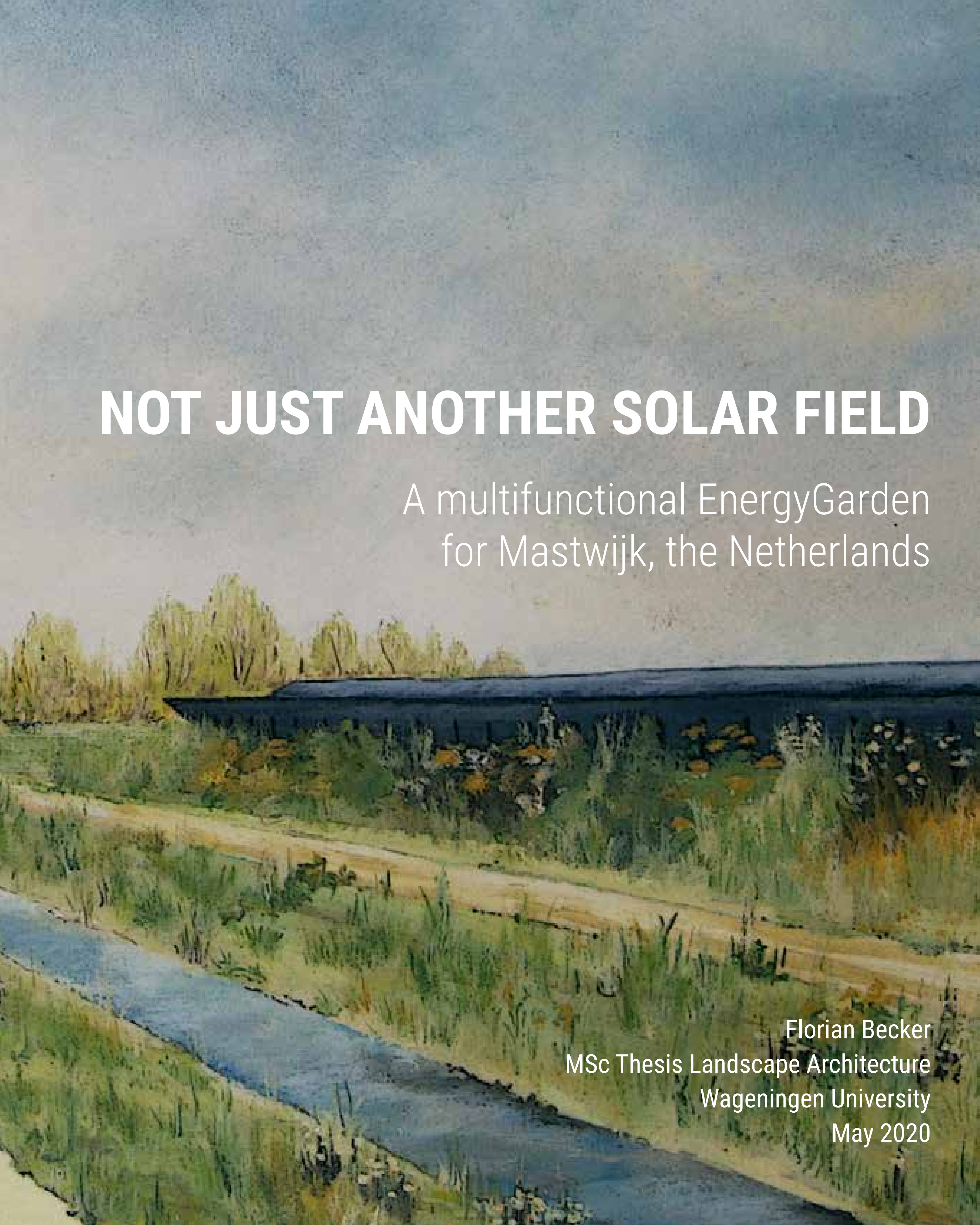

NOT JUST ANOTHER SOLAR FIELD

A multifunctional EnergyGarden for Mastwijk, the Netherlands

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Abstract

By 2030, the regional energy strategy (RES) U16 Regio around Utrecht demands to provide 3.6TWh of renewable electricity. In more concrete terms, this means a surface of 3,600 hectares of solar fields that are arising in the landscape within the next nine years. Though this goal might not be realistic, even the appearing of a single hectare of solar field in the landscape should not go without careful planning anymore. Plenty of research has demonstrated that solar fields can host many additional functions without decreasing their productivity. Especially in densely populated regions like the RES U16, scarce surfaces should not simply be allocated to single function land uses.

This master thesis builds upon existing knowledge on multifunctional solar fields to identify a set of design guidelines. These are combined with guidelines of garden design to inform the recent concept of EnergyGardens. After forming a set of design guidelines, a fraction of them is tested in a design for an EnergyGarden of Mastwijk in the province of Utrecht. The EnergyGarden Mastwijk is a real project, which is currently developed and planned to be implemented in 2021. The research of this master thesis was used to inform the design of the EnergyGarden Mastwijk, which goes hand in hand with the design presented in this thesis. The inclusion of an extended participation process with residents enabled to adjust the general design guidelines found in the research into design principles that reflect the local demands.

The result of this thesis is an extensive collection of relevant design guidelines for EnergyGardens and a design that demonstrates how they can be translated into a specific case that serves stakeholders and residents. The design illustrates that the concept of EnergyGardens can be a valuable approach to the energy transition on a small scale.

Keywords:

EnergyGarden, Energietuin, Solar field, multifunctional, recreation, education, biodiversity, spatial quality, design guidelines, Mastwijk

Preface

This thesis is written for the completion of the master programme landscape architecture at the University of Wageningen. It is meant to push the boundaries of solar fields as they can be seen in many landscapes. By employing comprehensible and straightforward measures that can easily be incorporated by stakeholders involved in the design of solar fields. The case of the Energy Garden Mastwijk demonstrates that the movement towards multifunctional solar fields leads to a lot more support of the public, while it contributes to more goals than only the energy transition.

Although I am convinced that the energy transition is one of the key challenges of our generation, the inner belief, that it has to be possible in a responsible way, developed on a field visit to several solar fields in the southeast of Germany. While the visited parks were built in the early 2000s and featured many additional functions in innovative ways, on the eight-hour drive, I came along dozens of recently built solar fields that featured nothing but a fence and did not even try to shield the view on the PV system. To me, that raised the question at what point in these two decades, we stopped to get better in how to improve the energy transition in the landscape, and how the quality of future solar fields can be improved again.

I want to thank my supervisors Sven Stremke, Merel Enserink and Dirk Oudes, who provided me with helpful tips and guidelines from the beginning of my thesis and always took the needed time to support me with any question. Joint activities like a road trip through entire Germany to visit solar fields or the active involvement in an extended participation process with various stakeholders made this Master thesis a memorable experience.

I also want to thank Afvalzorg, Energiezorg and NMF for letting me participate in the process around the EnergyGarden Mastwijk. The already fully managed participatory process enabled me to focus on preparing the right content for the right time, rather than preparing the process itself.

Furthermore, I want to thank my friends and family who carried me through the process of this thesis and provided moral support, even not knowing exactly what I was doing.

I hope that this master thesis inspires others to see the energy transition and the connected emergence of solar fields as a chance to improve our landscapes, rather than a thread.

Terminology

Within this report, various technical terms are used, mainly for describing the PV system. While some words are introduced in the specific chapter or subchapter, others require prior knowledge. To inform readers that are not familiar with the terminology of solar fields, the list below provides help

PV panel
A photovoltaic module to transform sunlight into electricity. The standard PV panel comes with measurements of 1m x 1.65m.

Arrays and Rows
An array is a string of many PV panels. The array is defined by the number of panels lying vertically above each other (rows) and the number of arranged panels horizontally next to each other (width). The PV panels can be oriented both horizontally or vertically on the array

Angle
The whole array is tilted to the azimuth angle to catch the most sun during the day. The most common implementation within Western Europe is between 30°-40° towards the south. Other angles are possible with a slightly decreased yield productivity of the PV panel. An alternative is orienting the arrays towards the East and West, featuring a lower angle. This allows for catching more sun in the morning and evening, while the yield per hectare is increased.

Pitch size
Between each array, an empty corridor arises to minimise shadow on the array behind, which is called a pitch. The required pitch size depends on the highest and lowest edge per array, as well as the azimuth degree of the location that determines the lowest position of the sun during winter.

Patch / Patch size
A group of arrays that host PV panels is defined as a patch in this report. The patch size describes the total surface that is required for the arrays and their associated pitches.

Inverter
Since PV panels produce electricity in direct current (DC), but electricity is commonly required in alternating current (AC), an inverter is needed to host the change. Inverters of PV installations come in small boxes of around 0.6m x 0.4m x 0.4m and are often mounted below the arrays.

Transformer
The AC electricity coming from the multiple inverters within a solar field needs to be adjusted to join the regular electricity grid. Transformers can often be recognised as concrete blocks sized around 2m x 1.5m x 1.5m, that are positioned near roads. Though transformers exist with various capacities, they are required in much lower quantities than the inverters.

A solar field can be divided into three levels, to discuss its components and taken measures; the PV system, the solar landscape, or the host landscape (see figure Term1).

The **PV system** describes the technical components of a solar field with its panels, arrays, framework structure and wiring. This category also includes the inverters and transformers.

The **solar landscape** describes the whole piece of land that is considered in the design. It includes the PV system and grounds it with several spatial components and a layout. It is important to note that the boundary of the solar landscape is not necessarily the location of a fence or the edge of the used parcel.
Furthermore, the solar landscape is responsible for forming a reasonable transition to its wider context, the host landscape.

The **host landscape** describes everything around the solar field, including spatial, social, and ecological structures that are relevant for the solar landscape.

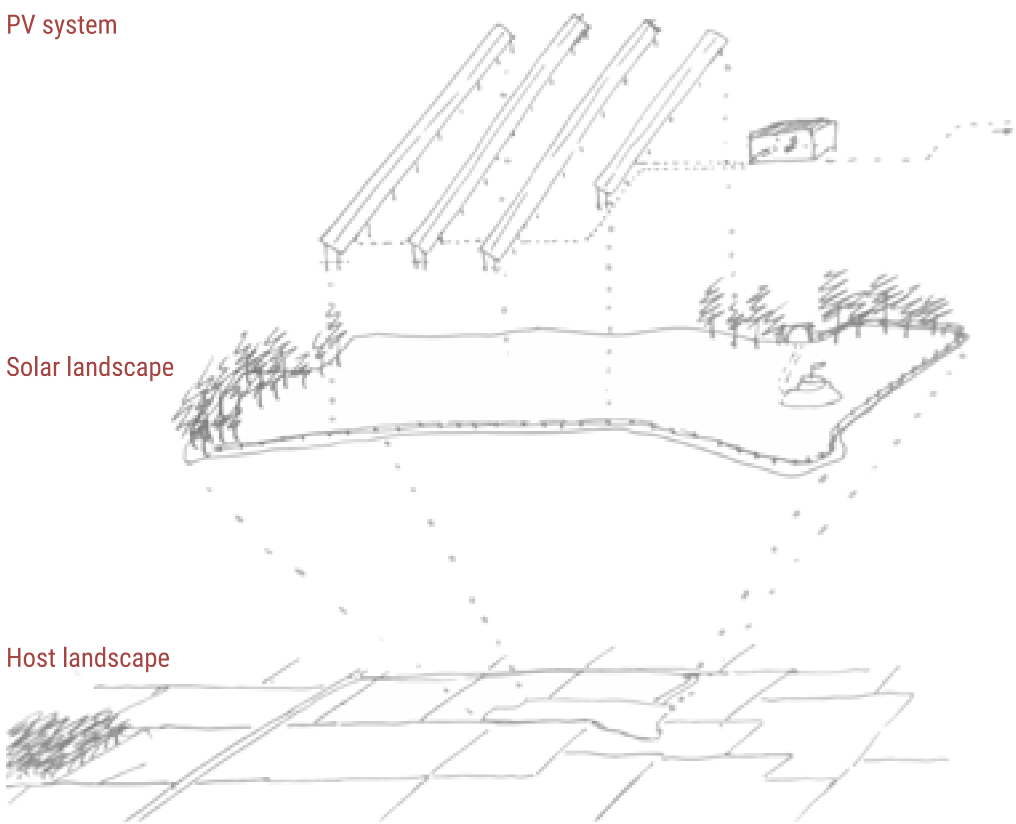

Figure Term.1: Visualisation of PV system, solar landscape and host landscape

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Figure 1.1: Landfill Mastwijk (Hofland, 1965)

Chapter 1
Introduction

1.1 Introduction

Europe demands a massive amount of electricity, and it is desired to be as green as possible and with emitted gasses kept to a minimum, to slow down the climate change we are experiencing. Agreements like the Paris climate agreements or the Dutch 'Klimaatakkoord' increase the pressure on developing green energy in the short term (Ministerie van Economische Zaken en Klimaat, 2018). One phenomenon resulting from this pressure is the propagation of solar fields in the open landscape. These solar fields can be established easy and fast, and due to their low height, they can be locally hidden, often reducing regional opposition as it can be found with wind turbines. However, it is essential to remark that the extent of protest is strongly dependent on the land that is used to establish the solar field, especially with agricultural land protests are arising in the Netherlands. Compared to solar installations on roofs, solar fields in a landscape demand fewer inverters, wiring and supporting structures to produce the same amount of electricity, leading to lower costs per MW installed (Van der Zee et al, 2019).

In Germany, many gigantic solar fields on former agricultural land have been implemented in the last decade. Due to their scale, these solar fields make a significant contribution to the total renewable energy produced in Europe. Still, to cover the total amount required electricity with solar fields, a considerably higher amount of open areas would have to be filled with them, meaning a severe interference in the landscape as we currently know it (Doolaard, 2017).

A compromise to avoid the decrease of landscape quality, while providing more sustainable energy, is the implementation of multifunctional solar fields that enable to use their surface for nature development, recreation, or other functions as well. First examples of these multifunctional solar fields, especially those combining with nature, can already be found. However, they are only scratching on the surface and miss out on many possibilities.

To enhance the quality and detailing of multifunctional solar fields, Natuur & Milieu Federaties (NMF) invented the concept of *EnergyGardens*, where providing electricity, recreation, education, and nature development go hand in hand. By implementing these EnergyGardens, scarce space is increasing its value, and the public support, which is essential to reach the climate goals, is likely to increase (Sütterlin & Siegrist, 2017).

The results of this research are translated into the design of the first EnergyGarden, measuring 21 hectare, on a former landfill at the Dutch polder Mastwijk (see figure 1.1.1).

This thesis is not meant to discuss priorities that should be assigned to the respective land uses, but it is intended to point out design approaches for multifunctional land use in EnergyGardens that support the Dutch climate goals. To bypass the conflict between the production of electricity and food, this thesis will only discuss the establishment of EnergyGardens on brownfields that are not suitable for agriculture.

1.2 Problem statement

As mentioned before, a large amount of solar surface needs to be implemented in the Netherlands to meet the requirements of the *Klimaatakkoord* in 2030 and 2050, and since using the built-up area is not enough with the current technologies, solar panels in the landscape are inevitable (Zeehandelaar, 2019).

For the majority of currently developed solar fields, the interaction with its surrounding stops at a standardized industry fence, while it is known that solar fields can provide space for many additional functions (Van der Zee et al, 2019). If treating of landscapes continues this way, the decrease of landscape quality is undeniable, and the increasing reluctance of residents is a reasonable response.


Figure 1.1.1: Bird view on former landfill Mastwijk located in the polder (Afvalzorg, 2019)

1.3 Knowledge gap

Regarding the technical requirements of PV systems and the possibilities to increase biodiversity around them, previous research is done. Likewise, on the experience and design of parks and gardens, a lot of literature exists. The knowledge gap lies thus in the responsible combination of these three components into EnergyGardens that set a new standard for multifunctional solar fields (see figure 1.3.1).

Habitat development in solar fields

In the past decades, ecologists have done a lot of research on habitat needs of native insects and birds, and how these can be stimulated on parcels that are in use for solar fields. While research results differ, the overall conclusion is that biodiversity can be improved within solar fields, offering a sound basis for further research to support the design.

Economic & technical requirements

Because of the economic pressure, there is a reasonable amount of research done to increase the efficiency of solar panels in a field, including angle, height and the size of a field for economic feasibility. This information is helpful to experiment with the balance between solar panels and other functions, but also to stretch the technical manners of installing the panels.

Experience of gardens and parks

The extended development of gardens led to a wide range of insights on how the experience of parks and gardens can be improved. Even though EnergyGardens differ from known gardens, design guidelines on perception can be extrapolated to support the design process.

In the case of the Dutch polder Mastwijk, the knowledge also comprises the geography, demography, local history, and local nature, creating a more detailed and tailored example of an EnergyGarden.

1.4 Research question

This research aims to expedite the development of multifunctional EnergyGardens in Western and Central Europe, to improve their appearance in the landscape and to broaden public support. Previous designs of solar fields are evaluated, and aspects of these designs are tested in a Dutch case study.

The general research question of this thesis is:

General research question:
Which spatial guidelines of multifunctional solar fields and garden design are relevant for the design of an EnergyGarden in the Dutch polder Mastwijk?

It will be answered by addressing two specific research questions:

Research question 1:
Which guidelines and spatial components that help to realize an EnergyGarden can be retrieved from

a. Four implemented multifunctional cases in Europe?

b. Scientific literature on multifunctional solar fields?

Research question 2:
Which garden design guidelines on spatial layout and integration into the landscape are relevant for an EnergyGarden?

Knowledge question 1:
Which geographical, demographical, or historical factors influence the design of the EnergyGarden Mastwijk?

Knowledge question 2:
What kind of EnergyGarden is desired by the local stakeholders of Mastwijk?

Design question:
How to apply these design guidelines in the polder Mastwijk, considering the desires of local stakeholders and the identity of the site and its surroundings?

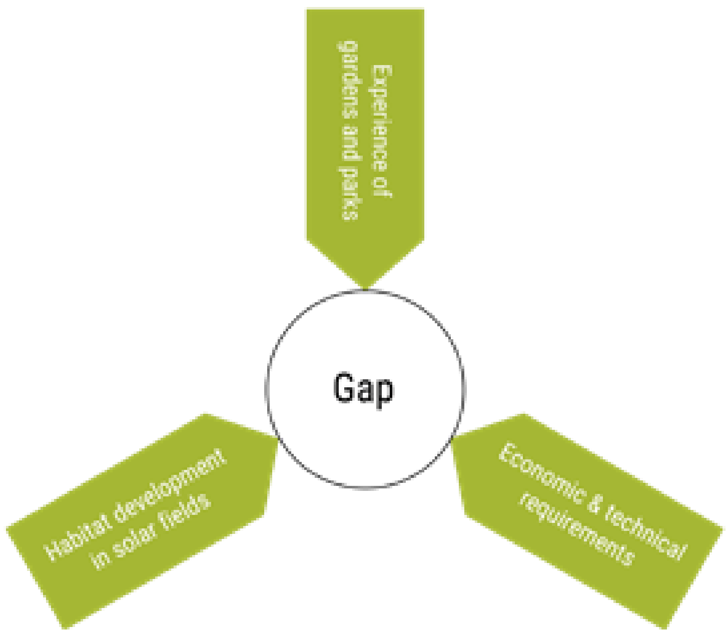


Figure 1.3.1: Defined knowledge gap

1.5 Research design

To gain knowledge on the spatial and technical layout, as well as strengths and weaknesses of implemented multifunctional solar fields, a literature study and site visits were conducted, in order to answer research question 1a and 1b. The site visits, including discussions with stakeholders involved in multifunctional solar fields, formed the basis for the analysis of four relevant multifunctional solar fields.

The analysis of the four cases was conducted utilizing a map analysis after Stremke & Schöbel (2018), in which mainly the layout of the PV system and solar landscape plays a significant role. In using subcategories, it enables to look at multiple components of the system in a detailed way and to compare design choices between the four cases.
The literature study, site visits and talks with stakeholders were parallel executed to gather information on the development of biodiversity in combination with solar fields. The expertise of various scientific sources resulted in several guidelines that were extrapolated to serve the concept of EnergyGardens.

For research question 2, an extended literature research was conducted on design guidelines of gardens, that can be relevant for the concept of EnergyGardens. This method was expedient since it enables to find information compiled over several decades in which parks were designed, improved, and maintained. The literature review is meant to find a broad selection of relevant guidelines, rather than detailed information on how to implement them. This was relevant since the garden design guidelines were be matched with the guidelines found in research question one before they can be applied. A matching step that also included the information of knowledge question 1 and 2 evaluates if the guideline fits the EnergyGarden Mastwijk. The joining step was done before the design, in chapter 7 where all information was gathered in a guideline evaluation matrix.

Knowledge question 1 focussed on the site and its context, including the landscape typology, the residents, and history of the place. The best way to get design-relevant information on this topic was an extended site analysis which includes observations during field visits at different days and times, the study of historical pictures, newspaper articles and books that deal with the region and its history.

The second knowledge question discusses the desires of the local stakeholders of Mastwijk and was crucial to develop a purposeful design for the case that is supported by residents and the municipality. The required input was obtained by actively joining participatory sessions organized at the location. These participatory sessions were not only held to get insights into the desires of local stakeholders but also to get feedback on design concepts for the project site. The group of participants consisted of approximately twenty locals and was relatively consistent for each session, making the participatory process stable and targeted. The whole participatory process consisted of more than ten sessions (until end May 2020), starting with the primary forming of ideas and desires, and developing towards a detailed design influenced by the participants.

The participatory process was not designed for this thesis, but it allowed to work towards a design that will be implemented. The results of this thesis shaped the participation process noticeable. In return, all input of the stakeholders was considered and implemented in the design, leading to extended design development.

As a subsequent step, the applicable guidelines of the guideline evaluation matrix were selected and translated into the specific design for Mastwijk. Together with two knowledge questions, the design question of this thesis can be answered by research through design by developing a tailored plan containing various reconsiderations and adjustments (see figure 1.5.1).

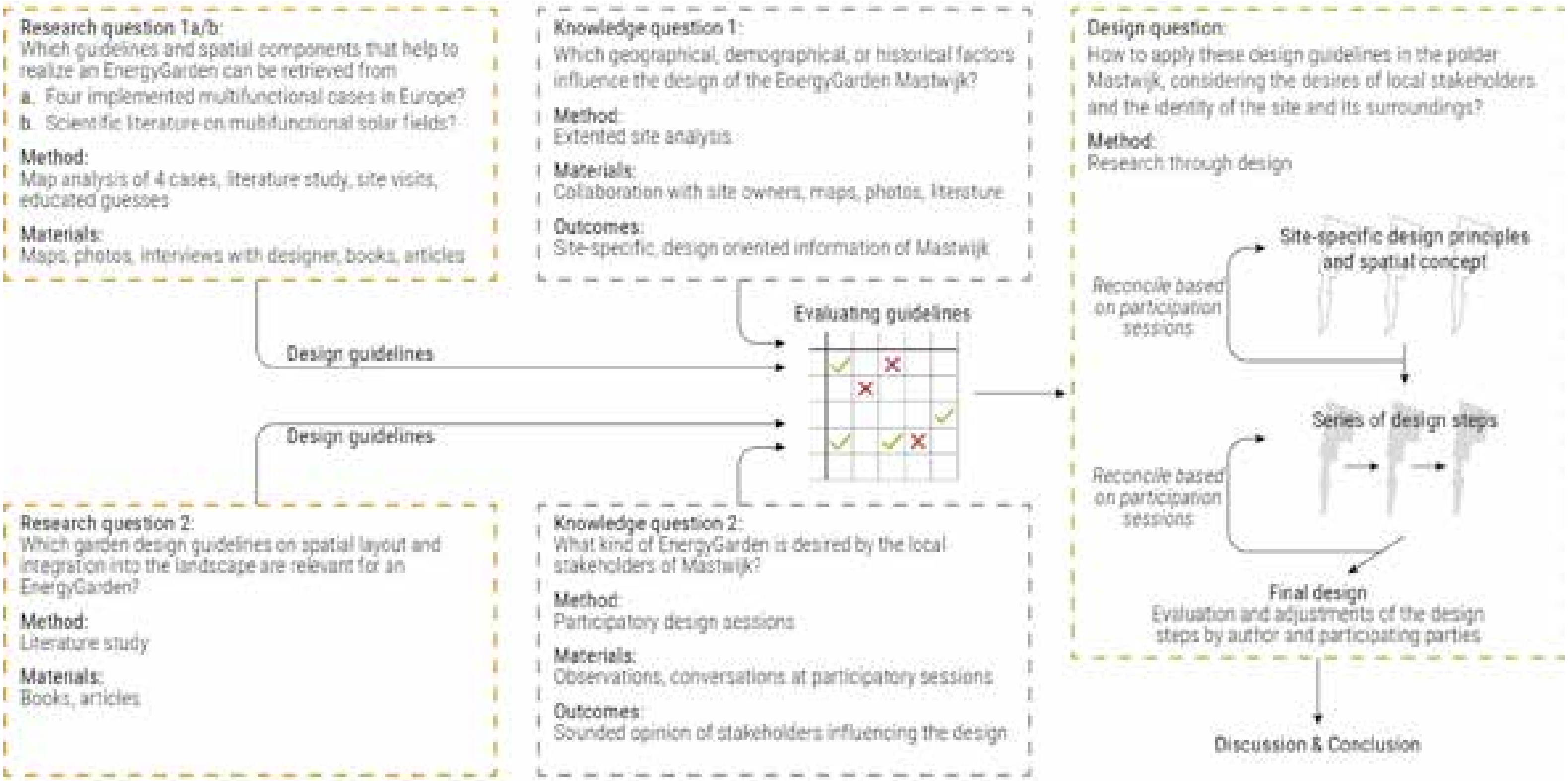


Figure 1.5.1: Research design

1.6 Methods

In this thesis various methods are used to work towards a final design for the EnergyGarden Mastwijk. This section is meant to give a short overview of the used methods per question mentioned in subchapter 1.4. The detailed approach is described in the respective chapter.

The project can be divided into two separate parts with the "research-for-design"-part as well as the "research-through-design"-part

While the former includes research question 1a/b and 2, as well as Knowledge question 1 and 2, the latter one comprises chapter 7 *Application of design guidelines* and chapter 8 *The Design*. While set apart in this chapter for clarity reasons, the two methods cannot be separated and are constantly alternating.

Research question 1a

For researching design guidelines and spatial components of implemented multifunctional solar fields, an extended case study analysis was conducted, using the framework of Stremke & Schöbel (2018) on design considerations of a solar field. It was extended by the analysis of ecosystem services that are provided by the solar fields as an indicator for their multifunctionality.

The search for potentially relevant solar fields to be visited was done by entering solar field synonyms in combination with the four key words multifunction, recreation, education, biodiversity in the standard Google browser to reach out for non-scientific sources such as newspaper articles, websites etc. These keywords are relevant since they are described in the definition of EnergyGardens by NMF. Additional support was received from Dirk Oudes, a professional on research into multifunctional solar fields, who was able to reference relevant examples and helped in the evaluation of potential solar fields.

Supplementary input was received from Helmut Wartner from Wartner & Zeitzler Landschaftsarchitekten, a company that was involved in the designing process of several multifunctional solar fields.

Between the many solar fields that offered additional functions and were found in scientific literature, articles, or on websites of energy cooperations, six relevant fields were chosen to be visited. At a second look, four of the multifunctional solar fields were chosen to be analysed in detail.

Research question 1b

To support the findings of RQ1a with scientific sources and to broaden the knowledge on current trends of the solar business a literature review was conducted, using the extended search function of Google Scholar with the following search terms:

Multifunctional AND "solar field" OR "solar park" OR "PV park"

Recreation AND "solar field" OR "solar park" OR "PV park"

Biodiversity AND "solar field" OR "solar park" OR "PV park"

Education AND "solar field" OR "solar park" OR "PV park"

The choice for the terms 'recreation', 'biodiversity' and 'education' were made since those are explicitly mentioned in the definition of an EnergyGarden (section 2.1) and were expected to be most common in combination with a PV system. Afterwards, the same setup was repeated in Dutch and German language to include international results that are more tailored to Central and Western European landscape types.

Since most relevant results were found for the search term 'biodiversity', a snowballing strategy was conducted to identify more relevant scientific sources within this scope.

Research question 2

Since there is no such thing as an EnergyGarden in the extended world of garden design, scientific literature on three different perspectives towards garden design was reviewed. The definition by NMF can be broken down into three views within the park and garden architecture:

1. The traditional garden architecture, with centuries of development on spatial quality, microclimatic comfort, and landscape experience.

2. The concept of performative landscapes, which not only evolve intending to please the human experience but to serve a higher goal, e.g. the energy transition.

3. Community gardens, with their focus on collective achievement and conservation, while reinforcing social cohesion within a group, village, or district.

To keep this chapter concise, the extended description of how the literature for the three perspectives was detected, is moved to chapter 4.2.

Knowledge question 1

For the site analysis of Mastwijk`s no specific method was used while relying on studying maps, photos and newspaper articles. Furthermore, the book "Linten in de leegte", which was published on behalf of the municipality Montfoort, was read which revealed a lot of information on the landscape typology and its historical context. Site-specific information on the parcel and its components was received in multiple conversations with representatives of the owning company Afvalzorg.

Knowledge question 2

For the participative process, an iterative learning method was used, which includes the close connection of actions to the feedback received (Salter, Robinson, Wiek, 2010). For the participatory process, it means that approaches to sessions, as well as the provided materials, were continuously adjusted to fit the demands of the participants and to find tailored ways to communicate with the group.

The theoretical framework explains the essential concepts of this thesis, to define the scope clearly and to provide the reader with the required information to understand the research and design results.

First, the previously named EnergyGarden is defined, followed by the terms *nature development* and *extensive recreation* which are part of the EnergyGarden definition. Finally, to support the understanding of this thesis, the concepts of ecosystem services and design considerations of solar fields are explained.

2.1 EnergyGarden (Energietuinen)

The concept of the EnergyGarden was recently invented by Nature & Environment Federation Netherlands (NMF). It builds upon the transition towards multifunctional solar fields as it can be recognised in Europe lately, with solar field De Kwekerij at Hengelo (GLD) as the most prominent example within the Netherlands. NMF is planning to develop three EnergyGardens with Mastwijk being one of the pilots to be developed.

The ambitions for EnergyGardens are high, but it is self-evident that the developed quality depends on various factors. Furthermore, not all goals can be achieved at all locations. Determining factors can be the participation of residents and companies, as well as the will of landowners and developers to allocate expenses to the development of nature and other functions instead of gaining increased profits from the PV installation.

NMF defines an EnergyGarden as:
"An accessible site for everyone, on which renewable energy is harvested in a sustainable manner. This happens in combination with other functions such as nature development and recreation. These elements are combined in a[n] […] innovative integral design for a landscape with high spatial quality. On the site education […] is provided about sustainable renewable energy and nature. Local inhabitants are involved in the development of the energy garden, they can participate in the (design)process and/or share in the ownership of the energy garden"
(Natuur en Milieufederaties, 2019).

While sufficient qualitative goals are mentioned within the definition, none of them are defined quantitatively, like, e.g. the percentual surface that needs to be allocated to other functions. This allows for stretching the definition of an EnergyGarden and diminishes the value of the term. Therefore, in chapters five and six, quantitative standards are defined, to add to the definition of EnergyGardens before starting the designing process for Mastwijk.

2.2 Nature development

Within the definition of EnergyGardens, the term *nature development* is mentioned as a potential function to be combined with renewable energy. Since the term nature development is used in various ways, it is defined for this thesis, using the definition of Baerselman and Vera (1995):

"A complex of human interventions in nature and the landscape and regulation of practical activities aimed at desirable ecological development".

These entities further divide this complex set into the implementation of new, or the restoration of former nature values inside an area of various scale. According to their definition, an area can either develop its own ecological system, or it contributes as a small part of a bigger ecosystem surrounding it. Often nature development is measured in terms of biodiversity of species which can be monitored and evaluated.

For solar fields research has been conducted on the ability to stimulate nature development, with most of the cases developing from former agricultural land use, featuring low biodiversity. But also, cases like former airports or military bases have been monitored in terms of nature development when turning into a solar field, with consistently significant improvements (Van der Zee et al, 2019). However, several authors alert that solar fields should not be implemented in nature reserves where the quality of nature is already high. Construction works, the limitation of sunlight, rainwater, natural fertiliser, and rigid maintenance, would most likely decrease the biodiversity within the solar field (Van der Zee et al, 2019; Raab, 2015). To stimulate nature development within the EnergyGarden, it will be crucial to look for native and local species and to promote species that are already existing within the area (Cesar et al, 2018). It is also advisable to research nature reserves and habitats in the surrounding that can potentially function as an overarching ecosystem, for the case (Baerselman & Vera, Hobbs & Norton, 1996).

2.3 Extensive recreation

In the definition of an EnergyGarden, the term *recreation* is noted, which can include all types of activities, with many of them not fitting a solar field and the other desired goals like development of nature. In combination with the location of Mastwijk and its peaceful and rural character, narrowing down the term recreation towards extensive recreation seems useful.

Extensive recreation means limited land use for recreation purposes in a mainly ecological environment. Activities include walking, running, fishing, and cycling, but also sitting in meadows, pick-nicking or exploring nature and its variety. Types of entertainment that are excluded are, e.g. intensive water sports, festivals, fairground rides or motor crossing. These types of recreation should be avoided since they conflict with sensitive solar installations and delicate species of flora and fauna that are supposed to develop in an EnergyGarden. In the broader sense, the concept of extensive recreation can be compared to ecotourism, which focusses on visitors that are satisfied by the nature of a place, rather than a unique attraction (Cater & Lowman, 1994).

Furthermore, attraction tourism can lead to large numbers of visitors (Innovatie Recreatie & Ruimte), leading to disturbance of the close-by residents in the environment of the EnergyGarden Mastwijk, which is not desired. The concept, thus, mainly focusses on the inclusion of local and sub-regional residents and not stimulating visitors coming from far away, often by car (Briedenhann & Wickens, 2004).

2.4 Ecosystem services

The concept of ecosystem services can be used to assess qualities provided by a landscape to the human being, in the case of this research, the qualities that are provided by multifunctional solar fields. The ecosystem services are divided into the three sections 'Provisioning', 'Regulation & Maintenance' and 'Cultural' which are all divided into biotic and abiotic systems. These sections are again divided into divisions, groups and classes, allowing a detailed overview of all services (Haines-Young, Potschin, 2018). Ecosystem services can be classified and reported with, inter alia, the Common International Classification of Ecosystem Services (CICES), giving the user the ability to compare the ecosystem services of various landscapes. For this research, the CICES V5.1 version is used, which was published in 2018 and had multiple improvements compared to its previous versions.

The framework is mainly used in the comparing process of four solar fields in chapter 4, to get a more in-depth insight in provided functions. After classifying inputs of the four different solar fields into the CICES, it is possible to compare them and evaluate how these are provided by means of design. The extent of the functions, however, is not analysed in the CICES framework, which requires a critical reflection on the value that the added functions offer. It is also crucial to note that the ecosystem service mapping for the solar fields only discusses functions that are intended by the design of the solar field and are identifiable in the current situation. Ecosystem services that are provided by every parcel of vegetation are not considered, in order to maintain a clear focus on the added values of the solar fields.

2.5 Design considerations of solar fields

Since the PV system is a crucial part of the EnergyGarden and likely to take in a significant part of the surface, it must be designed very carefully. Existing multifunctional solar fields offer relevant input that can be extracted and reused. The design considerations of solar fields after Stremke & Schöbel (2018), in which mainly the layout of the system plays a significant role, can be utilised to do that. While in the literature the analysis is divided into eight subcategories (shape, size, orientation, physical distance, visual distance, protection, the transition to landscape, and colour), for this thesis it was reshuffled into five categories. This allows a more straightforward overview and comparison between different solar fields possible to a higher degree. The five new categories, and their indicators are shown below (figure 2.5.1). The detailed description of content analysed per category is described in the method section of chapter 4, right before the concept is applied.

While this method is incorporated to analyse the four existing solar fields in chapter 4, it is also utilised in the decision making during the design process of the EnergyGarden of Mastwijk and plays a significant role throughout the whole thesis.

1. Spatial characteristics of PV system
- Orientation
- Colour
- Height, width, angle, shadow

2. Visibility & screening
- Protection
- Ratio open and closed from edge and landscape user

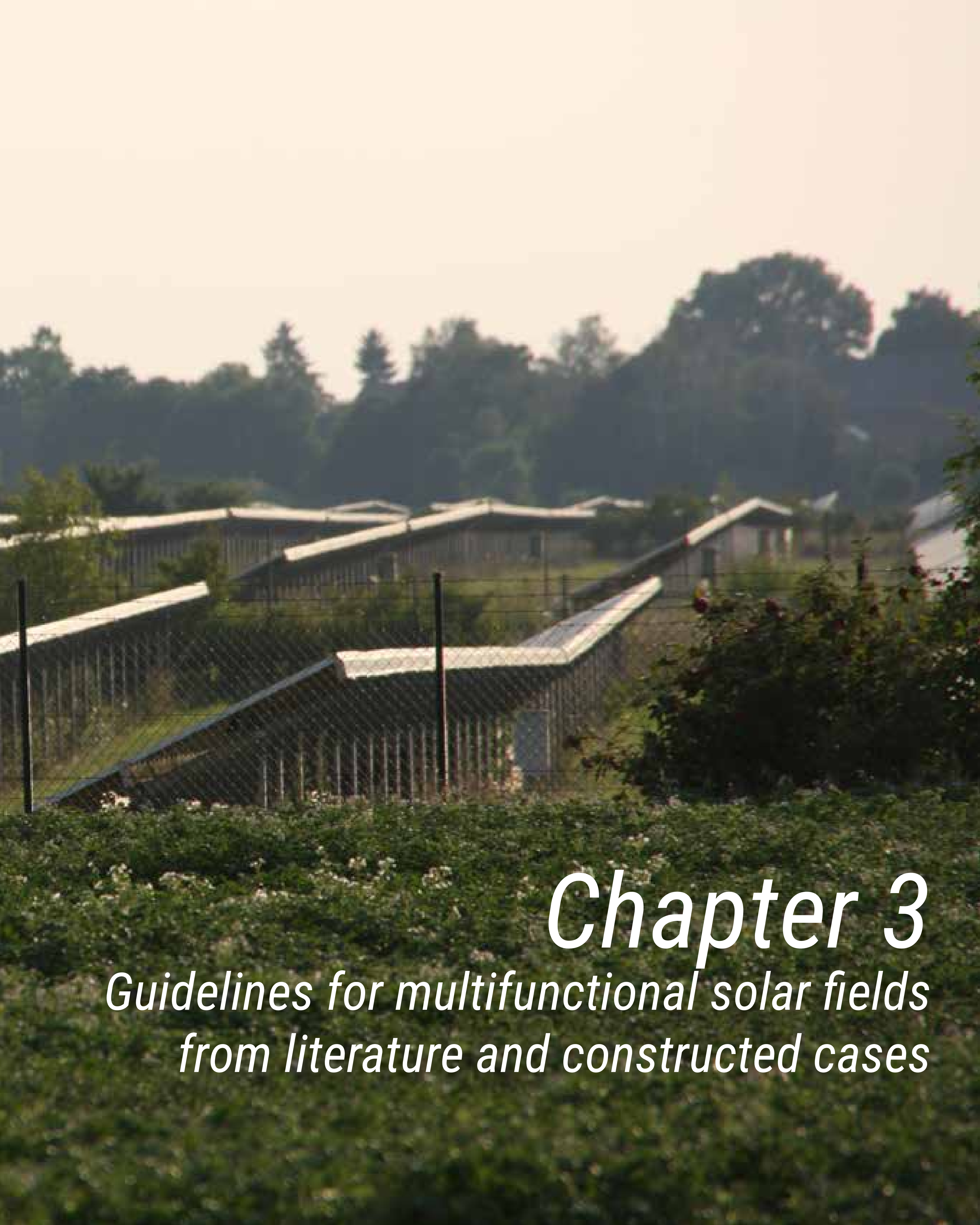
3. Parcel size vs. patch size
- Parcel shape and size
- Parcel border

4. Transition landscape
- Transition to surrounding
- Transition through time

5. Multifunctionality
- Division of added functions

Figure 2.5.1: New categorization of design considerations for solar fields

Figure 3.1: Solar field Gänsdorf



Chapter 3

Guidelines for multifunctional solar fields from literature and constructed cases

3.1 Introduction

As a starting point towards the design of an EnergyGarden for Mastwijk, four multifunctional solar fields in Western Europe were analysed, to get an insight in best practices and pitfalls that need to be circuited.
Scientific literature was used to explore current trends of the solar business, new potentials and to follow on leads that were discovered during the site visits.
In sub-chapter 3.2, the four cases are described, and it is explained how the analysis is structured.

In chapter 3.2.2 the case of Neukirchen-Vluyn is analysed exemplary, to illustrate how results were formed from the case studies. The analysis of the other three cases was shifted to appendix A, due to space limitations of this report.

The most crucial numbers and findings of the four analysed solar fields are cumulated in a case comparison matrix, that allows to compare the four cases directly and to create conclusions that lay the basis for designing the EnergyGarden of Mastwijk. This matrix is followed by a short conclusion on the research question 1a, before continuing with the literature review of question 1b in sub-chapter 3.3.

The chapter is concluded with a series of visualized and explained design guidelines that are relevant for the design of an EnergyGarden, answering the question:

Which guidelines and spatial components that fit the definition of an EnergyGarden can be retrieved from

a. Four implemented multifunctional cases in Europe?

b. Scientific literature on multifunctional solar fields?

These design guidelines will support the design process for Mastwijk described in chapter 7.

3.2 Case study analysis

After visiting six multifunctional solar fields, the cases of Hemau, Hengelo, Neukirchen-Vluyn and Gänsdorf were chosen to deliver most relevant insights regarding their spatial layout and featured functions, which makes it valuable to analyse these cases in detail.

Below a short overview of each field is given, including location, size, and its unique characteristics.

Hemau, Germany

The solar field of Hemau is the oldest one visited, and its reaction to a shortage of materials during that time leads to interesting effects. It was developed from a military brownfield and contains exciting development of biodiversity and small-scale agriculture.

17.2ha 4MWp 2002

Figure 3.2.1: Solar field Hemau (Oudes, 2019)

Hengelo (GLD), the Netherlands

The entirely accessible solar field of Hengelo is the only one located in urban adjacency and is by far the smallest one. It comes closest to the definition of an EnergyGarden by combining recreation, education, and nature development successfully.

7.1ha 2MWp 2016

Figure 3.2.2: Solar field Hengelo

Neukirchen-Vluyn, Germany

The solar field at Neukirchen-Vluyn features recreational and educational functions, but its strength is the development of various habitats to increase biodiversity. These are joint with the PV system, leading to better use of the surface available.

24.4ha 3.5MWp 2013

Figure 3.2.3: Solar field Neukirchen-Vluyn

Gänsdorf, Germany

The solar field of Gänsdorf is the largest one that was visited and required interventions on a whole other scale. Still, the used design measures are of relevance to smaller fields. Especially on nature development and visibility, this case is a good example.

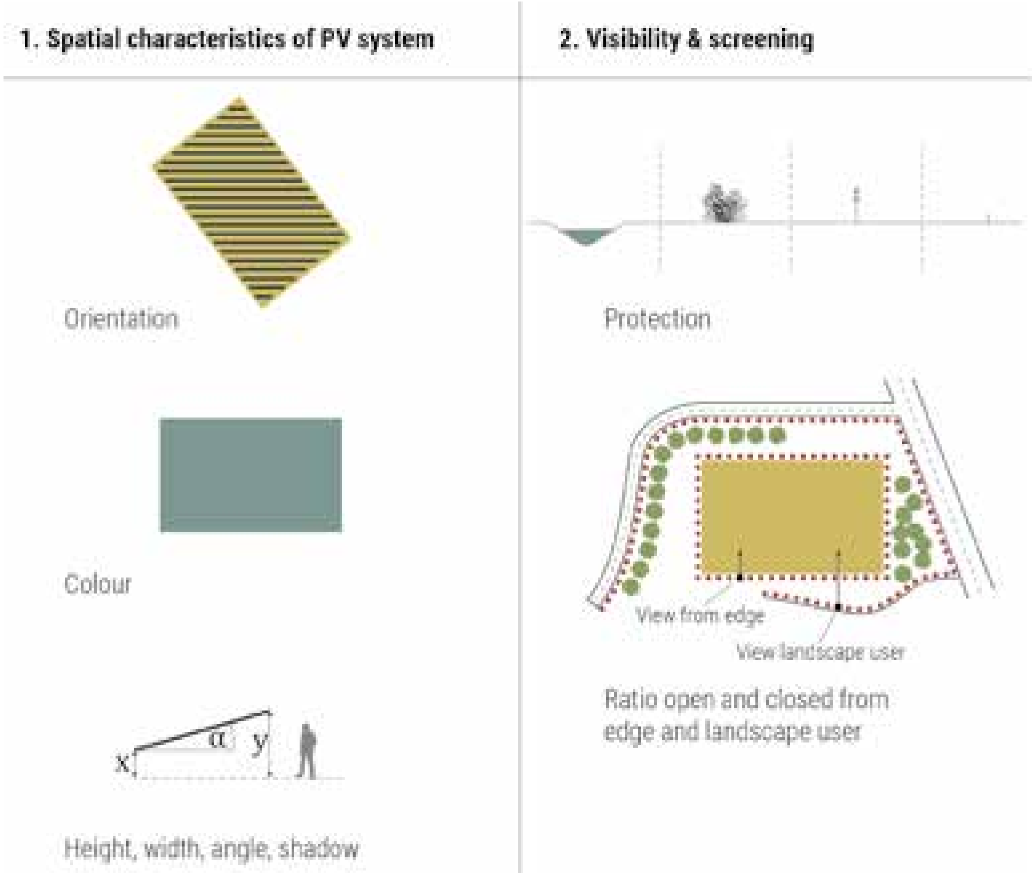
180.9ha 54MWp 2009

Figure 3.2.4: Solar field Gänsdorf

3.2.1 Detailed analysis method for case study

Hemau, Hengelo and Neukirchen-Vluyn were, at least partially, brownfields with existing structures from previous land use and already developed nature, leading to limited options for further development. Gänsdorf was built on high qualitative agricultural soils, making its location is questionable, but still, the case contains many relevant design decisions. Regarding their scale, Hemau and Neukirchen-Vluyn come close to the site of Mastwijk, while Hengelo and Gänsdorf deviate a lot. However, the used method allows for putting aside the size of the solar field to a certain degree since it has only limited effects on design decisions regarding spatial layout or multifunctionality.

