Next to a sensible integration in the landscape, XXL MIX park offers an experience that raises questions about our own consumption behavior and the extend to which the landscape can bear the spatial results of a lasting desire for a growing economy. Figure 3.94 shows XXL MIX park Dodewaard on a regional scale level.

Figure 3.94: masterplan of XXL MIX park Dodewaard in a regional context.

Fold out

4. Proposed guidelines

Figure 4.1: docking of trucks, a XXL warehouse in Venlo.

Proposed guidelines

Answering the main research question:
What guidelines can improve the placement and design of XXL warehouses in the Netherlands?

By answering the three sub research questions in respectively the principle development, the placement study, and the design synthesis; the design proposal XXL MIX park was extensively explored. The main products of this exploration are a placement strategy for the Netherlands and a landscape design in Dodewaard.
In a final evaluation of these products, guidelines were developed. In this chapter, first the developed **design guidelines for XXL warehouses** in the Netherlands are presented. Secondly, the developed **placement guidelines for XXL warehousing** in the Netherlands are presented.

4.1 Design guidelines for XXL warehousing

The final design made clear that by aiming for clustering from a national planning perspective, integration of a renewable energy function and meaningful landscape design, successful integration of XXL warehouses in the landscape of Dodewaard could be achieved. Therefore, steps taken to develop the 'XXL MIX park' in Dodewaard could be applicable in other cases as well. Furthermore, because the sequence of applying the principles determined the successfulness of the design, the design guidelines follow a particular sequence as well. The following design guidelines are proposed:

1. Determine the space available for clusters of XXL warehousing by interpreting large-scaled and natural landscape units
The design synthesis made clear that because of their unprecedented scale, XXL warehouses can only be integrated within existing landscape structures if they have a large-scale as well. This means integration shouldn't start with structures like existing lanes, existing buildings, or existing ditches, but should start on the base of whole natural landscape units. In the case of Dodewaard, levees and alluvial plains formed the starting point of the design, but what landscape units are used, will differ per case.

2. Create a larged scaled landscape framework within the landscape units, based on existing characteristics.
Within the landscape of the large-scaled landscape units, a firm landscape framework should be developed to assure a balanced integration of the XXL warehouses. Motives for developing this framework should be searched for in existing landscape characteristics like local flora, parcel structure, local roads, or cultural-historical elements. In the case of Dodewaard, wetland forests, the Linge water system, parcel structure of the land consolidation, existing tree lanes and the estate of Hemmen were utilized, but what landscape characteristics are employed, will differ per case.

3. Aim for a synthesis of industrial functionality, energy efficiency and a meaningful landscape within the landscape framework.
Within the developed landscape framework, there should be aimed for a synthesis of industrial functionality, energy efficiency and a meaningful landscape. To do so, the following points should be considered:

a. Efficient use of energy
Integrate cryogenic energy storage systems and utilize its (cold) energy losses to cool refrigerated warehouses. Integrate refrigerated warehouses close to the cryogenic installation. Utilize the refrigerated warehouses for energy balance and utilize the energy losses for the heating of the XXL warehouses. Integrate XXL warehouse close to the refrigerated warehouses and utilize their total roof surface for large-scaled solar fields, that can be used to charge the cryogenic storage system.

b. Uniformity of shapes and colors
Built the XXL warehouses in uniform, and functional shapes and make use of unified colors and materials. Focus on overarching expression above individual expression of companies.

c. Buildings as a natural boundary
Organize the warehouses in such a way that they are connected to the main infrastructure on the one side, and connected to the natural landscape on the other side. This can be achieved by applying a 'comb' road structure, and one-sided docking in warehouses.

d. Readable and accessible landscape
Preserve existing local infrastructure as much as possible, to maintain the existing readability of the landscape. Add new

roads, to improve local connections and to create accessibility for the new functions. Adapt the landscape framework to create views from the accessing infrastructure and create places were the meaning of the design can be experienced.

e. Experiential elements
Experiential elements could be utilized to clarify the meaning of the park and make the unprecedented scale of elements palpable. In Dodewaard, 'high-voltage giants' (Choi+Shine, 2008), served this goal, but the elements can differ per case.