First, for each of the four solar fields, a more detailed description is given, and secondly each solar field is analysed based on five categories according to the design considerations of solar fields after Stremke & Schöbel (2018). As mentioned in chapter 2, these were slightly adjusted and reshuffled to fit the scope of this thesis and allow a more straight-forward overview of the four cases. On the right side, the categories, their purpose and content are described in general terms.



Spatial characteristics of PV system

This category contains the analysis of orientation, height, width and angle of arrays, the type and colour of panels, the pitch size, and the supporting infrastructure (i.e. inverters, transformers, substation) of the solar installation.

The cases are analysed and compared both on maps and on a section of their arrays. Additional photos give insight into the design of the arrays and the type and the colour of panels used.

Visibility & screening

This category contains the analysis on how landscape users can or cannot experience (parts of) the PV system and the solar landscape, and on measures that were taken to shield the view on the system. To analyse if measures were taken, a view analysis is done from the edge of the solar landscape, indicating measures along the edge and within the solar landscape. Additionally, existing shielding outside the solar landscape is investigated by analysing the view from the closest landscape users. If sufficient shielding is found outside the solar landscape, on-site measures may (partially) be unnecessary.

Sections that are provided in category *4.Transition landscape* can also be consulted to get a better understanding of the visibility and screening.

Since three of the four cases are not accessible to the public, this analysis focusses mainly on the view from outside the solar landscape. However, since this project works towards an accessible EnergyGarden, observations from inside the solar field play an essential role as well.

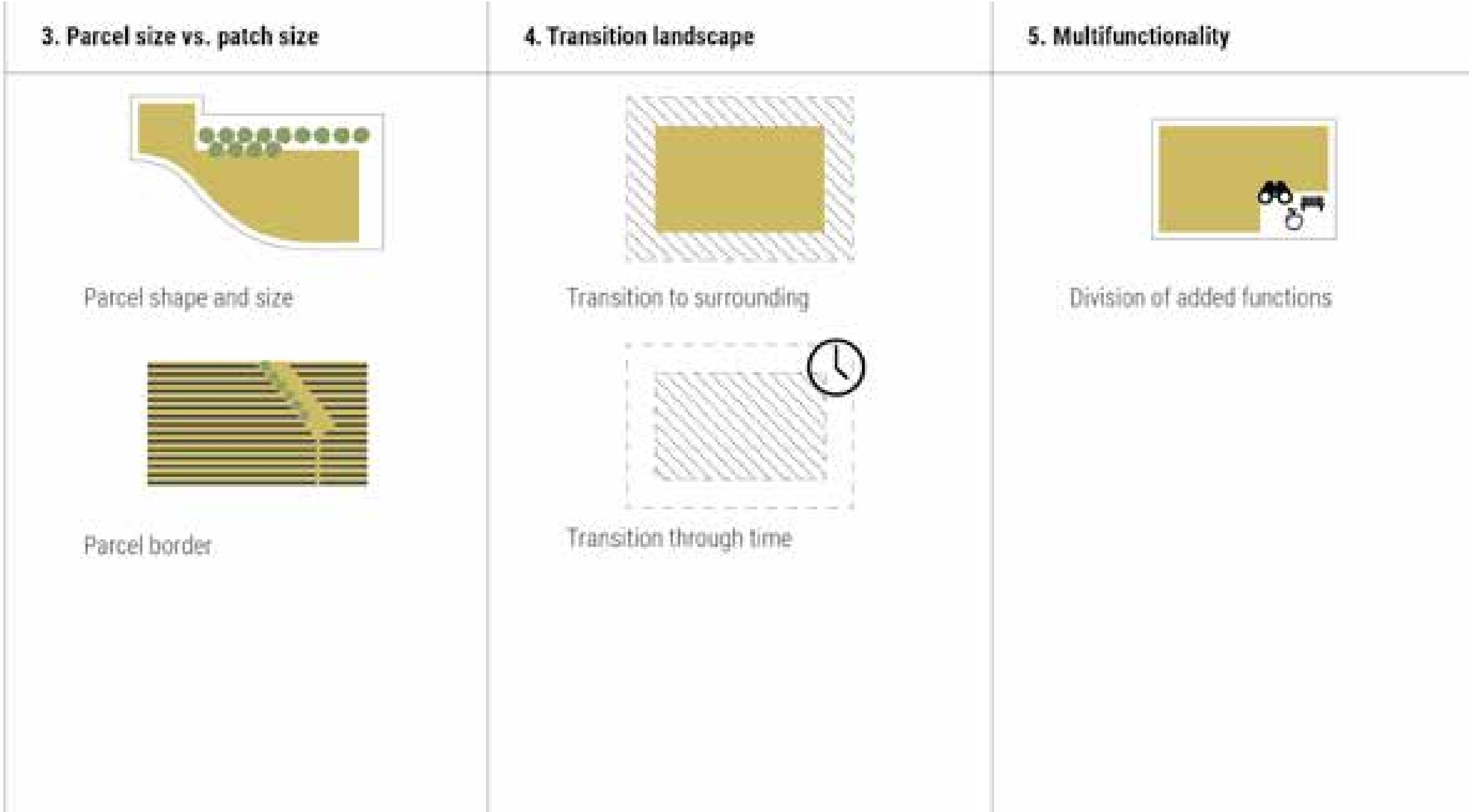


Figure 3.2.1.1: Design considerations of multifunctional solar fields. Based on Stremke & Ströbel (2018)

Parcel size vs patch size

This category is focussing on divisions within the PV system, leading to several patches, which can have various shapes. The patches are either shaped solely by technical aspects, like consistent array lengths, but can also interact with the parcel shape and existing nature on the terrain.

Often the division into patches allows the (potential) landscape user to move through the solar landscape, which makes it an essential aspect of research. Mostly the patches are made to allow maintenance staff to reach all parts of the system quickly, or to cluster an amount of power and connect it to one transformer.

Changes in parcel size and shape, as well as surfaces reserved for the PV system, are analysed within this category. Even though the analysis of parcel and patches can best be done on maps, the user experience, which is communicated by sections, plays a significant role as well.

Transition landscape

In this category, measures that are taken to integrate the solar landscape into the host landscape are analysed. This includes both beneficial measures to improve the relationship between the solar landscape and its surrounding, but also unfavourable measures like the extensive cutting of trees, which disrupts the landscape and diminishes the natural shielding of the PV system.

Furthermore, the transition over time is analysed to monitor both positive and negative changes that are connected to the implementation of the solar landscape and PV system.

The transition to the host landscape is shown in maps and sections that show the landscape and vegetation between the solar- and host landscape up to the closest landscape users. The indicated distances are meant to provide the magnitude of the respective edge.

Multifunctionality

This category analyses the various functions that the multifunctional solar landscape cases fulfil and the way they are allocated. It is researched where functions are placed, how they are interconnected, and how much space they got allocated compared to the parcel size. The provided functions are classified in ecosystem services and categorized according to the CICES 5.1 framework.

Next to the quantitative analysis, a qualitative judgement is executed on the value of each function. In that way, the results are less likely to be faded due to ticking-boxes policy of nature-friendly solar fields.

3.2.2 Case Neukirchen-Vluyn, Germany

The multifunctional solar field at Neukirchen-Vluyn was established in 2013 at a former gravel mining location. The 3.5MWp solar field can be recognised by the big lake in the middle that is embraced by solar panels.

Due to valuable nature development in the past, only 16.6ha of the 24.4ha of the parcel were developed as solar landscape. The existing nature was kept, and its development stimulated where possible (Schlothmann Landschaftsarchitekten, 2011). Within the solar landscape, new nature development was initiated for various species, for example, below the arrays of the PV system.

Only a minor part in the south of the solar landscape is accessible to the public, which features an elevated viewpoint and an energy trail (ENNI Solar, 2013). Furthermore, the solar landscape is connected to a regional bicycle network to attract visitors to the remote location. Although in my opinion in practice the recreational and educational functions offer a minimal amount of entertainment, the design was able to win several prices on its combination of PV, nature development, recreation, and education (Energie & Umwelt Niederrhein GmbH, 2015).

Figure 3.2.2.1: Impression of atmosphere at Neukirchen-Vluyn

Figure 3.2.2.2: Viewpoint and energy trail

Figure 3.2.2.3: Stimulated vegetation below arrays

Spatial characteristics of PV system

While the technical specifications of the PV system at the ENNI solar field are not exceptional, its layout is of great interest. The arrays are made of alloy frameworks and galvanised steel foundations are drilled into the ground like at Gänsdorf and Hengelo. The arrays are equipped with four horizontal rows, with all 14,600 panels in the same colour. All arrays are south oriented and have a height of 2.4m. In combination with a pitch size of 5.4m and the local azimuth angle, there is only a minimal shadow zone of 1.5° (see figure 4.5.6).

The inverters are placed below the arrays, and two transformers in standardised concrete blocks are located at the centre of the parcel, making them less visible to landscape users.

The layout of the solar field adapts to the existing landscape structure of the parcel and has an organic shape which embeds it better into the landscape. For that reason, almost all arrays have a different width.

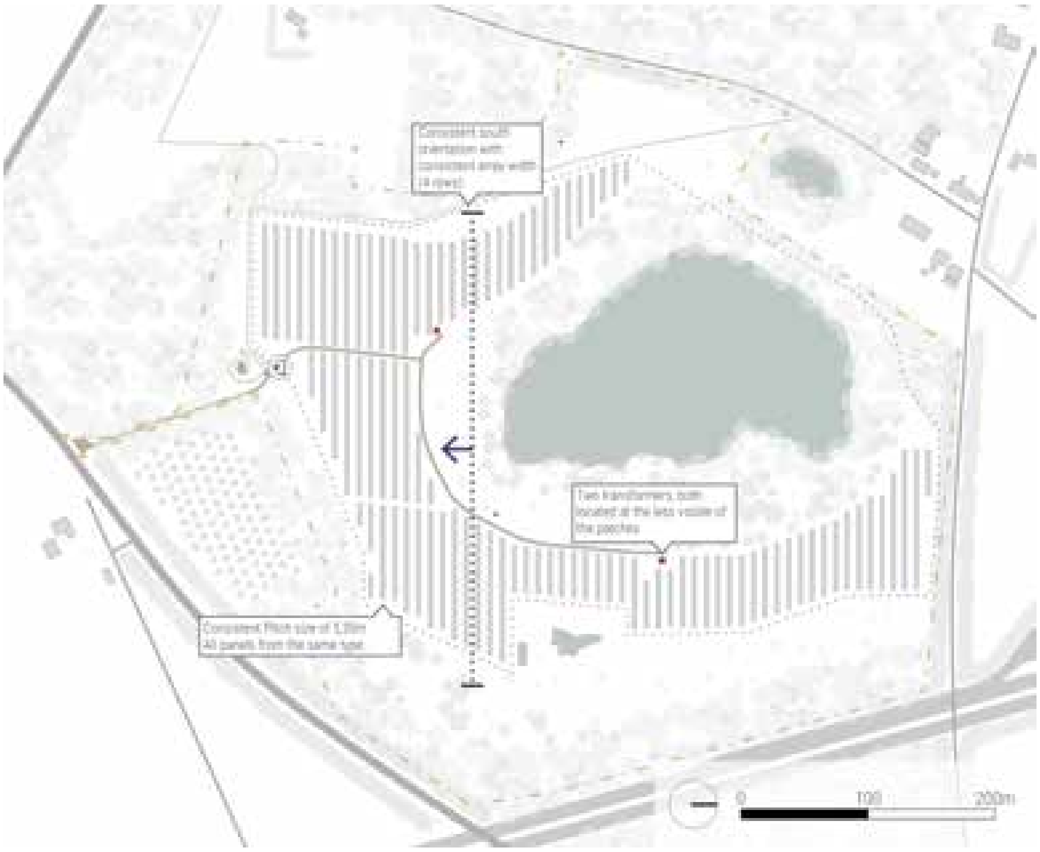


Figure 3.2.2.4: Map analysis, Spatial characteristics

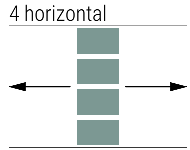


Figure 3.2.2.5: Schematic layout of arrays

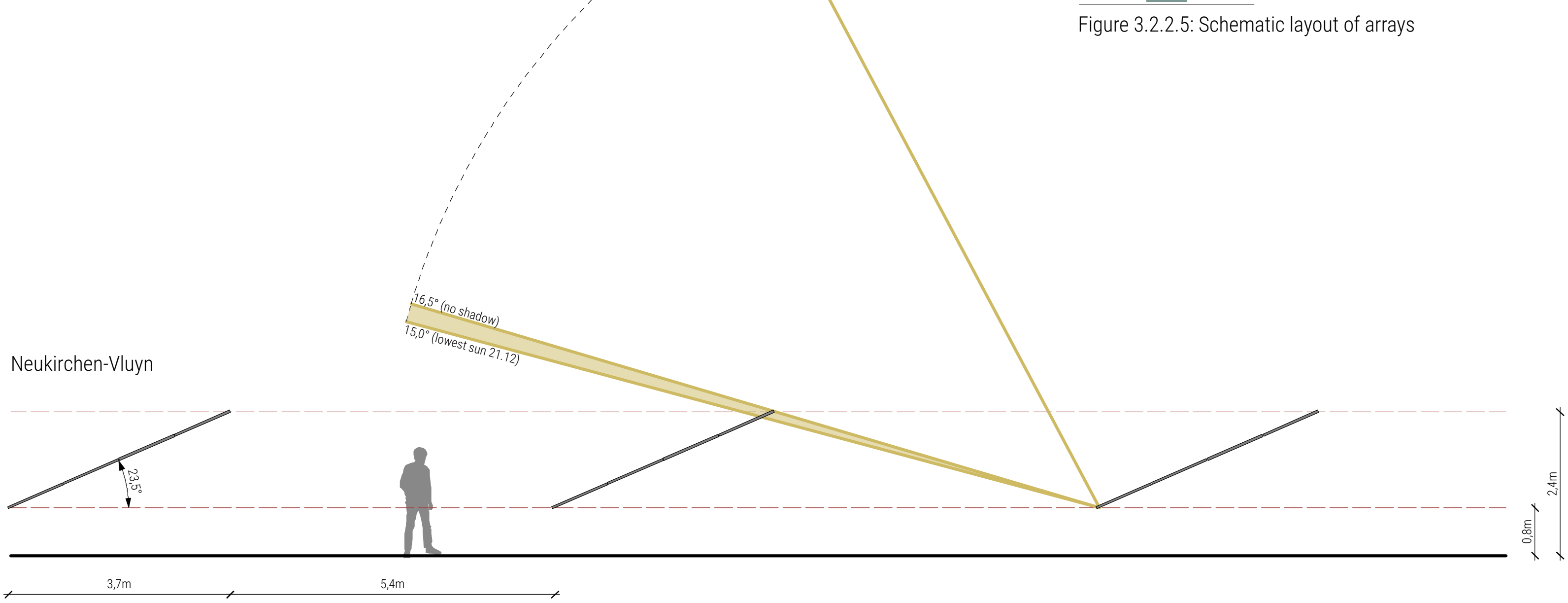


Figure 3.2.2.6: Section analysis, Spatial characteristics

Visibility & screening

The solar field at Neukirchen-Vluyn is surrounded by tree lanes and dense hedgerows which make the PV system almost invisible from the surrounding streets. The vegetation, however, was not planted for the solar field but was able to evolve there since the parcel was going out of use for gravel mining. At the east side, an additional sound barrier for the bordering highway hides the solar field.

The only designed path for landscape users is approaching from the south towards the elevated viewing point. Yet, during the field visit, mud paths were discovered between the village at the west and the southern road, going along the viewing point. Since these look regularly used and dog excrements along the trail were spotted, a route for walking dogs is likely. Even though the path was not designed (Schlothmann Landschaftsarchitekten, 2014), in the view analysis, it is handled as the closest position for landscape users to come to the solar field.

When analysing from this trail, hardly any measures to shield the PV system can be found, since only the fence is separating the landscape user from the system. No hedges are implemented, and in the pitch between the fence and the first panels the grass is kept low, and no shrubs are planted.

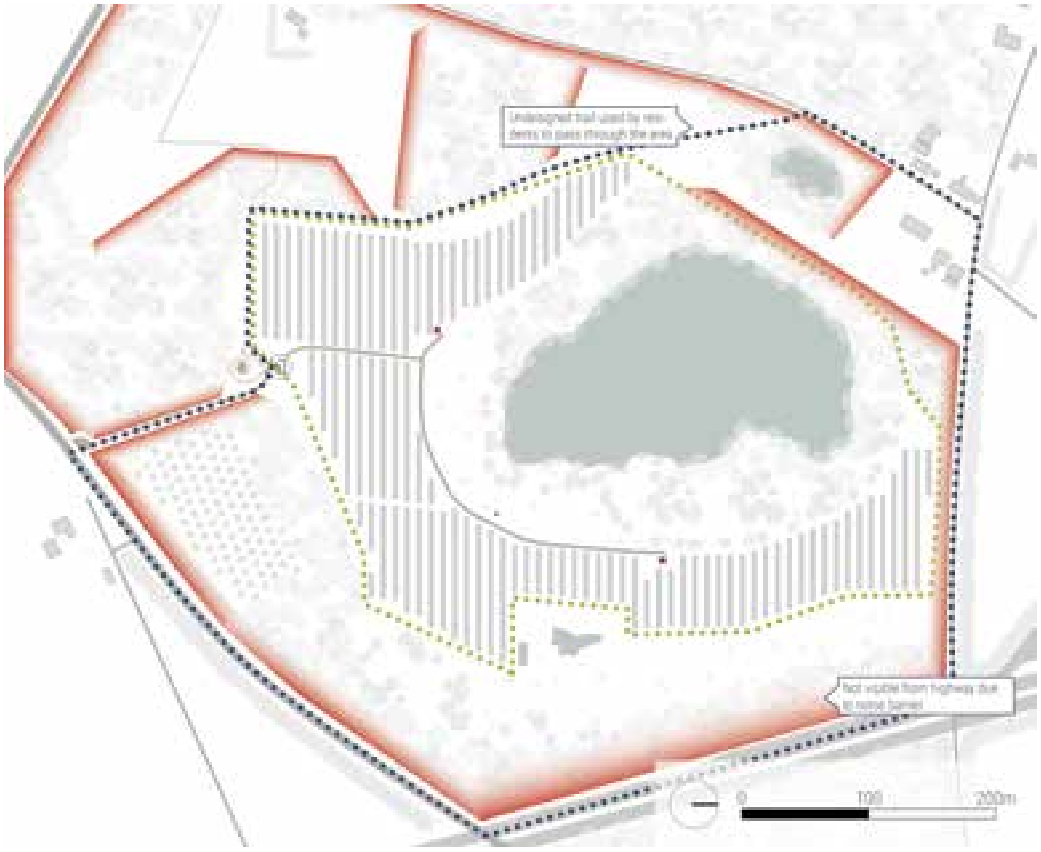


Figure 3.2.2.7: Map analysis, Visibility & Screening

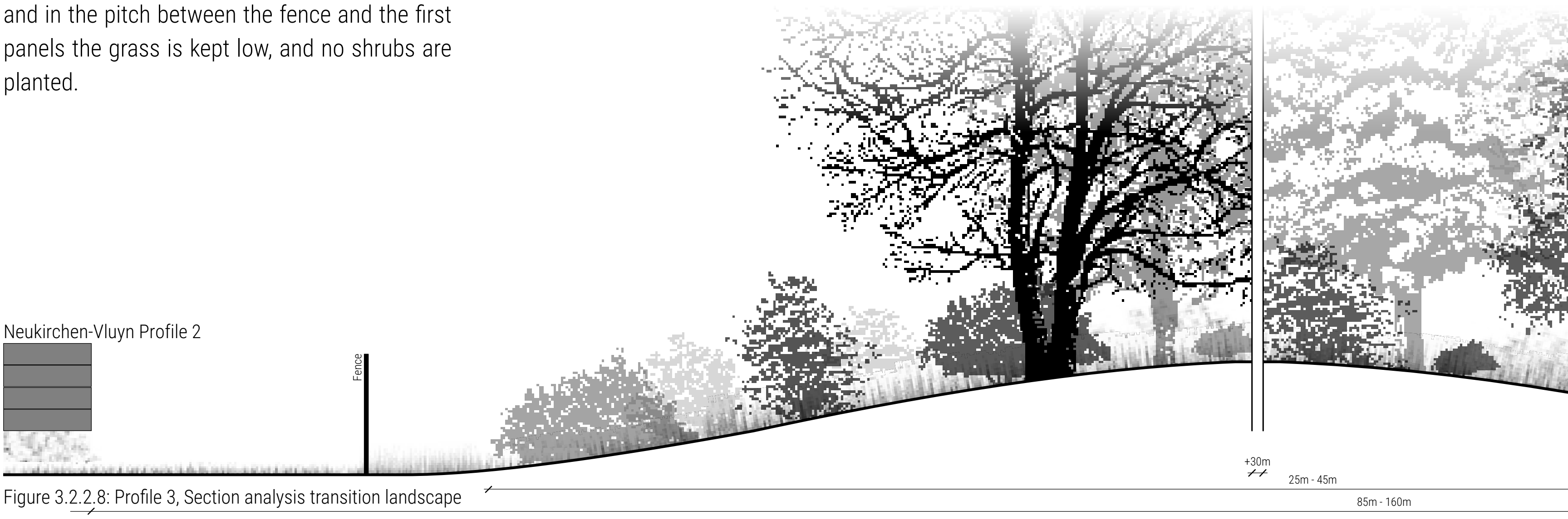


Figure 3.2.2.8: Profile 3, Section analysis transition landscape

From the elevated viewpoint in the south of the parcel, the visitor gets a better impression of the solar field size, but still, it cannot be overseen completely. The lake in the middle is entirely hidden by high vegetation, even in the winter. For a (potential) landscape user within the solar landscape, this central mass of vegetation provides a beneficial spatial division that gives the solar landscape a more human scale.

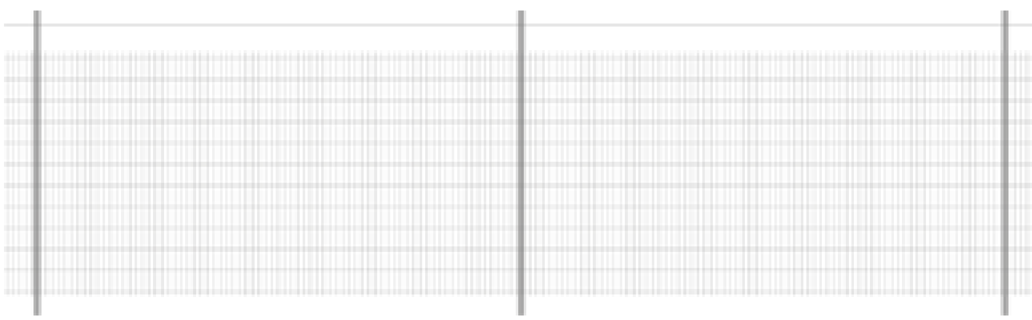


Figure 3.2.2.9: Fence type

Parcel size vs. patch size

The most striking aspect of the solar field is its huge parcel of 24.4ha compared to the small solar installation of only 5.8ha. This gives other functions (designed and not designed) more space on the parcel and contributes to a natural distance between the PV system and bordering parcels. Reasonably only the solar landscape, 16.6ha comprising the PV system and the lake, is fenced off, leaving the rest of the parcel accessible to visitors and especially wild animals that cannot trespass the fence. It stays unclear why the lake itself is fenced off, while it could be beneficial to various animals around the site. One reason for this decision could be saving costs for the fence since the required length is more than halved.

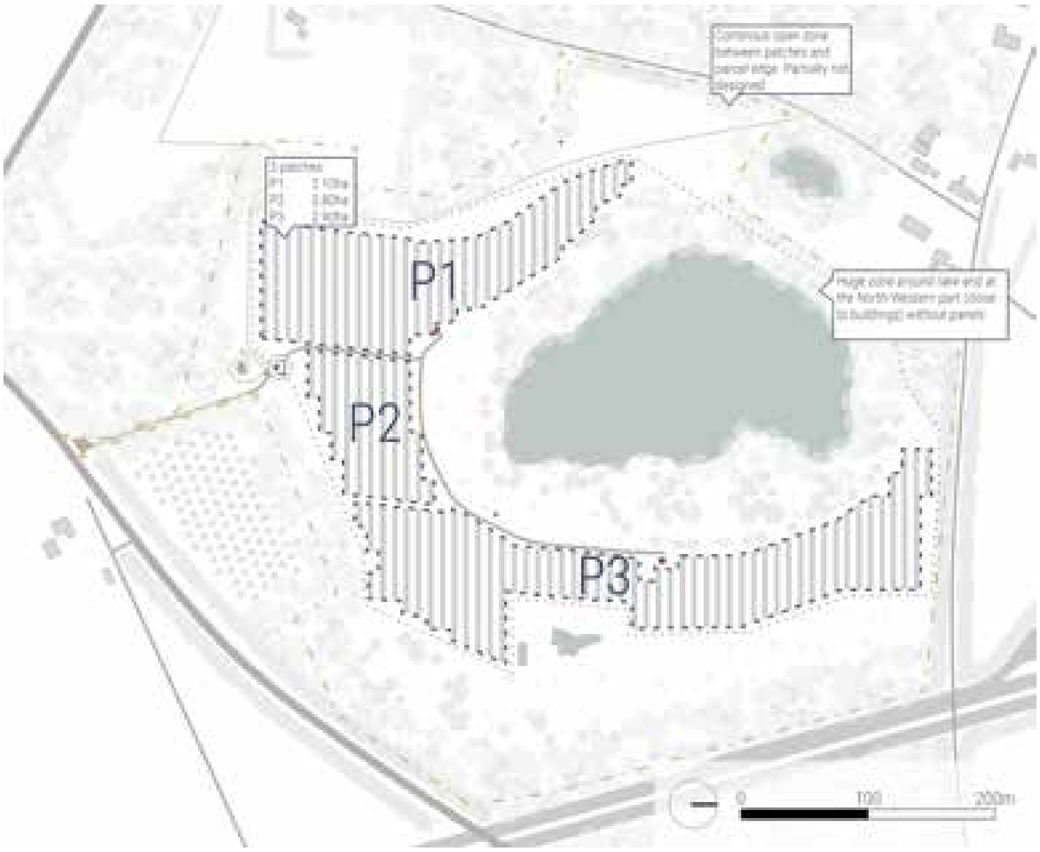


Figure 3.2.2.10: Map analysis, Parcel vs patch size

The PV system itself can be divided into three recognisable patches, while patch one and two computationally belong together regarding size and the transformer capacity. The patches are not spread through the parcel but are concentrated in a ring around the central lake. The patches are divided by small, unpaved maintenance paths of five to six and a half metres.

The vegetation around the lake is the only spatial division between the patches, along the maintenance road no vegetation was implemented. This can be traced back to the inaccessible site, which diminishes the use of border planting between patches.

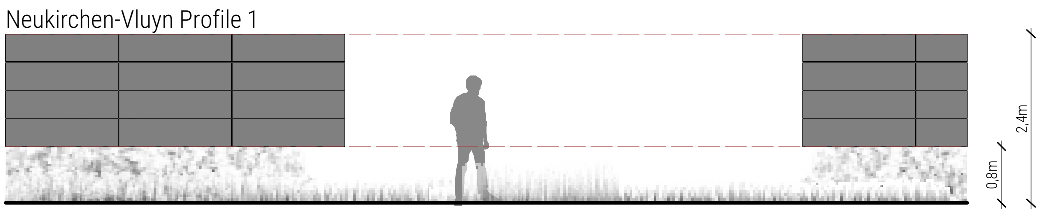
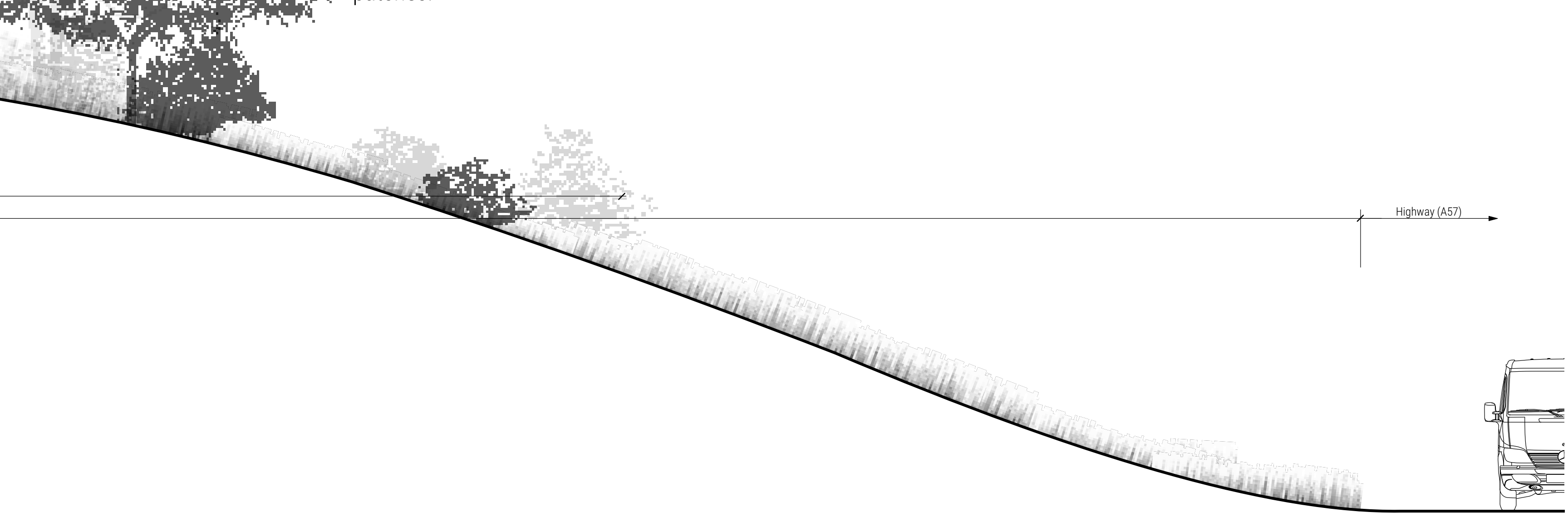


Figure 3.2.2.11: Profile 1, Section analysis patch border



Transition landscape

As mentioned before, the site was transformed from a gravel mining location that stopped processing, leaving a deep lake in the middle of the parcel. After the mining process, the area was unused for several years in which a wide range of wet habitat was formed. During that time the noise barrier in the east of the parcel was built, which lead to denser habitats (Schlothmann Landschaftsarchitekten, 2011), see profile 2.

When the solar field was built in 2013, most of the existing landscape structures were kept, with most recognisable the lake, the access road, and the widespread nature on the parcel. Since no buildings were left from the sand mining era, only the lake can transmit the former identity. Even though it is not buried, landscape users cannot access it, see it and its origin is not communicated, losing the history of the location.

There is no visual transition to the current surrounding since the solar field is surrounded by vegetation, as mentioned before. However, since the vegetation was not planted in for the solar field was established, it can be argued that it does not count as a measure of the design. Even though the visual barrier prevents local opposition, it also prevents a well-designed connection to the urban areas around. Regarding the amount of housing in the area and a potential urban extension, the natural solar landscape would have had great potential to become a suburban park in the future. The intensive mud paths on the parcel show that landscape users do want to use the parcel for local recreation purposes. However, the design does not promote them to do so.

A signposted branch of a regional bike path is approaching the solar field from the south, but due to a busy country road without bike- or foot-path, it is dangerous to reach the solar field form there.

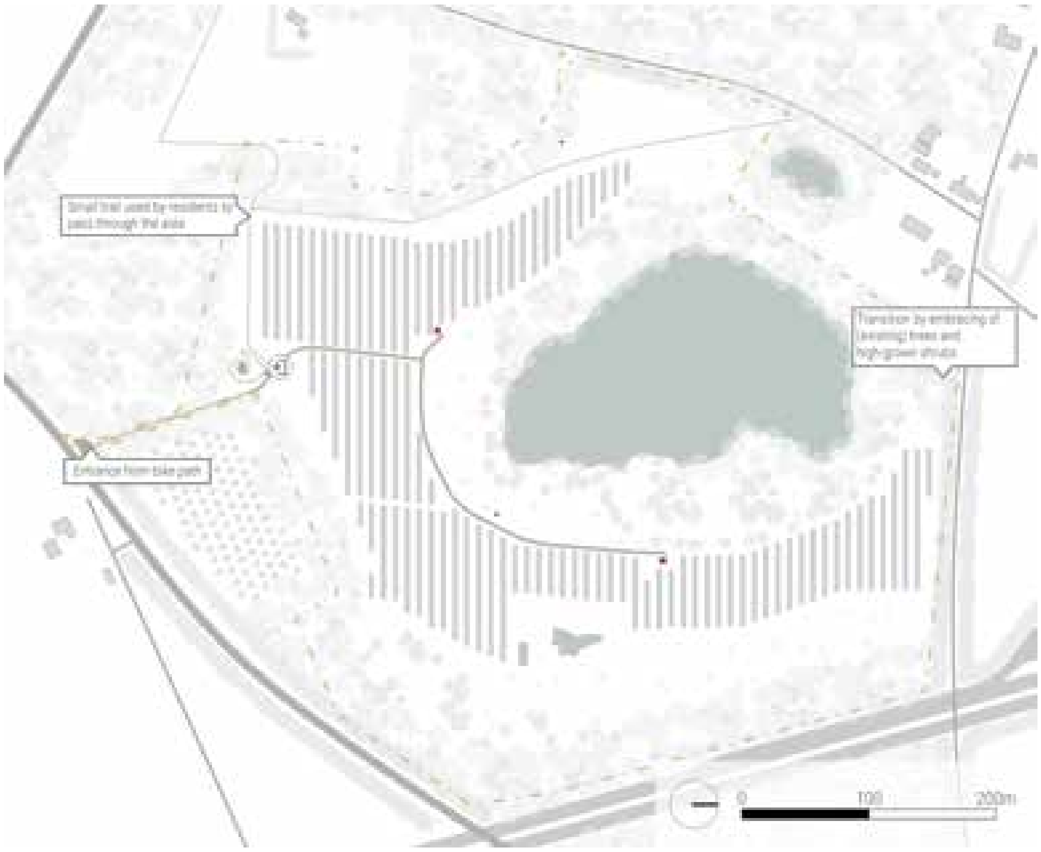


Figure 3.2.2.12: Map analysis, Transition landscape

Figure 3.2.2.13: View on historic windmill and stockpile from coal-mining era

Figure 3.2.2.14: Section analysis, Transition Profile 3

Multifunctionality

The most prominent function next to the provision of electricity is the improvement of nature at the ENNI solar field. Regarding surface and effort that was done during designing, nature benefited above-average compared to the other cases.

Extraordinary examples of the nature development are a pool for amphibians and a staged vegetation pattern below and between the arrays with different species and heights (see figure 3.2.2.3) (Schlothmann Landschaftsarchitekten, 2011). As seen before in other cases, also in Neukirchen-Vluyn the fence is elevated to allow small animals to pass inside the solar field. During site visits, various animal trails below the fence were found, certifying of a vigorous use of this measure. Outside the fence, the retained nature offers multiple spots for animals of all size to breed and hide all year round since landscape users do not come there. Excrements and tracks in the mud certify that roes have been on the parcel recently.

Another function that was not found at other solar fields is the implementation of perches on the parcel which allow hunting on wild animals. As shown on map, one is located next to the lake, and one in the west, outside the fence. Regarding the frequency of use, no further information was found.

Besides the measures to improve biodiversity on the parcel, also recreational and educational functions were implemented. The elevated viewpoint in the south of the parcel, which is also connected to a regional bike route, allows landscape users to see more of the PV system while also having a look onto an old windmill in the west and two large close by dumps from the coal-mining era.

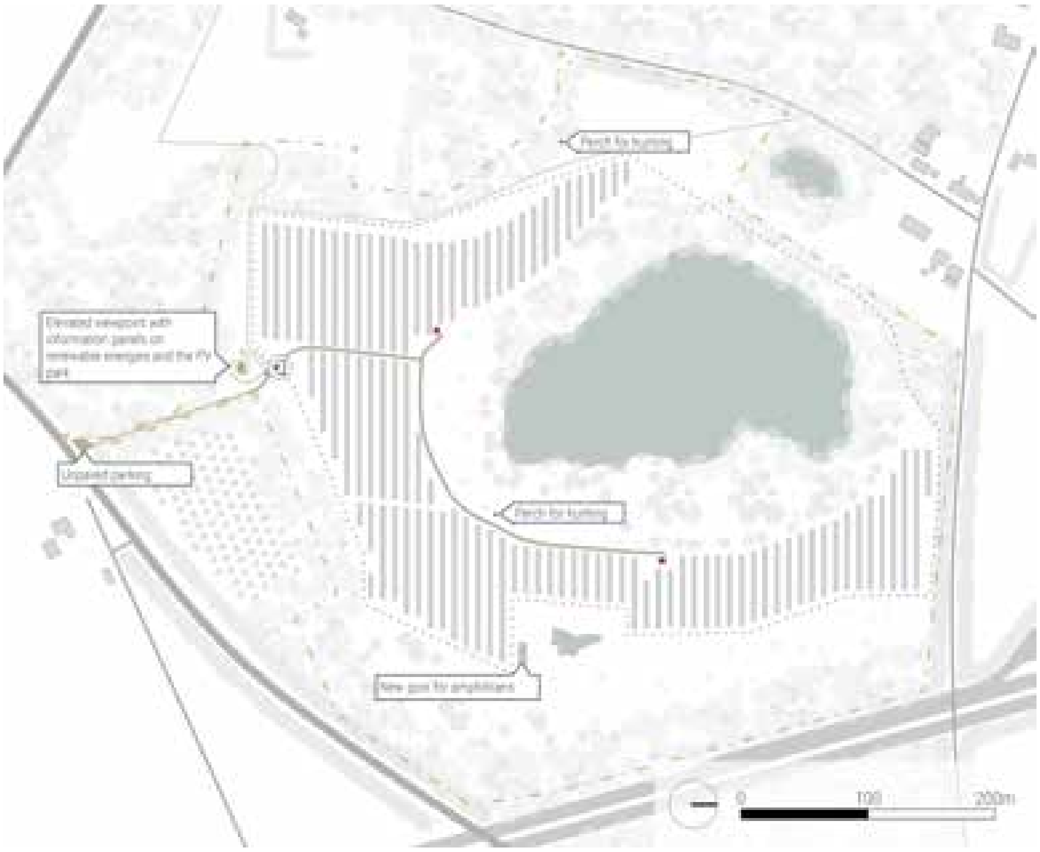


Figure 3.2.2.15: Map analysis, Multifunctionality

For educational purposes, a so-called energy trail was designed, which explains various aspects of renewable energy on five information panels on the way up to the viewpoint (EnergieAgentur. NRW, 2016). Although efforts were made to design boards and the trail, in my opinion there are many missed out chances in stimulating the interaction between visitors and the solar landscape. Those mainly regard measures that were taken on-site and the prominent witnesses of former energy supplies in the surrounding (i.e. stockpile from coal mining and historic windmill).

Section	**Code**	**Simple descriptor**	**Operational descriptor**
Regulation & Maintenance	2.1.2.3	Screening unsightly things	Existing vegetation
Regulation & Maintenance	2.2.2.1	Pollinating our fruit trees and other plants	Flower mixes; wide range of species supporting insects
Regulation & Maintenance	2.2.2.3	Providing habitats for wild plants and animals that can be useful to us	New amphibian pool; wet habitats below panels; lake with natural slopes; accessible vegetation also for large animals
Cultural	3.1.1.2	Watching plants and animals where they live; using nature to de-stress	Diverse flora and fauna species can be spotted along the not designed trail
Cultural	3.1.2.2	Studying nature	Information on species on-site are provided and can be spotted along not designed trail
Cultural	3.1.2.4	The beauty of nature	Contrast between 'untamed' natural surrounding and straight arrays of the solar system
Cultural	6.2.2.1	Things in the physical environment that we can experience actively or passively	View point over solar field, energy trail providing information on the energy transition

Table 3.2.2.1: Ecosystem services at Neukirchen-Vluyn

3.2.3 Case comparison matrix

	Spatial characteristics of PV system			Visibility & screening				Parcel size vs patch size	
	Array height Array surface Pitch size Ratio pitch/ height (bigger = better)	Arrays tilted to parcel orientation (Degree)	Inverters/ transformers located out of sight	Visibility on PV from edge of SL,as indicator for measures located within SL (%)	Visibility on PV from closest landscape user (%)	Existing measures for shielding	Added measures for shielding	Surface of SL used for PV patches (%)	Surface of SL accessible
Hemau	2.7m 3.45m 5.5m **1 : 2.03**	No	Partially Inverters hidden in bunkers Trafos visible along maintenance path	**76%** Visible **24%** Partly visible **0%** Not visible	**8%** Visible **13%** Partly visible **79%** Not visible	Dense evergreen forest	-	56%	0%
Hengelo	1.75m/2.3m 3.3m/5.0m 4.5m/6.7m **1 : 2.57** **1 : 2.91**	No	Partially Inverters clustered and covered by vegetation Trafos visible	**8%** Visible **35%** Partly visible **57%** Not visible	**8%** Visible **15%** Partly visible **77%** Not visible	Trees of nursery Dense tree row along road	Hedge New trees Artificial hills	35%	100%
Neukirchen-Vluyn	2.4m 4.0m 5.4m **1 : 2.25**	No	Yes Inverters below arrays Located centrally and hidden by arrays	**84%** Visible **0%** Partly visible **16%** Not visible	**30%** Visible **0%** Partly visible **70%** Not visible	Dense rows of grown-up trees and shrubs Noise barrier	-	36%	5%
Gänsdorf	2.0m 3.3m 4.3m **1 : 2.15**	No	Yes Inverters below arrays Trafos located centrally and hidden by arrays	**2%** Visible **17%** Partly visible **81%** Not visible	**0%** Visible **16%** Partly visible **84%** Not visible	-	Dense hedge Fruit tree clusters	67%	21%

Table 3.2.3.1: Case comparison matrix

Parcel size vs patch size			Transition landscape			Multifunctionality			
Patch size (ha)	Interacting patch shape (Everywhere, often, hardly, nowhere)	Spatial division between patches (Everywhere, mainly, hardly, which)	Landscape typology	Distance from PV to closest group of housing (>5)	Measures taken to improve embedding into host landscape	SL surface division	Ecological functions	Recreational functions	Educational functions
2.5ha Average **1.6ha** Smallest **3.1ha** Biggest	Yes Everywhere	Hardly Bunkers on parcel	Agricultural landscape with large dense evergreen forests	1300m	-	**0%** Unchanged **0%** Only PV **56%** PV with other function **44%** Other function	Stony habitat Amphibian pools Wet areas Flower meadow Hedges	-	Information panel with displayed yield
0.18ha Average **0.04ha** Smallest **0.43ha** Biggest	Yes Everywhere	Hardly No division at southern patches Artificial hills divide the northern patches	Bocage landscape in urban fringe	50m	Hedges and shapes typical for landscape typology Keeping of existing trees	**12%** Unchanged **0%** Only PV **35%** PV with other function **53%** Other function	Dry habitats Hedge Flower meadow Different aged trees Bee-hotel Pools	Viewpoint Picnic tables Walking paths Water feature Parking lot Benches	Information on species and functions on parcel
1.9ha Average **0.8ha** Smallest **2.9ha** Biggest	Yes Everywhere	Mainly Vegetation around existing lake	Semi-open bocage landscape	200m	Improved maintenance of existing vegetation	**64%** Unchanged **0%** Only PV **35%** PV with other function **1%** Other function	Shrubs below panels Flower meadow Amphibian pool	Viewpoint Perch Bench Bicycle rack	Energy trail
19.5ha Average **4.8ha** Smallest **38.5ha** Biggest	Nowhere	Everywhere Mixed hedge on one side	Open agricultural landscape	150m	Mixed hedge Fruit tree clusters Keeping agricultural functions partly Flower meadows	**12%** Unchanged **67%** Only PV **0%** PV with other function **21%** Other function	Flower meadow Fruit trees Hedges Seed mixture testing Historic crops	Viewpoint	-

SL= Solar landscape

3.2.4 Conclusions case study

The detailed analysis and comparison of the four multifunctional solar fields give various insights within the five categories that can be the basis for the design of an EnergyGarden. The specific numbers and percentages resulting from calculations on edges and surfaces can be utilized as quantitative input for the division of surfaces within the EnergyGarden of Mastwijk.

To present the results of this chapter comprehensibly, the structure of the five categories is kept. It is advised to read the conclusions in combination with the case comparison matrix presented on the previous page.

Spatial characteristics

While all four solar fields are working towards a proper embedding into the landscape, strikingly none of them tilted the arrays to follow the direction of the parcels and thus ensuring a better edge. Especially for Gänsdorf, this measure would have been of value since the North-South parcel lines are prominent, and the tilted arrays would not lead to a considerable decrease in yield.