4. Add a large-scaled energy storage function
Prescribed guidelines can be applied to clusters of XXL warehousing at strategic locations along logistic infrastructure. Placement around high-voltage stations opens up extra possibilities for a regional energy storage function. Directly connected to a high-voltage station, large-scaled energy storage systems can serve as a regional battery in the energy grid. In the design in Dodewaard, a future representations of the BlueBattery energy storage system was considered to fit this purpose. The technique and its futuristic scale proved itself suitable in the design of Dodewaard, since the shape of the water tanks is flexibel, and since water is an environmentally friendly ingredient, the water tanks can be integrated in the natural landscape. However, what energy storage system is used, can differ per case, and is strongly depending on the development of the mostly preliminary techniques as currently available.

4.2 Placement guidelines for XXL warehousing

Because the design proposal XXL MIX park could be successfully applied in the case area, the placement strategy is further validated as well.

The final design in the case area contains 70 hectares of logistics storing capacity. Assumed that the other locations of the placement strategy can enhance a comparable amount, the potential logistic storage capacity of the placement strategy is 700 hectares. Since the expected grow of XXL warehousing in the coming five years is expected to be 400 to 1000 hectares (Stec, 2018a) (Verweij, 2018a), this is a very relevant amount, and can thereby avoid fragmentation of XXL warehousing in the Netherlands.

The final design in the case area contains 26 000 MWh of storage capacity and a power of 840 MW. Assumed that the other locations of the placement strategy can incorporate a comparable amount, the ten locations together can have an installed power of 8400 MW, a relevant amount, maybe even overstated, since in the future scenarios of Tennet an inland storage systems for national grid balance with a total power of 1200 MW is proposed (Tennet, 2010).

These promising estimates and the successful integration of design proposal XXL MIX park in Dodewaard leads to the following placement guidelines for XXL warehousing in the Netherlands:

1. Cluster XXL warehouses around the high-voltage station of Dodewaard

2. Explore to what extent the landscapes around the high-voltage stations of Geertruidenberg, Maasbracht, Doetinchem, Zwolle, Ens, Lelystad, Maasvlakte, Borssele, and Eemshaven can be developed according to the design guidelines as presented in this thesis.


BARGE TERMINAL TILBURG
PASSION
FOR LOGISTICS
BARGE TERMINAL TILBURG
DFDS
DFDS LOGISTIC
WERKENDAM

5. Discussion

Figure 5.1: inland container terminal in in Tilburg.

In this discussion, the research approach, the results and the relevance of this thesis are critically reviewed. Subsequently, personal recommendations and reflections are shared.

Research approach

The societal consternation regarding placement and design of XXL warehousing is relatively new. Therefore, in this thesis an explorative research through design was executed. Since the Rijksadviseurs mentioned that a perceived urgency can never be an argument to settle for an inferior spatial and social quality (Alkemade et al., 2018, p. 10), in this thesis the placement and design of XXL warehousing was explored from a holistic and long term perspective. Maher states that to achieve sustainable development goals in research through design, five research principles are of particular value, broad problem framing, integrating diverse perspectives, mazimize synergy, multiple feedback loops and thinking visually (Maher, Maher, Mann, & Mcalpine, 2018). All principles were considered in the research process as the following points will describe.

Broad problem framing and integrating diverse perspectives

In this thesis, a broad and multi oriented hypothesis was stated. It was referred to as XXL MIX park and built upon three working assumptions. Together, these working assumptions combined industrial, energy and landscape perspectives. Thereby, the integration of multiple perspectives was assured. The theoretical framework of this thesis was anchored in the research process, and further specified and underpinned the XXL MIX park. In this principle development, theories, ideas and concepts from literature and interviews were directly translated into a set of principles for the XXL MIX park. It resulted in a clear overview that could be used in the next research phases. However, the developed principles might not reflect the full range of meaning that was originally intended by each of the authors.

Maximize synergy, multiple feedback loops and thinking visually

In the placement analysis, thinking from a national perspective was considered as essential, since it would give a truthful alternative to the current, local oriented business park planning. However, a placement analysis from national perspective resulted in the need of combining detailed datasets for a big surface. To maximize synergy, 24 datasets from different perspectives were combined. Due to time constrains, and for clarity in the storyline of this thesis, only the idea of placement around 380 KV stations was examined in detail, though other interesting strategies could be developed by combining the datasets of this thesis.

By scoring the locations according to the placement principles, the extend of synergy could be assessed. Preferably, in further research, assessing locations should be combined with a more quantitative approach for scoring.

In the design synthesis, the integration of multiple perspectives in a landscape design with small-scaled cultural landscapes at the one hand, and elements of 50 000 m^2(!) at the other was a big challenge. To tackle this challenge and aim for maximal synergy, the design process contained design techniques as prescribed for constructivist research through design. Many of the classical 'creative' reflection-in action techniques of the repertoire of the landscape architect were undertaken, such as drawing (physical and computer drawing), crafting, building scale models and ideation techniques such as 'stepping out of the box' and 'doodling' (Lenzholzer, Duchhart, & Koh, 2013). An iterative feedback loop was executed three times to guarantee a solid argumentation. It would have been an improvement to evaluate every preliminary design together with experts from industrial, energy and landscape perspective, but this wasn't a possibility within the context of a master thesis.

Results and relevance

Because this research regarded multiple perspectives and placement as well as design of XXL warehouses, the research process was complex and extensive.
It makes the outcomes of this thesis two-sided. On the one hand, a complete storyline is created that contains a lot of new insights and constructs for placement and design of XXL warehousing. Furthermore, this thesis shows how guidelines for placement and design of XXL warehousing in the Netherlands can be developed.
On the other hand, the research relates to so many perspectives and future developments, that it contains more information and fact-checking than a person can possibly do single-handedly. Assumptions were made, and as the case with explorative and qualitative research, personal influence was part of the research process.

Because of the described complexity of the design, some parts of the design are still open for further exploration. Some examples are described:

- Many energy storage systems are in a preliminary stage, as is the case with the BlueBattery systems and the Cryogenic energy storage system. On the base of an interview with Emil Goossen (Goossen, personal communication, 24th of October, 2019), substantiated assumptions in terms of expected storage capacity could be made. But still, the presented numbers represent far future expectations and do not reflect the contemporary capabilities of the system. Integrating the BlueBattery system in storage tanks like the ones in the harbor of Rotterdam should be further examined as well. Before the idea of large-scale storage around the high-voltage stations can be definitively stated, additional (technical) research is needed.
- As indicated by Maarten van Riet (personal communication, 28th of may, 2019), data-centers can be an interesting addition to the XXL MIX park. Due to time constrains and clarity reasons, they were not integrated in the design.
- The natural system of the wetland, containing Poplar/Willow forests, natural grasslands and shallow lakes should be explored in further detail. Possibilities to exploit the forests as climate forests (klimaatbossen), or to combine them with the local tree nurseries are not considered in the design.

- The water system is designed on a large-scale, but should be further explored, concerning detailed flow direction, water depth and soil permeability.
- To be able to explore freely, existing planning regulations as well as financial constraints were not considered.
  A financial analysis comparing the proposed 'XXL MIX park' with the existing planning regulation would be an interesting addition to this thesis.

To answer the main research question of this thesis, guidelines were developed by evaluating the placement strategy and the final design. This evaluation was executed by the author only. Therefore, the guidelines are biased as they include intuition and personal preference. In explorative research through design, this personal influence cannot be completely avoided. However, in a more ideal situation, it would be valuable to share the placement strategy and the final design with experts from different disciplines.