In all four cases, measures were taken to locate inverters and transformers out of landscape users sight, while in some cases, the efforts were higher, leading to an improved experience.

The careful placing of inverters and transformers, as well as following parcel directions is considered a must-have for the EnergyGarden of Mastwijk.

Visibility

The visibility analysis shows that independent from the measures taken within the solar landscape, the view of surrounding landscape users on the PV system is kept to a minimum. The only exception is Neukirchen-Vluyn, which can hardly be counted since the trail from which landscape users can see the PV system unshielded was not considered in the design.

Before designing an EnergyGarden, the surrounding of the parcel must be analysed critically to investigate at which parts of the solar landscape additional shielding will be required. The cases show that shielding can come in various forms and can host additional functions. By solely choosing measures that fit in the typology of the host landscape, the EnergyGarden will be integrated more fluently in the host landscape, and public acceptance is likely to increase.

Parcel vs patch size

The patch shape can have a significant influence on the natural character of a solar field, especially if it interacts with organic forms of existing planting patches on the parcel. Essential to keep in mind is, that, especially with large arrays, soft and rounded edges are impossible. The characteristics of PV arrays always lead to a zig-zag edge that can only be avoided with additional measures at the end of each array.

To be considered a multifunctional solar field, PV patches should not take in too much of the solar landscape surface. While Neukirchen-Vluyn and Hengelo only allocate around 1/3 of the solar landscape to the PV system, Hemau uses more than half and Gänsdorf even 2/3 of the surface. This difference in the spatial hierarchy can be experienced when walking through the solar landscape and is a crucial variable for the design of an EnergyGarden. For the following design process, the maximum surface of the PV system in Mastwijk is limited to 50% of the solar landscape, as an average result of the analysed cases. For a satisfying experience of the EnergyGarden, at least ¾ of the solar landscape should be accessible to the public.

High vegetation or another shielding between the PV patches can lead to a natural look of the solar landscape and reduce the ability to overview the whole PV system from the landscape perspective. This provides the feeling of enclosure and brings huge installations to a more human scale, making it more attractive for visitors to spend time within the solar landscape.

The visits to case studies have shown, that moving through various loose patches, instead of one uniform system affects how the solar landscape is perceived. Still, the cases do not allow a conclusion on the optimal patch size. It can be concluded that patches of different sizes lead to a more varied and exciting experience.

Transition to surrounding

Since the cases are located in different landscape typologies and settings, the measures taken to improve the landscape transition differ as well. The distance to landscape users was found to have a significant impact on the required actions to improve the transition. While in Hemau, with its remote location, no measures are taken at all, in Hengelo, with its directly neighbouring houses, various measures are taken. To improve local opposition in the EnergyGarden Mastwijk, the distance and location of landscape users outside the solar landscape is a significant concern.

If the project boundary of the solar landscape allows space at the borders towards the parcel edge, current land use may be maintained, as seen in Gänsdorf and Neukirchen-Vluyn, to realize a smoother transition to the host landscape.

Multifunctionality

The analysis shows that the requirement of functions very often is related to the position in the landscape. It influences the usage, social control and maintenance, leading to the conclusion that solar fields can be better off with a limited but perfect tailored set of functions. Recreational functions in Neukirchen-Vluyn and Gänsdorf are superficial, and observations and conversations with designers have shown that they are hardly used, making their added value questionable. In contrast to that, the added functions in Hengelo are used by several neighbours which was observed and mentioned in talks with visitors. The use of the solar landscape in Hengelo varies from walking dogs to meeting friends for a picnic. For the future, plans even include the creation of a community garden patch in the solar landscape.

With the findings of this case comparison, the question remains if the solar landscape at Hengelo is used much more intensive because of the larger number of added functions, or its proximity to potential landscape users. Interviews with the visitors and observations during different days and time slots would be required to get a better insight wat the main factor is. For the design of Mastwijk, the assumption can be made that for nearby residents a limited amount of featured functions is sufficient since activities like walking a dog do not require a landscape with a vast amount of services. For attracting long-distance visitors, more efforts need to be taken, which make it enjoyable to travel to the remote solar landscape. A lack of facilities in the surrounding (e.g. toilets, cafes, restaurants) as it is experienced at all four solar fields avoids a stay of users for longer times. In combination with a time-consuming arrival and departure, the concept of long-distance tourism cannot work for those cases.

The reasoning above leads to the assumption that view towers at the remote solar fields are only used by locals. However, the view over a static PV system is a one-time-experience and does not invite to be experienced multiple times since nothing can be observed which differs from, for example, bird spotting locations. If there is something to be seen, e.g. birds, deer or the sunset with a proper perspective, at least furniture for sitting needs to be featured that invites for more extended stays.

The stimulation of nature is found to work well and with different efforts in all four cases, which allows the assumption that the combination of PV and nature development is the most valuable found. The successful development of improved biodiversity at all analysed cases makes it a must-have function for the EnergyGarden of Mastwijk. This includes increasing the factor 'PV with other function' as much as possible, by implementing, e.g. vegetation below the panels to stimulate biodiversity.

In educational terms only in Neukirchen-Vluyn and Hengelo creditable efforts were done, with at Hengelo the overview of featured functions and species within the solar landscape. In Neukirchen-Vluyn, the taken efforts are higher, by designing a whole energy trail where next to site-specific information also general knowledge on the energy transition is provided. Although the spatial layout and completeness of this energy trail are questionable, it is a good approach to an educational component for EnergyGardens.

3.3 Literature review

As mentioned at the beginning of this chapter, additionally to the case studies, a literature review was done to support findings of the previous analysis and to get an insight on recent findings in science on multifunctional solar fields. The seven most important sources for this literature review are shortly summarized below, while many other sources were considered as well. To link the underlying information per design guideline to its source, a numbering system is introduced. Each of the seven sources received a number in a square that relates to the applicable design guidelines per source. Information that was identified in conversations with various designers, who perform research on the topic of solar fields as well, is indicated with an eight in a square.

1

Zonneparken natuur en landbouw. Van der Zee, F. et al. (2019):
This scientific paper is cutting on various components of solar fields and gives a valuable overview of up-to-date practices and research results regarding plant development, changing soil qualities and spatial layouts of the PV system.

In contrast to other literature on multifunctional solar fields, this paper also highlights the drawbacks of some function combinations like the development of bird habitats and dirt on PV panels.

2

Research through design for energy transition: Two case studies in Germany and the Netherlands. Stremke, S., & Schöbel, S. (2018):
This scientific article is mainly focussing on the spatial layout of solar fields, including the location of the PV patch, its visibility, and accessibility. It provides general guidelines on how a solar field can be embedded into the host landscape and examines them at a real site. It offers an approach for landscape architects to design multifunctional solar fields by research through design and thus provides a reasonable basis for the design of the EnergyGarden Mastwijk.

3

Photovoltaic landscapes: Design and assessment. A critical review for a new transdisciplinary design vision. Scognamiglio, A. (2016):
In contrast to windmills or other extensive facilities related to the energy transition, solar fields offer various possibilities to be embedded and (partially) hidden in the landscape. This paper presents an approach to do so and argues for the need for solar landscapes to provide more than only electricity but to fulfil other goals of the society and environment.

4

De constructieve zonneladder, in vijf stappen naar lokaal beleid voor een goede inpassing van zonne-energie. Natuur en Milieufederaties (2018):
This document is meant for provinces and municipalities to allocate solar fields at the right locations, considering various variables. It provides information on the political processes that stay apart from the designing process, but it also offers a set of must-haves to create a well-planned solar field.

5

Erneuerbare Energien und Naturschutz– Solarparks können einen Beitrag zur Stabilisierung der biologischen Vielfalt leisten. Raab, B. (2015):
This article is focussing on the potential development of habitats within a solar field, and analyses monitored developments at existing solar fields. It defines maximum distances to other habitats for species and sets minimum requirements for the successful development of habitats between and below arrays.

Furthermore, it advises on the yearly maintenance of flower meadows and other measures to maintain and increase the quality of biodiversity on the parcel.

6

Zon op recreatiewater: Studie naar de toepassing van zonne-energie op recreatiewateren. Innovatie Recreatie & Ruimte (2019):
Even though this paper is focussing on the development of PV systems on water surfaces, it provides valuable insights on the visibility and the experience from landscape users. It also relates the shape and size of potential PV systems to the typology of host landscapes.

7

Zonnepanelen en Natuur. Hoe zonnepanelen kunnen samengaan met natuur-een eerste praktische handreiking. Cesar, I. et.al (2018):
This document is working towards an arguable embedding of solar fields into the landscape and connection with other functions such as agriculture. Potential measures for shielding the view towards the PV system are analysed regarding their multifunctionality and added quality for biodiversity.

8

Other source

3.4 Resulting design guidelines

The design guidelines that result from the analysis of the four multifunctional solar fields and the literature review are presented in this sub-chapter divided into the PV system, solar landscape and host landscape (as described in the theoretical framework).

The sources of information utilized per guideline, are indicated with a number in either a square or a circle. As explained before, number one to eight in a square refer to the sources from literature. Number one to four in a circle refers to the four implemented solar fields of the case study.

(1) Hemau

(2) Hengelo

(3) Neukirchen-Vluyn

(4) Gänsdorf

3.4.1 The PV system

A1 Vegetation beneath/behind arrays

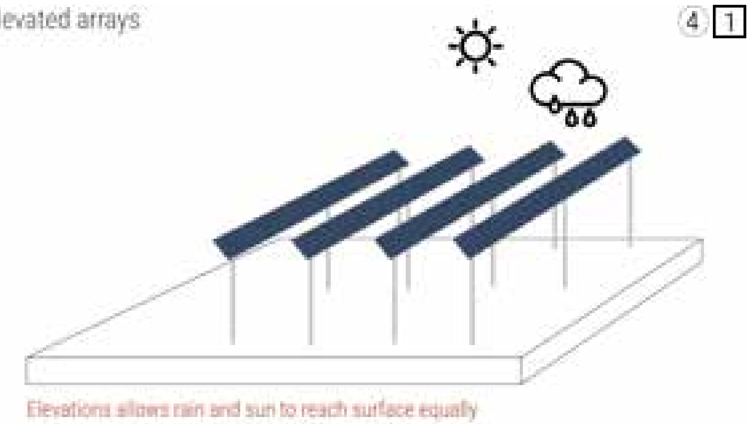
By implementing nature beneath or behind arrays, the surface can be used more efficiently by producing electricity and creating habitats for flora and fauna. At the same time, the nature beneath the arrays hides the backside of the panels, which is often experienced as an irritating factor of solar panels. If vegetation is placed behind loose south-facing arrays, it can have an appropriate height without shading the array. By that, clusters of PV panels could even be integrated into an orchard, creating extraordinary spatial layouts.

Vegetation below/beneath arrays (1) (3) [5]

A2 Elevated arrays

While in most solar fields the panels are positioned as shallow as possible above the ground, many scientific articles argue that PV panels should be implemented on elevated structures. This guideline can already be seen with agrivoltaics, where the elevated structure allows to cultivate crops below the panels. While not meant for crop cultivation, ecologists argue that this setup enables nature to evolve almost unrestricted below the panels due to unhindered penetration of sun and water by diffusion. While this provides great benefits for ecology, it has giant effects on the visibility of solar panels, even from greater distances.

Elevated arrays (4) [1]



A3 Alternative construction materials

Construction by metals as aluminium or galvanised steel can be thin and require fewer diagonal bracings. They create the impression of a lightweight structure but still provide the feeling of industrial land use because of the associations with the strict grid of metal supports and frames. Wooden constructions, as they can be found in Hemau, provide a much more natural impression and the material blends into natural colours over time. However, the wooden construction requires many diagonal bracings to keep the arrays straight and stable. Still, the wooden frames keep warping and reacting to weather influences, leading to irregular slanting arrays and PV modules. In the worst-case, single modules can even break due to torsions from the frame.

Alternative construction materials (1) [8]

A4 Concrete foundations

The metal supports can be anchored into the ground directly, making it look like a part of the natural environment. Wooden poles, however, necessitate a foundation of concrete that is cast into the ground or put on the ground. Surface concrete foundations can prevent groundwork at, e.g. landfills and can fulfil a multifunctional role and, e.g. stimulate nature development. In the case of Hemau, the development of mosses is still minimal after 16 years, which comes close to 2/3 of its planned life span. With another type of concrete, the development of these rare mosses takes place faster, offering habitat to many species of flora and fauna.

A5 Rotating arrays

An alternative to arrays with fixed angle are arrays or clusters that can rotate either on one or two axes (solar trackers). The rotation leads to a higher yield since the ideal degree towards the sun can be kept over more hours of the day. Furthermore, the angle of the system can be adaptive to extreme winds and snowfalls, leading to a lighter framework since lower loads must be absorbed. Furthermore, it can be interesting to observe how one by one adjusts its angle over time, and it can be used in an educational way to illustrate the travel of the sun over the day.

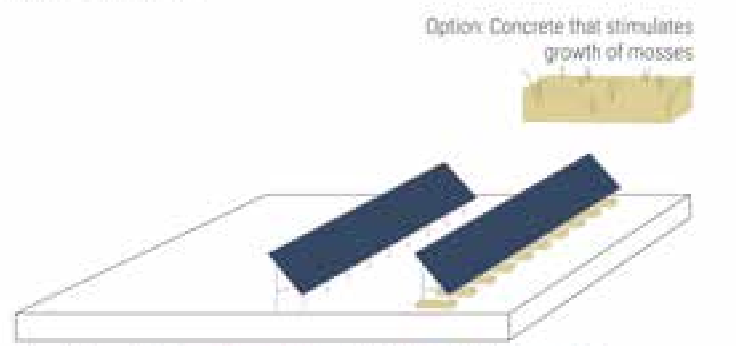
A6 Low angle of arrays

The ideal angle for PV panels in Western Europe is 35° to catch most of the sunlight, but a lower angle with a slightly lower efficiency can have various advantages. While fitting the same number of rows above each other, the notch height of the array can be lower. The lower height can be advantageous in case of municipal restrictions, allows landscape users to look above the PV system and visual barriers can be lower and better fitted into the host landscape. Additionally, the ratio between pitch size and panels per hectare is improved, which is beneficial with a limited or restricted surface for the solar field. In combination with the decreasing prices for PV panels, this guideline can be of great value.

A7 Individual clusters

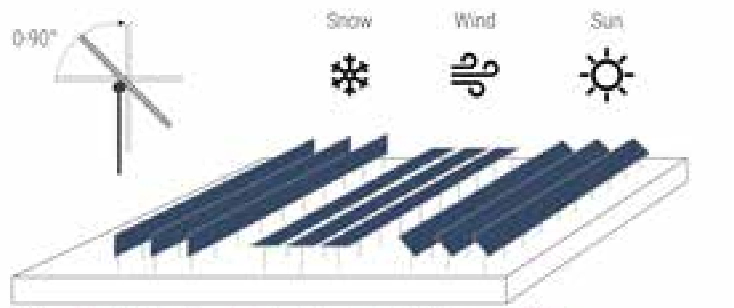
In terms of panels per hectare, classical array shapes are the most efficient layout and are most common. However, arranging the panels more freely, allows the PV system to be more interactive with the solar landscape and react to existing shapes and patches of nature on a parcel. Furthermore, the clusters can react to soil subsidence with less pressure on the framework and PV panels. A layout of loose clusters allows designing more openings for animals and landscape users to move freely through the solar landscape and search their ways through the PV system. However, the costs for wiring and framework increase.

Concrete foundations 1 8



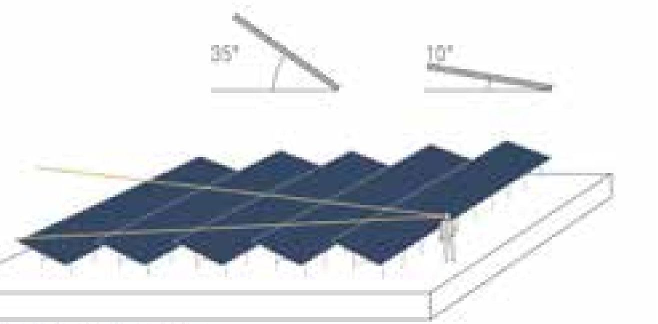
No distortion of soil needed, advantage with toxic or concrete grounds

Rotating arrays 4 8



Increased yield and decreased requirements for wind and snow loads

Low angle of arrays 6 8



Low arrays not blocking the view

Individual clusters 1 3

Individual clusters allow more interesting routes and spatial division

A8 Spacing between panels

An often-named concern on solar fields is the decreased biodiversity below arrays, which results from the limited amount of sunlight and rain available. One solution to this problem was found in literature where a spacing of 10 centimetres between the panels is handled to allow enough light and rain pass through. By ensuring a steady soil quality, this measure may be beneficial for ecology, but it can have a huge impact on the look of a solar field. The spacing visually highlights the frames of the PV panels, which stresses the PV system instead of blending it into the natural setting.

Spaing between panels 1

Spacing allows sunlight and rain to pass through

A9 Ascending rows of panels

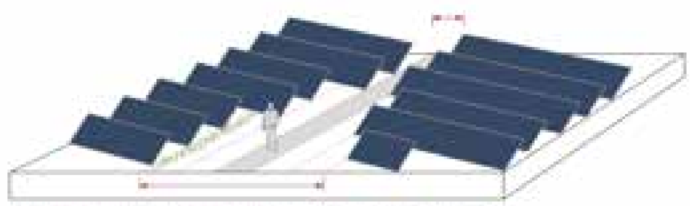
From the edge of a larger PV patch, its height is hard to estimate. That makes it possible to work with an increasing number of rows per array towards the middle/end of a patch. Meaning that where the landscape user is standing lower arrays are placed which fit the human scale better and that higher arrays are located on larger distances, where no direct interaction takes place. By that a high yield can be generated without interfering too much in the landscape users view. This measure can lead to visual disturbance if the patch is visible from various perspectives because the different heights do not blend in together from the sides.

Ascending rows of panels 2 8

A10 Distance and type of patch border

If the border between two patches is accessible to landscape users, its characteristics have a huge influence on the perception of the PV system and solar landscape. Relevant aspects are the height of the arrays, the width between the two patches and the presence and extent of vegetation. While a narrow and open border with high arrays communicates the feeling of standing right inside the PV system (see Hemau), a wider border with vegetation and semi-high arrays pretend to stand in a natural surrounding with PV only as an incidental addition to the landscape (see Gänsdorf).

Distance and type of patch border 1 2 4 3



Borders between patches should differ in width and typology

A11 Solar panels on hills

An alternative to poles can be earth walls that are constructed to host the arrays. The artificial hills can fulfil a valuable increase in the variety of habitat for flora and fauna. The dry top of the hills is favoured by other species than the lower, soggier areas.

The backsides of the modules disappear in the view, increasing the natural atmosphere. A comparable design is used at Hengelo where vegetated artificial hills are used to divide parts of the solar landscape visually.

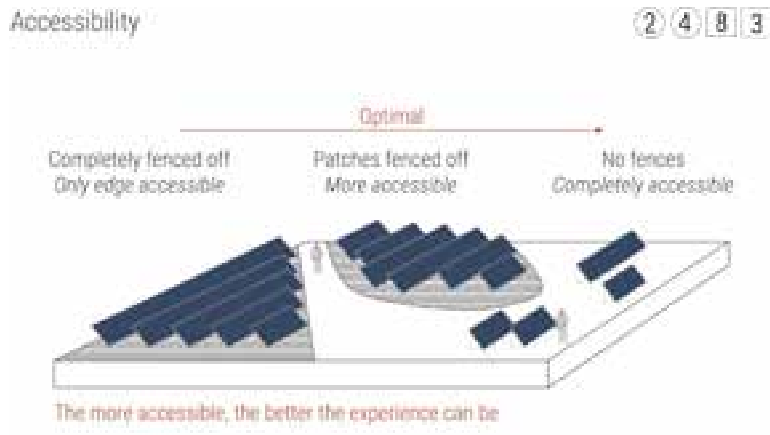
Next to increased labour, the tight position to the ground decreases the passive cooling and means a decrease in efficiency of the modules.

Solar panels on hills 2 1

Southside of hills features PV panels, Northside features vegetation (dry-wet)

A12 Accessibility

While most solar fields are not accessible at all, to be considered an EnergyGarden at least the basic means of accessibility must be ensured. This contains that the PV system is fenced off, while the solar landscape around it is accessible (see Neukirchen-Vluyn). The increased level is a solar landscape with a few fenced-off patches which allows the landscape user to access more of the parcel and experience more of the solar landscape (see Gänsdorf). The optimal scenario is a solar landscape with a PV system that requires no fencing at all and allows the landscape user to truly get into contact with the PV panels (see Hengelo).

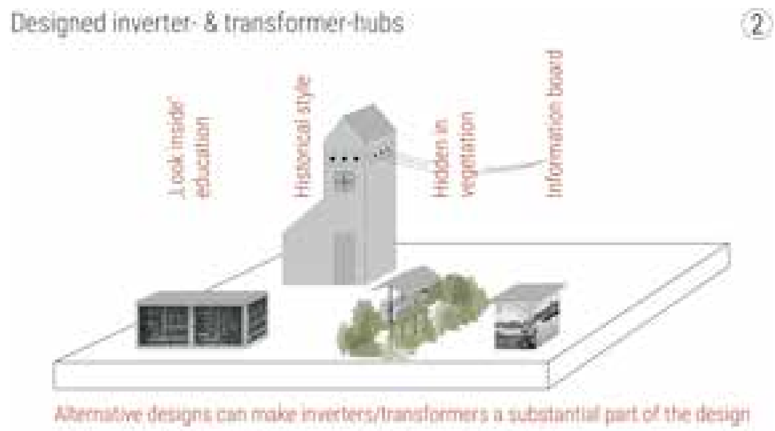


A13 Multiple types of panels & installations

Working with varying types of set-ups and installations can imitate the versatility of a natural environment and can more easily blend into such. It draws the visitors' attention and makes the PV system more enjoyable to walk through. This contrast can be found between Morbach, used as test-site for various installations which draw attention, and Hengelo where an exciting solar landscape is accompanied by a monotonous grid of arrays. Even though Morbach is an extreme example that features too many installations to form a unity, it demonstrates the effect on landscape experience and educational value well.

A14 Designed inverter- & transformer-hubs

Inverters can be installed below arrays which keeps them safe from weather influences and keeps the DC cable length at a minimum. When installed in this position the inverters do not disrupt the visitors' view, which makes it a good choice for positioning regularly. However, in case of accessible fields the expensive and sensitive inverters need to be placed in another way. They can be fenced off in vegetated clusters as in Hengelo or placed in a container that functions as an information board or educational hotspot to convey its function within a PV system.

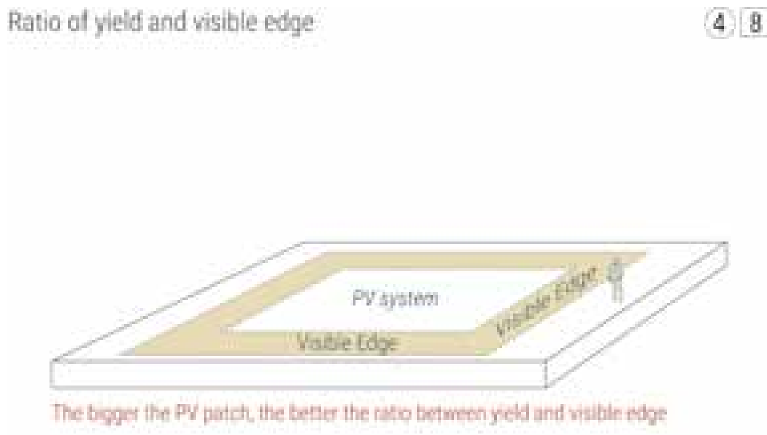


A15 Hiding inverters and transformers

If available, existing buildings can be transformed into hubs that take the technical installation out of sight and give a new function to unused space. The history of such buildings can be kept and reinforced as it is done in Hemau where the inverters are placed into former bunkers. This approach does not only improve the visual quality but also prevents noise pollution as it was observed in Mühlhausen where the transformers are placed directly next to the walking path. At the edge of the solar landscape, constant background noise from fans can be recognised, interfering with the natural environment.

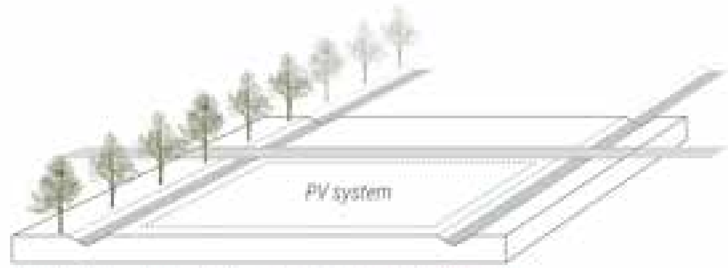
A16 The ratio of yield and visible edge

Especially with larger PV systems or patches, surfaces can hardly be estimated in a landscape. That allows fitting greater surfaces of PV panels into the landscape without creating too much visibility for landscape users. In the case of the huge solar field at Gänsdorf, this guideline is working well for standard landscape users. The immense extent is only revealed when seeing the PV system from the viewpoint of the solar landscape. At the same time, it illustrates that this guideline cannot work if the host landscape features any height differences in the close surrounding.



3.4.2 Solar landscape

Keeping existing landscape structures 4 1 2 3 8

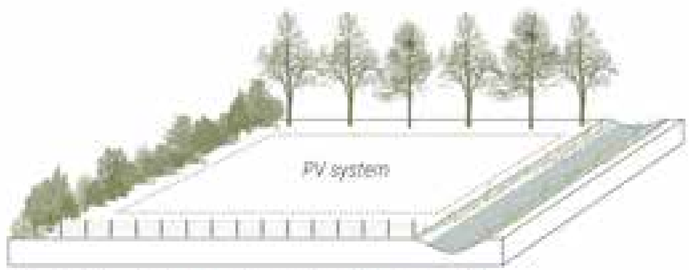


Exisisting parcels, ditches, tree lanes as basis for new layout

A17 Keeping existing landscape structures

While most solar fields feature standardised PV systems, that are perfectly oriented to the south and fill up the whole available surface of a patch, some examples consider landscape structures of the host landscape and shape the PV patches inside the solar landscape accordingly. As an advantage, the solar landscape and the PV system are better embedded into the host landscape and are perceived as less alien-like. The point of departure can, for example, be parcellation, ditches or alleys.

Diverse edge 2 5 8

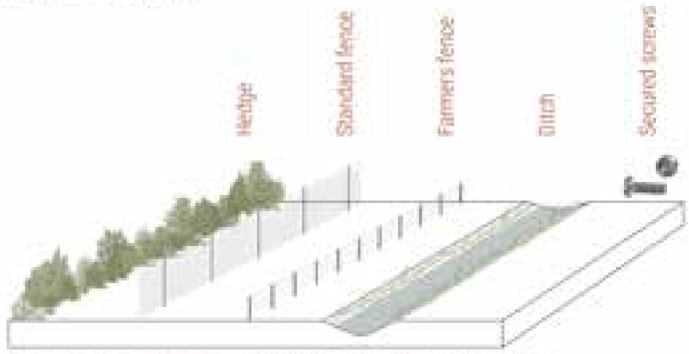


Diverse borders lead to a more interesting solar landscape

A18 Diverse edge

If the edge of the solar landscape features various types of vegetation or visual shielding, the design can be more exciting and attractive from both in- and outside. This heterogeneity can be a counterpole to the often-monotonous PV system that is not enough to amuse a visitor during a walk through the solar landscape. At the same time, the distinct edge can help to better integrate the solar landscape into the host landscape, which may vary in typology on the different edges like in Hengelo. However, all edge types should fit the general tone of the host landscape.

Security for PV system 1 2 4 2 8



Prefering alternative security measures over standardized fences

A19 Security of PV system

The security level of a PV system that is required by insurance companies is often a limiting factor for the accessibility and quality of solar landscapes. While the ideal situation would be a two-metre-high, easy-to-maintain fence that is closed at all time, the EnergyGarden definition asks for almost the opposite. However, more and more insurance companies start to accept other securing measures like (thorny)hedges, natural fences, ditches or secured screws (see Hengelo). These measures allow a better embedding inside the host landscape or more accessibility, without being expensive or taking too much risk of theft.

Considering structure and shapes on parcel 3 5

Keeping representative landscape structures anf height differences

A20 Considering structures and shapes on parcel

Just as structures of the host landscape, as it is described in guideline A17, existing structures on the parcel itself can be a good point of departure for the solar landscape and the PV system. Due to a minimum of groundwork, this can protect habitats that have already been developed (see Neukirchen Vluyn), but it can also reinforce the history of a place as it is the case with the former bunkers in Hemau. Furthermore, keeping the main structure of a parcel can increase the support of local stakeholders that have a long-term bounding to the place.

A21 Wet habitats underneath panels

While wet habitats for flora and fauna or hardly desired on agricultural grounds and limited in their extend in urban green areas because of their messy and boring look, they can be assigned large surfaces within a solar landscape. For the structures of the PV system, the wet soil does not matter, and the panels do not have to be accessed regularly. In case of planned maintenance or for cleaning the panels, a dry season can be chosen in which wet habitats with low water depth often dry out.

Wet habitats underneath panels 1 3 5 7 8

Extensive maintenance of PV systems allows wet habitats underneath arrays

A22 Green shield on patch borders

When implementing vegetation between PV patches, natural corridors can be created through a larger parcel. These natural corridors can help to cover the extent of the PV system by shielding the view to at least one side and distracting the landscape user from the PV system itself. Furthermore, these natural corridors can give unity and continuity to the solar landscape, which is crucial to provide a pleasant stay for landscape users. For little and slow-moving animals, these small-scale corridors can offer a supportive basis as well.

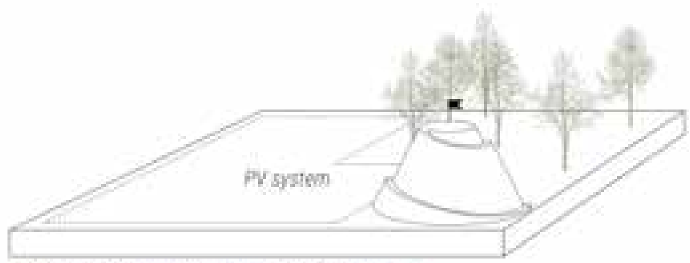
Green shield on patch borders 2 4 5 8

If border between patches accessible on long distances, shield view on one side

A23 View (-point) over the solar landscape

Since the array height of most solar fields extends the eye-level of visitors, elevated viewpoints or view towers that allow visitors to oversee the whole solar landscape and the PV system are often featured. While building a small hill with grounds that remain during the construction process is a fast, inexpensive and natural measure, a real view tower can react in a unique way to the design language of the solar landscape. However, view towers are often expensive, require static planning and can have more restrictions by municipalities. The careful placing of the viewpoint is crucial to communicate the strengths of the design while not highlighting its weaknesses.

View (-point) over solar landscape 2 3 4



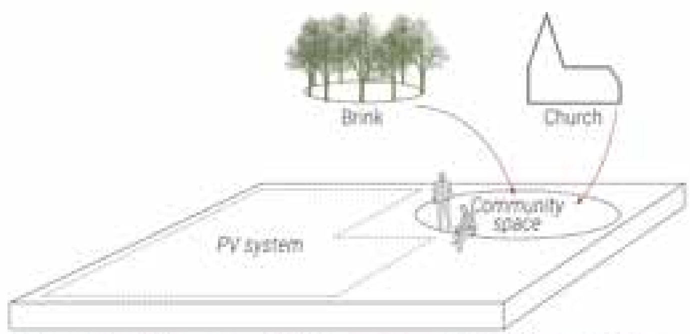
Enabling view over PV system and solar landscape

A24 Contemporary gathering point

A solar field that features recreational functions for neighbouring residents can become a central gathering for a village or an urban district as it was common with churches or the Dutch ‘brink’ in the past (Daniels, 2019).

To stimulate this process, facilities that seduce visitors to stay longer, such as seating accommodations, a café and a shelter against rain and wind. Additional functions such as a community garden or collective maintenance on the parcel increase the attachment to the place even further. Chances for this development strongly depend on the site and its social surrounding, and the general interest of residents.

Contemporary gathering point 2



EnergyGardens as new community spaces, as seen with churches and 'Brinks'

A25 Enclosure vs maximum sunlight

While the PV system requires as much sunlight as possible, a comfortable solar landscape for visitors includes largely vegetated areas that offer shadow during the hot summer days. Furthermore, the (partial) enclosure by vegetation provides a safe feeling to human beings and makes the solar landscape more exciting to walk through. Wide-open areas with only PV panels do not offer stimulation to the human brain and can be boring to walk through. A clear division between the PV system and solar landscape might seem as an easy solution but contrasts with the definition of EnergyGardens where the PV system is integrated into the landscape.

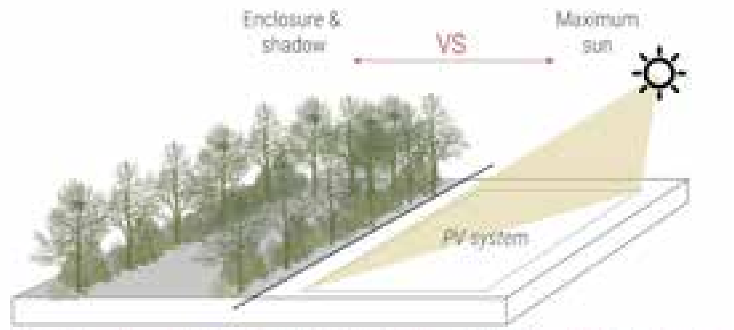
A26 Use of time span

The regular life span of a PV system is 15-20 years, but due to improved quality, new systems can work efficiently for up to 30 years. Afterwards, the parcel can be used again, and due to a fast-developing energy sector, chances are low that PV panels on land are implemented again in 2050. This development means that the parcel will host a new function, which might be housing development or suburban park depending on the site characteristics and location. If a parcel is expected to become a valuable green spot in 30 years, from now a spatial layout and vegetation type can be used that can easily host a new function later and offer, for example, already grown-up trees.

A27 Limiting effects on habitats during (de-) construction

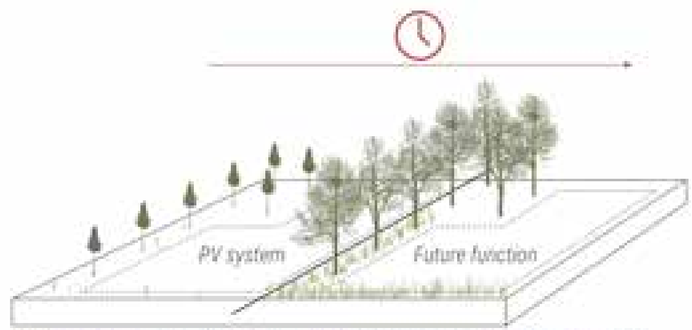
During the construction and deconstruction process of a solar field, grounds are often levelled and compressed simplifying the work process, but at the same time disturbing ecological habitats that may have developed before or during the life span of a PV system. By making use of special transport constructions for heavy equipment, as seen in Gänsdorf, soil compression can be limited to a minimum. Also, the planning of specific construction corridors from where the system is (de-)constructed can be an option to protect the precious nature that developed within 30 years.

Enclosure vs. maximum sunlight (1) 8



Mismatch between enclosure of garden and maximum sunlight required for PV system

Smart use of time span (4) 4



Spatial division that allows future functions to make use of developed nature

Limiting effects on habitats during (de-) construction (4)

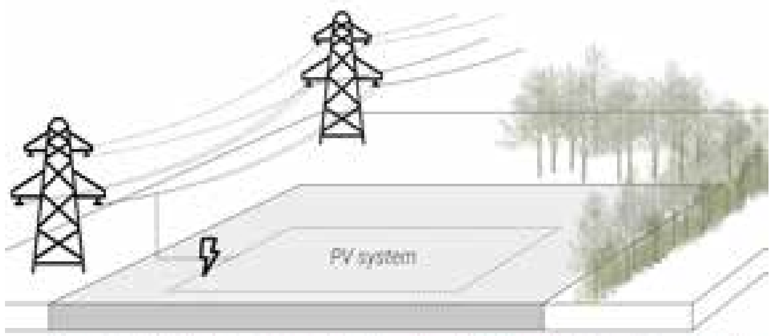
Only defined areas can be used for (de-)construction to keep habitats intact

3.4.3 Host landscape

A28 Choosing site based on characteristics

Often the location for a solar field is chosen based on ownerships, cheap land prices and speculation. At the same time, several characteristics should shape the decision for locating a solar field. The use of brownfields, e.g. a landfill, is to be chosen over agricultural soils, and the distance to the main power grid should be kept to a minimum. Lower distances keep prices for expensive wiring to a minimum and prevent the formation of new power corridors through the landscape. Existing green structures are beneficial as visual shielding for landscape users.

Choosing site based on characteristics 4 8

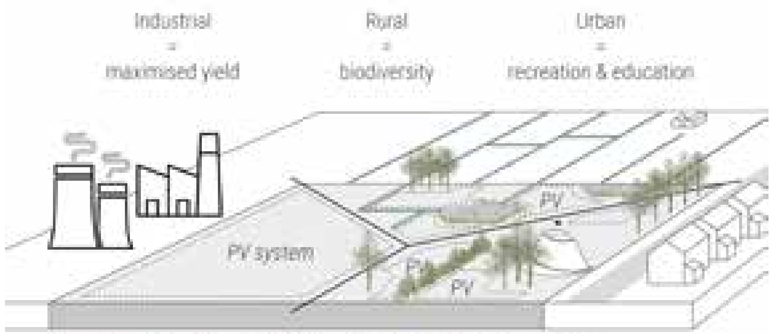


Close to electricity grid, no agricultural grounds, existing natural shielding beneficial

A29 Considering local needs

While the definition of an EnergyGarden requires multifunctionality of a solar field regarding ecology, recreation and education, not all functions may have a purpose at each location. A (sub)urban area may require more recreational and educational functions and a rural environment may require a focus on increasing biodiversity with recreation as a minor matter. An industrial area with no ecological or recreational networks in sight may even be better off with a PV system that is designed to have a maximum yield and feature hardly or no additional functions.

Taking into account local needs 1 2 4

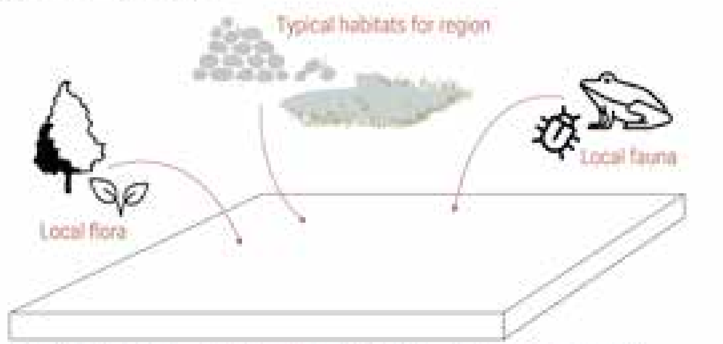


Layout and functions of solar landscape defined by host landscape

A30 Supporting local species

For landscape architects supporting local flora and fauna is a well-known measure, but at solar fields, this guideline is not always consulted. While local species are easier to attract and more likely to evolve, their appearance can also distinguish one EnergyGarden from another. Furthermore, the analysis of local species in combination with site characteristics can help to limit the number of different habitats that are featured in a solar landscape and give unity to the design. Some solar fields have been found to overcompensate by as many different habitats as possible that do not necessarily fit the location.

Supporting local species 1 2 3 4 1 3 5 7 8

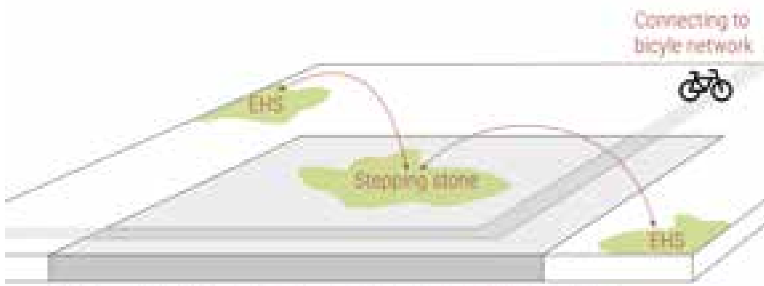


Careful choice of stimulated species and habitats (not everything on one site)

A31 Considering existing/planned networks

When designing the functions of an EnergyGarden, diverse networks of the host landscape should be considered. As mentioned before, local species can be stimulated by creating habitats, while their movement and their requirements can best be analysed by looking at existing and planned EHS and Natura2000 structures in the close surrounding. In that way, an EnergyGarden can become a steppingstone inside a greater network. The same approach leans itself for touristic networks that can be connected to an EnergyGarden to close or enrich, for example, a regional bike route.

Considering existing/planned networks 1 3 4 8



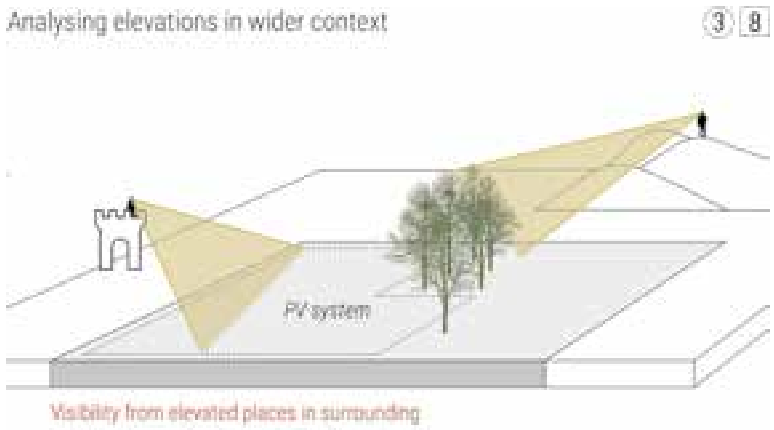
Analysing opportunities to connect to nature- / recreational networks

A32 Visual shielding fitting the landscape typology

Multiple landscape elements offer different methods of shielding the view towards a PV system. Often used are wooded banks, tree lanes and hedges, but these do not fit in all landscapes typologies. To make a tailored design for a specific site and landscape typology, historical and contemporary vertical elements of the host landscape and the parcel itself should be analysed. An alternative was, for example, found in Ouddorp aan Zee where sand walls (Zandwallen) are a typical historic landscape element and were utilised to shield a small solar field in the traditional landscape.

A33 Analysing elevations in a wider context

While the desired view over the PV system and solar landscape was discussed earlier, elevations in the host landscape can lead to undesired views over the installation. Visual shieldings that are implemented on the edge of the solar landscape are then eventually too small. This effect is found in Neukirchen-Vluyn where a green barrier cannot shield the view from the intensive elevated Halde Norddeutschland. While at that project, the visual connection is not problematic and even creates an interesting link between the two energy landscapes, at, e.g. historical valleys, it can have a negative impact.



3.5 Conclusions case studies and literature review

Consulting a wide field of literature and analysing four cases has brought together a wide range of insights, which is helpful as a basis for the design of EnergyGardens. Even though more than thirty design guidelines were spatialized and described, the selection is still limited and missing several guidelines can be found. These are often more basic or are considered to be part of the general toolbox of landscape architects, giving them space in the design of Mastwijk either way.

In the scientific literature, relevant information on (multifunctional) solar fields can be found, but the sources are mostly assessing one specific aspect of the solar field instead of analysing the overall concept. Much information is found regarding ecological development in combination with PV systems and the correct maintenance of such ecological values. These results are valuable for the maintenance planning of an EnergyGarden and its planting design. Still, they leave many questions unanswered regarding the spatial components of a desirable multifunctional solar field.

The topic least considerd in the scientific literature is the visibility of a PV system from the solar- and the host landscape, and innovative measures that can be utilized to shield the view partially. The actions that are named in the literature remain at a basic level such as the planting of hedges, which cannot be considered to give an EnergyGarden a unique experience. For the design of the EnergyGarden Mastwijk, a more distinctive solution must be found.

At the visited cases, multiple design guidelines were found to fit the definition of an EnergyGarden and can function as a basis for the design. The detailed analysis of the design considerations helped to understand underlying processes in the design process of multifunctional solar fields and its drawbacks better. The categorization into PV system, solar landscape, and host landscape works well for displaying the design guidelines, but to investigate complex relations, synergies and drawbacks within a multifunctional solar field, the detailed categorization is indispensable.

The presented list of design guidelines show that many design guidelines and spatial components can already be retrieved from implemented multifunctional solar fields. Since the selected guidelines and recommendations all follow the definition of EnergyGardens, they can be accounted as relevant basis to design such.

It must be emphasised, that the quality of the designed EnergyGarden does not result from the amount of implemented guidelines, but on the mutual coherence of the chosen guidelines, the project site and the demands of involved stakeholders.

Figure 4.1: Orchard at Paris

Chapter 4

Guidelines for garden design

4.1 Introduction

In the previous chapter, various design guidelines for the PV system and its spatial integration were presented. To design an EnergyGarden, guidelines on the design of a garden are required as well. These are explored in this chapter, answering the question:

Which guidelines of contemporary garden design regarding spatial layout and embedding into the landscape are relevant for an EnergyGarden?

For guidelines on garden design, the literature study was split into traditional gardens, performative landscapes, and community gardens.

1. The **traditional garden architecture**, with centuries of development on spatial quality, microclimatic comfort, and landscape experience.

2. The concept of **performative landscapes**, which not only evolve intending to please the human experience but to serve a higher goal, e.g. the energy transition.

3. **Community gardens**, with their focus on collective achievement and conservation, while reinforcing social cohesion within a group, village, or district.

4.2 Method & data

The literature review was conducted in the same way as done for research question 1.