Concluding, the results of this thesis shouldn't be considered as fixed solutions and ideas, but as carefully designed 'exploration products', open for further research and discussion.

Having discussed the limitations of this research, it can be said that until now, no research existed on placement and design of XXL warehouse parks that combines an energy, an industry, and a landscape perspective. Thereby, this thesis distributes important new knowledge for placement and design of XXL warehousing in the Netherlands. When considering the proposed placing and design guidelines, this thesis can help to prevent big areas of landscape being ineffectively and inconveniently developed. Furthermore, being among the first researches into this topic, this thesis can be a valuable starting point for future research on the placement and design of XXL warehousing.

Recommendations and reflection

The challenge to integrate XXL warehouses sensibly in the landscape was a big one. Being in the beginning of my career as landscape architect, I am still an inexperienced designer and researcher which partly explains these struggles. However, since I was very committed to create a proper thesis, and learned about many aspects of XXL warehousing as well as the local landscape, I assume that my struggles to find a successful integration of XXL warehouses also implies something else: it is a major challenge to integrate XXL warehousing in the landscape in a sensible way (see figure 5.2)!
This raises a question. To what extend can the landscape bear the unprecedented grow of XXL warehousing in a sensible way? My feeling after writing this thesis is that we are on the edge. When the biggest landscape entities (such as levees and alluvial plains, see final design), are needed to find an acceptable integration of only a few warehouses, a problematic situation occurs. The landscape is not endlessly able to provide space for such a scale, and if so, the integration of the enormous elements is a very challenging one. Therefore, future construction projects of XXL warehousing should be strategically and carefully chosen. Landscape architects should have an important role in this process since

they can have a pivotal role in combining multiple spatial objectives, crossing disciplinary boundaries, and bringing together varying interests and values (van den Brink et al., 2019).

Creating awareness on the spatial problem caused by XXL warehousing is the first step to achieve a more sensible and careful integration of XXL warehousing in the landscape. This process has already started, shown by the growing attention in the media about the 'verdozing' of the landscape, and for example by the debate organized by Deltametropool and the Rijksadviseurs about XXL warehousing at the 28th of October 2019.

To be of value in this awareness process, next to an aim for a functional landscape design, this thesis aimed to develop a meaningful landscape design, containing elements intended to provoke people to become aware of how their actions affect the environment (Meyer, 2008). Building on the manifest of Meyer, I assumed that when people become truly aware of how their behavior relates to the unprecedented scale of contemporary industrial elements in the landscape, they might change their consumption behavior and energy use. The design did not try to hide an inconvenient truth (of mass consumption and energy use) but aimed to express this truth palpably and experienceable in the landscape. With this meaning included, the design outcomes of this thesis can be used for an interesting discussion about the way we integrate our industrial activities in the landscape, and what role landscape architects can or should play to create awareness through designs and landscapes (figure 5.3).

Figure 5.2: it is hard to make a sensible landscape design with XXL warehouses.

Figure 5.3: from a fight against water to a fight against ourselves. Should landscape architects provoke people with their own behavior through landscape design?

Figure 6.1: XXL warehouses in Venray.

6. Conclusion

The aim of this thesis was to develop guidelines for an alternative way of placing and designing XXL warehousing in the Netherlands. To do so, the research explored the design proposal 'XXL MIX park'. This design proposal emerged from the hypothesis stating that combining the ideas of 1. clustering of XXL warehouses from a national planning perspective, 2. integration of a renewable energy function and 3. meaningful landscape design, could lead to a better placement and design of XXL warehousing. To explore to what extent this hypothesis could be confirmed, the following main research question was outlined:

What guidelines can improve the placement and design of XXL warehouses in the Netherlands?

In this chapter, the results of the research are summarized by answering the three sub-research questions. Finally, the main research question is answered.

Sub research question 1

What are the principles for placement and design of the 'XXL MIX park'?

By combining scientific literature, contextual literature and expert interviews, placement and design principles were developed (chapter 2.1). It resulted in 8 placing principles and 12 design principles that outline what the placement and design of the design proposal XXL MIX park should contain.

Placement principles

- In between Sea harbor and hinterland
- Accessibility/multimodality
- Space available
- Labor available
- Connected to the energy grid
- Close to rail terminal and/or inland shipping terminal
- Place on existing industrial parks
- Place on evident locations in greenfield

Design principles

- Easily accessible and appealing workplace
- Combined logistic activities for efficient supply chain
- Utilizing ecological concepts
- Functional design for logistics transport
- Saving energy by connecting and stacking of buildings
- Utilizing energy losses
- Utilizing roof surface for solar panels
- Include large-scaled energy storage systems
- Integrated in existing landscape structures
- Form-full design
- Evidential design
- Palpable and experienceable design

Sub research question 2

Which locations in the Netherlands can be suitable for placing the 'XXL MIX park' according to the placement principles?

In a placement analysis, the placement principles were used to develop a placement strategy for XXL warehousing in the Netherlands and to select a case study area (chapter 2.2). The placement strategy states that XXL MIX parks can be best placed in landscapes around 380 KV high-voltage stations, along logistic infrastructure (preferably rail and waterway), and with enough space available. Within this strategy, 10 locations in the Netherlands fitted the requirements:

- Geertruidenberg
- Maasbracht
- Dodewaard
- Tweede Maasvlakte
- Lelystad
- Emst
- Doetinchem
- Zwolle
- Eemshaven
- Borssele

Sub research question 3

How can an 'XXL MIX park' function, and be integrated and expressed in the landscape according to the design principles?

In a design synthesis, the design principles were used to develop a landscape design in the selected case study area (chapter 2.3). An iterative design process was executed three times, and each iteration led to a preliminary design. In the third iteration, the design principles were optimally combined in the landscape of Dodewaard. Therefore, this preliminary design was developed into a final design.

The final design, 'XXL MIX park Dodewaard' showed how a cluster of XXL warehousing, combined with an energy function, can be meaningfully integrated in the landscape of Dodewaard. The design combines 4 000 000 m² of nature development, 700 000 m² of logistic storage capacity, 48 MW of solar power capacity and a energy storage capacity of 25 000 MWh. The park and its meaning can be experienced from many different perspectives and by different users.

Main research question

What guidelines can improve the placement and design of XXL warehouses in the Netherlands?

In a final evaluation, guidelines were extracted from the placement strategy and the final design (see chapter 4). The following guidelines for placement and design of XXL warehouses in the Netherlands are proposed.

Design guidelines:

1. **Determine the space available for clusters of XXL warehousing by interpreting large-scaled and natural landscape units**

2. **Create a structured landscape framework within the landscape units, based on existing characteristics.**

3. **Aim for a synthesis of industrial functionality, energy efficiency and a meaningful landscape within this landscape framework by:**
   a. Efficient use of energy
   b. Uniformity of shapes and colors
   c. Buildings as a natural boundary
   d. Readable and accessible landscape
   e. Experiential elements

4. **Add a large-scaled energy storage function**

When applying these design guidelines at all of the 10 locations of the placement strategy, 70 – 170 % of the expected grow of XXL warehousing could be integrated in a more sensible way then currently the case (figure 6.2, 6.3). Therefore, the following placement guidelines are proposed:

Placement guidelines:

1. **Integrate a XXL MIX park around the high-voltage station of Dodewaard**

2. **Explore to what extent the landscapes around the high-voltage stations of Geertruidenberg, Maasbracht, Doetinchem, Zwolle, Ens, Lelystad, Maasvlakte, Borssele, and Eemshaven can be developed according to design guidelines as previously explained.**

Figure 6.2: accommodating the expected growth in XXL warehousing in the Netherlands by proceeding the current routine.

Figure 6.3: accommodating the expected growth in XXL warehousing in the Netherlands by applying the guidelines as developed in this thesis.

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