The search terms that were used both in Google scholar and the WUR library were adjusted to the three perspectives described, always utilising the addition AND “design guideline” OR “design principle” to ensure that all papers abstract their findings to a more general level. The abstraction of the knowledge was supposed to simplify translating the results of scientific knowledge into the concept of an EnergyGarden. The range of potentially useful literature was too broad to filter out the relevant papers. By using a snowball system and checking various papers and reviews the book “Garden Design” by Sylvia Crowe (1958) was found, which provided a general overview on the traditional garden architecture, highlighting its facets and providing general guidelines to garden design. The aged book received many positive reviews in scientific papers because of its general overview that enables to refine traditional guidelines.

For the review of traditional garden architecture, the aged book was useful, but for the contemporary concept of EnergyGardens, a more recent perspective on landscapes was desired. The idea of performative landscapes is quite contemporary and thus fits that requirement, and it is expected to work well with PV panels as the performative component of a design. To study the design guidelines of performative landscapes, the book “Designed ecologies” by William Saunders (2013) was investigated, leading to several interesting insights that can be extrapolated to EnergyGardens.

Finally, since the involvement and participation of local stakeholders is an essential requirement according to the EnergyGarden definition, literature research was done on community gardens. Community gardens experienced extended development within the last century and offered various insights on participation during the planning and after implementation. To get relevant guidelines on this perspective, multiple sources that were identified in the online search are assisting.

Due to time constraints and a page restriction, the guidelines that were collected are not visualized and spatially represented. In contrast to research question 1, not all the guidelines are spatial, since some focus on colours, ideology, or processes.

The used literature sources are shortly described on the following pages, and for each of the sources, relevant guidelines are given that were found to be extrapolatable and fit the EnergyGarden definition. Guidelines that are named repetitively in the different sources are only listed once.

As mentioned before, the book “Garden Design” by Sylvia Crowe was first published in 1958 and is thus missing many recent developments in garden- and landscape architecture. However, since the author describes several centuries of development that include the most significant movements in garden architecture, the book does not lose any value for this research.

In the book, a division is made between historical epochs, different style movements and their relevance for ‘today’s’ gardens, leading to a set of six garden types for the future. Of those six types, mainly the ‘shared garden’ is relevant according to the definition of an EnergyGarden and is therefore elaborated on.

Shared gardens come close to community gardens in many characteristics. While community gardens may inhabit private or semi-private lots, shared gardens are entirely open to the public. This means that decisions are formed democratically, and no solo efforts are taken.

Due to the various demands of all users and stakeholders, success is only guaranteed if users develop cooperation, restraint and tolerance, a behaviour that is required in an EnergyGarden as well. Especially with regards to the sensitive and expensive PV installations, accessibility can only be granted if users learn to restraint and respect and learn to appreciate the cooperation with the owner. But also in the participation process, residents must respect each other’s opinion to reach a collectively pleasing goal. While this behaviour was found to be very important for the participation process of Mastwijk, it is a social skill that can hardly be taught by a landscape architect.

For the shared gardens, some guidelines were found that are valuable to EnergyGardens:

B1 Spreading of users
Since shared gardens host many different types of users who not always go well together, the visitors must spread over the whole parcel. Not one single route should host all users, but small trails should leave space to discover the plot for more calamity.

B2 Pockets
Connected to the previous guideline, it is recommended to create small pockets that offer calm spaces for visitors to relax. These pockets should not be joined as a chain but should be designed as one-way streets, preventing a continuous stream of visitors walking along.

Next to the guidelines for specific types of gardens, Sylvia Crowe also introduces guidelines that can be relevant to every garden. She divides those into the seven categories *unity, scale, time, space division, light & shade, texture, and tone & colour.*

B3 Shape mismatches (*Unity)*
Avoiding organic design language in a straight-lined landscape typology (e.g. polder).

B4 Isolated colours (*Unity)*
Placing isolated groups of colours can lead to a miss of unity and a distraction in the garden.

B5 Amount of functions (*Unity)*
By limiting the number of functions on the parcel, a coherent image is created, providing calamity and avoids ‘fun-park’ character.

B6 Rhythm of landscape (*Unity)*
Keeping the natural rhythm of the host landscape by stimulating typical landscape components and key species.

B7 Architectural language (*Unity)*
Reinforcing architecture language that the garden belongs to. In EnergyGardens, this is mainly the PV system.

B8 Special views to landscape (*Unity)*
Not interrupting unique views to the surrounding landscape by adding ‘highlights’ in sight. This requires a view analysis on sight.

B9 Long walks with highlights (*Unity)*
For narrow and long gardens long walks are beneficial with a terminal feature on both sides, stimulating the visitor to explore the whole parcel.

B10 Static vs progressive (*Unity)*
By applying static or progressive design language carefully landscape users’ behaviour can be controlled to some extent. While progressive tree lanes invite to keep on moving, static, closed shapes by trees or pavement invite to stay.

B11 Mystery (*Unity)*
A garden requires mystery to make it attractive for more extended stays and walks. By high vegetation and pocket structures, views over the whole parcel are denied, leading to curiosity of visitors.

B12 Scale of elements (*Scale)*
All elements in the garden must fit regarding their scale and proportion. This is important for vegetation or artworks, but in an EnergyGarden, it also relates to the PV layout and measurements.

B13 Enclosure (*Scale)*
The enclosure of a garden (by e.g. vegetation) bridges the scale difference between human and the infinite sky.

B14 Proportions of an axis (*Scale)*
If introducing a new axis with trees, the width and distance between trees must fit the image that is supposed to be created. In urban developments, this is often forgotten.

B15 Vegetation development (*Time)*
For all vegetation, time plays a significant role. While with, e.g. conifer hedges, a final image can be created fast and maintained for many years, deciduous trees keep on developing, and a ‘final’ picture cannot be achieved.

B16 Vegetation vs other lifetime spans (*Time)*
Planning the development time of vegetation in comparison to artificial objects in a garden. A pavilion may be deconstructed before the tree next to it is grown up. In EnergyGardens, this is mainly relevant for the life span of the PV system.

B17 Open vs closed (*Space division)*
A garden requires both open and closed areas for an exciting experience. The allocation of this division must serve the overarching concept of the garden, highlighting unique components.

B18 Visual barriers (*Space division)*
If applying visual divisions on the parcel to create, e.g. mystery, they always must extend the eye-level. The only exception can be viewpoints, but it is not advised to decrypt all secret of the garden from that perspective.

B19 straight vs organic (*Space division)*
Visual divisions can be formed straight or organic, but the style should be consistent. Exceptions are limited and are only advisable if for sound reasoning.

B20 Illuminating highlights (*Light & shadow)*
If applying highlights in a vegetated area, it is advisable to densify the vegetation around while using a complete opening at the object. By that, the object gets emphasized by the illumination of the sun.

B21 sun in back or front (*Light & shadow)*
An object placed in the south will mostly be illuminated from its back which emphasizes more of its shape. An object in the North is illuminated from the front, emphasizing its texture

B22 Colour scheme (*Colour)*
Western European gardens are mostly set in soft and restrained colours that are defined around the colour of the grass. The range is set from the dark colour of the river to the light colour of the skies. This is contrasting to gardens in, for example, Spain where colours are powerful and daring.

(Crowe, 1994)

The book ”Designed ecologies“ on the landscape architecture of Kongjian Yu, written by William Saunders is focussing both on the significant projects of the famous office Turenscape, managed by Kongjian Yu as well as his career and development in the architectural world. This book was chosen as a leading source on performative landscapes since most of the major projects by Turenscape served a crucial additional function in the design. This varied from large scale water retention to the conservation of local heritage. Even in Kongjians general perception of landscape architecture, the bounding to performative landscapes is obvious. He argues about the naughtiness of landscape architecture to feature aesthetics solely for the sake of aesthetics while they are not useful to achieve any specific goal.

While his view may be exaggerated and does not have to be supported, it is evident that an EnergyGarden is a performative landscape that dedicates a lot of surface, qualities, and efforts on the PV system. The system may be designed carefully and towards the aesthetics of a garden, but the division of priorities cannot be discussed.

Below a selection of design guidelines on how Kongjian Yu handles priorities within performative landscapes is presented. Again, only the guidelines that can be extrapolated to support the definition of an EnergyGarden are chosen and further developed.

C1 Designing with nature

The major finding that comes back in all the described projects is the use of nature for designing. Saunders emphases that nature should not be shaped or regulated too much but should get its space to develop and evolve. While for example, shading on PV panels is a hard boundary in EnergyGardens and must be avoided, the guideline itself is valuable.

C2 Bold interventions

While the design philosophy of Turenscape promotes to keep interference in landscapes to a minimum, it also encourages that if an intervention takes place, it is bold and easily distinguished from the unplanned developments. The probably best-known example is the striking red bench that meanders through the whole red ribbon park. The guideline of a bold intervention can be of value to an EnergyGarden to distinguish it from other EnergyGardens.

C3 Continuous object

By implementing a continuous object, like the red ribbon, it leads visitors like a handrail and can control the routes that people are taking to some extent. This can be of interest if visitors are not wanted in some parts of the EnergyGarden. However, it can also lead to the feeling of marching through the area without a real experience.

C4 Useful ornaments

Connected to his perception of aesthetics, Kongjian Yu argues that ornaments in a garden should not only look good, but they should be useful for the landscape user. While providing, for example, benches, their ornamental design can distinct the EnergyGarden from others.

C5 Aesthetic of low effort

If working with local plants, the chances for a self-regulating system with low maintenance efforts is more likely. The evolving of beautiful nature without intensive labour should be the ‘new aesthetic’. For EnergyGardens, it cannot be maintained as often and intense as regular gardens, thus this is an important guideline.

C6 Creating new aesthetic

The combination of park landscape with, for example, industrial heritage structures was found to work well all over the world (e.g. Duisburg Nord, the Highline). However, this is a recent shift in mindset, and comparably, a mindset can be achieved regarding PV panels in a beautiful and interacting landscape.

C7 Space for adventures

By creating possibilities for leaving the main route, space is designed to experiment in the landscape, which makes the experience more memorable and invites the user to come back.

C8 Pavilions

To create protection from sun and rain, it is argued that pavilions should be included, that are by their design both a visual focal point as a social gathering point.

C9 Changed setting, new nature

By changing settings in the landscape, for example, creating pools on elevated spots, differences develop in the ecosystem, leading to diverse habitats with different species development which can have a valuable educational effect.

C10 Avoiding developed nature areas

When designing a park or garden, spots that already show valuable nature development should not be touched to not interfere with the succession process. While in an EnergyGarden, this can be difficult due to surface shortage, the strength of an intervention is dependent on the nature development (coverage of arrays).

C11 Elevations

Elevations, either natural or artificial, can provide visitors with a good view over the park and the implemented features. In artificial form or with an added highlight, they can function as a focal point.

(Saunders, 2013)

4.5 Community gardens

The concept of community gardens is relevant to be explored in this proposal since the shared use by stakeholders is a crucial part of the definition of an EnergyGarden. Compared to a regular garden or a park, the concept of a community garden includes the social component to the design and emphasis the cohesion that can be created by a shared piece of land.

Furthermore, the balance between public and semi-public ownership of a community garden is an interesting phenomenon to inform this thesis, since EnergyGardens will most likely have one overarching owner. At the same time, local stakeholders will be involved, for example, in the establishment or maintenance of the park, or simply by (shared) usage of the space. Below, a community garden definition is presented that fits the required perception in the context of the EnergyGarden:

“A community garden is any piece of land (publicly or privately held) that is cultivated by a group of people rather than a single family or individual. Unlike public parks and other green spaces maintained by local governments, community gardens are generally managed and controlled by a group of unpaid individuals or volunteers – usually the gardeners themselves. There are many variations on the theme of community gardening. […]”
(Ecolife dictionary, 2019).

Additionally, it must be mentioned that this research is not focussing on small lots that are given to residents in various community gardens, but on the public shared surfaces where decisions are made for the common good. Because of restrictions at the site of Mastwijk, no research is done on possible cultivation of vegetables, fruits, or other foods within an EnergyGarden.

Two supplementary articles on this topic that helped to find out more on the benefits, practices but also pitfalls of community gardens are presented in this sub-chapter to develop more guidelines for an EnergyGarden.

The first literature source that is used to extract design guidelines for community gardens is a case study of the Alex Wilson Community Garden in Toronto that is located in and designed for a social housing district. Next to the quiet peace of nature, it provides a social gathering point for the neighbours and space for cultivating their vegetables.

D1 Economy, community, environment

The primary guideline of the case study can be found in its contribution to the three major pillars that were identified by Wilson. While the garden offers space to grow their vegetables, it decreases the economic pressure on the direct neighbours that can make free use of the garden and its products. At the same time, the garden stimulates the group activities of the neighbours, and corporate workshops improve the community even more. Finally, the green oasis in the built environment, that hosts various species and allows nature development improves on environmental issues that are recognized in cities all over the world. This guideline can entirely be extrapolated to EnergyGardens which desire improvement to all three topics, even if in another setting.

D2 Social history

The analysed community garden is referring to the social history of the place and its residents, leading to a tailored programme for its users. While the history of a place was mentioned before, the social history is a new layer, that reacts to events that influenced the residents. It can comprise both positive or negative experiences and act on them in the design.

D3 Sustainability of design

The approach of the Alex Wilson community garden includes the early involvement of neighbours to achieve collective goals, but also to give the neighbours a sense of responsibility for the garden. The garden can only be sustainably designed, if the users themselves are responsible for maintaining the values of the garden. For an EnergyGarden this guideline seems very important because the added functions are mainly meant for direct neighbours and residents. However, to make a good design feasible, the same residents using the garden must take care of it, or at least feel responsible for keeping an eye on its quality. As seen in chapter 3, for the solar field in Hengelo this works very well.

(Irvine, Johnson & Peters, 1999)

The second article “Realising ecological sustainability in community gardens: a capability approach“ is more focussed on the human wellbeing that can be improved by community gardens. While this is not the focus of this thesis, still the paper provides useful guidelines for a community garden and thus potentially for an EnergyGarden. The scope of those guidelines is mainly the factor ‘time’ for a design.

D4 Infinite development

The development of a garden is never finished, not in a single household garden, and not in a community garden. For centuries, the garden expressed the current needs of its users, and while those may not frequently change for a single user, for groups of users like in a community garden, these never settle. The task of a community garden design is thus to allow the development of the design through time to satisfy its users. While for an EnergyGarden with fixed components and requirements, this is a challenging design task, its relevance is unaffected. If the design is not able to evolve through time, new users will hardly be attracted.

D5 Nature succession

The article proposes a natural development according to permaculture and succession that sustains itself by adapting to its environment. In that way, required maintenance is reduced, and the variable nature leads to exciting fluctuations through time.

D6 Loose components

The more loose components are featured in a community garden, the more likely a change by visitors is, leading to the desired development of the design. While loose elements can be everything from a bench to a pop-up pavilion, it stimulates the creativity of the landscape user. Again, in the case of EnergyGardens, many components are fixed and cannot be changed, but modular clusters of the PV system could be changed on a small scale, leading to development of the PV system as well.

(Clavin, 2011)

4.6 Conclusions

The research on contemporary gardens has shown that although garden design is a very wide field and EnergyGardens do not exist yet, relevant approaches are applicable to multifunctional solar fields. The set of extrapolated design guidelines is only a fraction of existing guidelines, but the mentioned ones are assessed to work well in the context of an EnergyGarden. Nevertheless, while designing, they will have to be adjusted, and not all the guidelines are expected to be relevant for the design of the EnergyGarden Mastwijk. This is not problematic since the presented result can be seen as a toolbox from which a set of guidelines can be picked. It is not mandatory to use all of them. When selecting a set of guidelines to implement in the design, these should go well together, and it should be remembered that not all are equally important.

Furthermore, it is not expected that all the presented guidelines go well with each other and are connectable with the design guidelines that were identified in chapter three. To investigate possible connections, required adjustments and the applicability for Mastwijk, a matrix is hosted at the beginning of the design chapter 7.

While some of the guidelines found in the literature are comparable, the investigation of garden design from the three different perspectives was helpful. With the research on traditional garden design giving a general overview of components to consider, it laid the basis for further analysis. However, it was missing out on the specific design task of an EnergyGarden that is not only meant to please its visitors but generates an essential contribution to the energy transition. The inclusion of performative landscapes enabled approaching the EnergyGarden like landscapes that contribute to a higher goal and please humans and nature only as an added value. Finally, the confined research on community gardens brought insides on the behaviour of user groups and how to involve and manage those.

Figure 5.1: Mastwijk, view from elevated part (South-East corner)

Chapter 5
Site analysis

5.1 Introduction

To move from general guidelines for EnergyGardens towards a tailored design for the EnergyGarden Mastwijk, information on the site and its surrounding is essential. In this chapter, the location is analysed from three different perspectives, starting with the regional perspective or as framed earlier, the host landscape. As a basis, the book “Linten in de leegte”, which was published on behalf of the municipality Montfoort, offered information on the typology and the local landscape components. Afterwards, the site itself is investigated from a development perspective, showing the rich history of land uses that the site has known and that lead to the current situation. Finally, the six most important characteristics of the parcel in the actual state are presented, since they are the limiting factors of the following design.

5.2 Regional structures

Landscape structure

The site for the EnergyGarden Mastwijk is located in the rural landscape of the polder Mastwijk near Utrecht (see fig. 5.2.1). Only a few houses are in its direct environment, and the character of the ‘Groene Hart’ landscape is boosted by the vast and open views over the agricultural fields. The pattern of the scene is dominated by the repetitive rhythm of the Cope-parcels, which are typical for this region and provide a rational atmosphere (De Leeuw, et al., 2008).

The Hollandse IJssel, which is meandering through the polder landscape, can be recognized at many spots when cycling through the polder Mastwijk and Achthooven, and lead the landscape user like a thread through the area. Nowadays, the river is mainly used for recreational purposes on water and cycling along it. The edging of the site to the Hollandse IJssel is offering various chances to branch visitor streams that come along the IJssel.

Since the main agricultural product of the polder is grass (MEES, 2019), and hardly rising components can be found, the sky dominates every view at the polder and works as baring element for atmospheres. The homogenous land use of grass and maize leads to decreasing natural value of the agricultural lands, and washouts of fertilizers diminish the quality of ground and surface water inside the polder, requiring the development of ecological habitats at other locations (De Boer, 2017). In former times, many small patches to produce copsewood (Geriefenbosjes) were located in the polder, enabling flora and fauna to develop mostly uninterrupted. However, due to agricultural upscaling, most of those parcels were removed, leaving the landscape even more open with hardly any shelter for species (De Leeuw, et al., 2008).

Typical for the region are orchards for cherries at the front side of parcels, facing the (Mastwijker) dijk that is the access road to the polder. This is because of the different soil conditions that were formed by the river (Hollandse IJssel) and its fertile sediments. For many children, the cherry orchards were a job opportunity every summer, and nowadays, an orchard in the same environment can bring back childhood memories (Historische Kring IJsselstein, 1986).

In former times, along the Hollandse IJssel, many brick factories were located, dominating the view with chimneys within the landscape. In contrast to other regions, none of the chimneys was kept as a historical landmark or focal point in the flat landscape.

Figure 5.2.1: Location within the Netherlands and the ‘Groene hart’

Regional energy strategy

Mastwijk is located within the RES U16 area of the regional energy strategy that develops goals and approaches towards the energy transition. The U16 comprises 16 municipalities inside the province of Utrecht including the city Utrecht. That results in huge energy demands that need to be satisfied with renewable approaches in the coming decades. Regarding electricity, the RES U16 developed different scenarios, including potentials for energy savings. But even in the most optimal one (most energy saving), in 2030 3.6TWh renewable electricity must be provided. Until 2050 this number has to be increased up to 10.8TWh (Spil, et al., 2020). As a comparison, this stands for 3,600ha solar field or 240 huge wind turbines and 10,800ha solar field or 720 wind turbines, respectively.

The strategy includes placing of solar fields within the open landscape and specifies the desire to give those multiple functions. These can be a combination with agriculture, nature development or recreation areas for the residents of Utrecht. It also advises placing solar fields as much as possible at locations with limited usage potential for other functions such as sewage treatment plants, landfills, or along with infrastructure (Spil, et al., 2020). In that sense, the concept and location of this thesis project perfectly fit the desires of the RES U16 strategy.

Accessibility & recreation

As mentioned earlier, the city of Utrecht is close to Mastwijk and plays a significant role in work opportunities, various facilities and especially tourism. Research, as well as input from residents, have proved that the polder Mastwijk is intensely used by (racing) cyclists in the weekends, with most of them coming from Utrecht and connected suburbia like Leidsche Rijn. Those cyclists mainly arrive via the National road N228 coming from Utrecht and then turn on to the Mastwijkerdijk which is located closer to the agricultural fields and features better views into the polder (Roncken, 2018) (see figure 5.2.2).

Connected to the concept of the Ringpark Utrecht which is to be developed by the province of Utrecht, a new bicycle path is planned, running in the centre of the polder, featuring more rest and relieving pressure on the Mastwijkerdijk and other comparable narrow roads in the polder (Imoss, 2018). The concept of the Ringpark is needed because the 353,000 resident city is expected to grow with 29% until 2040, increasing the requirement of more recreational facilities in the direct nature surrounding (Gemeente Utrecht, 2019).

Although future recreationists from Utrecht at the EnergyGarden Mastwijk are expected to come mainly by bike, the site can easily be reached by car as well. Public transport is not likely to play an essential role since a 1.7km walk is required to the nearest bus stop. Recreationists from the neighbouring town Montfoort with almost ten thousand residents (CBS, 2019) can easily reach the EnergyGarden by bike and car. Additionally, the edging river Hollandse IJssel allows transport by small boat and dingy.

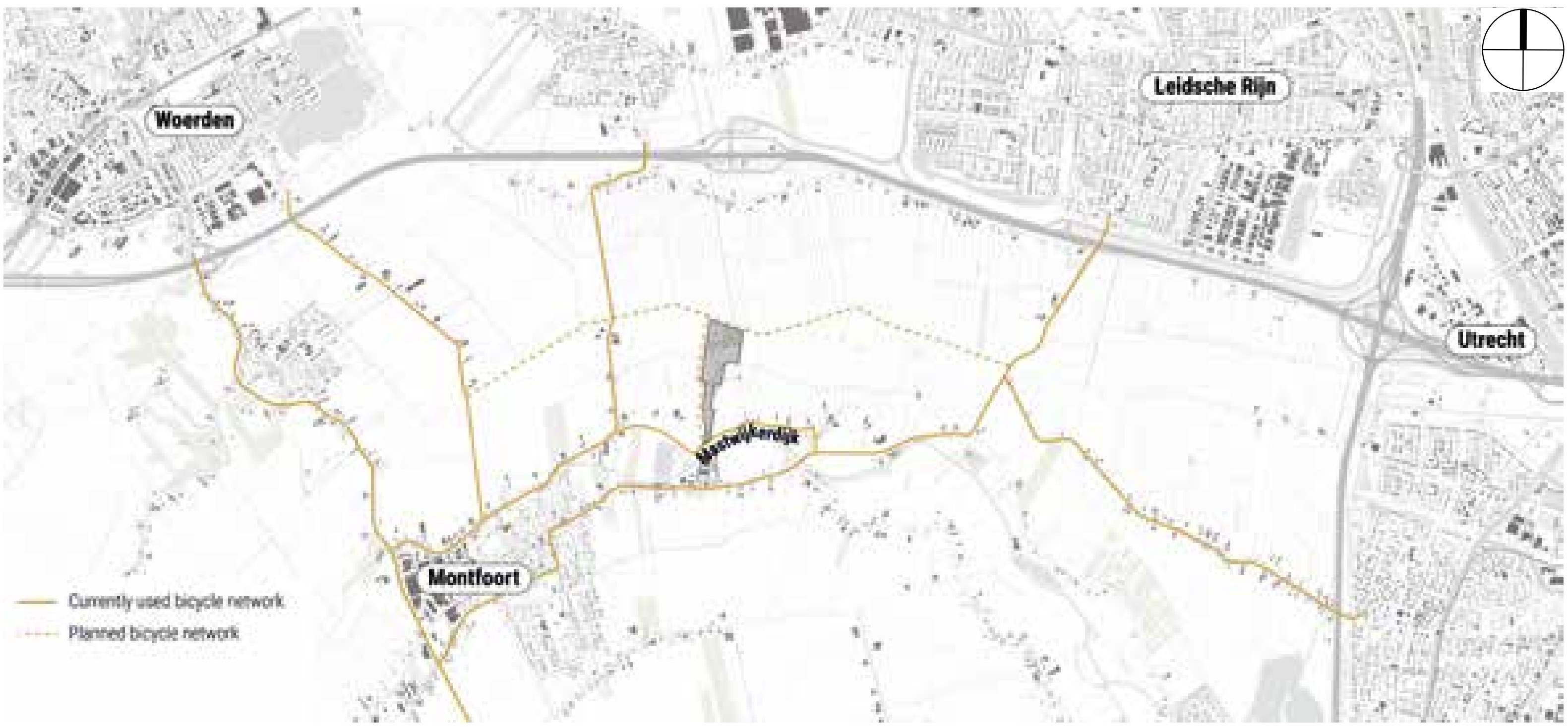


Figure 5.2.2: Regional map of Mastwijk (Based on Openstreetmap & Endomondo bicycling)

In the history of the site, the city of Utrecht played a leading role, as it was used for sand winning for the highway to Utrecht and to dumb waste of the town. Following, the most important events of the site are described explaining how the current situation developed. After, the contemporary characteristics of the parcel are represented on a detailed scale, clarifying the limitations and must-have elements for the design of the EnergyGarden Mastwijk.

Land reclamation period

In the 12th century, the land reclamation of the polder Mastwijk and Achthoven started, transforming the wet and swampy peat grounds into agricultural land (Storm van Leeuwen, 1985). To drain the area ditches were dug, generating Copes (parcels) of 115m wide and 1250m long. Reclamation started from the existing dikes along a river, in this case the Mastwijkerdijk, and was proceeded until the next dike or hard landscape structure. In the case of Mastwijk, the northern end of the reclamation process was defined by the reclamation process coming from the North. The wide ditch (wetering) at the north edge of the parcel is the border between the two reclamation directions. Besides the wide ditch for drainage, these boundaries often featured a wooded bank to mark the border between two parcels visually (De Leeuw, et al., 2008).

Figure 5.3.1: Map of land reclamation (Hoekwater, 1901)

Sand winning

After a long period as agricultural land, in the 1940s some parcels close to the Hollandse IJssel were excavated to extract sand for building the highway A12 (MEES, 2019). Because of the high water levels, instead of pits, large 'lakes' formed with depths of up to 20 metres (Van der Poel 1995). Connected to the excavation of the grounds, the parcellation of the parcels disappeared, leaving one large 'plot' instead (see figure 5.3.2).


Figure 5.3.2: Aerial photograph after sand excavation, 1945 (Royal Air Force)

Landfill

From the 1950s on, the lake was used to dumb household and construction waste of the city Utrecht (see fig. 5.3.3). To facilitate transport of sand, the parcel was connected to the Hollandse IJssel and easily reached by waste boats. The trash was dumped in the water without any treatment or selection process, leading to high and unpredictable toxic washouts into the groundwater and river Hollandse IJssel (Van der Poel 1995). It is unclear until when waste was dumbed at Mastwijk, but a newspaper article of 1971 is writing about the extension of the permit to dump garbage at the location (Reformatorisch dagblad, 1971). Therefore, it can be estimated that the dumbing process continued until the late 1970s.

Figure 5.3.3: Photo of landfill Mastwijk (Hofland, 1965)

Soil cover

After the landfill was closed, the terrain was covered with a layer of four to six meters of sewage sludge and dredge to diminish the amount of gas that leaked the landfill. This layer that lead to the partial elevation of the plot was not enough to prepare the location for new land use (Waterbodem, 2003)(see fig. 5.3.4).

From 2005 on, the new owner *Afvalzorg* covered the site with an additional one-metre layer of dredge, to prepare the site for a new function. To avoid large numbers of trucks, the 400,000m^3 of dredge were pumped to the site in a pipeline (Sjaarda, 2005).

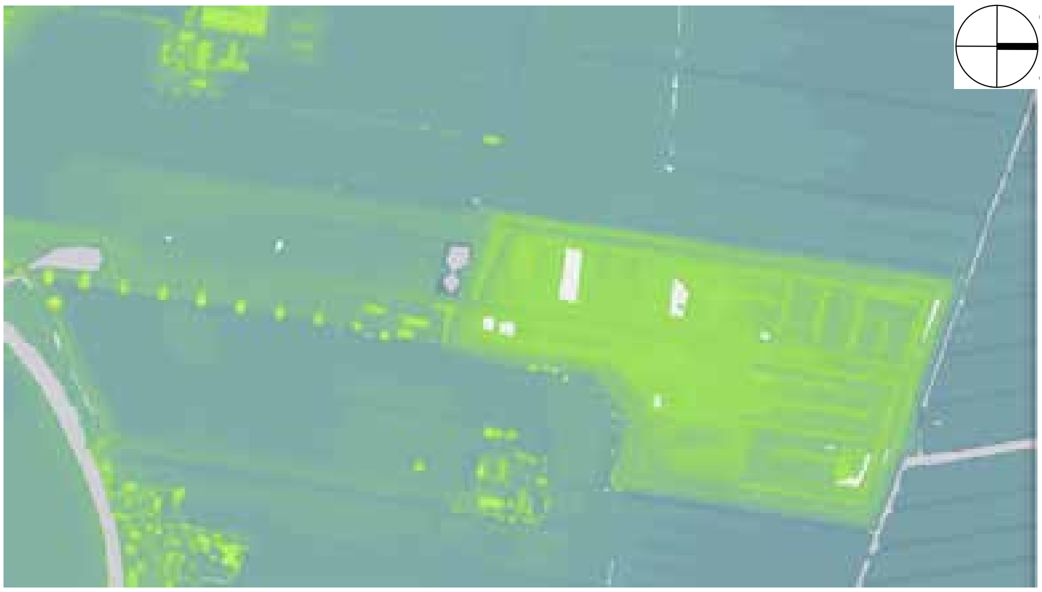


Figure 5.3.4: Elevation map (AHN3, n.d.)

Redevelopment

In the past there were several plans for redeveloping the site with a new function, reaching from an extensive recreation area (Brons & Partners, 2007) up to an estate with housing function (Bosman, Binnekamp, Dwarshuis, et al, 2005). However, due to the insufficient quality of the cover layer, the plans had to be cancelled in the early 2000s (Sjaarda, 2005).

As a reaction, the new layer of dredge was brought onto the parcel by Afvalzorg. Now the quality of the top layer seems to be sufficient to develop a new function; however, due to gas leakage functions such as housing and food production are not advised on the parcel.

Figure 5.3.5: Proposed estate for the site (JoustraReid Architecten, 2001)

5.4 Current situation

Micro elevations

As mentioned, the final layer of the northern part consists of one-metre wet dredge that was pumped to the site. To keep and dry the dredge small ‘dikes’ of one to two metres were built, creating several compartments to keep the dredge in place. During the completing phase in recent years, the elevations were partially removed and faded, but especially at the northern end, the elevations are still recognisable with a height difference of 0.5-1m.

Preferably these micro elevations are kept to prevent interference with possibly toxic layers and to protect flora and fauna species that require a transition between higher (dry) and lower (wet) soils.

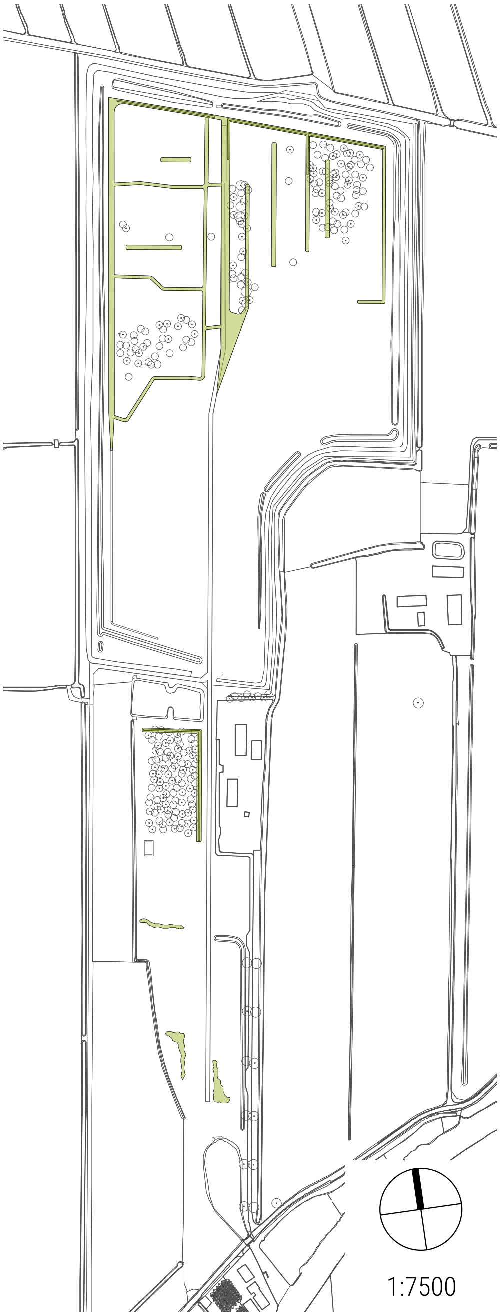


Figure 5.4.1: Micro elevations

Wet areas

For the drying process of the wet dredge inside the compartments special drainage shafts were placed at the ‘dikes’ of the compartments which allow regulating the water level per compartment. Especially at the northern end of the elevated part, where the compartments are still distinct, wet areas can be found where rainwater stays for extended periods because it can only drain slowly through the dredge and cannot run off on the surface.

By regulating the drainage shafts, it is still possible to steer the water levels per compartment, leading to chances for further development of wet habitats during large parts of the year.

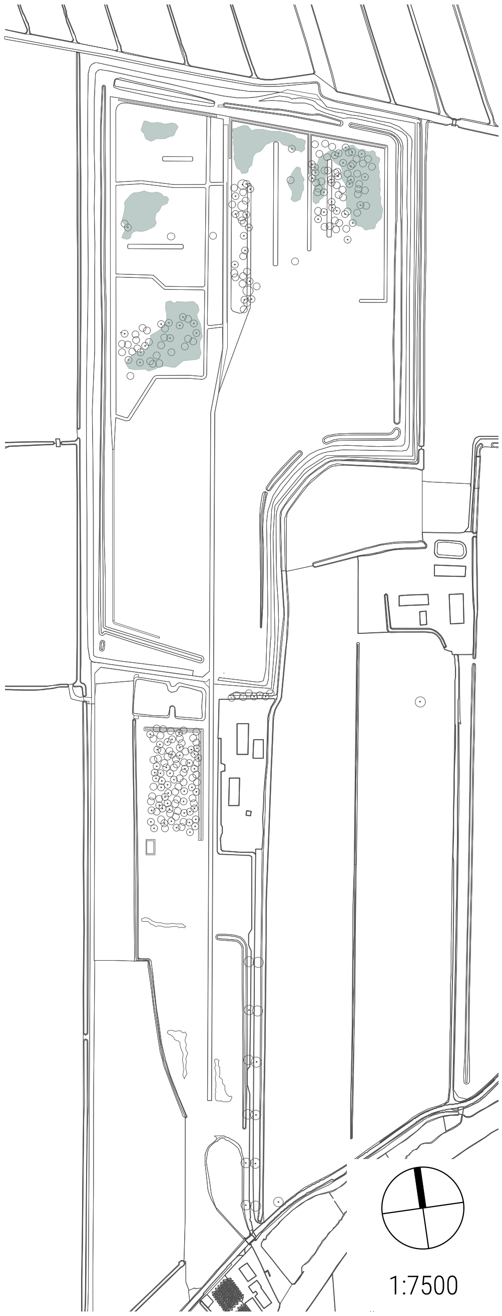


Figure 5.4.2: Wet areas

Soil subsidence

In the drying and settling process of the pumped dredge, subsidence occurs, which depends on factors like the layer thickness and thus leads to a heterogenic surface with various heights. Next to the top layer, also other layers of waste, soil, and sewage sludge are compressing over time irregularly. The soil subsidence is especially of importance on the elevated part of the parcel, since there are the thickest layers of new material. The ongoing and expected subsidence was ranked per compartment with ten as most-, and one as least critical subsidence. (R. Bakker, Afvalzorg, personal communication, April 16, 2020)

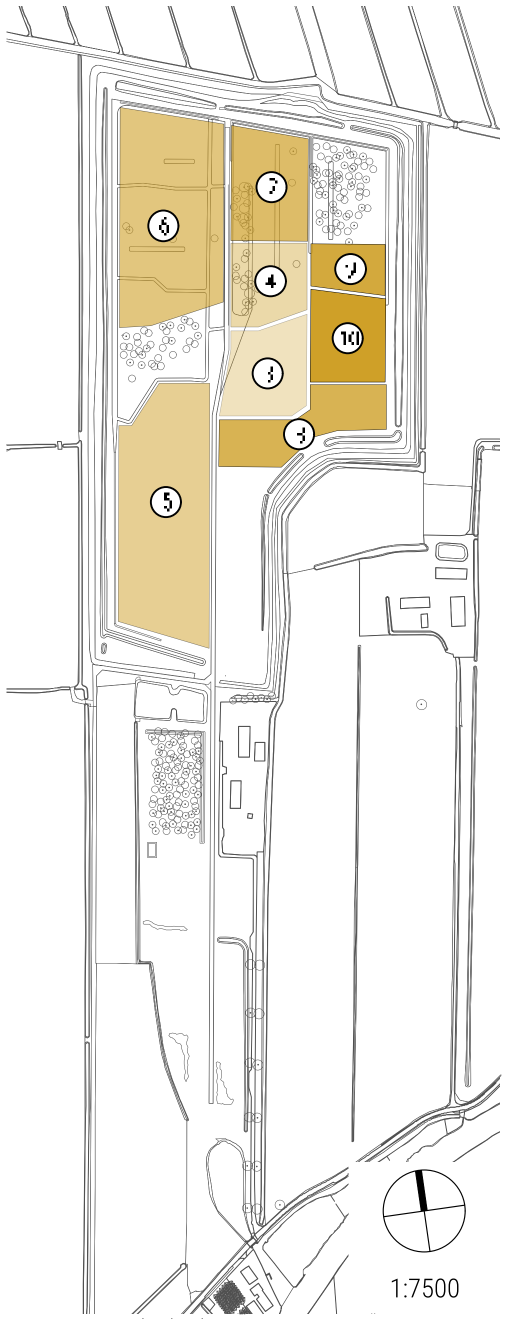


Figure 5.4.3: Soil subsidence

Leachate treatment

Since there are toxic materials on the terrain and their status is not always known, the leachate water on the parcel is gathered at a central basin and pumped to a treatment station in the west of the site (Van der Poel, 1995). Especially on the elevated part of the parcel, the leachate treatment system is recognisable, where a second ditch, running parallel to the clean ditch, was created to collect the leachate water and lead it to the basin. There is a chance that the subsystem is not needed anymore, because the toxic washouts are low enough. Further research would be required before touching the system. In the absence of this research, the subsystem cannot be removed or changed (R. Bakker, personal communication, April 07, 2020)

Ecology

The ecological development in the compartments is in several development stages, due to the ongoing process of covering the landfill with soil throughout the last decades. Especially in the northern part, the compartments can be classified regarding to their ecological qualities and habitats, with ten ranked as the highest-, and one as the lowest value. During ecological research, various flora and fauna species were identified, with particular attention to the Natterjack toad and the Moor frog, which require protection in the new design (Hartog, 2019). Four patches of willows can be found, with the most developed one of ten years in the northeast. Ecologists indicated that these willow patches may inhabit bats and should be kept. (MEES, 2019)

Accessibility

Currently, the parcel is accessible via a road of Stelcon plates which runs almost all the way from the south to the north end of the plot in a straight line, with one branch in the middle that connects the maintenance road to a second entrance in the west. One requirement of Afvalzorg is to keep the current path of Stelcon plates as much as possible, to ensure reliable access during all seasons. It is both expensive and time consuming to establish a new maintenance road for heavy machines and trucks on the weak soil. The thickness of the Stelcon plates allows a slightly unstable soil condition also for higher weights of cars and trucks.

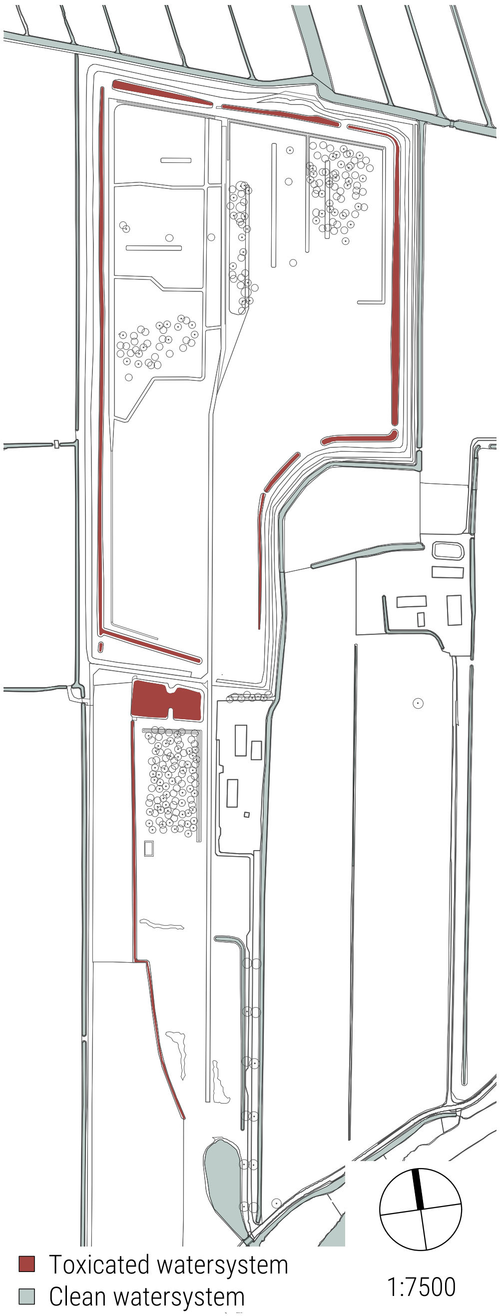


Figure 5.4.4: Leachate treatment

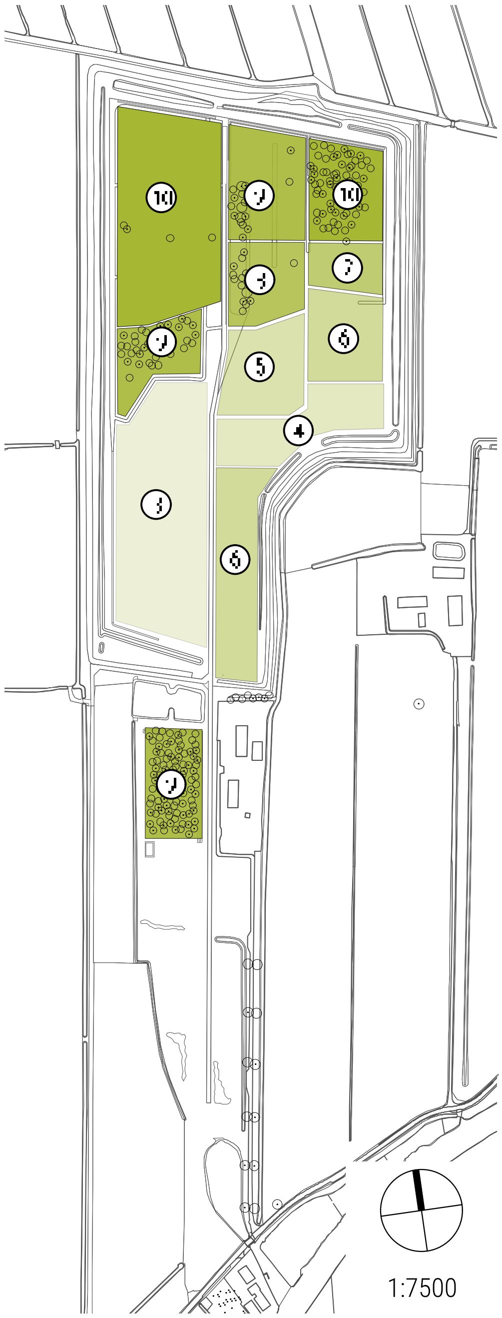


Figure 5.4.5: Ecology

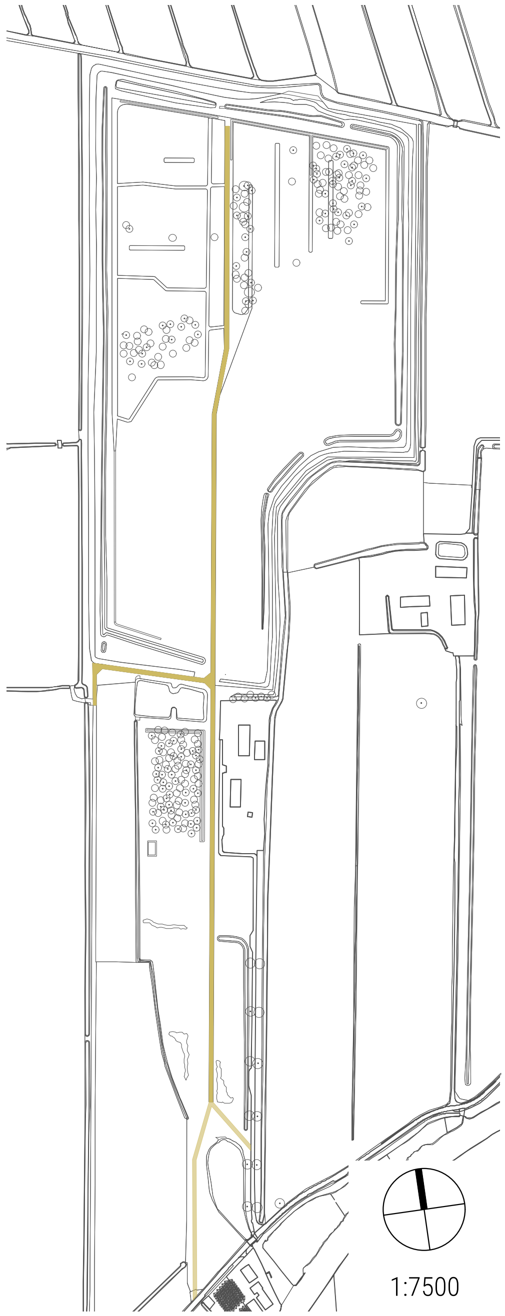


Figure 5.4.6: Accessibility

Figure 6.1: Site visit with participants (Van Etteger, 2019)

Chapter 6
Stakeholder demands & Participatory process

6.1 Introduction

The process around the EnergyGarden Mastwijk is accompanied by various stakeholders, who all have their interests. The spatial design of the parcel is the component where many of those interests must be weighed and matched as far as possible, making it a complicated and time-consuming task.

This chapter presents the most significant engaged stakeholders of the design process and their roles within the project. In the following the process itself is shortly summarized, explaining how the different inputs were dealt with and how decisions and questions were communicated towards the participating residents.

To adapt to the space available in this report, the extended content of stakeholder meetings, design sessions and expert meetings that was gathered over the past year is streamlined into a table in chapter 6.4. It is essential to mention that not all demands that were mentioned at some point can be listed, since they are not all equally important, and some may interfere with each other. In that case, the demand that was agreed on is listed. Furthermore, much of the information was not available from the start on and developed during the process, which made considerations between different interests harder than it may seem in the given overview. A time-line of the various design steps is provided in appendix B.

6.2 Involved stakeholders

Natuur & Milieu Federaties (NMF) are involved as the initiator of the EnergyGarden concept. For each pilot they appointed a local project manager, who is in the lead in the pilot. Their interest is the realization of this solar field as closest as possible to the given definition to communicate the value of multifunctional solar fields. They want to include as many different expertise as possible, while pleasing nature, recreation, education, and the demands of the local stakeholders.

Afvalzorg is the owner of the parcel and responsible for the last decision on the design, business plan and evolution of the process. The interest of the company is to find a viable land use that allows paying the expenses to maintain the landfill. Also for Afvalzorg, the EnergyGarden can be used as a marketing strategy.

Energiezorg as a side branch of Afvalzorg is supporting the process of establishing the EnergyGarden, while especially giving expertise on the technical development of the PV system. The company hardly has interests in the look of the design since it is engaged to support Afvalzorg. They are supposed to make design and process feasible for implementation.

Wageningen University & Research is involved in the development of all three EnergyGardens that are planned and is focussing on the spatial design. The interest of the team of landscape architects and designers is the establishment of contemporary multifunctional solar fields that are pioneers in the advanced energy transition. Furthermore, the goal is to make the definition of NMF tangible and developing it into a unique experience that goes hand in hand with its surrounding landscape, generating as little drawbacks as possible.

Finally, the involvement of **local residents** was a significant aspect of the design for the EnergyGarden Mastwijk for various reasons. The main incentive can again be found in the definition of an EnergyGarden that requires a participatory process for residents, to ensure that the final design is pleasing the local surrounding as the main user of the design. The second reason is found in the problematic history of the site with its various attempts to develop a new land use for leaving the somewhat troubled history of the landfill behind, as described in the previous chapter. Also, the earlier design processes included participation, and most of the residents are still the same, leading to an increased suspicion towards new and shiny concepts like the EnergyGarden.

While also represented in the group of residents, there are **direct neighbours** at Mastwijk, that live literally on the south-eastern edge of the parcel, leading to a strong influence of all measures taken on the site. This group tended to investigate actions on visibility and transition to the landscape even more detailed than other residents. To ensure that there are no drawbacks of the EnergyGarden several interests of different stakeholders were deferred to satisfy the direct neighbours.

6.3 Participatory procedure

The participatory process for the EnergyGarden Mastwijk can be split into two categories. On the one hand, there is the involvement of all interested residents that were informed of the process and design and were able to ask all questions that came up. This group contained on average twenty people, and in the beginning, the approach was made to host drawing sessions with the whole group, but it was quickly figured out that this procedure delivered limited results because of too many different levels of knowledge, interests and repeatedly asked question and inputs.

As a result, an additional group of participating residents was formed that only consisted of five residents (Core group) with each a specific background as representative for a distinct demanded category like nature development or technological innovation. The formation of this group enabled to speed up the process and make decisions regarding the content of the EnergyGarden. In larger intervals, the wide public was informed of the developed plans and was able to give their input.

Until the end of May 2020, five meetings with the wider public, and four meetings with the core group have been hosted. Additionally, more than ten design meetings with the concerned companies around the EnergyGarden were hosted, to reconcile inputs, make internal decisions and to prepare meetings with the residents.

Participation methods

To stimulate the participation of residents during meetings, various methods have been performed and tested, following the structure of iterative learning. As described above, the first meetings were meant to make small groups of people sketching on maps to get insight into their spatial perception of the parcel combined with PV panels. Preceding this meeting, a collective visit was made to the site to ensure that people have a good sense of the site (see figure 6.1).

To force more interaction in the somewhat languid and silent group of participants, a poll was made with multiple positions inside the room, which led to useful insights and a light-hearted atmosphere (see figure 6.3.1).

Furthermore, 'thematic-tables' were made, which each had a specific topic. In multiple rounds, the participants were able to sit on tables for which they had a particular idea or question. In that way, the barrier to interact was lower, while at the same time, the process was better structured. This method was found to work well since it also clarified on which topics most question marks existed for the residents.

Communicating the design

To communicate ideas that were formed together with the core group and within the design-team, various methods were tried. During the first meeting, aerial photographs were used to draw on, which were hard to read for many residents. For the following sessions, design principles were developed, which were presented as preparation for the first spatial concept. While the design principles were understood well, and the content was mainly focussed on the input of the previous participation meeting, the residents had great difficulties with reading the spatial concept. This led to many questions and hardly new input during that meeting. As a result, the next meeting with the broader group was supported by both sections and renderings to visualize the map and, for example, explain the low visibility of the PV installation. This was found helpful since there was much more clarity amongst the residents, and mostly positive feedback was received.

For the upcoming meeting, a physical model was built to make the interventions more feasible for the participants and show the exciting while restrained improved design for the southern part of the EnergyGarden. Due to the Covid19-pandemic, this meeting could not be hosted yet. The clarifying effect of the model is estimated to be significant. The construction method of the model enabled it to develop together with the design as a backbone of the spatial process. The various materials that were used to communicate the design steps can be found in appendix B.

Figure 6.3.1: Poll of all participants

6.4 Overview of stakeholder demands

	PV system	Other renewable energies	Nature development	Recreation
NMF	(Partially) accessible for visitors Combined with other function	Supporting a combination of multiple energy sources Limiting height and extend to scale that fits the landscape Biomass accepted	Developing as many habitats as possible Giving the EnergyGarden a really green character Natural shores for amphibians	Establishing recreation in the style of eco-tourism Showing the interventions undertaken at location
Afvalzorg	Viable to cover installation and connection to main grid (minimum 11MW required) Distanced form gas leakage for safety reasons Not interfering with residents to ensure implementation	Other sources of renewable energy only if they do not block the process Biomass accepted	Nature that stabilizes the top soils Nature that embeds the PV system into the landscape Limited maintenance costs No excavations for natural shores	Limited extent of recreation that does not disturb the area
Energiezorg	Standardized system to lower costs Less accessibility to cut insurance costs Centralized system to cut costs for cables Increasing yield to make efforts more profitable	Only if viable Focussing on technologies that are developed far enough to be implemented immediately	Limited maintenance costs No shading on PV system	Limited to some locations, considering insurance and required safety measures for electrical components Only during day for social control
Wageningen University & Research	(Partially) accessible for visitors Combined with other function No standardized system that could be placed everywhere Multiple types of installation to create heterogeneity Pushing borders towards more acceptance	Accepting multiple types of renewable energy regarding their educational effect Limiting height and extend to scale that fits the landscape Significantly have to add to the experience	Nature development fitting the site and landscape Focussing on key species that are supported Wet areas below panels Keeping height differences	Connection to regional bike path Allowing as much surface as possible for recreation in combination with other function Extensive recreation that does not require many added facilities
Residents	Kept to the minimum required size Hidden as much as possible Limiting height strictly Dividing parcel into PV (north) and other functions (south)	Only on small scale Hardly visible, located at northern edge Small turbines with axis height of max. 10-15m No industrial character Biomass accepted	Green area for experience No shadow and seeds breezed on surrounding agricultural fields Keeping open character of polder vs Total enclosure PV with planting	Extensive recreation No additional facilities (buildings) for recreation Regional bicycle path okay but not impairing traffic situation on Mastwijkerdijk Improving facility for fishers at southern lake
Direct neighbours	Completely out of sight Dividing parcel into PV (north) and other functions (south)	Completely out of sight No noise pollution If wind turbines only on northern edge	Total enclosure of PV system with planting As much surface for nature development as possible (Superior to PV, recreation & education)	Very extensive recreation Recreational movements and activities at the west side or in the northern part Improving facility for fishers at southern lake

Table 6.4.1: Overview of stakeholder demands

	Education	Accessibility	Other functions	Non-spatial demands
	Viewpoint for solar landscape Energy trail providing information on PV system and development of site	Increasing the accessibility as much as possible (in line with EnergyGarden definition) Locating small parking lot for visitors	Charging point for bikes and boats	Moderating a satisfying participation process that is beneficial for all stakeholders
	Communicating development of the site	Keeping maintenance path on parcel as much as possible Parcel has to be accessible for maintenance at all seasons	No excavations on site	Improving image of the landfill Mastwijk and the company
	-	Limited accessibility to cut costs for insurance	Transformer station located at an always accessible location	-
	Education on the energy transition, PV system, site development and combination with other functions Increasing awareness for responsible energy transition	Increasing the accessibility as much as possible to increase social acceptance and experience value No division between fenced PV installation and other accessible functions	Test site for monitoring the development of species with various PV layouts	Constructing a coherent concept Exciting landscape experience
	Viewpoint for solar landscape Information on EnergyGarden and site development	Preference for increased accessibility No high, standardized fences in landscape	Preventing waste of visitors Charging point for bikes and boats Keeping sheep on parcel Landing stage for new recreational electric boat coming from Montfoort	Using as much as possible of the electricity locally Good maintenance planning (!) No waste in landscape No visitors after sunset Leaving cleared site afterwards
	-	Parcel only accessible during day All movements on the site only in western part of parcel Removing existing maintenance road in east along neighbours	Keeping cows on parcel No additional functions that lead to visual or noise pollution	Good maintenance planning (!) No waste in landscape No visitors after sunset Leaving cleared site afterwards

6.5 Conclusions

The participatory process for the EnergyGarden Mastwijk delivered many vital insights and shaped crucial parts of the design. While this may make the design process complicated and time-consuming, it ensures support of the residents for the final design, which can be considered as the most crucial factor. Especially since the design will mainly be used for local recreation, direct neighbours and communities must be committed to the design and find functions that they demand.

A problem that is common for participatory processes and was also experienced in the process of Mastwijk are the contrasting opinions between stakeholders, but also between members of one stakeholder group. Regarding the first, most of the conflicts were dissolved in favour of the residents if possible. Regarding the latter, the democratic way was chosen if possible, and if not, the design team and companies simply made the better-substantiated decision. Some conflicts, like the "filling the whole parcel with PV panels vs making a responsible design", were quickly answered by the definition of an EnergyGarden and received no further attention.

Comparing the findings of this participatory process to the design guidelines that were found in research question 1, it can be recognized that the functions that are found at other multifunctional solar fields are not necessarily demanded at Mastwijk. Comparably, some of the local desires at Mastwijk, were found to be standardized and uncreative measures at other solar fields and in literature. One example for this is the placement of a viewing platform which was found to be hardly used at all the visited solar fields and adds minimal value to the quality and experience of the solar landscape.

Figure 7.1: View on polder Mastwijk from Western edge

Chapter 7

Application of design guidelines

7.1 Introduction

This intermediate chapter is meant to conclude the various findings of the conducted research, before entering the design process of Mastwijk. A matrix is provided in which the design guidelines of research question 1a/b & 2 and the information gathered in the stakeholder process, and site analysis is compared. On the one hand, this comparison is meant to investigate desirable combinations of multifunctional solar field guidelines with garden design guidelines. On the other hand, the compatibility of the discovered guidelines with the site and the stakeholder demands is inspected. This is crucial since the explored design guidelines only have the scope of an EnergyGarden but are not site-specific. If required, guidelines can be adjusted to fit the location and the stakeholder demands, which is noted in the second last column of the matrix.

Important to mention: Stakeholders were not interviewed on every guideline, but educated guesses are based on the observations of one year

A1-33 = Guidelines on multifunctional solar fields

B1-22 = Guidelines on traditional garden design

C1-11 = Guidelines on restorative landscapes

D1-6 = Guidelines on community gardens

7.2 Guideline evaluation matrix

Code	Descriptor	Matching stake-holder desires	Matching site characteristics	Perfect fit with	Not to combine with	Required adjustments	Use for Mastwijk
A1	Vegetation below/ behind panels	Yes Shielding view	-	A2 A8	A5	-	✓
A2	Elevated arrays	No Height of PV	No Bad soils	A1	A4 A5		✗
A3	Alternative con-struction materials	-	Yes Corrosive soils	A4 A7		Recycled plastic instead of wood	✓
A4	Concrete founda-tions	No Industrial look	No Not required	A3			✗
A5	Rotating arrays	No Possible noises	Yes Less foundations		A1 A2 A7		✗
A6	Low angle of arrays	Yes Shielding view	-		A2	To reduce pitch size and max. height	✓
A7	Individual clusters	Yes Natural setting	-	A3	A2	Kept to minimum since inefficient	✓
A8	Spacing between panels	No Increased visibility	-	A1			✗
A9	Ascending rows of panels	-	No Patches accessible		A2 A5		✗
A10	Distance and type of patch border	Yes Exciting experience	Yes Existing defines	A7	A2	Various edge types for experience	✓
A11	Solar panels on hills	Yes Increased visibility	No No new soils to site	A3 C11 B2	A1 A4 A5 A9		✗

Table 7.2.1: Matching design guidelines (1/4)

Code	Descriptor	Matching stake-holder desires	Matching site characteristics	Perfect fit with	Not to combine with	Required adjustments	Use for Mastwijk
A12	Accessibility	Yes Increase to max.	-	A2 A7	A16	Some patches may be fenced	✓
A13	Multiple types of panels/installations	Yes But limited	-	A2 A5 A7 C5		Only different layout, no crazy structures	✓
A14	Designed inverters & transformers	Yes Camouflaged	-		A15		✓
A15	Hiding inverters and transformers	Yes Out of sight	Yes Possible in forests		A14	Transformer station hidden in forest	✓
A16	Ratio of yield and visible edge	Yes Out of sight	No Patches accessible		A12 A2 A5 A6 A12		✗
A17	Keeping landscape structures	Yes Connect typology	-			Line structure adapted, ditches not possible	✓
A18	Diverse edge	No Blend in	Hardly Already diverse		A32		✗
A19	Security of PV systems	Yes Invisible security	Hardly No new ditches	A1 A2		Using ditches, small fences and screws	✓
A20	Considering structures on parcel	Yes Increase biodivers.	Yes Compartments			-	✓
A21	Wet habitats below panels	Yes Increase biodivers.	Yes Keep wet soils	A1 A3	A4	Regulated by drainage shafts for maintenance	✓
A22	Green shield on patch borders	Yes Shield view	Yes Keep willows	C1 C7	A2	Existing trees, partially shrubs	✓
A23	Viewpoint over solar landscape	Yes Desired feature	Yes Already elevated	B5		Limited to 4m and partially shielded view	✓
A24	Contemporary gathering point	No Not desired	No Too remote				✗
A25	Enclosure vs maximum sunlight						**=B13**
A26	Use of time span	Yes Devlp. nature area	Yes No use foreseen	B16		No disadvantages for PV system allowed	✓
A27	Limiting effects construction	Yes Limit construction	No Bad soil will destroy	A2 A3	A4 A5		✗
A28	Site choice on characteristics	-	Yes Landfill, brownfield			Remote from power grid though	✓
A29	Considering local needs	Yes Participation	Yes Improving biodiv.	D4		-	✓
A30	Supporting local species	Yes Local plants	Yes Improving existing	A1		-	✓
A31	Considering networks	Yes Connect to bikepath	Yes Enhance connection			EHS area too far removed	✓
A32	Shielding fitting to typology	Yes Increase dike	No No new soils		A18		✗
A33	Analysing elevations of context	-	No No elevations				✗
B1	Spreading of users	Yes Small side-trails	Yes Extended parcel	A2 B2 C7	B9	Small side trails and various paths on parcel	✓
B2	Pockets	Yes Pockets of nature	Yes Compartments/nature	A1 A11 B1	A6	‚Pockets' framed by PV patches/arrays	✓

Table 7.2.1: Matching design guidelines (2/4)

Code	Descriptor	Matching stake-holder desires	Matching site characteristics	Perfect fit with	Not to combine with	Required adjustments	Use for Mastwijk
B3	Avoid shape mis-matches	No Meandering paths	Yes All aligned			Stakeholder input kept to minimum	✓
B4	Avoid isolated colours	No Colourful plants	Yes Homogeneous grass	A3			✓
B5	Limiting functions	Yes Make extensive	Yes Not much possible	A23	C8	Walk, cycle, canoe, fish, view, relax, charge bike	✓
B6	Replicate rhythm of landscape	Yes Open/Copse	Yes Willow patches exist	A1 A3			✓
B7	Reinforce architec-tural language	No All natural shaped	Yes Rectangular structures	A3 A5			✗
B8	Clear special views to landscape	Yes View to landscape	Yes No existing barriers			Path located outside the visual barrier of PV	✓
B9	Long walks with highlights	Yes Art and view tower	Yes Stretched parcel		B1		✓
B10	Static vs progres-sive	Yes Progre. at neighbours	No Height difference			Hard to implement in practice with limits	✗
B11	Mystery	Yes Hide parts	Yes Complex site	A1 C11		By elevations, existing & new vegetation	✓
B12	Scale of elements	No PV everywhere small	Yes Two typologies	A3 A5	A4	PV small scale South PV large scale North	✓
B13	Enclosure	Yes Partially	Yes Partially	A1 A2		By existing & new tree patches	✓
B14	Proportions of axis	No Shading on agriculture	Yes Good axis fits area				✓
B15	Vegetation devel-opment	No Not understood	Yes No new use planned	A1 A2 A8	A4 A5	Nature development without final picture	✓
B16	Vegetation vs other lifespans	-	Yes Second PV lifespan	A26 C9 D3	A1	Second lifespan of PV possible on this site	✓
B17	Open vs closed	Yes Diverse landscape	Yes Existing situation		A2	Exiting willow patches and open fields as basis	✓
B18	Visual barriers extending eye-level	Yes Shield view	Yes Existing situation	A1	A6	Exiting willow patches are higher than view tower	✓
B19	Straight vs organic	-	No All straight	A1			✗
B20	Illuminating high-lights	-	No No highlights in woods				✗
B21	Art with sun in back or front	-	-	A5		Simply matching since sun rules perception	✓
B22	Limited colour scheme	No Colourful design	-	A3			✓
C1	Designing with nature	Yes Keep existing	Yes Existing nature rules	A1 A22 D5	A2	Existing willow patch-es rule PV system	✓
C2	Bold interventions	No Not desired	No Many restrictions	A3 A5			✗
C3	Continuous object	-	-		A7 B1	Not smart to spread visitors	✗
C4	Useful ornament	Yes Many elements desired	-	A3 A4 A5 D3		Info, tower, bench, trash-can, gate as ornament	✓

Table 7.2.1: Matching design guidelines (3/4)

Code	Descriptor	Matching stake-holder desires	Matching site characteristics	Perfect fit with	Not to combine with	Required adjustments	Use for Mastwijk
C5	Aesthetic of low effort	No No aesthetic measures	-	A1 A5 A13		Not trying to imitate existing aesthetics	✓
C6	Creating new aesthetic	No Not desired	-	A1 A3 A5	A4	Integration that may stim-ulate aesthetic perception	✓
C7	Space for adven-tures	Hardly Keep them on trails	Yes Diverse scenes	A22 B1 D6		Trails invite to explore the area and its nature	✓
C8	Pavilions	No Disturbs view	No Height restriction		B5		✗
C9	Changed setting, new nature	-	No Reduce changes	B16 D5			✗
C10	Avoiding developed nature areas	Yes Protect nature	No Space required for PV	D5		As good as possible but space required for PV	✗
C11	Elevations	Yes Quiet education	Yes Existing	A11 B11		-	✓
D1	Economy, commu-nity, environment						
D2	Social history						
D3	Sustainability of design	No Not interested	-	B16 C4	A1		✗
D4	Infinite develop-ment	No Not interested	No Many restrictions	A3 A4 A7 A29	A2 A5		✗
D5	Nature succession	-	Yes Nature defines species	A2 C1 C9 C10		Current species are used as basis for planting	✓
D6	Loose components	No Not interested	No Many restrictions	A3 A4 A7 C7	A2 A5		✗

Table 7.2.1: Matching design guidelines (4/4)

Cannot be matched spatially (shaded rows)

7.3 Conclusions

The guideline evaluation matrix shows that most guidelines of multifunctional solar fields can be combined with the detected garden design guidelines, which confirms the concept of EnergyGardens. The major exception is found at the design guidelines of community gardens, where the infinity of the design process is emphasized, which can hardly be combined with a technically developed PV system.

For the application at Mastwijk, also considering the stakeholder demands, two-thirds of the design guidelines were evaluated to fit in general terms. To incorporate them into the design, many require little adjustments which were briefly mentioned in the matrix. The extensive integration of the chosen guidelines is part of the design process and is found in chapter 8.

The fact that some of the guidelines are not incorporated in the design does not mean that they are not valuable to EnergyGardens, but they simply do not fit the case of Mastwijk or other chosen guidelines. Generally, it is not required to use all the identified guidelines, and it is even advised to choose a selection of guidelines to design a coherent spatial concept. Guidelines, like A1 vegetation beneath panels, may generally be found applicable and could be featured in the guideline selection of every EnergyGarden.

Figure 8.1: Visualisation of path trough maintained willow patch

Chapter 8
The Design

8.1 Introduction

In this chapter, the knowledge that was formed and gathered on research question 1a/b and 2, as well as Knowledge question 1 and 2 is translated into a design for the EnergyGarden Mastwijk. The relevant design guidelines that were defined in the previous chapter are the starting point for site-specific design principles which then translate into a spatial concept. The concept is accompanied by general information on the design language to inform details of the design.

The design is described in two ways that reflect the structure of this thesis. First, its components are explained with the scope of regular landscape design. This includes general information on the PV system, the developed ecology, recreation, education and a set of used materials that unify the design. However, in contrast to conventional landscape designs, the EnergyGarden Mastwijk features many measures that lead to the responsible integration of the PV system into the landscape and allow an exciting experience. Therefore, a second description of the design is added, analysing taken measures, that are based on the identified design guidelines for multifunctional solar fields. The same framework that was used to analyse the four cases is applied, allowing a direct comparison between the case studies of chapter 3.2 and the EnergyGarden Mastwijk.

If a previously defined design guideline is used in parts of the design or a visualized image, it is indicated with its code (A1-D6) as superscript numbers in fluent text, enabling the reader to browse back to the matrix of chapter 7.2. By that, for some of the EnergyGarden guidelines, it is exemplary revealed how they are translated into case-specific design principles.

The design chapter does by far not include all the steps that were taken to get to the final design, to keep its clear structure and sort out components that lost their relevance. Additional materials that illustrate the design development can be found in appendix B.

8.2 Spatial concept

The desire of a spatial combination of PV installation and recreational functions, to create a tangible experience, is mentioned throughout the whole report. However, in the design process, it became clear that a division is required to some extent, to create a more exciting landscape experience and to satisfy the residents of Mastwijk. Furthermore, the shape of the parcel, which is narrow and hosts many high components in the south, while being wide with open views in the north, proposes a division into different landscape types. Resulting, the parcel is developed as a gradient from an enclosed, small scale garden towards a wide and open landscape in the north. The PV system can be found everywhere distributed on the parcel, with its scale and extend tailored to the experience per area on the plot [B12].

Peak-density of PV system

The density and layout of the PV installation is a peak shape that is projected on the plot (see figure 8.2.1). Starting in the south where only a few single clusters are implemented [A7], towards the north of the not elevated garden where the number of panels increases while still using a low setup which can be overseen. From there, the scale of the PV system increases rapidly towards its peak, and translates into an east-west installation with the highest yields possible. From there, the PV density decreases again while keeping the scale of the wide landscape typology in the north. In that way, the PV system features the whole range of low density in small scale landscapes, over maximized yield, towards low densities on a bigger scale [A13].

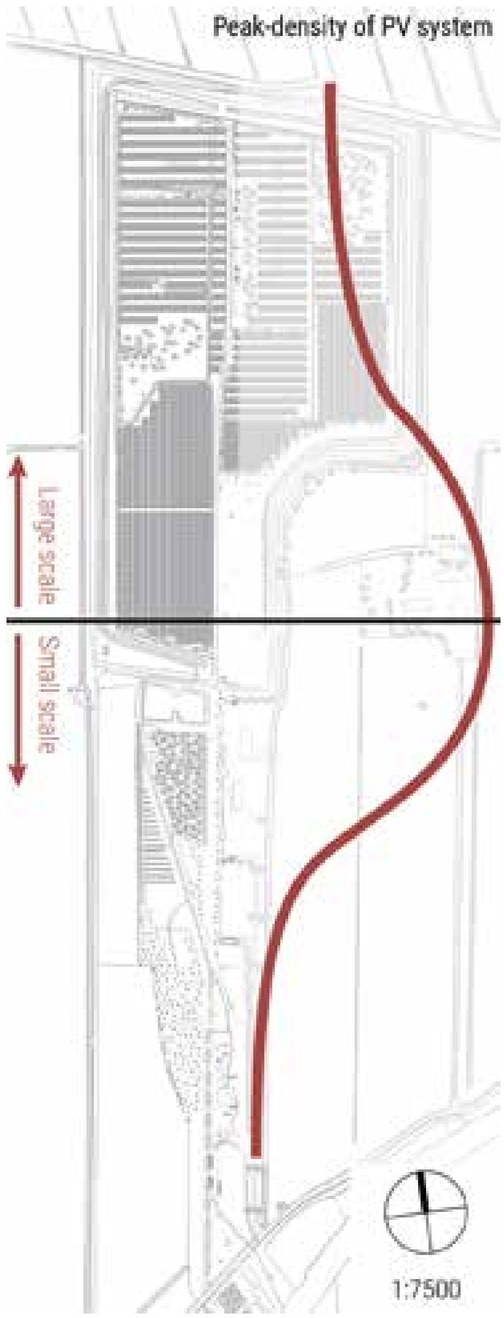


Figure 8.2.1: Peak-density of PV system

Guiding visitors away from direct neighbours

One demand of the direct neighbours was the relocation of the southern maintenance road to prevent visitors near their plot. This demand is fulfilled by relocating the maintenance road to the west side of the parcel. With planted vegetation on the embankment of the current maintenance road, visitors would probably keep using it to get to reach the north. To prevent arising nuisance, the embankment of the current maintenance road is transformed into a pasture. It inhabits three highland cattle that are currently living on the parcel, fulfilling another stakeholder demand. To divide the cattle from visitors, a fence is introduced (figure 8.2.2), also disabling people to walk on the embankment while still looking like a natural division (see figure 8.4.3.2).

Connection to the regional bike route

As described in the site analysis, the province will establish a bicycle path in the north of the parcel and desires a branch passing through the EnergyGarden [A31]. While the idea is tolerated by most stakeholders, it is demanded to be placed as much in the west as possible to prevent nuisance. In the south of the parcel, the bicycle path connects to the Mastwijkerdijk.

Adventurous trails for informal recreation

Additional to the paved bicycle path, the area features many unpaved trails that stimulate the spreading of visitors through the area[B1] and allows to experience the nature from a lot closer. On the elevated part, most of the trails follow the compartment structures that were described in chapter 5 [A20]. The unpaved trails create the impression of freely discovering the nature and PV system [C7], while in fact the trails are carefully located so that they do not interfere with the PV installation or lead to nuisance with the neighbours.

Figure 8.2.2: Guiding visitors from direct neighbours

Figure 8.2.3: Connection to regional bike route

Figure 8.2.4: Adventurous trails for informal recreation

View connections and axes

The erected shape of the parcel with its already existing view connections was taken as an inducement to reinforce the view connections and implemented several axes [B9]. The direction of the axes is retrieved from the two polder directions that are featured around the parcel and reintegrate it into the former polder structure [A17]. At two ends of axes a highlight is added, with one an artwork, and one a view tower, as demanded by the participants [A23]. The highlight, which is highlighted by the sun at the end of the dark axis, triggers to walk the long distances on the parcel [B21] (see figure 8.2.5 & 8.4.3.2).

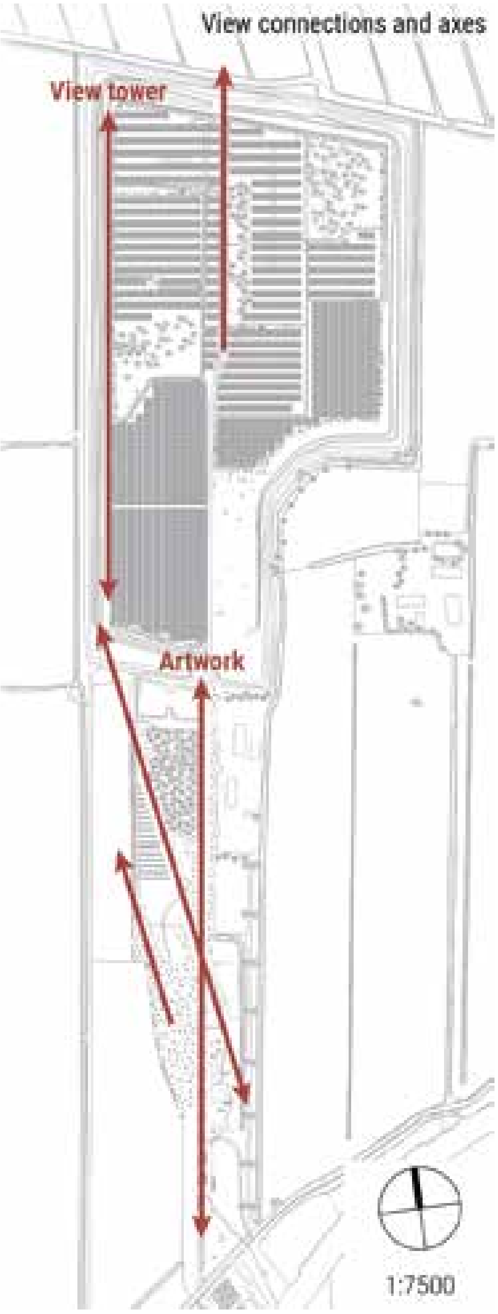


Figure 8.2.5: View connections and axes

Design language

The design language of the taken measures follows the shapes and typology of the polder landscape, resulting in rational lines and open views. However, a crucial part of polder landscapes has always been the interplay between the empty agricultural fields and copses in the landscape. A copse is a parcel that is used for wood production by repeatedly cutting young trees near the ground, leading to multiple stems and faster growth. The interplay between the open and closed parcels in the landscape makes moving through polder landscapes exciting while it brings the scene to a more human scale. The interaction of open and closed areas is introduced in the design by many vistas and height differences by panels and existing elevations, giving the EnergyGarden a certain extent of mystery.

The multi-stemmed trees of the mentioned copse can also be found at the existing patches of willows on the terrain and transmit the impression of spacious natural growth. However, the process of coppicing and the exactly planned placing of those copse in the polder landscape perfectly shows the rationality of this landscape typology.

The concept of multiple stems is added to the design language and can be found in all artificial elements that are placed in the EnergyGarden [B6]. It may vary in scale and purpose, but it is always consisting of three equal poles that are tilted 10° form the central axis, giving the rationality to a natural-looking group (see figure 8.2.7). This ornament can be found back in benches, info panels, waste bins and gates, informing the visitor of his arrival at the EnergyGarden [C4].

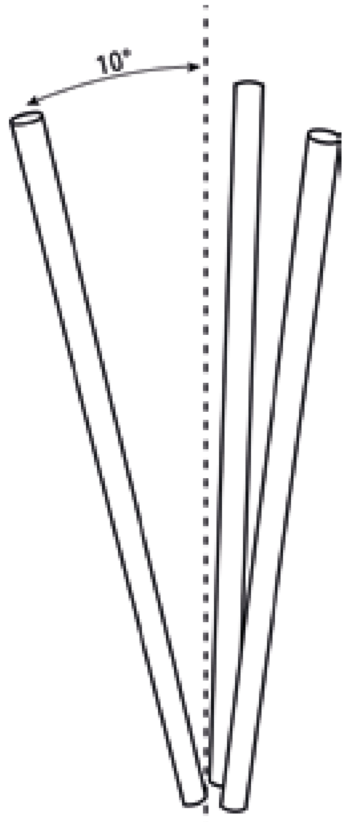


Figure 8.2.7: Schematic view of multi-stemmed ornament


Figure 8.2.6: Multi-stemmed trees by coppicing

8.3 Graphic plan

(for large version see appendix C)

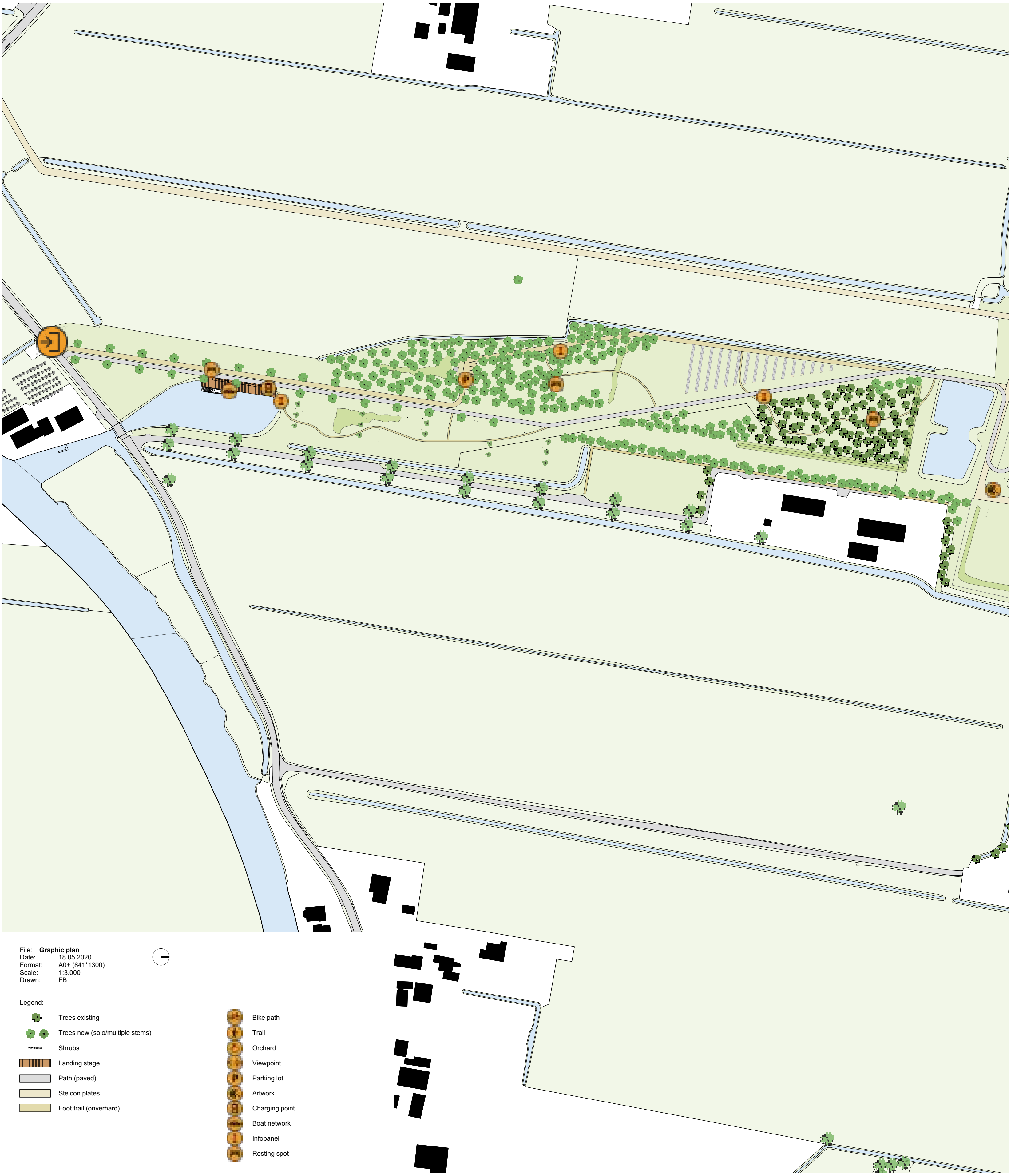


Figure 8.3.1: Graphic plan

8.4 Design experience

8.4.1 PV system

As described in the spatial concept, the density of the PV system follows a peak shape. In the south of the parcel, where solar energy is implemented on a small scale, only a limited surface is reserved for the PV system, which translates into loose clusters at the orchard (see figure 8.4.1.1) and short arrays with two rows. This leads to a low height that enables cyclists to look over the arrays, while the wide pitch size allows visitors to scroll through the PV system or even have a picnic in the shaded grass behind the panels [B2].

When walking on towards the north of the parcel, the scale and density increase heavily, resulting in an east-west setup that leaves hardly room for any added functions. Solely some nature development at the patch borders can be seen[A22]. From there, the density of the PV system decreases again while the scale of the setup stays big, matching the scale of the landscape in the northern part of the parcel with its wide views (see figure 8.4.1.2). Spatially this translates into wide patches of huge south-facing arrays with a low angle. The pitch size of those patches varies and reaches its maximum at the northern end of the parcel where previously developed nature is spared by a diffused PV setup. All the south-facing patches feature small paths allowing visitors to experience the system from close by and move freely through the whole solar landscape. The locating of different PV layouts is based on existing soil quality and nature development. The east-west setup is placed at low soil and nature quality, while the wide spacing is located at already developed areas to maintain nature values, according to the site analysis presented in chapter 5.

The technical details and choices of the PV system are explained and visualized in chapter 8.5.1

To be able to access the PV system with a truck at all seasons, a stable maintenance road is required. Since the direct neighbours demanded to remove the existing maintenance road, a new route was planned for the southern part.

Figure 8.4.1.1: PV clusters in orchard [A7]

In contrast to the current situation, it is not made of Stelcon plates but gravel which allows a more natural integration. The route runs from the south entrance towards the added parking lot for visitors and from there along the western border to the existing Stelcon road at the leachate basin. By that, the maintenance road is far removed from the direct neighbours and can even be used as an additional walking route from the parking lot.

Figure 8.4.1.2: Visualisation of added bicycle path on elevated dike in West (view on backside of East-West installation covered by vegetation) [A1]

8.4.2 Ecology

Besides the PV system, the creation of new- and conservation of existing nature development was the key design goal. The taken efforts can be found throughout the whole plan, and only the primary elements can be named in this report.

The most striking element in both the plans, as well as the real-life experience, are the patches of willow trees that were kept providing habitat for the bats on the parcel (Hartog, 2019). The patches are sustained by additional planting of willow trees in the southern part of the parcel, which shapes the patches towards the design without unnecessary cutting of trees. Since the patches are cultivated according to the process of coppicing, a high ecological value can be predicted, while the wood can be used as biomass.

Small paths through the willow patches allow the visitors to experience the nature development from close by while protecting them from the sun in the summer (see figure 8.4.2.1). The spreading of the willow patches leads to a comfortable variety of sun and shadow for both humans and nature [B13].

The wet compartments on the northern part of the parcel, that were described in chapter 5, are maintained, keeping the transitions between high and low and dry and wet, respectively. In the north, this leads to a huge surface for plants that enjoy wet soil conditions. The combination with partial covering by solar panels divides the habitat further into sun- and shadow tolerating species [A21].

In the southern part, where fewer PV panels lead to shadowing, the focus is laid on wide flower meadows in combination with an orchard and scattered shrubs. In combination with a series of insect hotels at the end of the PV arrays (see figure 8.5.5.1), this part of the EnergyGarden becomes a paradise for bees & co.

The planting scheme for the EnergyGarden was kept close to local species that partially already exist on the parcel [A30]. This has two main reasons. On the one hand, native species are often cheaper than exotic species that have to be imported, keeping the costs for the nature development of the EnergyGarden low to ensure its implementation. This may seem like a minor detail next to the costs for the PV system, but all expenses are critically weighed in the business plan by the responsible stakeholders.

On the other hand, the native species that are acclimatized to the landscape characteristics require less maintenance to prosper and survive many years. This is crucial since, in comparison to traditional gardens, the EnergyGarden only schedules maintenance for plants once or twice a year[D5].

Figure 8.4.2.1: Visualisation of path trough maintained willow patch

8.4.3 Recreation

Next to the improvement of ecological goals, several recreative functions are included in the design. Most prominent in the design is the bicycle path that enters the parcel on the northside and crosses through it up until the Mastwijkerdijk in the south. It is placed on the elevated outer dike of the northern part, enabling cyclists to overview the polder landscape and parts of the solar landscape. Since the path is climbing from the north, the view is revealed bit by bit. When reaching the southern part, a great view is enabled on the deeper, small-scale solar landscape [C11]. In this part, also the path bends more often and the pattern of open and closed changes frequently [B17], which creates an exciting journey (see figure 8.4.3.2).

When using the bicycle path in the other direction, the terminal feature of the western axis is an added view tower. Due to its height of four meters and the elevated position in the landscape, it is easily recognizable in the flat polder landscape (see figure 8.4.3.1).

Its design language is based on multi-stemmed trees as they are described at the start of this chapter. By placing the platform on three groups of each three stems, the view platform provides the impression of a treehouse in the polder. By its total height of only four meters, it fits the restrictions of the municipality while it is high enough to overlook the PV system. The maintained willow patches cannot be overseen which preserves some mystery of the solar landscape [B18, B11] and invites to explore the whole parcel [C1].

Besides by bike, the EnergyGarden Mastwijk can be reached by car. A small parking lot is hidden in a patch of new-planted willows to prevent visual nuisance for residents (see figure 8.3.1).

Furthermore, residents desired to develop a landing stage that can be used by electrical boats coming from Montfoort to transport visitors in a sustainable way (Gemeente Montfoort, 2010). The landing stage is designed as a small waterfront where residents that entered the EnergyGarden from the south can take a break at the water.

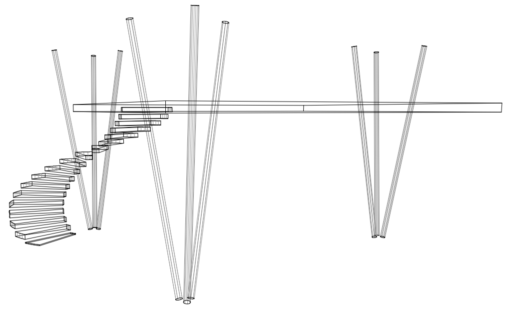


Figure 8.4.3.1: Potential shape of view tower

Figure 8.4.3.2: Visualisation of vista in southern part

8.4.4 Education

To meet the definition of an EnergyGarden, an educational component was added to the design of Mastwijk. The detailed research on implemented solar fields has shown that an energy trail can be a good way to communicate relevant information to visitors.

However, since a predefined route through the EnergyGarden contrasts with several selected guidelines, the points where information is provided are spread over the whole parcel and information does not build upon each other.

The first and most apparent method to transmit information is the use of information panels where visitors can find information on the history of the site, the solar landscape, its ecological development, and the general topic of energy transition (see figure 8.4.4.1).

The second and less common way of communicating the knowledge is the use of strictly selected materials that connect to the image of the EnergyGarden by being either renewable, recycled or reused. In combination with information panels on, e.g. embodied energy, visitors are taught the choices behind specific materials.

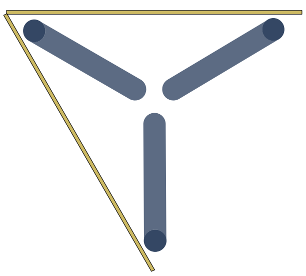
The third way of transferring information within the EnergyGarden is observation. While this channel may seem self-evident and hardly designable, trails are located to come as close as possible to the different PV setups, their ecological development, the different aged willow patches, and the dike structures with their habitats. In this way, visitors can collect many different impressions that are reinforced on the information panels. The ability to get in touch with the mentioned components distinguishes the EnergyGarden from analysed solar fields like Neukirchen-Vluyn, where the read information cannot be experienced.

Figure 8.4.4.1: Scale model of info-panel

8.4.5 Materials

Since the EnergyGarden aims to communicate an environmentally friendly character and to fulfil an additional educational purpose, the partial recycling or reusing of materials is an inexpensive and aesthetic way to reach two goals at the same time [C5, C6]. The visitors are informed on the embodied energy of materials, communicating how much energy was saved by not producing new materials for e.g. asphalt walkways or steel poles for information panels.

Below the used materials of the design are described, and their use explained.



Recycled plastic & wood

Benches, trash bins, information panels and gates all come along with three equally tilted poles and are made from black recycled plastic. Since these poles are made of residual waste, just like the waste that was dumped on the site, a nice link can be laid (Möller & Jeske, 1995). The black 'stems' of recycled plastic, give the idea of toxic trees that get their nutrients from the infinite source of domestic and construction waste below the solar landscape. In combination with light wood that transmits a sustainable character, a paradox for the human eye and brain is created.

By the different ways of reacting to sunlight the contrast is even more increased: While the black poles absorb most of the light and keep their dark toxic appearance, the light wood reflects the sunlight and appears even brighter.

Next to the philosophic approach towards this material, there are several rational choices made. The poles of recycled plastic are resistant to the wet and partially chemical soils on the plot while they are cheap, very sustainable and reinforce the energy-friendly character of the EnergyGarden. With a lifetime of 50 to 100 years, the furniture elements can stay on-site even when the lifespan of the PV system is reached (Eng, 1993). The used wood can be of local or regional origin and is a renewable and inexpensive material that almost works as a bearer of sustainable development. Its reflecting characteristic ensures that it is nice to sit on the benches even in the direct sunshine.

Figure 8.4.5.1: Pole of recycled plastic (Koppel-Group, n.d.)

Also for the PV system, the use of recycled plastic is proposed. If not applied as poles but as profiles, the material was found to be resistant to shocks, as well as horizontal and vertical forces on guardrails (Eng, 1993). Research on the soil circumstances for ramming the anchors of the PV system at Mastwijk has found that at several spots the ground features particles that will react aggressively to concrete and steel profiles of the PV system (Hurler & Kleynmans, 2020). The company that did the test is advising at least an additional coating for the profiles to keep them from corroding. By its composition, recycled plastic is less sensitive to many toxic particles, which could potentially lead to an excellent synergy [A3].

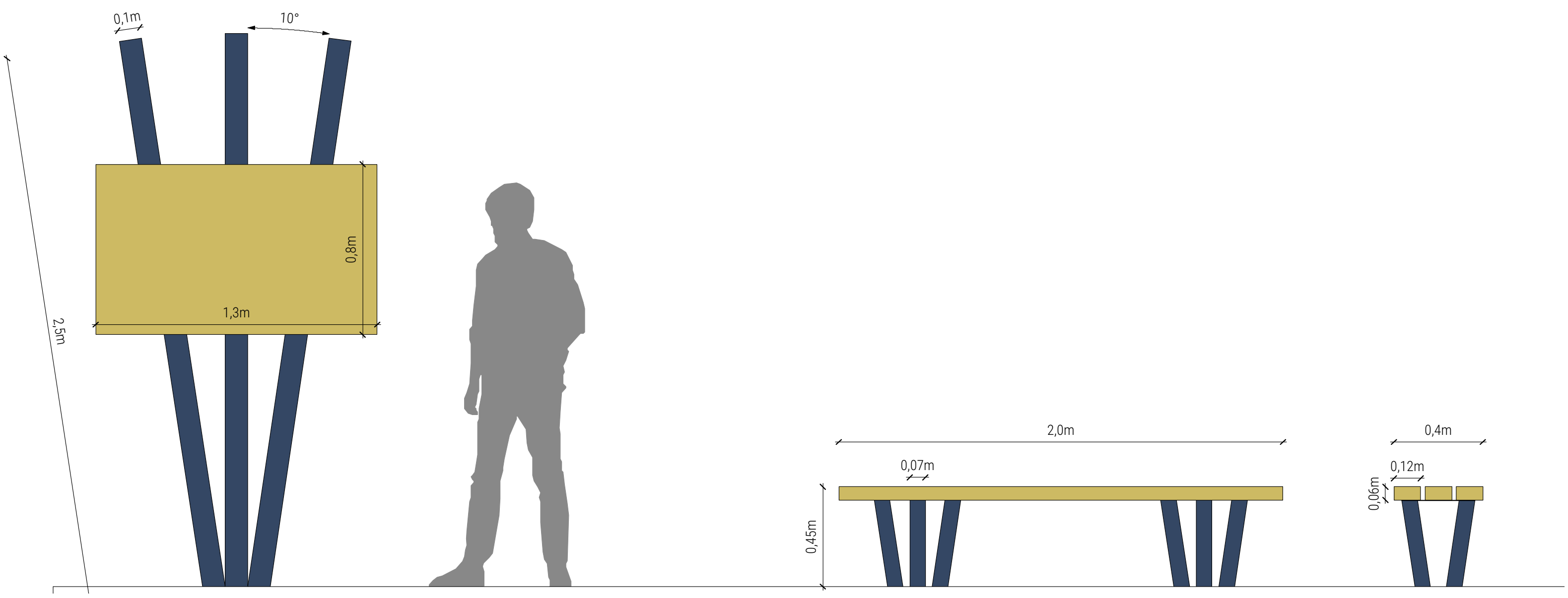


Figure 8.4.5.2: Technical drawings of ornaments made from the recycled plastic & wood


Figure 8.4.5.3: Scale model of bench made from recycled plastic and wood, following the ornament structure


Figure 8.4.5.4: Scale model of trash-can made from recycled plastic and wood, following the ornament structure

Stelcon plates & gravel

As mentioned in the site analysis in chapter 5, one requirement of Afvalzorg was to keep as much of the existing maintenance road of Stelcon plates as possible, to ensure reliable accessibility of the parcel during all seasons. Due to the serious request of the direct neighbours to relocate the maintenance road in the southern part, the Stelcon parts are removed there. On the elevated part, where the ground is worst, they stay a requirement since their thickness allows a slightly unstable soil condition for higher weights of cars and trucks. The Stelcon plates all have a weathered look with faded yellowish concrete colour, which easily blends them into the surrounding light green grass colours.

The gravel of the new maintenance road is retrieved from shredded concrete parts, leading to a comparable colour range like the Stelcon plates and reinforces the sustainable character of the EnergyGarden (see figure 8.4.5.5/6).

Yellow IJsselsteentjes

For the cyclepath on the site soecial type of material is desired. It is chosen for IJsselsteentjes, a local type of small-sized bricks that were produced along the river Hollandse IJssel in former times. The bricks that were produced in the close surrounding of the project area feature a unique yellow colour, generated by the baking process and type of clay in the region (RHC, 2018) (Modderman, 1997).

The bricks have a size of 160 x 80 x 40 mm and are the smallest format of bricks in the Netherlands (figure 7.4.5.13). Based on their production by hand, every stone is slightly different in its size, colour, surface, and rounded edges, which gives them a very natural look compared to regular bricks as they are produced nowadays (Stenvert, 2012).

Yellow IJsselsteentjes were produced for houses, churches, castles, and monasteries from the late 19th century. Since many of those buildings were scrapped in the past decades, the bricks became accessible for low prices as second-hand building materials. Since quality and condition of those stones are insufficient for constructing new houses, they can hardly be used in the building sector and lean themselves to function as paving for light traffic, i.e. walking or cycle path (Stenvert, 2012).

The local character of the yellow IJsselsteentjes increases the place specificness of the EnergyGarden Mastwijk at the same time and distinguishes it from the other two designs of the over coupling project.

For the layout of the pavement, different versions were tested, ranging from standard solutions (figure 8.4.5.7/8) to designs that react on the typology of the landscape.

Figure 8.4.5.5: Stelcon plates on site

Figure 8.4.5.6: Gravel made of shredded concrete

Figure 8.4.5.7: Mock-up stretcher bond

Figure 8.4.5.8: Mock-up herringbone 45°

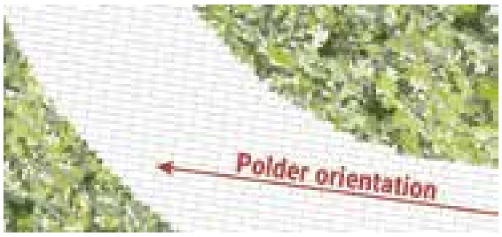


Figure 8.4.5.9: Schematic drawing stretcher bond parcel direction

Figure 8.4.5.10 proposes a layout that always follows the direction of the parcel, in the case of Mastwijk 8.35° deviation from the north. The pattern sticks to this degree, even if the path is curving. This pattern can lead to an exciting experience when cycling on it, while the elongated parcel shape is reinforced (figure 8.4.5.9).

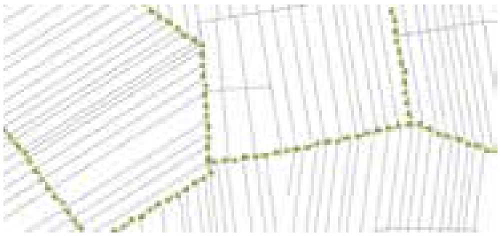


Figure 8.4.5.11: Schematic drawing polder pattern with wooded barriers

Figures 8.4.5.11/12 proposes a pattern that is based on the changing polder directions that occurred during the land reclamation process and can be recognized on aerial photographs of the polder. The wooded barriers at the end of each parcel form a natural string through the geometric polder pattern (see chapter 5). In the pavement, this effect is generated by the somewhat wider joints at the borderline of two pattern directions, that accelerates the process of forming mosses or grass.


Figure 7.4.5.13: Yellow IJsselsteentje

The bricks can perfectly be combined with shredded concrete for the unpaved trails running over the parcel as figure 8.4.5.14 shows.



Figure 8.4.5.10 Mock-up stretcher bond parcel direction



Figure 8.4.5.12: Mock-up polder pattern



Figure 8.4.5.14: Mock-up polder pattern combined with gravel

8.5 Design analysis

Since the analysis of the four cases with the method according to Stremke & Schöbel (2018) delivered many useful insights into multifunctional solar fields and related design guidelines, it is estimated valuable to investigate the proposed design with this method. It allows comparing the taken measures and efforts of the EnergyGarden Mastwijk to the four multifunctional frontrunner cases.

Furthermore, by analysing the proposed design with this detailed framework, more information on the implemented PV system will be revealed.

8.5.1 Spatial characteristics

The essential component of the EnergyGarden is its combination of four different PV layouts with even seven different pitch sizes. These vary from small scale clusters to extremely large arrays, presenting the full range of possibilities to the landscape user. At the same time, it presents what the scale means for the landscape experience and the ecology that can develop around it [A13]. Sections of the four layouts are provided in figure 8.5.1.1. The section of layout V5 deserves special attention. This is the largest set up in the park, and the arrays consist of seven rows. By an angle of only 12°, the huge number of panels can be fitted without conflicting with height restrictions of neighbours and the municipality [A6]. The limited height of the upper edge also decreases the minimum pitch size so that more arrays can be fitted per hectare. A study on possible PV layouts (appendix B2) has shown that this approach is, defiance its low angle that leads to a decrease in yield is the most efficient one for Mastwijk to reach the required 11MWp. The pitch size of this layout is varying between 5.8 and 3.5 metres depending on the amount of already developed ecology on the surface.

To improve the integration into the host landscape with the significant ditch structures, all arrays were turned by 8.35° to align with the polder structure. The loss of yield due to this improvement is limited to approximately 1% (Roos, 2015) and is evaluated as acceptable for better integration.

The exclusion of some surfaces on the elevated part makes the PV system very heterogeneous and gives it an interesting perception. Next to the mentioned sparing of the willow patches, also a large surface is maintained open. Due to gas leakage of the former landfill, it is prohibited to locate a PV installation on it. The open patch creates a nice contrast to the build-up patches of PV panels.

As mentioned in the previous chapter, for the construction of the framework, the use of recycled plastic is advised, which has not been seen in other cases but does offer many advantages.

For the power grid provider, transformer stations are a mandatory component to reach at all time. In Mastwijk it is placed at the parking lot, which is publicly accessible, while the concrete box is still located out of sight and not next to the main road [A15].

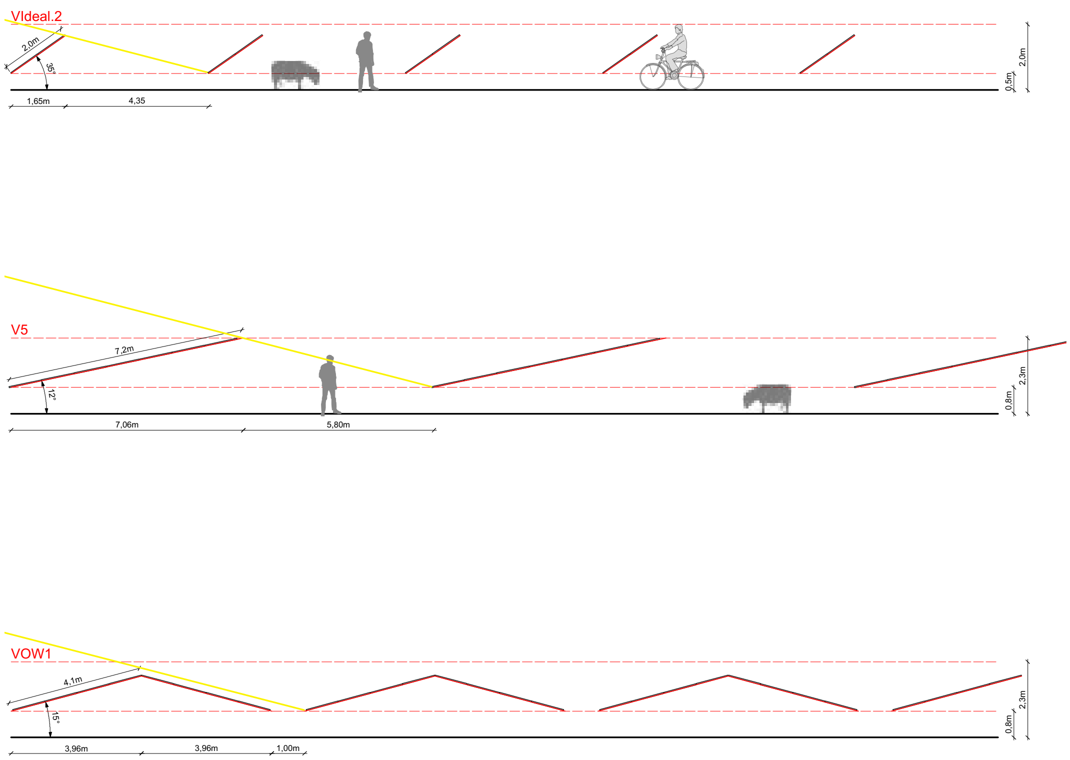


Figure 8.5.1.1: Sections of PV layout used in design

8.5.2 Visibility & screening

The polder landscape is defined by its wide-open areas that allow long view relations. For a PV park which is demanded to be out of sight, this is a challenge and all measures for shielding have to be taken within the solar landscape. In the final proposed design, most of the elevated part is embraced by shrubs that shield the arrays. While this does help to shield the view on the panels, it does not precisely fit the open landscape typology.

In previous approaches, a dike was erected on the elevated part to shield the panels, which worked as a logic increase on the existing slope of the elevation. Due to added restrictions of Afvalzorg to deliver new soils to the site, this approach had to be cancelled.

In the southern part, where already higher landscape elements were found, many trees are added that shield the view on the PV system from the outside. From inside the EnergyGarden, a playful, more daring integration of the PV system with the axes is generated.

The security of the PV system is developed as soft as possible, leading to hardly any fences in the landscape. The elevated part of the parcel can either be accessed from the north edge or via the maintenance road at the leachate basin. The rest of the elevated part is embraced by a wide ditch that is used to collect the leachate water. The pass-throughs of this ditch are removed, to eliminate other entrances to the PV system (see figure 8.5.2.4). Since it is an artificially regulated ditch, it can be ensured that the ditch is always filled to protect the PV system. The gates at the two entrances are open during the day and are closed with a magnet lock in the night. By designing the gates, they are not perceived as a mandatory barrier, but as a design object that builds upon the design language of the other elements in the EnergyGarden [A19] (see figure 8.5.2.3).

Additionally, some of the patches on the elevated part are fenced off with small agricultural fences below the panels. These do not prevent planned thievery, but they are an additional hinder to random vandalism. These fences are located with an offset of several meters towards the trails, so that landscape users do not have the feeling of walking through a strictly set corridor. If the fence is running parallel with a trail, it can be completely hidden below the array (see figure 8.5.2.1). The patches of willow trees, as well as patches with only a few PV panels are not fenced off.

The southern part of the parcel stays accessible during day and night, since the regional bicycle path, running through the EnergyGarden, always has to be usable. Since the amount of PV panels is very low compared to the 40,000 panels in the northern part, eventual damages have to be accepted and are included into the financial calculations [A12].

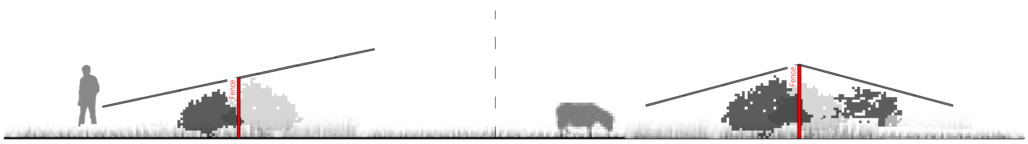


Figure 8.5.2.1: Additional fence running parallel to array

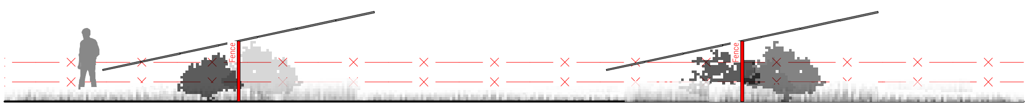


Figure 8.5.2.2: Additional fence running orthogonal to array

Figure 8.5.2.3: Scale model of gate from recycled plastic, following the ornament structure

Figure 8.5.2.4: Security measures for PV system

8.5.3 Patch vs parcel size

The PV system in the EnergyGarden Mastwijk consists of eleven patches of various sizes and with multiple edges that stimulate the landscape experience A10. The division into many patches, in combination with barriers that extend the height of the arrays, focal points are created and bring the space down to the human scale, making the stay within the PV system more pleasant. All patches respond to existing shapes on the parcel, like for example the compartments, or support the new forms that are introduced in the solar landscape. Since the patches almost all have a different spatial setup, leading to other nature developments, the structure of the compartments is visually reinforced (see figure 8.5.3.1).

Frequent separations of the PV system make the EnergyGarden visually attractive and lead to more habitats for various species on the area.

Regarding the relation of parcel border and the location of patches, it can be recognized that space for additional functions has not only been located at the edge of the parcel like it was found in other cases. The space for other functions is equally distributed, which leads to the heterogenous look of the EnergyGarden.

Figure 8.5.3.1: Visualization of PV system in compartments (seen from maintenance road on elevated part)

8.5.4 Transition landscape

The transition to the surrounding landscape is mainly made by reinforcing landscape structures that are typical for the polder landscape. These are, for example, the parcel direction in the north and the reintroduced parcel division by an axis (see figure 8.5.4.1). The introduction of an orchard in the south comes close to the historical landscape of Mastwijk, which featured orchard all along the Mastwijkerdijk on the river sands (Historische Kring IJsselstein, 1986).

By bringing back Copse in the landscape, a typical landscape element is brought back, shielding is implemented, and biomass as an additional energy source is produced. The transition is improved by the design of the ornament, referring to the traditional coppicing that played a significant role in polders.

All the described measures also have a positive influence on the development of biodiversity, which will most likely be local species. The improvement of habitats can also be evaluated as a positive transition to the surrounding landscape structures, even if not relevant for humans.

The main feature of the successful transition is found in the elaborate cooperation with the residents of Mastwijk, that enabled to consider spatial and non-spatial demands for the new EnergyGarden. It ensures that the new land use and its design are supported by the local community and is adopted by the landscape users [A29].

Figure 8.5.4.1: Reintroduced axis on former parcel border, enhancing the rhythm of the landscape

8.5.5 Multifunctionality

As described before, the EnergyGarden Mastwijk features several functions besides the production of electricity, while its focus is on nature development and extensive recreation.

The most apparent measures that are taken to stimulate nature development are the keeping of trees in both the northern and southern part of the parcel, to maintain habitats for pats and birds [A26]. These patches of trees are differently aged and offer, in combination with the newly planted woods, a vast range of development stages for various species. For species like the Moor frog that was recognised in the area, the compartments of the dredge settling process are maintained and are artificially kept wet during most time of the year. The resulting swale with a heterogenous height-profile allows space for many species with different requirements. Due to the PV panels with multiple pitch sizes, both sunny and shady spot are provided. Since most of the PV patches are divided from visitors by small fences (see chapter 8.5.2), nature is mostly unaffected by landscape users.

Although the planting of flower meadows was found in all the case studies and is not evaluated as an extraordinary measure, it provides habitat for many insects and can be considered a no-regret standard. The flower meadow is found in the orchard, together with scattered shrubs.

As an additional measure to stimulate insects in the area, insect hotels are designed as modules for the array-edges in the south. A perfect synergy is achieved since the modules enable a skew edge of the PV patch to fit the axis, while the height, direction and position are considered to fit perfect for inset hotels (Van Breugel, 2014). While the framework stays attached to the arrays, the substance which mostly consists of wood and other used materials like roof tiles can be replaced every two years, ensuring that the insect hotels are used for many years (see figure 8.5.5.1). The compilation of materials can be done by local schools, adding an educational factor to the biodiversity stimulation, and leading to a bounding of the children to the Energy Garden ("Look, Mom, this is my insect hotel!")

By adding a view tower, various information panels, and benches, recreational stays are made pleasant and invite t stroll through the EnergyGarden for multiple hours. By giving those elements a place-specific design, the experience of the EnergyGarden is unique, even if a higher number of comparable sites is following in the future.

The landing at the south of the parcel allows a potential development for a local boat network the connects the EnergyGarden to Montfoort. Still, even if this development cannot be concretized, the spot allows to have a picnic at the water or use it for fishing. A bike charging point with electricity from the PV system will be implemented at this spot, making it a potential gathering point for a Sunday-afternoon walk through the EnergyGarden.

Additional, biomass can be taken from the high amount of copsewood that is introduced in the design. As desired by stakeholders, the wood shreds received a spot at the parking lot to dry for several months after the trees are cut. This increases the transport efficiency to a biomass plant, while it fulfils an educational purpose of observing the energy related infrastructure in the solar landscape.

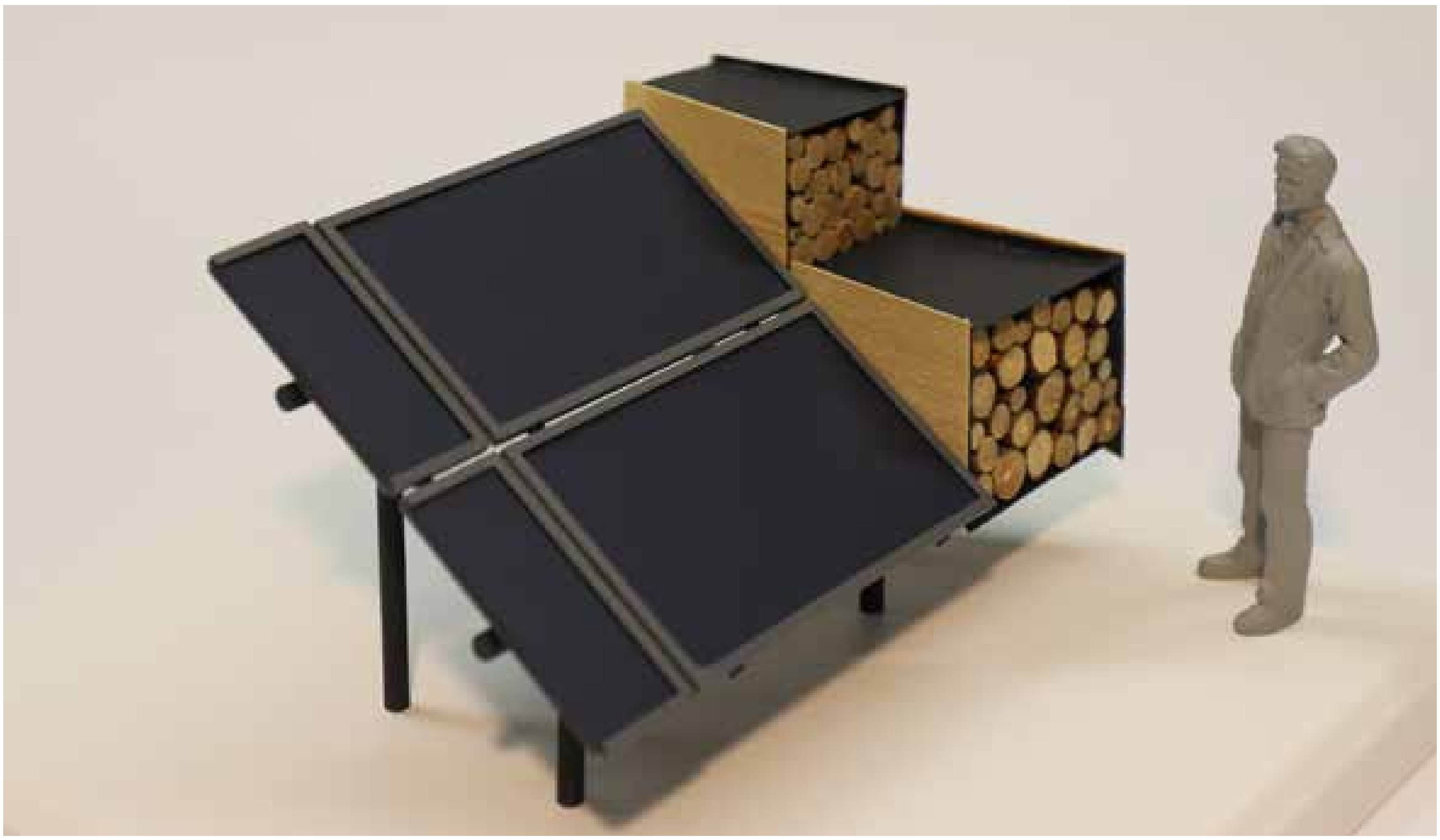


Figure 8.5.5.1: Scale model of end-modules for arrays functioning as insect hotel (recycled plastic)

8.6 Conclusions

The design for the EnergyGarden Mastwijk demonstrated, how from a set of chosen design guidelines, in combination with an extended site analysis and a participatory process, a design can be constructed that serves various user groups while serving the higher goal of the energy transition. While the focus is laid on the development of biodiversity on the former landfill, space was allocated for recreation and education various forms. The primary stream of visitors is to be expected on the newly established bicycle path coming from Utrecht, which cuts through the park. By locating this to the Western edge, a nuisance for direct neighbours can be prevented. Classical, yet innovative, measure like the location of a small fence with highland cattle behind it will avoid most visitors to come close to the parcel of the neighbours.

The surface of the PV system and other functions is equally distributed over the parcel, delivering a heterogeneous landscape that invites visitors to take extensive walks. These can lead through the meadows and small Copse woods and can end with a picnic in the middle of the PV system, enjoying the shadow of the panels on a hot summer day.

The various restrictions of the former landfill are experienced to complicate the design process. However, they also make the site unique and emphasize, that it is meant to become a solar field since hardly any other function could be hosted. Furthermore, relicts of its history, like the maintained compartments from the dredge depositing process, enable functions like the development and regulation of wet areas.

The development of the ornament specifically for the EnergyGarden Mastwijk is considered a successful intervention since it refers to the landscape typology, the historical developments of the site and hosts necessary functions of the garden while providing a distinguishing feature.

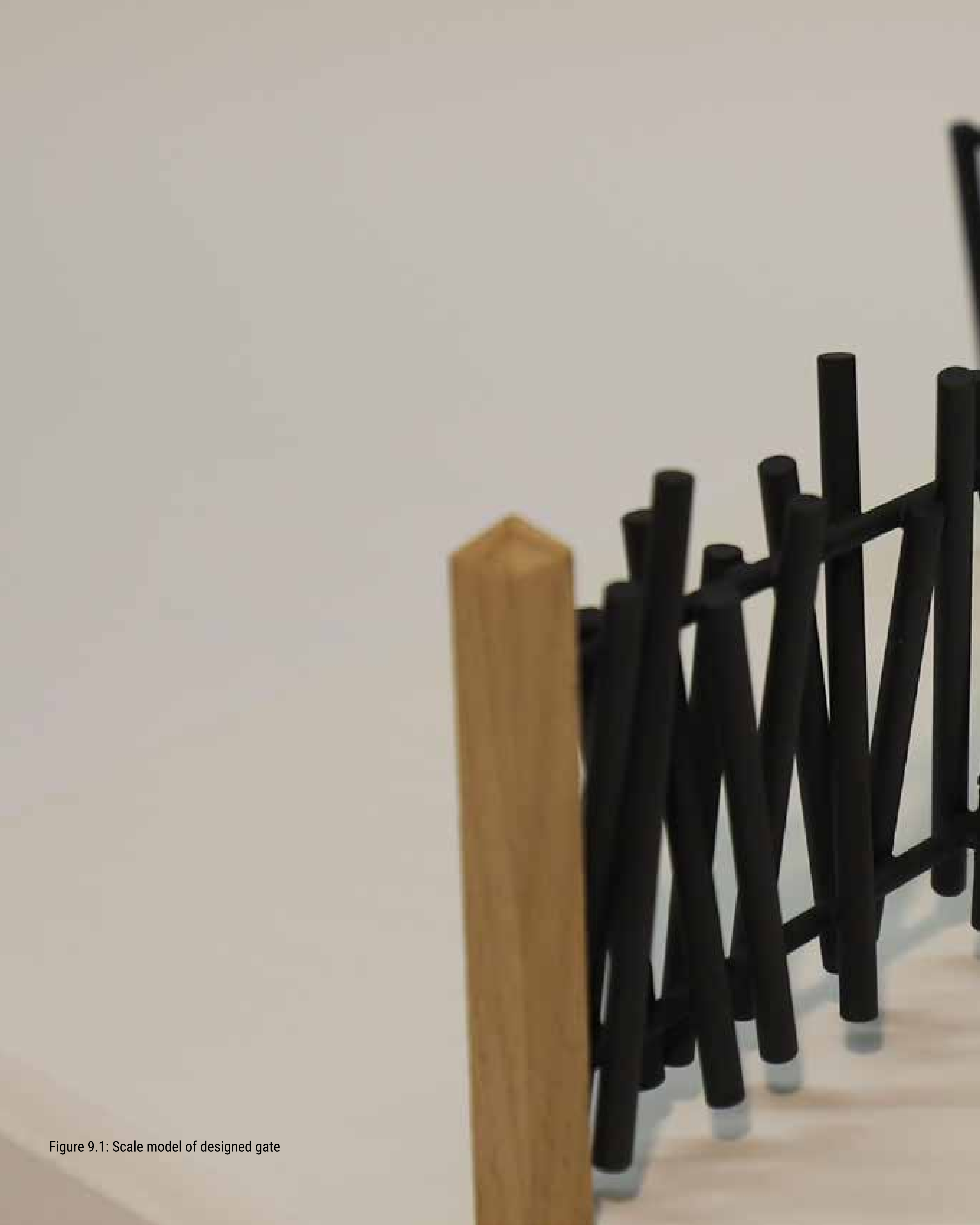


Figure 9.1: Scale model of designed gate

Chapter 9
Discussion and conclusion

9.1 Discussion

In this chapter, it is critically reflected on the research methods and outcomes. Finally, recommendations are given regarding further research and the processing of findings in this project.

Research methods

RQ1a

For researching design guidelines and spatial components of implemented multifunctional solar fields, an extended case study analysis was conducted, using the framework of Stremke & Schöbel (2018) on design considerations of a solar field. It was extended by the analysis of ecosystem services that are provided by the solar fields as an indicator for their multifunctionality.

While the case study analysis itself was of great value and provided many design guidelines for EnergyGardens, the analysis of ecosystem services did not add an extra layer of information to the case analysis. It would be required to bring the ecosystem mapping to either a quantitative or a spatial level, allowing conclusions on the extent of services or their placing within the solar landscape, respectively.

RQ1b

To support the findings of RQ1a with scientific sources and to broaden the knowledge on current trends of the solar business a literature review was conducted using solar field synonyms and the four key words multifunction, recreation, education, biodiversity as they are described in the definition of EnergyGardens.

This delivered many additional insights that were added to the results of the case studies, but the selection process of design guidelines is infinite. This is traced back to the four, very broad, areas of expertise that are mentioned in the definition of EnergyGardens. For the scope of this thesis, the selected amount of design guidelines on multifunctional solar fields is sufficient. Still, there are many more guidelines which can be found in literature and could lead to an even more informed design.

RQ2

For guidelines on garden design the literature study was split into traditional gardens, performative landscapes, and community gardens. While this led to multiple perspectives on the notion ‘garden’, the division was based on an educated guess and could have easily been different. If choosing for another movement to analyse, the results are likely to lead to other conclusions.

It would have been interesting and valuable to do more in-depth research after this general overview was created, but the time constraints of this project made that impossible. Furthermore, it must be remembered that the primary knowledge gap lies in the satisfying integration of a PV system into a garden-like landscape, not the other way around.

Next to literature study, visits to, for example, performative landscapes could have been beneficial to estimate if the guidelines that are mentioned in theory are applicable in praxis.

Forming design guidelines out of literature is a subjective task, and it is likely that the discovered findings were subconsciously adjusted to fit the prior knowledge on the developing design of the EnergyGarden Mastwijk.

KQ1

The analysis of the site was found to work well, mainly based on the specific knowledge that was shared by Afvalzorg. However, the moment of its availability did not always fit the design progress, which led to several regressions and mistakes in the design process. Nevertheless, the final design incorporates all the required information to provide a well-integrated design for the polder Mastwijk.

KQ2

To receive information on the stakeholder demands at Mastwijk, several approaches were tried to structure the participatory sessions. The process-related feedback was evaluated and processed in the procedure for the following design session, which was found to work well. However, we experienced that the comprehension of our input influenced the general mood of the group immensely and that a negative atmosphere in the group led to minimal amounts of constructive feedback. Since participatory sessions only took place once a month, limited feedback at one single meeting was already enough to decelerate the design progress a lot.

The research through design process, started with the evaluation and adjustment of design guidelines for the EnergyGarden Mastwijk and was found to work well. It was possible to incorporate many of the guidelines that were found in the literature. Due to the close connection of this thesis to the real-life project, the design process was stretched out a lot. While results were established fast in the beginning, vast amounts of new information were only available nine months after the design process had started. Since spatial concepts and elaborated plans already had been communicated to the participants, the often crucial information had to be added into the existing plans. This led to some awkward spots of the design that could have been circumvented.

For the development of future multifunctional solar fields and EnergyGardens, it is recommended to set clear rules for the demanded amount of stakeholders input, to prevent time-consuming regressions within the process. This is both relevant for involved parties that deliver specific information on the site (e.g. data of heights) but also for residents to set clear limits, up to which extend the use and layout of the parcel can be changed.

Research outcomes

RQ1a/b

The outcome of research question one is a selection of 33 design guidelines, found in scientific literature and four analysed cases. The selected design guidelines all fit the definition of an EnergyGarden provided by NMF and can thus be used as a basis for the design of the EnergyGarden Mastwijk.

RQ2

The literature review on different perspectives towards garden design delivered an output of 39 additional design guidelines that fit the definition of an EnergyGarden. Some of them were more general and although important to consider, hardly translatable into spatial interventions.

KQ1

The site analysis provided general information on the landscape typology, its history and six specific requirements that need to be considered on the parcel. Especially the six specific requirements shaped the design process significantly.

KQ2

The participatory process with residents and other involved stakeholders informed especially the programme and future functions of the EnergyGarden. The cooperation with direct neighbours also shaped significant parts of the design in the southern part.

Design question

The design process delivered various insights in possible combination of solar fields with functions such as nature development and recreation. Avoiding a hard division between the PV system and other functions, as is it was found in most of the visited cases, can be possible if stakeholder and residents are tempted with exciting visualizations of the possible connections. As a reward, the solar landscape can host much more exciting spatial layouts and functions because more surfaces are made available for multifunctional use.

While a hypothetical case would probably have led to more daring designs, the strength of this thesis can be found in its close connection to the real-world case. None of the proposed interventions is refused by the participating residents, and none of them is technically unfeasible, offering a reasoned and detailed basis for the further development of the EnergyGarden Mastwijk.

The design bridges the gap between the results that were found in science and requirements and desires found in practice. Equally the close collaboration with residents bridges the gap between designer and landscape user.

9.2 Conclusion

In this chapter, research questions and knowledge questions are answered. Combined, they inform the general research question.

Research question 1:

Which guidelines and spatial components that fit the definition of an EnergyGarden can be retrieved from

a. Four implemented multifunctional cases in Europe?

b. Scientific literature on multifunctional solar fields?

It was found that the selection of implemented multifunctional solar fields, as well as the scientific literature, already features many relevant design recommendations, that fit the definition of EnergyGardens, and can be extrapolated. The transformation of those design choices and recommendations into design guidelines was experienced as helpful to achieve an equal level of detailing. The structuring of these guidelines into the PV system, solar landscape and host landscape enable to discuss the output understandably.

Research question 2:

Which garden design guidelines on spatial layout and integration into the landscape are relevant for an EnergyGarden?

Despite the wide field of expertise and the many definitions of a 'garden', it was possible to find three perspectives that offer knowledge to be extrapolated for EnergyGardens. These are traditional gardens, performative landscapes, and community gardens. Especially the first and the second perspective provide valuable information to be translated in the design of EnergyGardens. The scientific sources that were used on community gardens mainly provided process-related information.

Knowledge question 1:

Which geographical, demographical, or historical factors influence the design for the EnergyGarden Mastwijk?

In the analysis of the location Mastwijk as preparation for the EnergyGarden, mainly historical factors were found to have importance for future land use. On the one hand, this is generated by the previous use as a landfill, which leaves the parcel with many restrictions. On the other hand, the historical information allows shaping the spatial components of the EnergyGarden, such as the typical orchard, former parcellation, IJsselsteentjes, or the ornament.

Knowledge question 2:

What kind of EnergyGarden for Mastwijk is desired by the local stakeholders?

The stakeholders involved in the process have various demands that the design needs to take care of. Not all of them are on the same line. Still, the general tone demands an EnergyGarden where mainly nature is developed, and recreation and education take place in an extensive way that does not lead to a nuisance for the local community. Furthermore, the majority of stakeholders demand hiding of the PV system in the landscape, so that they do not see it from the landscape. However, well-substantiated proposals for a more daring design were allowed to be discussed and even found incentive.

Design question:

How to apply these design guidelines in the polder Mastwijk, considering the desires of local stakeholders and the identity of the location?

The initial move can be executed by giving a preselection of design guidelines that are compatible among each other and with the desires of stakeholders and the restrictions of the site, a set of site-specific design principles can be created and implemented in the design of the EnergyGarden Mastwijk. In the received inputs we recognize various forms, from spatial division, over provided function, up to the design of a unique ornament.

General research question:

Which spatial guidelines of garden design and multifunctional solar fields are relevant for the design of an EnergyGarden in the Dutch polder Mastwijk?

For the design of the EnergyGarden Mastwijk, an extended set of spatial guidelines was found to be relevant. In this thesis, in total 45 of 72 guidelines, retrieved from multifunctional solar fields and garden design practices, were transformed to serve the final design. The selection of these guidelines stretches from small details on the PV system to general suggestions on the regional scale of the host landscape. This leads to a responsible and unique integration of the EnergyGarden into its context and the landscape...

... making it not just another solar field.

Relevance

In comparison to previous research on multifunctional solar fields, this research is assessing taken measures in case studies and the proposed design on a smaller scale. This leads to new insights on the experience of a multifunctional solar field, more precisely EnergyGarden. The identified measure can partially be extrapolated for multifunctional solar fields on larger scales and thus provide useful information for the energy transition.

While the concept of EnergyGardens is experienced to bring an innovative turn into the energy transition, it must be annotated that the energy transition could not be carried by interventions on this scale. With a power output of 11MWp, the EnergyGarden Mastwijk delivers 0.00935TWh each year. As a reminder, the RES U16 region of Utrecht requires 3.6TWH (2030), respectively 10.8TWh in 2050. This would mean a requirement 1,155 of these EnergyGardens in 2050, only in the surrounding of Utrecht!

Nevertheless, it provides a relevant support to the energy transition and allows to provide almost all housing of the neighbouring Montfoort with renewable energy. Also, its educational component can stimulate awareness on the energy transition.

A question that was raised during the process is if the notion of garden fits the proposed measures. The scale of the site, as well as the functions that are featured and the public usage, come closer to a park than a garden. Therefore, parallel to this thesis, research is done on the use of the term 'energy estate'. While the name may differ, the design guidelines that were identified and the approach to integrate them into a design are relevant also to, for example, an energy estate.

Recommendations for the EnergyGarden Mastwijk

If PV panels undergo further technical development, an increase of their efficiency will follow. Concludingly, the landfill of Mastwijk is predestined to host a second life circle of PV installation over 20 years. Since the site can hardly host functions besides nature in the coming decade due to its toxicity, a PV installation is a great way from a turning into a brownfield again. Efforts in terms of spatial planning, nature development and technical infrastructure such as cables that are invested now, can simplify the process of installing a new PV installation. This would increase the rate of return for the extensive efforts that are taken and would help to reach the RES goals of 2050.

By implementing the proposed weather-resistant recycled plastic pillars as a structure for the PV system, the framework of the solar field can stay at the location for a duration of 50-100 years. In this case, solely the PV modules and inverters must be replaced, increasing the cost-efficiency of the second life circle enormously, while avoiding the negative effects on biodiversity that the restructuring for a completely new PV system would have.

B&W Energy (2016). 2MWp Solarpark de Kwekerij. Retrieved from: https://www.bw-energy.de/referenz/solarpark-de-kwekerij/ [Online access 07.01.20 16:05]

Baerselman, F., Vera, F. W. M. (1995). Nature Development: An explanatory study for the construction of ecological networks. Ministry of Agriculture, Nature management and Fisheries, The Hague.

Bosman, S.J., Binnekamp, J., Dwarshuis, H.M.C, et al. (2005). Integraal Ontwikkelingsperspectief; Hollandse IJssel, meer dan water. KuiperCompagnons, Rotterdam.

Briedenhann, J., and Wickens, E., (2004). Tourism routes as a tool for the economic development of rural areas—vibrant hope or impossible dream? Tourism Management, 25, 71–79

Brons & Partners (2007). Landgoedontwikkeling Mastwijk. Retrieved from: http://www.bronsenpartners.nl/nl/projecten/project/Landgoedontwikkeling+Mastwijk/98/ [Access online 27.04.20 11:18]

Cater, E., and Lowman, G. (1994). Ecotourism: A Sustainable Option? Chichester: Wiley.

CBS (2019). Regionale kerncijfers Nederland. Retrieved from: https://opendata.cbs.nl/statline/?dl=2096B#/CBS/nl/dataset/70072NED/table [Access online 26.04.20 16:47]

Cesar, I., Slooff, L. H., Erberveld, M., & Lange, M. D. (2018). Zonnepanelen en Natuur. Hoe zonnepanelen kunnen samengaan met natuur-een eerste praktische handreiking. TNO, Wageningen

Clavin, A.A. (2011). Realising ecological sustainability in community gardens: a capability approach, Local Environment, 16:10, 945-962

Crowe, S. (1994). Garden design (3rd ed.). Garden Art Press.

Daniels, W. (2019). Het dorp - Een geschiedenis. Thomas Rap uitgeverij, Amsterdam.

De Boer, J. (2017). Landschapspijn: over de toekomst van ons platteland. Atlas Contact, Amsterdam.

De Leeuw, K. et al. (2008). Linten in de Leegte. Handboek groene bebouwingslinten in de Utrechtse Waarden. Impuls publiciteit, Alblasserdam.

Doolaard, C. (2017). Zonnepark zo groot als provincie Utrecht kan Nederland voorzien van stroom. De Persgroep Nederland B.V.. Retrieved from: https://www.ad.nl/binnenland/zonnepark-zo-groot-als-provincie-utrecht-kan-nederland-voorzien-van-stroom~ac927b45/ [Online access, 26.08.2019 21:24]

Ecolife Dictionary (2019). Definition of Community Garden. Retrieved from: http://www.ecolife.com/define/community-garden.html [Online access, 06.09.2019 17:44]

EnergieAgentur.NRW (2016). ENNI Solarpark mit Energiepfad: Picknick im Solarpark. Retrieved from: https://www.energieagentur.nrw/klimaexpo/enni_solarpark_mit_energiepfad_picknick_im_solarpark [Online access 20.02.20 19:11]

Eng, P. (1993). Use of recycled plastic for fence and guardrail posts. Alberta Transportation Utilities project, No. 91021.

ENNI Energie & Umwelt Niederrhein GmbH (2015). Erneuerbare zum anfassen. Moers: ENNI Kunden-Magazin, 3, 6-9.

ENNI Solar (2013). Aus heiterem Himmel. Retrieved from: https://www.schlothmann.de/referenzen/downloads/ [Online access 20.02.20 14:11]

Gemeente Montfoort (2010). Actualisatie Landschapsontwikkelingsplan Groene Driehoek 2005. Montfoort.

Gemeente Utrecht (2019). Bevolkingsprognose 2019. Afdeling Onderzoek, Utrecht.

Grein, R. (2003). Solarpark stellt alles in den Schatten. Donaukurier, 11.04. Neuburg. Retrieved from: https://www.donaukurier.de/lokales/neuburg/SOLAR10-Solarpark-stellt-alles-in-den-Schatten;art1763,343618 [Online access 27.02.20 18:43]

Haines-Young, R., Potschin, M. (2018). Common International Classification of Ecosystem Services (CICES) V5.1: Guidance on the Application of the Revised Structure. Fabis Consulting, Nottingham.

Hartog, L. (2019). Ecologische quickscan Mastwijk te Montfoort. Van der Goes en Groot, Kwintsheul.

Herden, C., Gharadjedaghi, B., Rassmus, J., Gödderz, S., Geiger, S., Jansen, S. (2009). Naturschutzfachliche Bewertungsmethoden von Freilandphotovoltaikanlagen. Bonn: Bundesamt für Naturschutz.

Historische Kring IJsselstein (1986). Uitgave no 36. Retrieved from: https://issuu.com/hkij/docs/o1986_1989_036_051/46 [Access online 17.05.20 12:25]

Hobbs, R. J., Norton, D. A. (1996). Towards a Conceptual Framework for Restoration Ecology. Restoration Ecology, 4 (2), 93-110.

Hurler, R., Kleynmans, D. (2020). Expertise for the determination of the necessary ramming depth for steel profiles as founding elements. Boden und Wasser, Aichach.

Imoss (2018). Provincie Utrecht, Ringpark en een integrale leefomgeving. Retrieved from: https://imoss.nl/project/provincie-utrecht-ringpark-u10/ [Access online 26.04.20 16:37]

Innovatie Recreatie & Ruimte (2019). Zon op recreatiewater: Studie naar de toepassing van zone-energie op recreatieateren. Zeist

Irvine, S., Johnson, L., Peters, K. (1999). Community gardens and sustainable land use planning: A case-study of the Alex Wilson community garden, Local Environment, 4:1, 33-46.

JoustraReid Architecten (2001). Landgoed Mastwijk Montfoort. Retrieved form: https://www.joustrareid.nl/portfolio/landgoed-mastwijk-montfoort [Access online 27.04.20 11:10]

Krone, N. (2004). Die Sonnenseiten der Landschaft. Hamburg: Ökologisches Wirtschaften, 5, 22-23.

MEES Ruimte & Milieu (2019). Programma van eisen, Energietuin Mastwijk. MEES, Zoetermeer.

Ministerie van Economische Zaken en Klimaat (2018). Voorstel voor hoofd-lijnen van het Klimaatakkoord. Den Haag.

Modderman, J.D.A. (1997). Het korte bestaan van der eerste ringoven in Nederland te Linschoten. Heemtijdinghen 33 (2).

Möller, R., Jeske, U. (1995). Recycling von PVC, Grundlagen, Stand der Technik, Handlungsmöglichkeiten. Forschungszentrum Karlsruhe.

Natuur en Milieufederaties (2018). De constructieve zonneladder, in vijf stappen naat lokaal beleid voor een goede inpassing van zonne-energie. Utrecht.

Natuur en Milieufederaties (2019). Definitie Energietuinen (translated). Retrieved from: https://www.natuurenmilieufederaties.nl/project/energie-tuinen/ [Online access, 18.09.2019 19:35]

Raab, B. (2015). Erneuerbare Energien und Naturschutz–Solarparks können einen Beitrag zur Stabilisierung der biologischen Vielfalt leisten. Laufen: Anliegen Natur, 37(1), 67-76.

RHC Rijnstreek (2008). Steenfabriek de Overwaard. Retrieved from: https://rhcrijnstreek.nl/bronnen/lokale-historie/IJsselstein/IJsselstein/steenfabriek-de-overwaard/ [Access online 27.04.20 18:27]

Rösch, C. (2016). Agrophotovoltaik-die Energiewende in der Landwirtschaft. GAIA-Ecological Perspectives for Science and Society, 25(4), 242-246.

Roncken, P. (2018). Advies de Utrechtse Ringparken. ArkAdvies, Utrecht.

Roos, M. (2015). Einfluss von Ausrichtung und Anstellwinkel auf den Energieertrag. Folie 69. Frauenhofer IWES.

Reformatorisch dagblad (1971). Eigenaar wil woonschepen weg hebben uit zandput. Retrieved from: https://www.digibron.nl/viewer/collectie/Digibron/id/721b2794b8e8df27cf01aff7626973a6 [Access online 27.04.20 11:35]

Salter, J., Robinson, J., & Wiek, A. (2010). Participatory methods of integrated assessment—a review. Wiley Interdisciplinary Reviews: Climate Change, 1(5), 697-717.

Saunders, W. (Ed.). (2013). Designed ecologies: the landscape architecture of Kongjian Yu. Birkhäuser.

Schlothmann Landschaftsarchitekten (2011). Eingriffs- und Maßnahmen Planunterlagen. Retrieved from: https://www.schlothmann.de/projekte/umweltplanung/landschaftspflegerische-begleitplanung/ [Online access 20.02.20 18:53]

Schlothmann Landschaftsarchitekten (2014). AUSSICHTSHÜGEL MIT ENERGIEPFAD SOLARPARK MÜHLENFELD. Retrieved from: https://www.schlothmann.de/neues/ [Online access 18.02.20 09:31]

Scognamiglio, A. (2016). 'Photovoltaic landscapes': Design and assessment. A critical review for a new transdisciplinary design vision. Renewable and Sustainable Energy Reviews, 55, 629-661.

Sjaarda, J. (2005). Veilige landschappen. NV Afvalzorg, Haarlem.

Solarenergie-Förderverein Deutschland e.V. (2003). Wald roden für PV-Anlagen? Dokumentarfotos aus Hemau. Retrieved from: http://www.sfv.de/lokal/mails/wvf/hemaubi.htm [Online access, 19.02.20 12:24]

Spil, E. et al. (2020). Regio U16 ontwerp RES. Tussenstand van de verkenningen voor de RES 1.0 met het concept bod voor duurzame elektriciteit.

Stadt Hemau (2010). Solargemeinde Hemau. Retrieved from: http://www.hemau.de/rathaus/stadtgeschichte/solargemeinde-hemau/ [Online access, 19.02.20 13:13]

Stenvert, R. (2012). Biografie van de baksteen. Rijksdienst voor het cultureel erfgoed, Amersfoort.

Stichting De Kwekerij (2019). De Kwekerij – Onze historie. Retrieved form: https://nlsolarparkdekwekerij.nl/historie-6/# [Online access 07.05.20 16:19]

Storm van Leeuwen, J.A. (1985). Van oude rijn tot leidse rijn : de afwatering van de gronden in en rondom vleuten-de meern in de loop der tijden. Historische Vereniging Vleuten, De Meern, Haarzuilens

Stremke, S., & Schöbel, S. (2018). Research through design for energy transition: Two case studies in germany and the netherlands. Smart and Sustainable Built Environment 8(1), 16-33

Sütterlin, B. & Siegrist, M. (2017) Public acceptance of renewable energy technologies from an abstract versus concrete perspective and the positive imagery of solar power. In Energy Policy. 106 (2017) 356–366

Van Breugel, P. (2014). Gasten van bijenhotels. EIS Kenniscentrum Insecten, Leiden.

Van der A, A., Hofman, E., Joppe, I., Van der Linden, E., Weijenbarg, G. (2018). Gelderse prijs voor ruimtelijke kwaliteit 2018. Provincie Gelderland, Arnhem

Van der Poel, M.A. (1995). Pilot study on: modelling of the groundwater flow and contaminant transport in the area of the landfill mastwijk (linschoten, the netherlands). National Institute of Public Health and Environmental Protection.

Van der Zee, F., Bloem, J., Galama, P., Gollenbeek, L., van Os, J., Schotman, A., & de Vries, S. (2019). Zonneparken natuur en landbouw (No. 2945). Wageningen Environmental Research.

Wartner & Partner Landschaftsarchitekten BDLA (2002). Landschaftspflegerischer Begleitplan; gesammelte Planunterlagen. Wartner & Partner, Landshut

Wartner & Zeitzler Landschaftsarchitekten BDLA (2013). Broschüre Deutscher Landschaftsarchitekturpreis 2013. Wartner & Zeitzler, Landshut.

Waterbodem (2003). Mastwijk wantrouwt nieuwe baggerstort. Retrieved from http://www.waterbodem.nl/waterbodem-nieuws_detail.php?id=954 [Access online 27.04.20 11:25]

Zeehandelaar, M. (2019) Waarom zetten we Nederland niet vol windmolens en zonnepanelen? NPO Focus. Retrieved from: https://npofocus.nl/artikel/7524/waarom-zetten-we-nederland-niet-vol-windmolens-en-zonnepanelen- [Access online 22.08.19 21:36]

Figures

1.1: Hofland, L.H. (1965). Photo of landfill Mastwijk. Retrieved from: https://hetutrechtsarchief.nl/onderzoek/resultaten/archieven?miview=inv2&mivast=0&mizig=210&miadt=39&miaet=14&micode=BEELDBANK_FOT_DOC_1B&minr=41534221 [Online access, 10.05.2020 22:05]

1.1.1: Afvalzorg (2019). View on former landfill Mastwijk located in the polder. Retrieved from: https://www.afvalzorg.nl/nieuws/eerste-utrechtse-energietuin-op-mastwijk/ [Online access, 13.05.2020, 18:11]

3.2.9: Oudes, D. (2019) Solar field Hemau

5.3.1: Hoekwater, W. H. (1901). Map of land reclamation. Retrieved from: https://vu.nl/library [Online access, 20.08.2019, 18:52]

5.3.2: Royal Air Force (1945). Aerial photograph after sand excavation. Retrieved from: https://library.wur.nl/WebQuery/wurpubs/492304 [Online access, 12.03.2020, 11:14]

5.3.3: Hofland, L.H. (1965). Photo of landfill Mastwijk. Retrieved from: https://hetutrechtsarchief.nl/onderzoek/resultaten/archieven?miview=inv2&mivast=0&mizig=210&miadt=39&miaet=14&micode=BEELDBANK_FOT_DOC_1B&minr=41534221 [Online access, 10.05.2020 22:05]

5.3.4: AHN3. Elevation map. Retrieved from: https://ahn.arcgisonline.nl/ahnviewer/ [Online access, 12.03.2020, 14:50]

5.3.5: JoustraReid Architecten (2001). Proposed estate for Mastwijk. Retrieved from: https://www.joustrareid.nl/portfolio/landgoed-mastwijk-montfoort [Access online 27.04.20 11:10]

6.1: Van Etteger, R. (2019). Site visit with participants.

8.4.5.1: Koppel.Group (n.d.). Recyclingpfahl frei Haus. Retrieved from: https://www.koppel-group.de/recyclingpfahl/83-10x200cm-rund-recycling-pfahl-frei-haus.html [Access online 27.04.20 15:30]

A.1.2: Oudes, D. (2019). Nature development at Hemau

A.1.8: Oudes, D. (2019). View from bunker

A.3.2: Oudes, D. (2019). Flower meadows and hedge between the PV patches

A.3.11: Oudes, D. (2019). Patch border with hedge on right side and unshielded fence on left side

Appendix

Appendix A - Analysis Case study

A.1 Hemau, Germany

The solar field of Hemau was established in 2002 and was, at that time, the worldwide biggest with 18ha and 4MW (Grein, 2003). It is located on a former ammunition depot, hidden in a large patch of dense forest in a rural surrounding. The site is marked by bunkers, military buildings and a watchtower that give a mysterious impression to the solar field. Usually, the area is not open to visitors, but in the context of this research, we were able to get a guided tour.

This case was chosen for several reasons, with a leading cause the combination of energy harvesting, increased biodiversity, and cultural heritage. Even though the latter one was not a vital element of the design (H. Wartner, personal communication, July 23, 2019), its presence leads to some interesting details like the placement of inverters inside the remaining bunkers. Although not open to the public, the place keeps its historical identity and meaning for the region.

For maintenance, a local farmer lets sheep and pigs graze below the solar panels and uses a former military building as a henhouse, giving an additional land use to the parcel.

Figure A.1.1: Impression of atmosphere at Hemau

When the design was made, specific interest was given to the creation of habitats for various species, including wet and shady areas, open sunny fields, and dry and stony spots for pioneer species. Meanwhile also the concrete paths and bunker facades have been conquered by mosses and other pioneer species over the past sixteen years.

Not only the building process included various local stakeholders that were able to profit from the project, but also the investment was made by many local stakeholders (Krone, 2004). Determined by the juristic restrictions of that time, every investor was only allowed to produce 0.1MW, leading to an amalgamation of 40 investors that established the installation together (H. Wartner, personal communication, July 23, 2019). While not intended in that case, it is an interesting way to spread profits and risks for a local project like an EnergyGarden.

Figure A.1.2: Nature development at Hemau (Oudes, 2019)

Spatial characteristics of PV system

The PV system of Hemau has several unusual characteristics which distinguish it from other solar fields. The most important one is the construction of the framework, which comprises solely wooden parts. Instead of drilled footings, these frameworks are mounted on aboveground cast-in-place concrete blocks to carry the solar panels. According to the designer, this decision was made because the market was not able to deliver such a massive amount of metal construction, and it enabled local farmers and non-professionals to construct the solar field. Also, the choice of the panels itself was guided by the availability on the market, leading to three different types of panels being used to supplement the 32,000 panels (H. Wartner, personal communication, July 23, 2019). These three types of panels come both in different colours and shapes leading to a more heterogeneous impression of the installation (see figure A.1.4), while the custom shaped wooden frames adapt to them.

Another big difference to the present-day standard is the construction of loose clusters of panels instead of continuous arrays. These clusters comprise each ten to sixteen panels and are only connected by wires. Compared to arrays, theses clusters allow a less precise construction and can react easily to bad ground conditions like soil subsidence. In the layout of the PV system, these clusters can have advantages since they allow more irregular shapes to free spots for e.g. ecological ponds on-site, or movement of visitors.

The south-oriented arrays have a total height of 2.7 meters and a pitch size of 5.5 meters, which is denser than at most other analysed cases. The combination of height, pitch size and the local azimuth angle are not leading to any shading during winter months when the sun is lowest (see figure A.1.5).

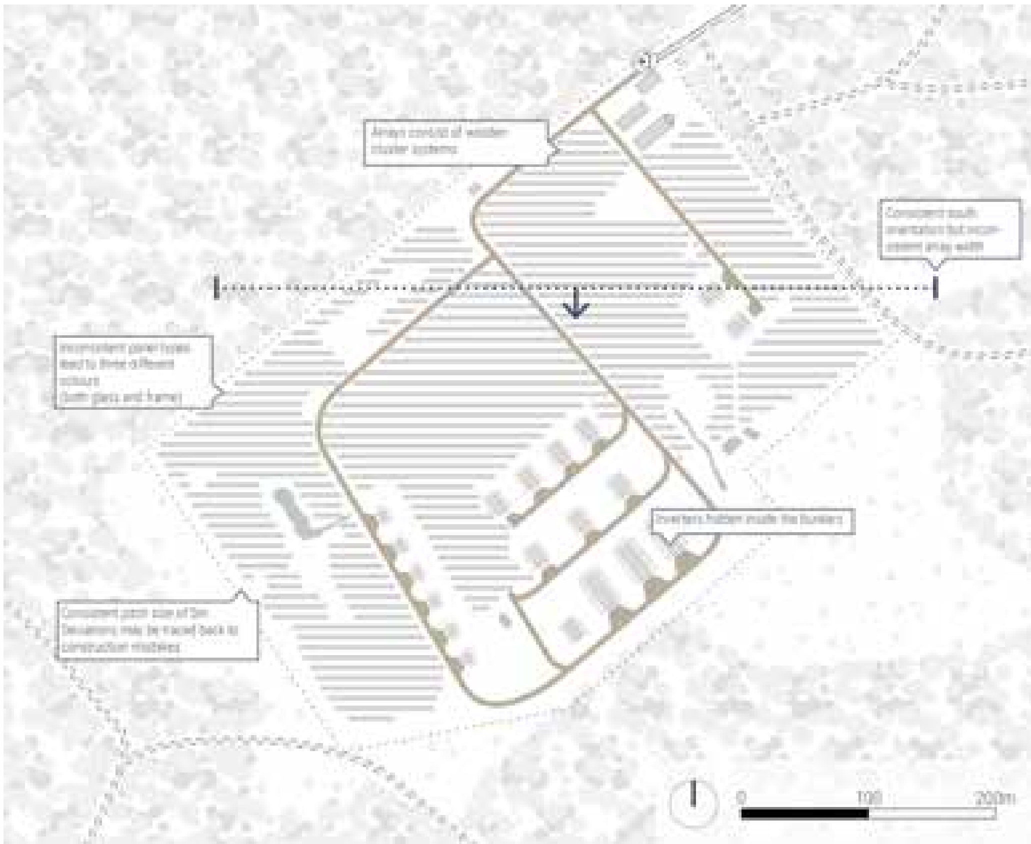


Figure A.1.3: Map analysis, Spatial characteristics

Another characteristic of the Hemau solar field is the positioning of its inverters in the former bunkers on site. While offering a great potential against theft, it also decreases the number of technical elements which dominate the view on site. The utilization of the bunkers gives a certain charm to the solar field at the same time. The transformers were not placed inside the bunkers but are positioned along the maintenance road in the middle of the parcel. This may be due to mandatory access at all times.

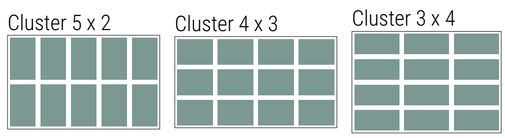


Figure A.1.4: Schematic layout of arrays

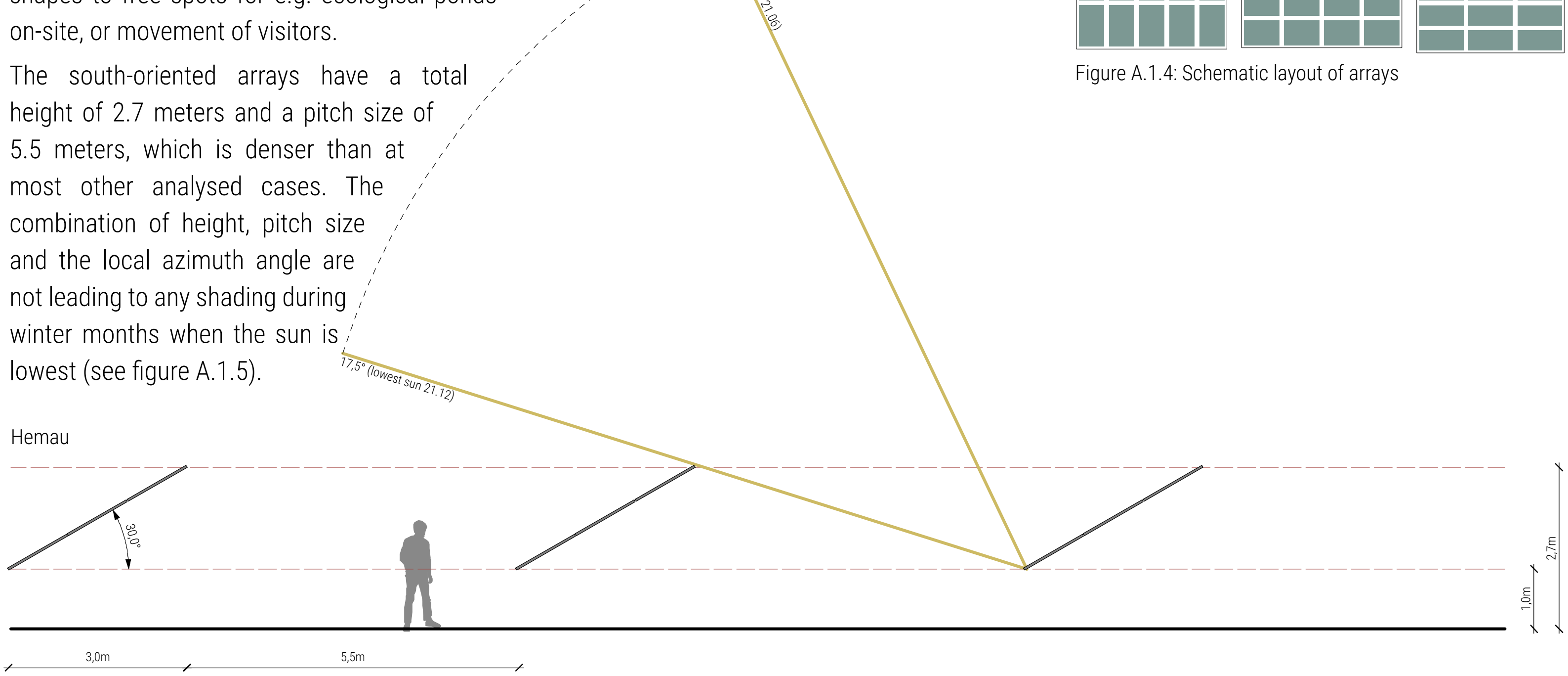


Figure A.1.5: Section analysis, Spatial characteristics

Visibility & screening

Since the solar field of Hemau is not accessible to the public, this section is mainly focussing on the outside experience, but also from there, the solar filed cannot be seen by many landscape users. The next village is one and a half kilometres away and as mentioned before a dense forest surrounds the parcel.

The only road that leads through the woods ends at the main gate of the solar field which only allows hikers or mountain-bikers to move through the surrounding on unpaved paths. At the Northeast and Southwest border of the parcel, those paths come close to the fence, enabling a view on the PV system. At these spots, no measures, as the planting of trees or hedges, have been implemented to shield the look on the PV system (see figure A.1.6). However, this can also be due to the approximately small number of landscape users that come along this parcel.

When analysing the visibility and screening from inside the solar field, the bunkers receive an essential role since they shield large parts of the PV system with a height of up to four meters and a substantially elevated surface. While on ground level the hills make it impossible to oversee the whole parcel, being on top gives a great view over the PV system and solar landscape with the former military buildings and the ecological development of trees and shrubs. The diversity of landscape elements in the solar landscape leads to a less focussed view on the PV system,

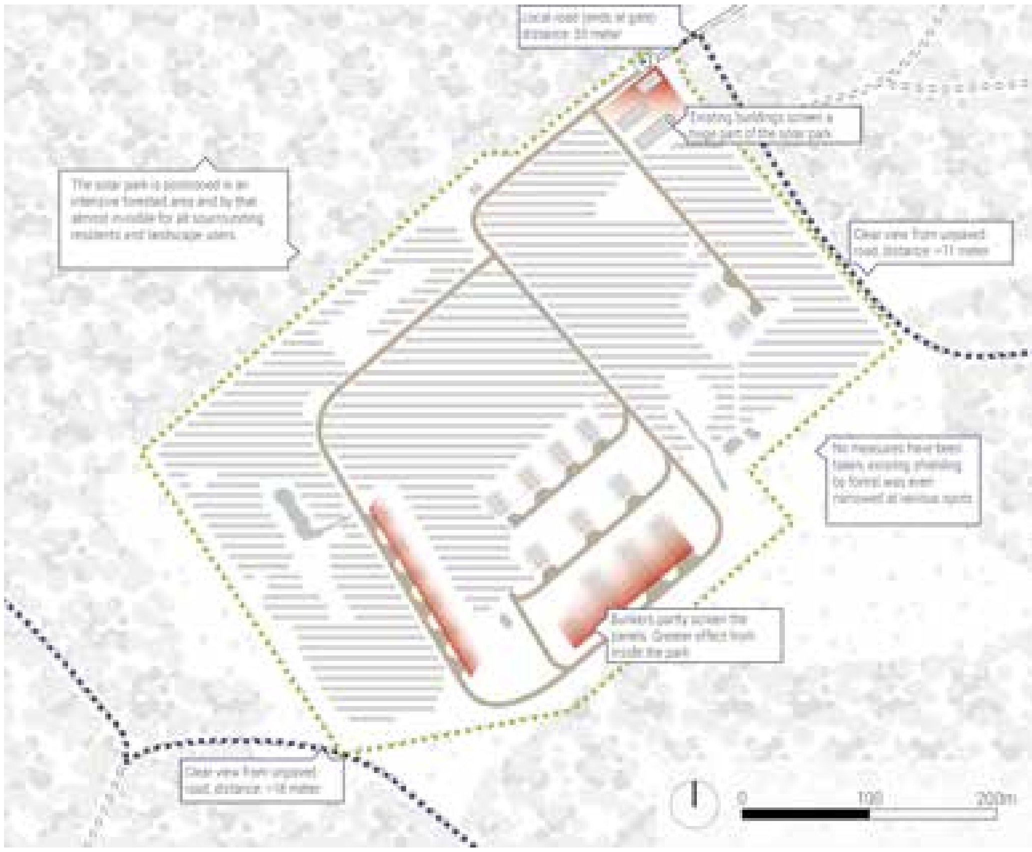


Figure A.1.6: Map analysis, Visibility & Screening

which contributes to the identity of the site and differentiates it form standardized solar fields.

Edge of solar landscape

Closest landscpae user

Figure A.1.8: View from bunker (Oudes, 2019)

The closed metal fence around the solar landscape is standardized with a height of two metres, and a dark green colour (see figure A.1.7). Even though it is not hidden or covered with vegetation, it blends well into the dark background of the forest and does not disturb the view.

Figure A.1.7: Fence type

Parcel size vs. patch size

The PV system of Hemau is divided into four, almost merging, patches that are not widely spread on the parcel. What strikes, is that the rhythm of the arrays is often interrupted by new and maintained habitats or the former bunkers of the military installation.

Resulting from the density of bunkers in the southern part, there no PV panels are built and the area was reserved entirely for natural development and small-scale agricultural use. Two types of borders can be found at the edges of the PV patches, which are visualized in figure A.1.10/11. Profile 1 can only be found at the boundary between P1 and P2 and is only 3.4m wide without any path implemented. At this profile, the (potential) landscape user experiences walking through the PV system and is not disturbed by any fences or vegetation. The closeness lets one feel the size of the arrays and creates a unique impression. Profile 2 can be found at the edge of all four patches and is a seven to an eight-meter-wide opening within the arrays. These edges are positioned at the existing roads of the military site, which now function as maintenance roads for the PV system. At these edges, the landscape user is less connected to the system and gets a view on a greater amount of the PV system.

In this case, the solar landscape is defined with the parcel outline since the design plans included measures on the whole plot. 56% of the parcel are in use for the PV system in combination with small-scale agriculture or with stimulated biodiversity improvement. No surface was given solely to the production of electricity without multifunctionality.

The other 44% of the parcel was developed to increase biodiversity and to serve small-scale agricultural without the production of electricity. According to the design plans, no areas of the plot stayed untouched. If a spot was not redesigned, at least its development was stimulated, and tailored maintenance indicated (Wartner & Partner Landschaftsarchitekten BDLA, 2002).

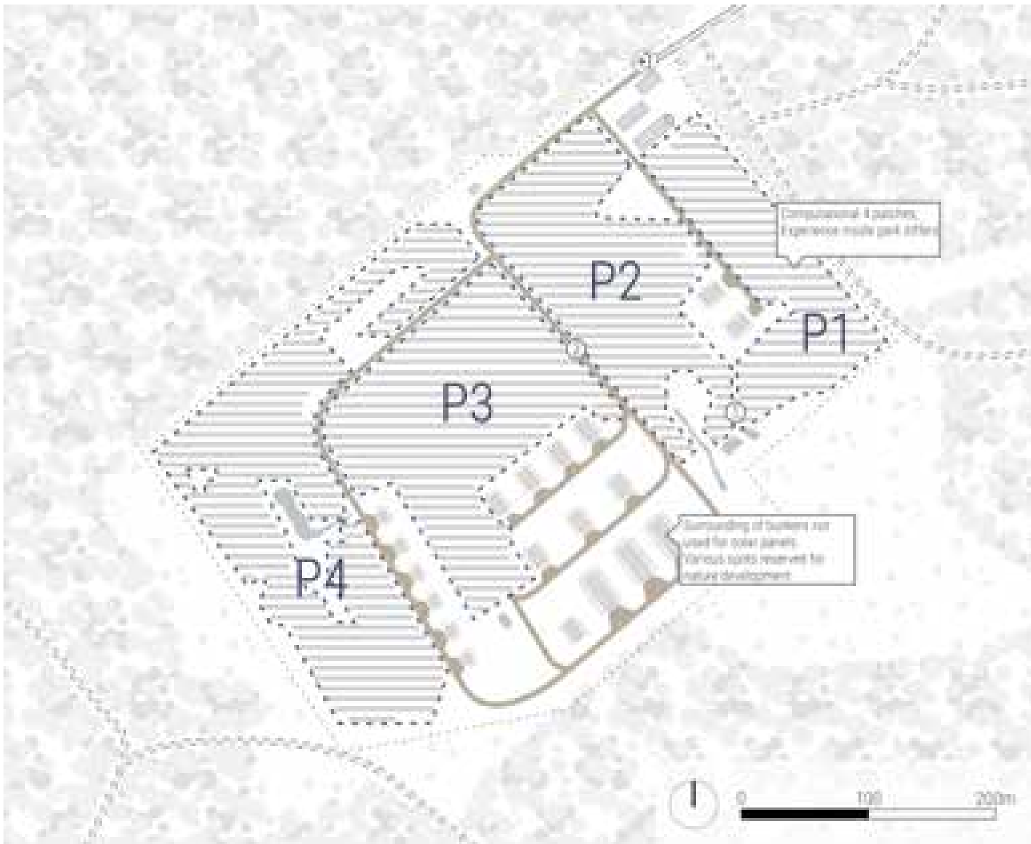


Figure A.1.9: Map analysis, Parcel vs patch size

Hemau Profile 1

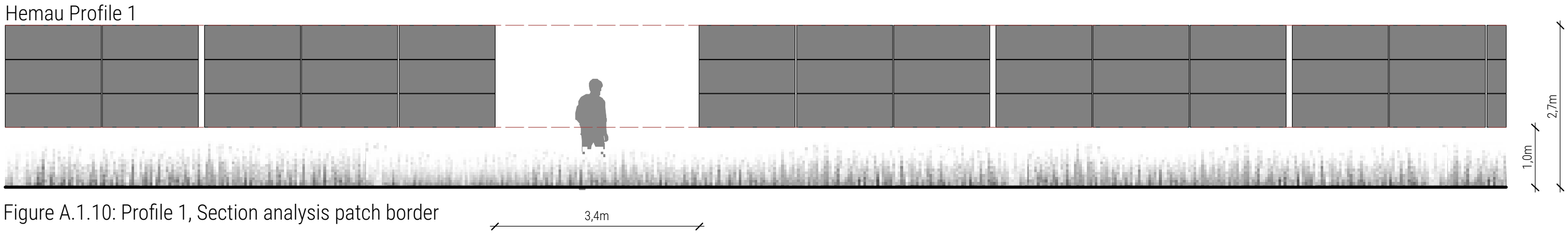


Figure A.1.10: Profile 1, Section analysis patch border

Hemau Profile 2

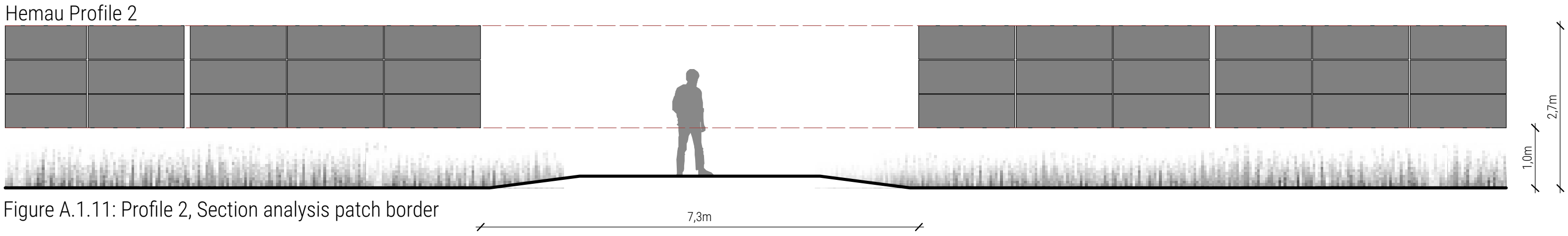


Figure A.1.11: Profile 2, Section analysis patch border

Transition landscape

Figure A.1.12: Map analysis, Transition landscape

The parcel of the solar field Hemau was transformed from a former military ammunition depot. Even though the bunkers and other military buildings on-site remained unchanged, the characteristics of the site changed clearly. To hide the depot from enemies, it was densely covered with conifers, blending into the surrounding conifer forest. For implementing the PV system, all these trees had to be cut down and to minimise shading also bordering forest parts have been cut down at that phase. While some professionals criticise the cutting of 15ha trees in the areas, others argue that the strict restructuring of the former monoculture has a hugely positive effect on the biodiversity (Solarenergie-Förderverien Deutschland e.V., 2003; Herden et al., 2009). Since the adjoining forest is still larger than 700ha, it can be argued that the decrease amount was reasonable.

The changing ecosystem, in combination with the rest of the site, enabled diverse pioneer species as mosses to conquer the large concrete surfaces on the parcel.

Since the number of landscape users is small, and the surrounding of the solar field is entirely consistent, the transition from the solar landscape towards the surrounding is less relevant than at other cases. Still, two different profiles can be found. In figure A.1.13/14 the different profiles are shown, including an indication of the presence along the edge. In both profiles, it is visible that no measures were taken onside the solar landscape to improve the transition to the surrounding landscape. Because of its remote location, this can be evaluated as a minor problem.

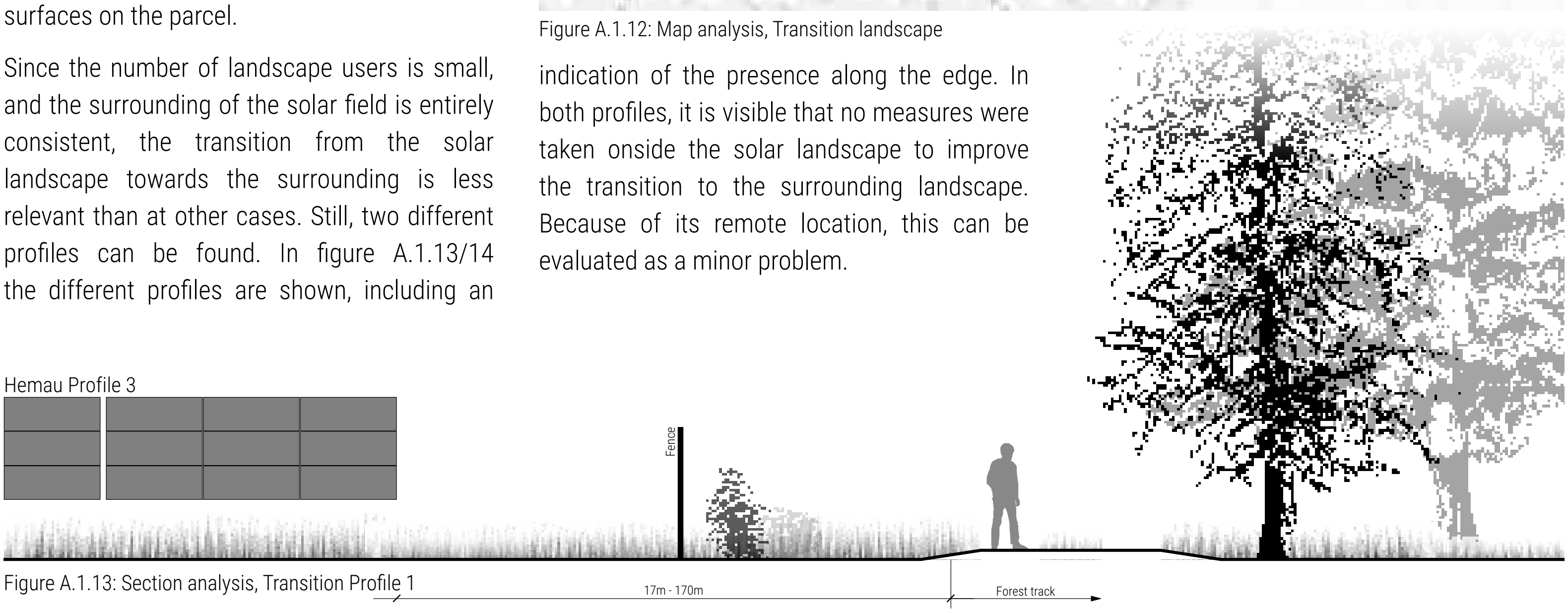


Figure A.1.13: Section analysis, Transition Profile 1

Figure A.1.14: Section analysis, Transition Profile 2

Multifunctionality

As mentioned before, the design of the solar landscape does provide space to small-scale agriculture and the improvement of biodiversity. The biodiversity improvements include the implementation of new pools for amphibians, dry and stony spots for pioneer species and wildflower meadows. The habitats are distributed over the whole parcel, whit a focus on the southeastern edge where the bunkers are located. From an ecosystem service approach, these functions can be analysed more specific, and other features of the solar landscape can be identified. In table A.1.1 the explored ecosystem services are presented.

A function that does not fit in the framework of ecosystem services is the support of local investors and provision of labour to farmers, which was made available during the building process (Krone, 2004; H. Wartner, personal communication, July 23, 2019).

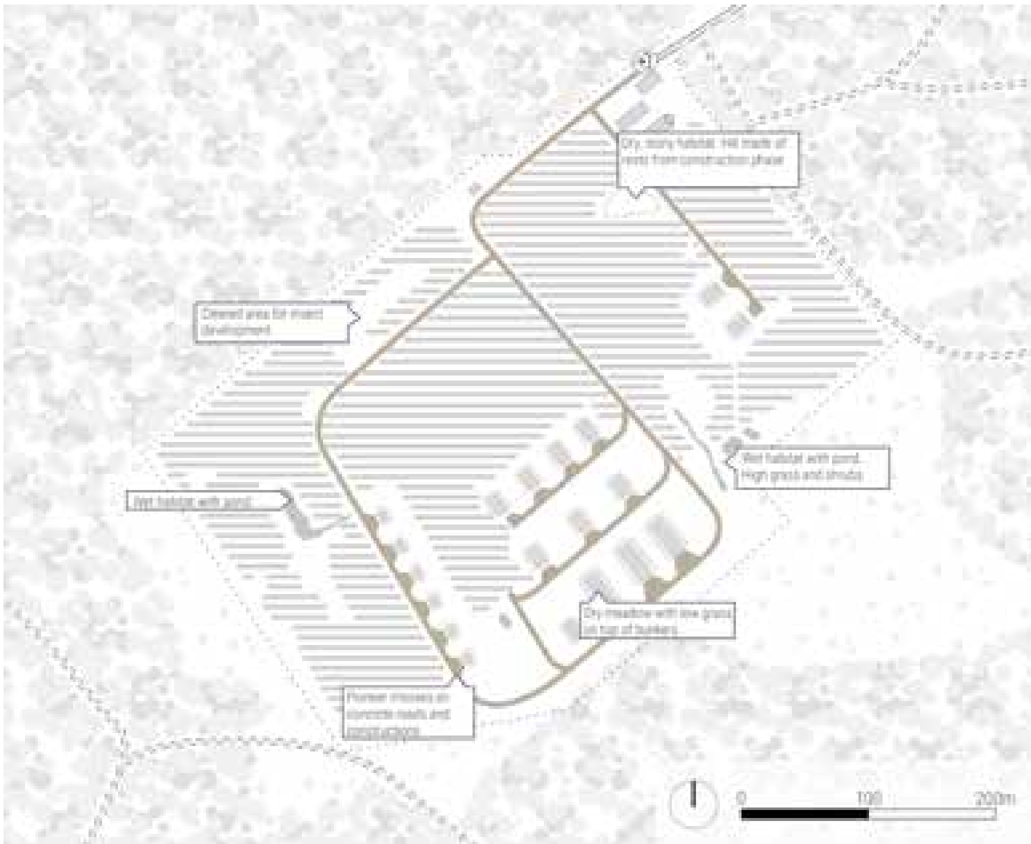
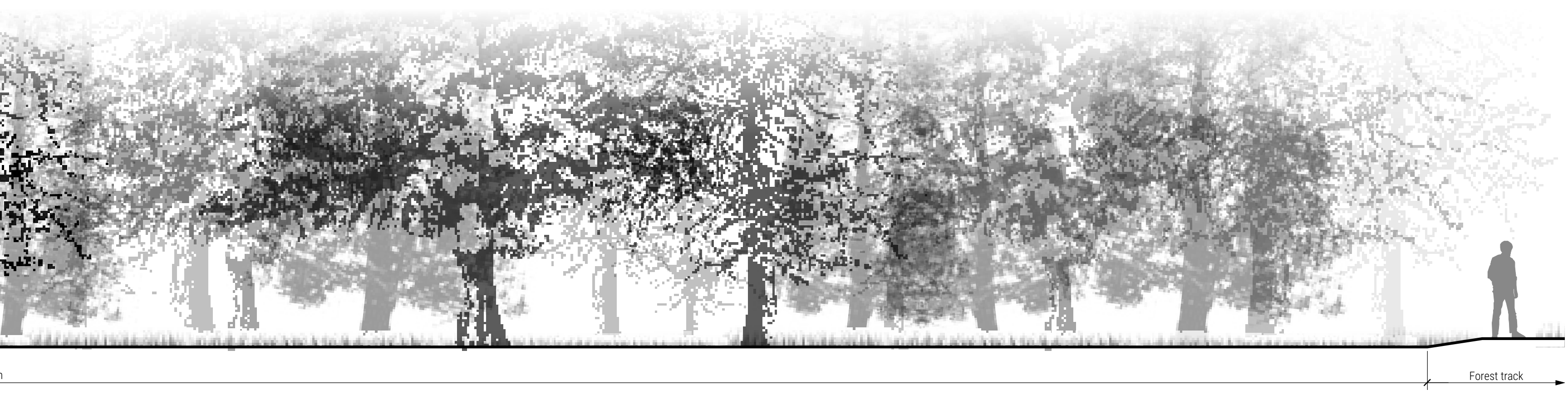


Figure A.1.15: Map analysis, Multifunctionality

Section	Code	Simple descriptor	Operational descriptor
Provisioning	1.1.3.1	Livestock raised in housing and/or grazed out-doors	Small scale agriculture
Regulation & Maintenance	2.2.2.1	Pollinating our fruit trees and other plants	Flower mixtures
Regulation & Maintenance	2.2.2.3	Providing habitats for wild plants and animals that can be useful to us	Maintaining insects, birds and endangered plant species to keep ecosystem in balance
Cultural	3.1.2.3	Things in nature that help people identify with the history or culture of where they live or come from	Bunkers and guard tower display the local history
Cultural	6.1.1.1	Things in the physical environment that we can experience actively or passively	Climbing on the hills of the bunkers Digital info panel on current yield (Stadt Hemau, 2010)

Table A.1.1: Ecosystem services at Hemau

No entry for visitors



A.2 Hengelo (GLD), Netherlands

Figure A.2.1: Impression of atmosphere at Hengelo

With only 7.1ha, the multifunctional solar field of Hengelo (GLD) in the Netherlands is the smallest among the analysed cases. It is located in the fringe of a recently developed suburban area and forms the transition to the rural landscape behind. The solar field, that was established on the parcel of a former tree nursery in 2016, features a power output of 2MWp (B&W Energy, 2016). This solar field is of interest since it features many different functions and meets as only one all the requirements of an EnergyGarden as defined by NMF. It is also the only one which is entirely accessible for visitors during the day.

At Hengelo more surface is reserved for other functions than to produce electricity, which is not common. The mainly recreational facilities, in combination with the early involvement of stakeholder demands, enabled the development of a gathering point for residents and neighbours which use the solar landscape regularly.

Additionally, nature is developed, and some information on the site and the species is provided. To embed PV system and the solar landscape into the host landscape well, the technical structures are implemented in more organic shapes and react to existing landscape structures. Existing trees from the nursery, as well as hedges and tree rows of the host landscape were kept and determined the design language for the solar landscape (Stichting De Kwekerij, 2019).

Figure A.2.2: Panoramic view form viewpoint towards North

Figure A.2.3: Panoramic view form viewpoint towards South

Spatial characteristics of PV system

The characteristics of the PV system at Hengelo are not exceptional, but there are still some excellent features to be explored and extrapolated to the case of Mastwijk.

The exactly south-facing arrays are constructed using standardised alloy parts for the framework and galvanised steel foundations which are drilled into the ground. The roughly 7,000 panels are all the same size and colour and are laid out in vertical rows. In the south of the parcel, where most recreative functions are positioned, two rows of panels are put on top of each other, whereas in the north, which is less visible to most landscape users, three rows are placed on each other. While in the southern part this results in an array height of 1.75m, in the northern part it is 2.3m, leading to a different experience for the landscape user. In both parts, the pitch sizes are chosen to prevent shadow in the winter when the sun is at its lowest point (see figure A.2.7).

Since the solar field is entirely accessible, the expensive and sensible inverters cannot be placed below the arrays, as it can be found at most solar fields. Instead, at solar field the Kwekerij they are clustered in roofed installations and fenced off to secure them against theft. The fence, in combination with a net, which also provides sawed out climbing plant the possibility to grow and shield the clusters completely in the future (see figure A.2.5). The transformers are placed in a standardised concrete block along the maintenance road in the northern part.

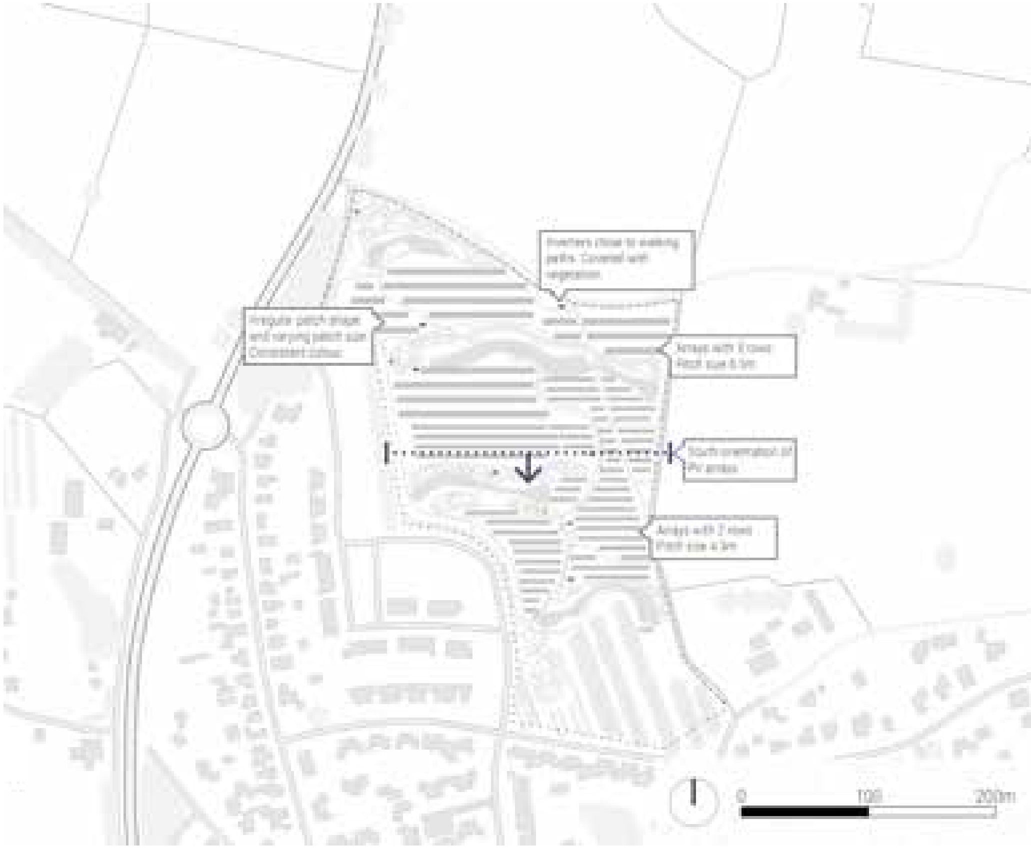


Figure A.2.4: Map analysis, Spatial characteristics


Figure A.2.5: Clustered inverters

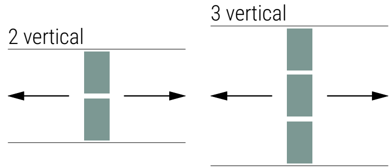


Figure A.2.6: Schematic layout of arrays

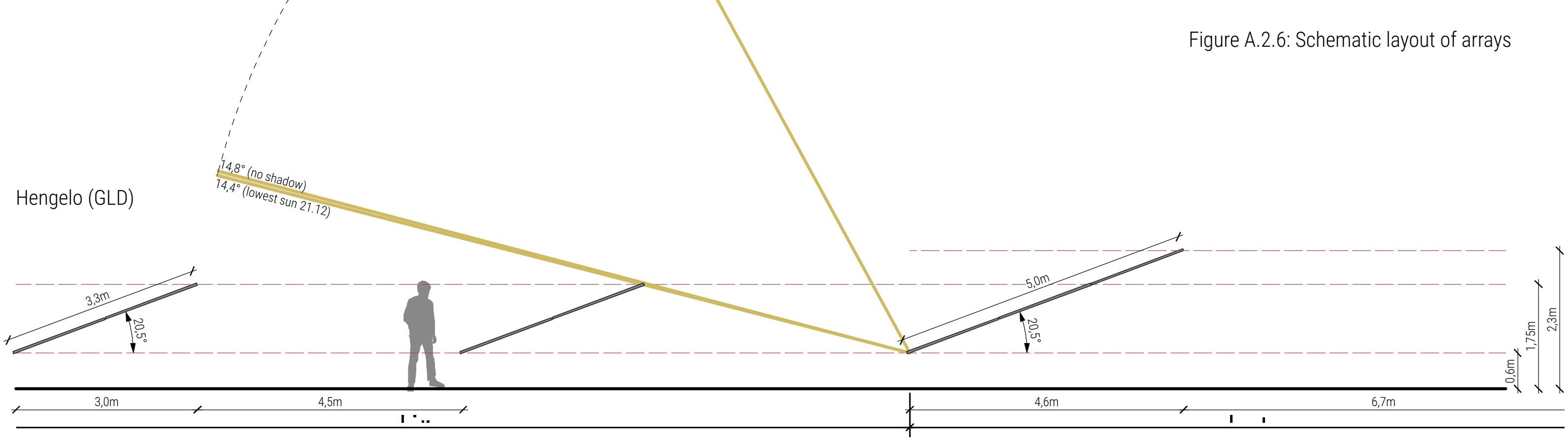


Figure A.2.7: Section analysis, Spatial characteristics

Visibility & screening

The visibility and screening are especially important for this case since it is in the direct urban periphery. Multiple measures ensure that there is enough visible distance between the landscape user outside the perimeter and the PV system, which comprise a combination of existing and newly implemented instruments. While existing trees of the former tree nursery provide an effective shielding from the south side of the parcel planted hedgerows offer a natural barrier at the north, east and west of the solar field. At the northwest, an existing tree row is shielding the view of landscape users driving on the provincial road.

The shielding measures along the border of the solar landscape are crucial because the solar field is not only approached by urban periphery at two sides but is also surrounded by pathways directly at its border. Landscape users can come up to five meters close to the PV panels, without being inside the solar landscape.

Inside the solar field, measures have been taken as well, to shield the landscape users view towards the whole PV system, and to give the small parcel more complexity and natural heterogeneity. Vegetated artificial hills of up to two meters are positioned between the PV system, making it impossible to overview the site form the ground level. One of these artificial hills is designed as an elevated viewing point for visitors, from there the solar landscape can almost be overseen completely, giving the landscape user a clue that the solar landscape is quite small compared to other solar fields.

Figure A.2.8: Map analysis, Visibility & Screening


Figure A.2.10: View from local road towards PV system


Figure A.2.9: Fence type

Parcel size vs. patch size

The PV system at solar field De Kwekerij is divided into fourteen patches, which are organically shaped and look naturally distributed. The patches differ in their surface, the array length and the array height as some consist of two and other of three rows as mentioned before. Most of the patches are in the northern part of the parcel whereas, in the southern fraction, more space is reserved for recreational, educational and biodiversity functions. In total, only 35% of the solar landscape is used to locate PV patches.

Figure A.2.11: Map analysis, Parcel vs patch size

The border between the patches differs both in width, as in the typology of the solar landscape in between. In order to be able to compare the edges of the patches, two main typologies are assembled:

Profile 1 can be found at various spots of the solar landscape and simply consist of grass and low vegetation between the patches with sometimes an unpaved walking path crossing and a distance of three to fifteen metres (see figure A.2.12). The landscape user can see the PV system on both sides and can look through the pitch to the edge of the solar landscape, which is most of the time a hedgerow.

Profile 2 can only be found in the north-south direction and at the larger distances between the patches. It comprises the artificial hills, in some cases the water retention basins, and medium-high vegetation which shield the view to the following patch effectively (see figure A.2.13). Even though the distance between the patches only ranges from 18 to 40 metres (at Gänsdorf, the minimum is 45m), the visitor experiences a natural environment, far from the PV system.

Hengelo (GLD) Profile 1

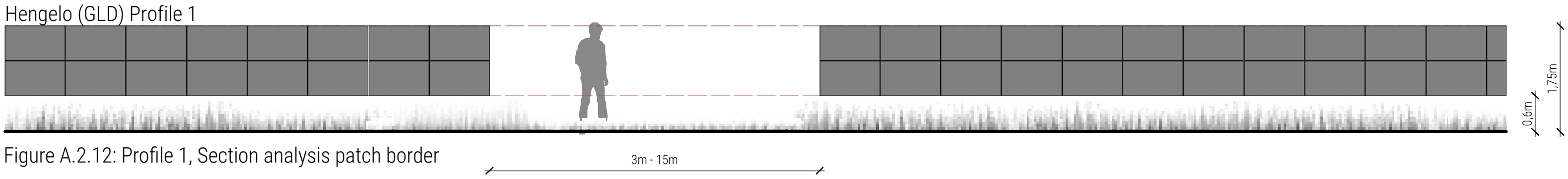


Figure A.2.12: Profile 1, Section analysis patch border

Hengelo (GLD) Profile 2

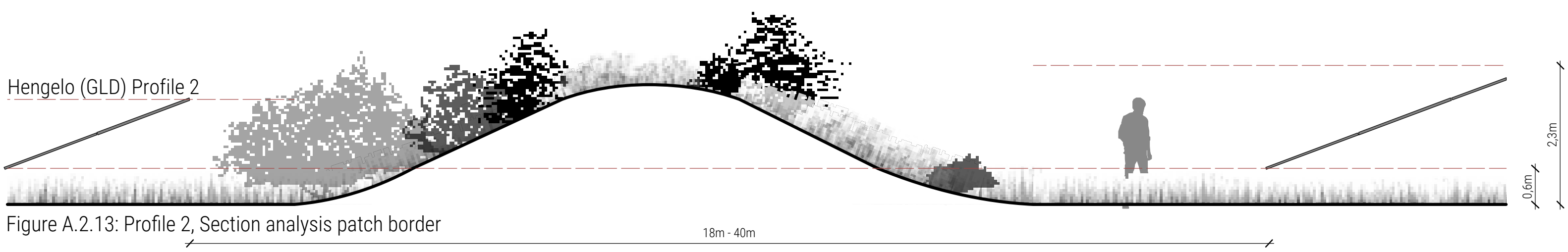


Figure A.2.13: Profile 2, Section analysis patch border

Transition landscape

The transition from the former land use of agriculture and tree nursery is still recognisable in some parts of the solar landscape, which relates the design more to the place and distinguishes it from other solar fields. Most recognisable are the medium to high trees in the south of the parcel, which follow strict lines since they remained from the nursery. Trees that were cut for the implementation of the design were transformed into wood for furniture in the park (Van der A et al., 2018). The former parcellation was removed and not translated into the design of the PV system or the solar landscape. However, this loss must be relativised, since the urban extension cut the parcel borders in the west either way, and the parcel still fits into the landscape typology regarding its scale.

Likewise, the artificial hills and the complete enclosure by hedgerows does not connect to the semi-open landscape typology ideally. However, it can be assumed that a certain shielding to the urban environment was of higher significance to gain acceptance than the perfect embedding into the agricultural landscape. Furthermore, the artificial hills, which lead to a significant higher heterogeneity on the parcel, make the solar landscape more attractive to visitors from the neighbourhood and thus improve the transition to the current land use.

Figure A.2.14: Map analysis, Transition landscape

The parcel can be accessed from five entrances which invite the residents of the village to use the park for recreational purposes regularly and connect them to the agricultural landscape behind. The high amount of locally desired functions makes it valuable at this specific location.

The most typical border of the solar landscape, a natural fence with a mixed hedge, is visualised in figure A.2.15.

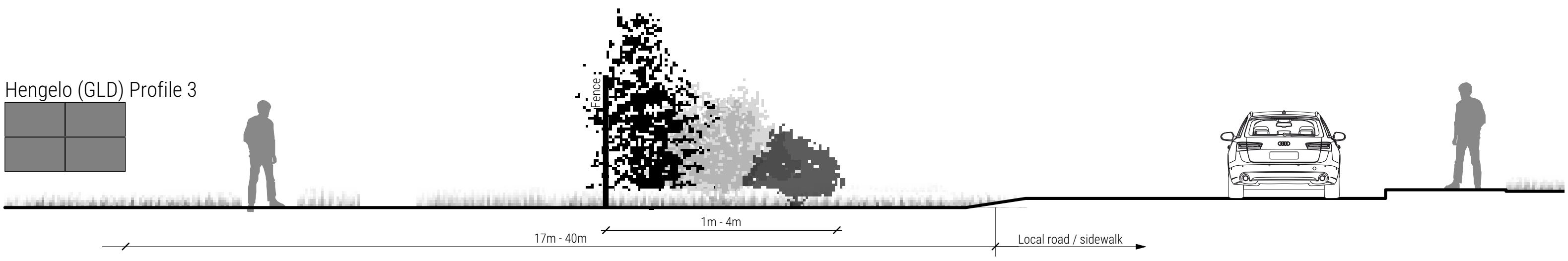


Figure A.2.15: Section analysis, Transition Profile 3

Multifunctionality

Because of its urban environment, the solar field in Hengelo is approached by many more landscape users than the other analysed case studies, demanding the design to fulfil various functions next to producing electricity. Departing from the number of functions that are provided, and the parcel size of only seven hectares, it appears more as a community garden.

The focus is put on local recreative functions for the residents of the neighbouring village, and from talks with visitors, the services seem to be used frequently. Examples are the unpaved paths running all over the parcel which allow for a short walk and walking the dog, picnic benches for a small break, water features where children can play, and the elevated viewing point. Currently, the residents are also developing a spot for community gardening in the southern part, which extends the recreative functions even more. For visitors from further away, a small parking lot is designed on the parcel, which is surrounded by vegetation shielding it.

For educational purposes, a board with superficial information on local nature and the PV system is implemented at the main entrance, and occasionally guided tours and nature-related workshops are offered (Stichting De Kwekerij, 2019). However, the educational component of the design is underexposed compared to the stimulation of recreation and biodiversity.

Figure A.2.16: Map analysis, Multifunctionality

For the improvement of biodiversity, mixed hedges, wet areas, flower mixes and diverse species of shrubs that feed animals, were implemented. The artificial hills allow having both umbrageous and sunny habitats for a wide range of flora and fauna species. Furthermore, a bee hotel, several aviaries and traditional local fruit species were placed, which also offer a recreational function (Van der A et al., 2018). However, the amount of nature development and its maintenance was found to be too expensive to be financed by the PV installation (Stichting De Kwekerij, 2019).

Section	**Code**	**Simple descriptor**	**Operational descriptor**
Provisioning	1.1.1.1	Any crops and fruits grown by humans for food	Planting of fruit trees (ca. 10)
Provisioning	1.1.3.1	Livestock raised in housing and/or grazed outdoors	Sheep grazing for maintenance
Regulation & Maintenance	2.1.2.3	Screening unsightly things	Hedgerows; existing vegetation;
Regulation & Maintenance	2.2.1.3	Regulating the flows of water in our environment	Water retention basins
Regulation & Maintenance	2.2.2.1	Pollinating our fruit trees and other plants	Flower mixtures
Regulation & Maintenance	2.2.2.3	Providing habitats for wild plants and animals that can be useful to us	Hedgerows; shrubs; artificial hills
Cultural	3.1.1.2	Watching plants and animals where they live; using nature to de-stress	Walking paths adjacent to increased biodiversity; elevated points for look out; benches
Cultural	3.1.2.2	Studying nature	Organizing lectures and tours. Physical space reserved in the field for meetings.
Cultural	6.1.1.1	Things in the physical environment that we can experience actively or passively	Climbing on the artificial hills, playing in the water retention basins

Table A.2.1: Ecosystem services at Hengelo

A.3 Gänsdorf, Germany

The multifunctional solar field of Gänsdorf, in the rural region of Straßkirchen (Bavaria), was established in 2009, guided by the firm Krinner Schraubfundamente. It is located on former agricultural soils and with 181ha, 250,000 panels and output of 54MWp, it is by far the largest one analysed in this thesis.

Mainly because of its size, it is special how well it is embedded into the host landscape. The border of the solar field is circled with a mixed hedge of medium height which consists of clusters and does not seem like a visual shield but like a typical landscape element. At some areas around the solar field also large nature restoration surfaces are created with various species of weeds and shrubs that offer habitat to birds and insects, particularly for bees. The nature restoration surfaces also function as testbeds for new plant species, maintenance methods and Agrivoltaics of Krinner.

Figure A.3.1: Impression of atmosphere at Gänsdorf

A unique detail about the solar field of Gänsdorf is that Klaus Krinner, the owner of the land, forced the investor to pay the taxes on profits received from the solar field to the municipality of Gänsdorf, leading to remarkably increased tax incomes for the small municipality. In return, that gives benefits to all its inhabitants of the region (K. Krinner, personal communication July 22, 2019).

Another extraordinary invention to prevent the agricultural soils from compressing too much was the construction of a new vehicle to transport the heavy transformers from the maintenance roads to the centre of the parcels (Wartner & Zeitzler Landschaftsarchitekten BDLA, 2013).

Figure A.3.2: Flower meadows and hedge between the PV patches (Oudes, 2019)

Figure A.3.3: View on solar landscape from elevated viewpoint

Spatial characteristics of PV system

The technical system of Gänsdorf is average compared to other cases of this thesis project. The use of panels is consistent in colour and size, with all panels facing the south. The panels are mounted on alloy arrays with two rows of vertical panels on top of each other and a standard array width of 100 metres. The arrays have screw foundations which makes it possible to easily remove them after the lifespan of the panels (K. Krinner, personal communication July 22, 2019). The lower edge of the panels has a height of 0.6m and total height of 2.0m, which is quite low compared to other fields. In combination with a pitch size of 4.3m and the local azimuth angle, the panels catch all the sun almost the whole year, which means that also soil and the vegetation inside the pitch get more sun hours during the year, which is beneficial to the soil quality and biodiversity of the parcel.

The inverters are placed below the arrays, which does not disturb the view inside the solar field and shields them from weather influences. The 45 transformers of the PV system are positioned at the centre of the patches, making them less visible from outside the patches. This is beneficial since the transformers are standardised concrete blocks which do not blend well into the landscape. This technology, however, does not work if the patches are accessible for landscape users.

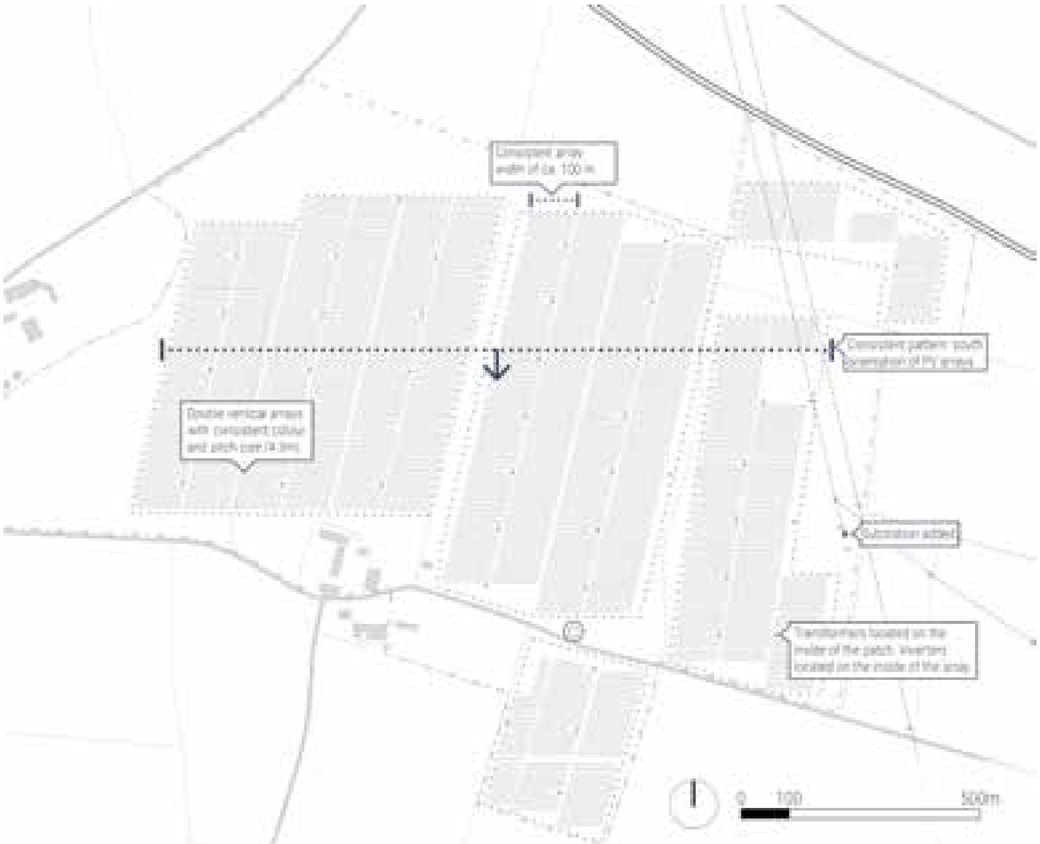


Figure A.3.4: Map analysis, Spatial characteristics

Besides the transformers, there is also a substation added at the east of the solar field to distribute the significant amount of electricity produced, to the main-grid, which can be recognised from far away because of the overhead powerlines.

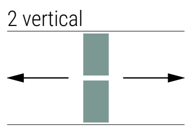


Figure A.3.5: Schematic layout of arrays

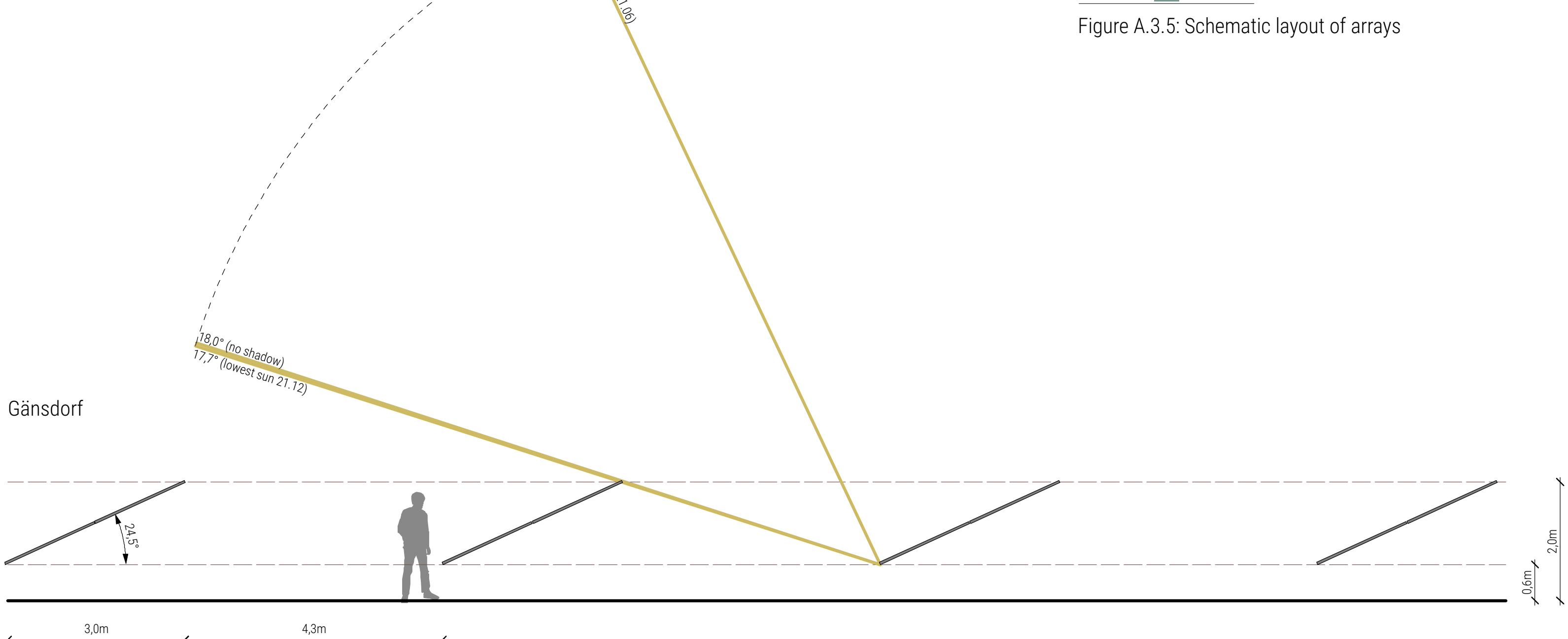


Figure A.3.6: Section analysis, Spatial characteristics

Visibility & screening

Despite its large size, the solar field of Gänsdorf is well hidden and integrated into the host landscape. This is mainly achieved by two aspects: The first one is the earlier mentioned low height of the arrays, which requires less shielding also from larger distances. The second one is the consequent implementation of dense, mixed hedgerows along the patch borders, which blend in the typology of the landscape (Wartner & Zeitzler Landschaftsarchitekten BDLA, 2013).

At the borders between two patches, the hedgerow is only placed on one side, which saves costs but also enables landscape users to get a view into the large patches of the solar field, with each approximately the size of the case Hemau.

The hedgerows which have an average height of four metres and a width of five metres also contain trees which will, when grown up, form green barriers as they fit in the local landscape (H. Wartner, personal communication July 22, 2019).

From the main road in the north, the solar field is entirely shielded by the hedgerows and fruit trees in the north-east, which form a green barrier. The shielding from this road was a well-informed design decision to prevent local opposition in the agricultural region (H. Wartner, personal communication July 22, 2019).

Due to the various hedges on the parcel, it is difficult to estimate the enormous size of the solar field and the high elevated view tower in the southern part is the only point from where the size can be estimated. Since the viewpoint is not located at the edge of the solar landscape, like it is done at Neukirchen-Vluyn, visitors get the feeling of being surrounded by more than 270° of solar panels.

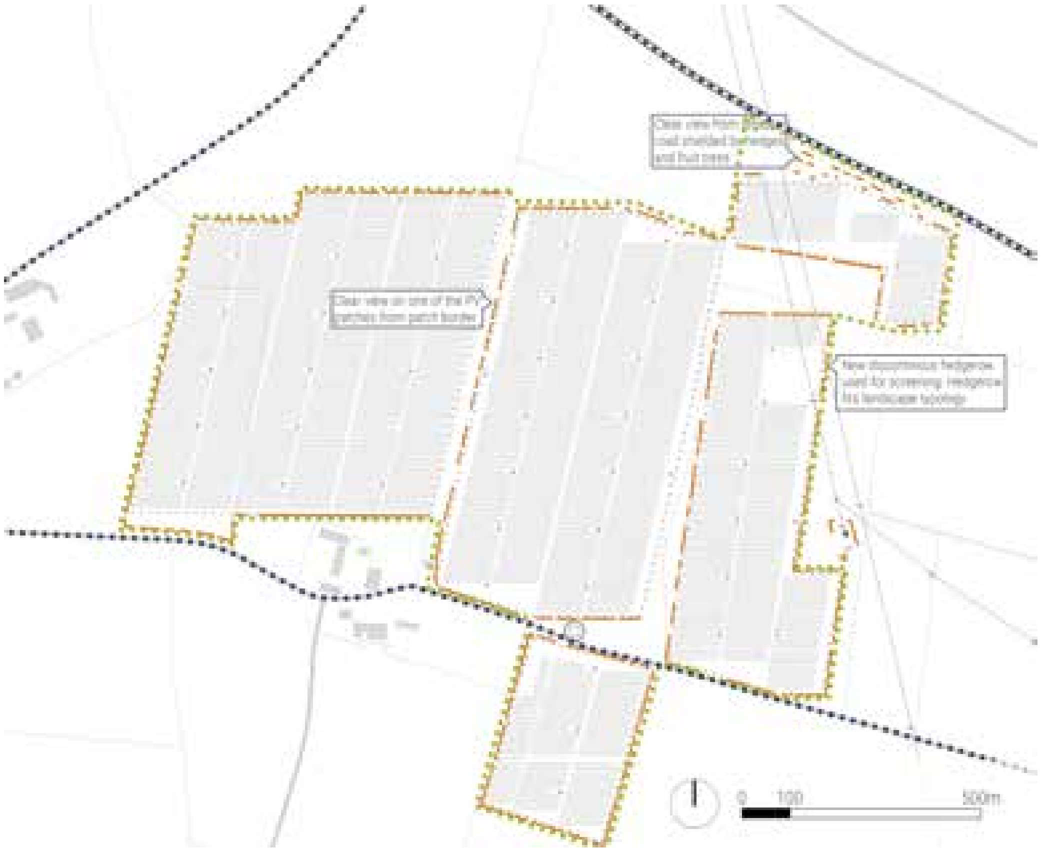


Figure A.3.7: Map analysis, Visibility & Screening

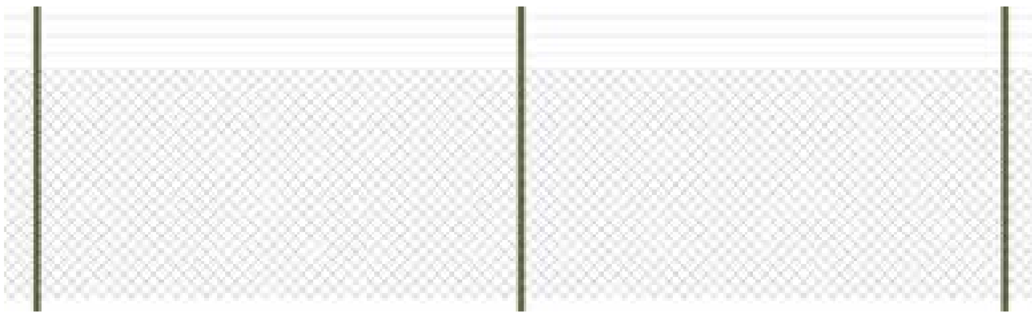


Figure A.3.8: Fence type

Gänsdorf Profile 1

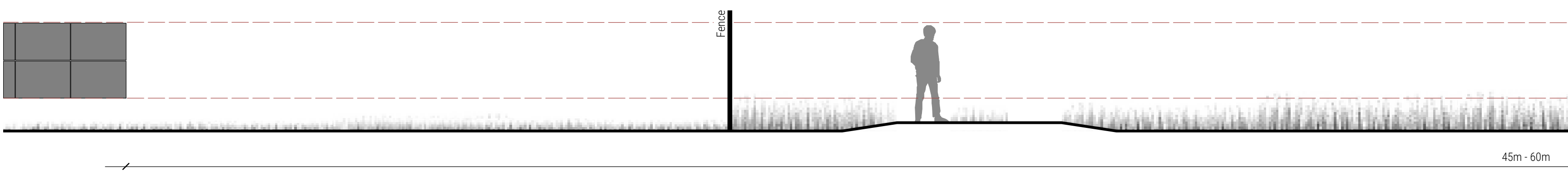


Figure A.3.9: Profile 1, Section analysis patch border

Parcel size vs. patch size

The combined parcels of Gänsdorf have a total size of 181 ha, while only 145ha were considered in the design forming of the solar landscape, with the residue staying in agricultural production. Within the solar landscape, besides five huge PV patches, large areas were transformed into test sites for different wildflower seedings, natural meadows, and other measures to increase biodiversity (Rösch, 2016). At the north-east, a whole plot is reserved for the testing with agrivoltaics and other combinations of agriculture with solar panels. The testbeds and wildflower meadows, which catch the eye within the homogenous agricultural landscape around, embrace the large PV patches and give the site a natural and diverse identity.

Since the single patches are fenced off, the public can walk 'through' the solar field and not only see it from the outside. Between the patches, wide borders with 45 to 60 metres can be found, with fences on both sides, a maintenance road and a hedge on one site which covers the fence. Even though the profile seems like a tunnel in figure A.3.9, in reality, the wildflower meadow, and the mixed hedge provide a feeling of naturality, and the wide arrays on both sides do not give the feeling of being in the middle of a huge solar field.

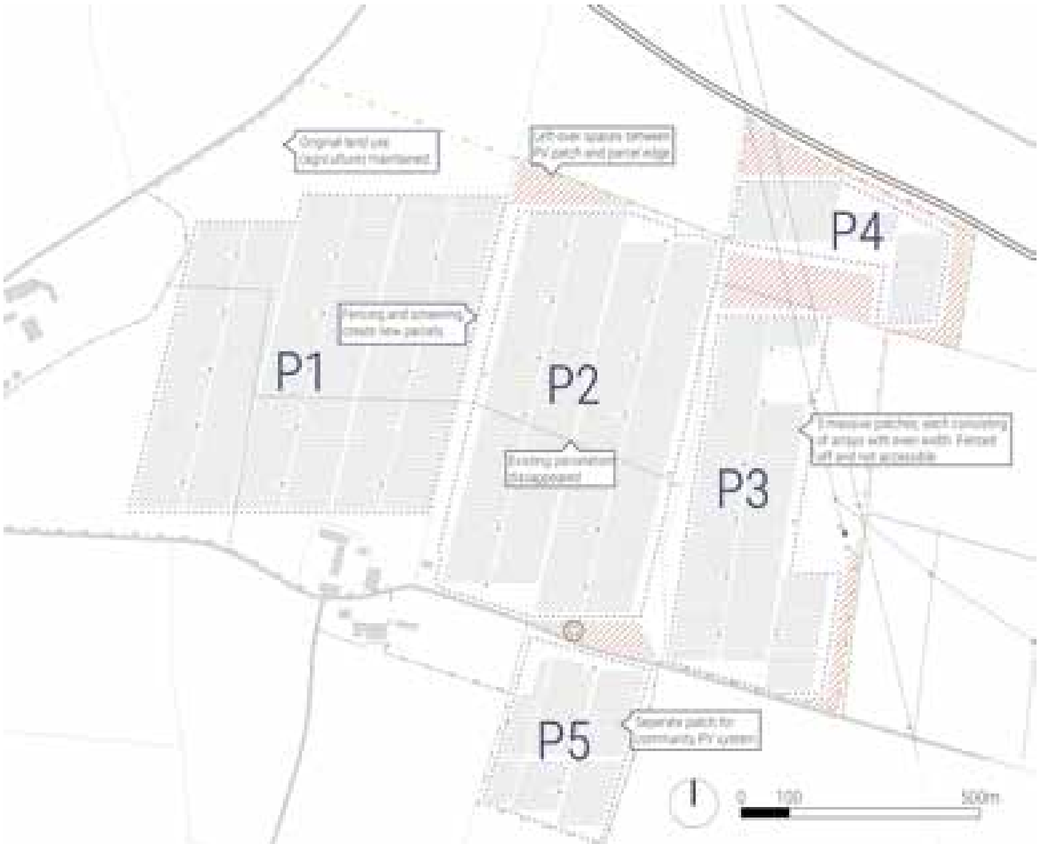
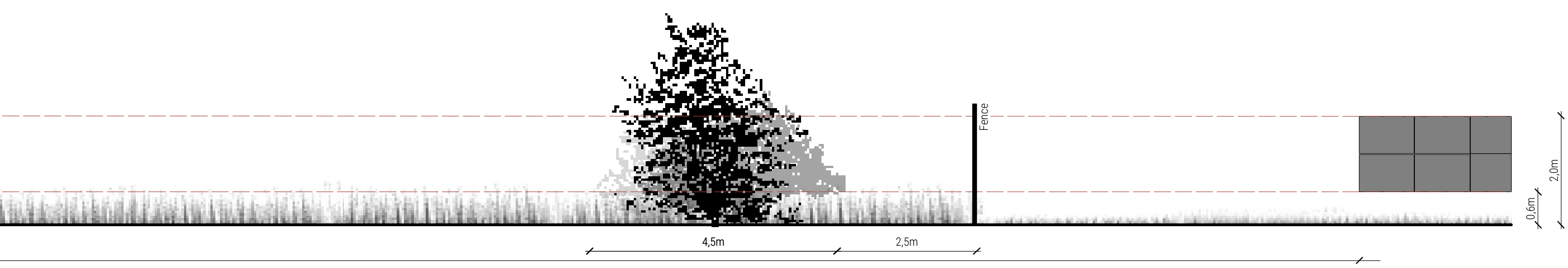


Figure A.3.10: Map analysis, Parcel vs patch size

Figure A.3.11: Patch border with hedge on right side and unshielded fence on left side (Oudes, 2019)



Transition landscape

Before becoming the basis for a solar field, the land was used for agriculture, and the soil was classified as one of the most fertile soils in the region (H. Wartner, personal communication July 22, 2019). The decision to use this land for the solar field was not made concerning the existing land use, soil quality or position in the landscape, but purely on the fact that the interconnected parcels were sold all at the same time, enabling the realisation of such a large project.

Since parts of the parcels are still in use for agriculture and the areas between the patches are still maintained by local farmers who can experiment with wild meadows, there is still a link to the former land use, and the whole site has an agricultural identity. Also, the experimenting with agrivoltaics on one of the parcels sets a strong relationship between the two identities. As was mentioned by the landowner, the plan is to bring the parcels back into agricultural use when the lifespan of the solar panels is reached. The mostly kept parcel borders make this transformation possible in the future.

Besides the transition to the surrounding agricultural landscape, also the relationship with the neighbouring residents was taken care of, by integrating the solar field as best as possible inside the landscape and offering recreational facilities.

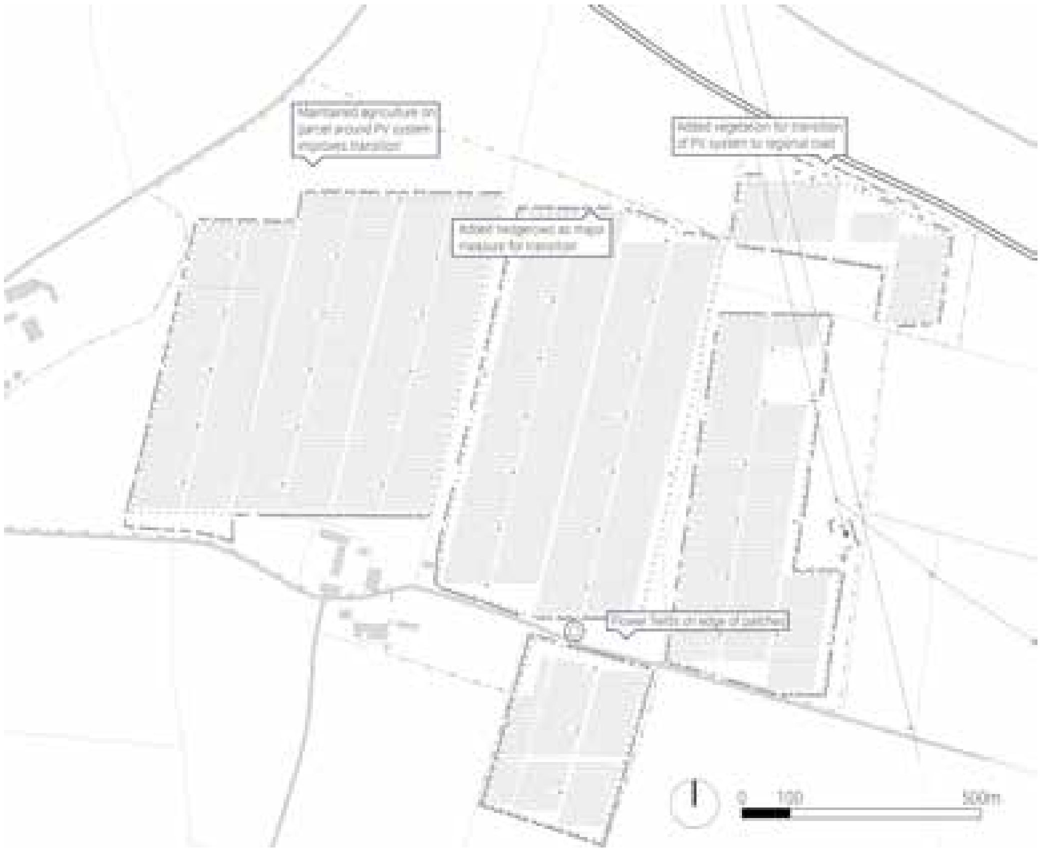


Figure A.3.12: Map analysis, Transition landscape

Besides a viewpoint, the possibility to walk through the area and a series of local fruit trees were implemented. However, since the solar field is in a rural area, there is no shortage of walking paths between fields, and most residents have fruit trees in their garden, making the measures less valuable at that site. The designer confirmed that he is one of the few people who pick the apples from the trees. If the solar field were located in a more dense and urban area, there would be a higher chance that these facilities would be appreciated.

Gänsdorf Profile 2

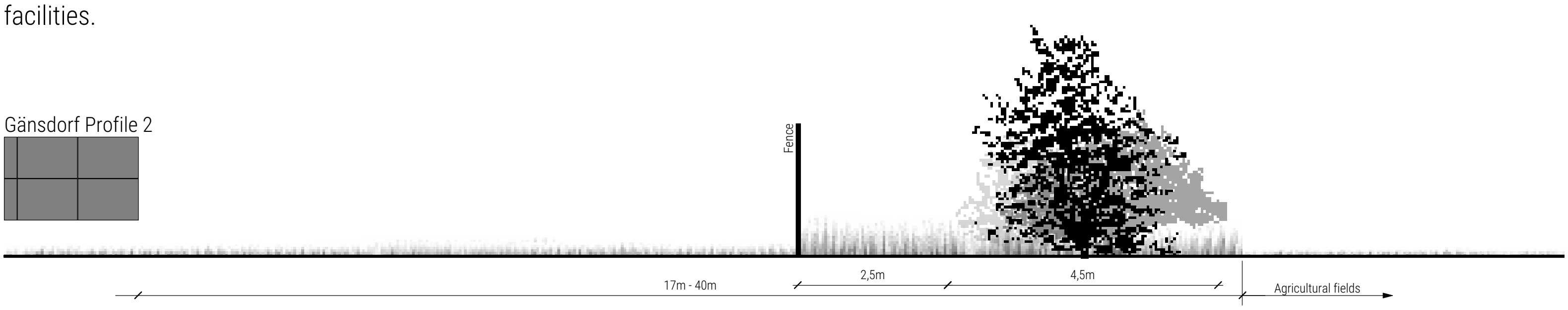


Figure A.3.13: Section analysis, Transition Profile 2

Gänsdorf Profile 3

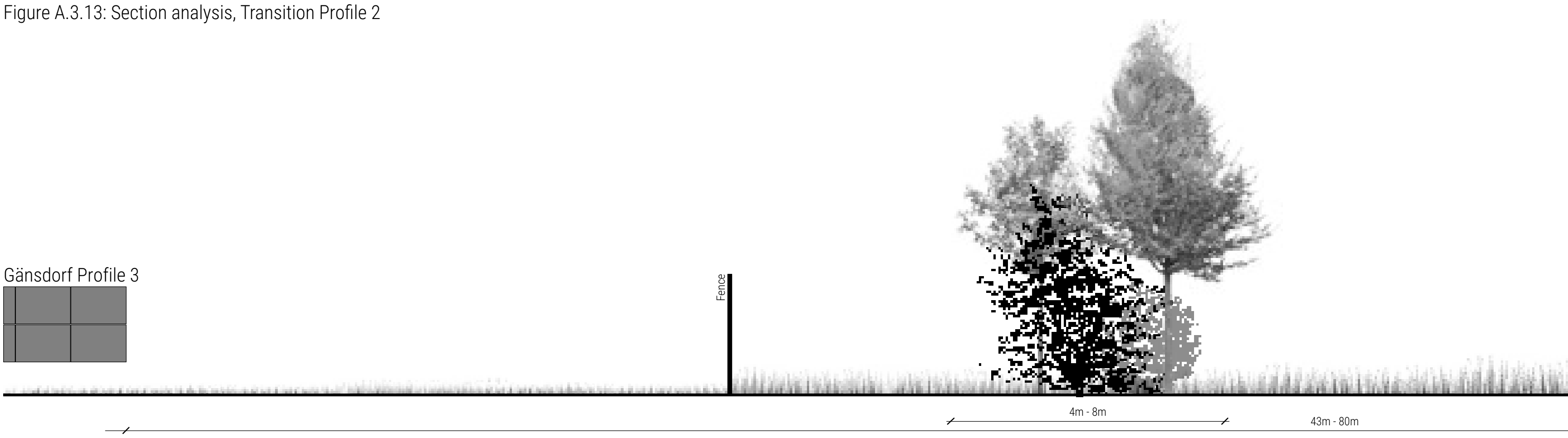


Figure A.3.14: Section analysis, Transition Profile 3

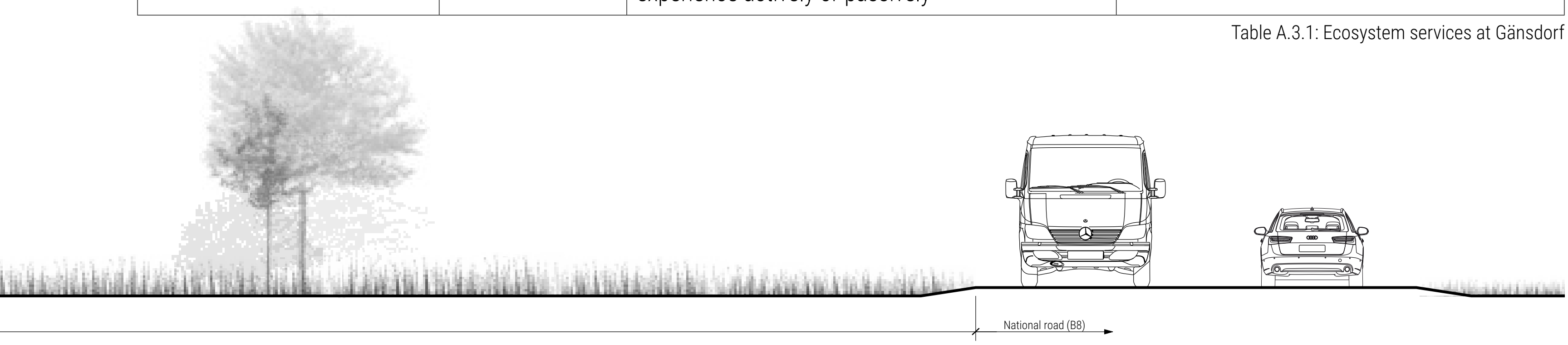
Multifunctionality

Next to the provisioning of electricity, the design mainly includes the improvement of biodiversity. With a focus on insects, taken measures are the implementation and testing of seed mixes for wildflower meadows, mixed hedges, fruit trees and beehives on the parcel. The solar field is also part of a national project on the improvement of habitats for insects. It is used by regional authorities to monitor the movement and development of species (Rösch, 2016).
The experimentation with agrivoltaics and other combinations of agriculture and PV systems is another added function which gives the solar field more importance for the future.
For recreational purposes, the elevated viewpoint adds another experience to the solar field; however, as mentioned before, on recreational and educational factors, the solar field is scoring low compared to other cases. Although not spatially recognisable, the local inclusion of residents and companies in the form of investments is an added function which offers advantages to the region.

Figure A.3.15: Map analysis, Multifunctionality

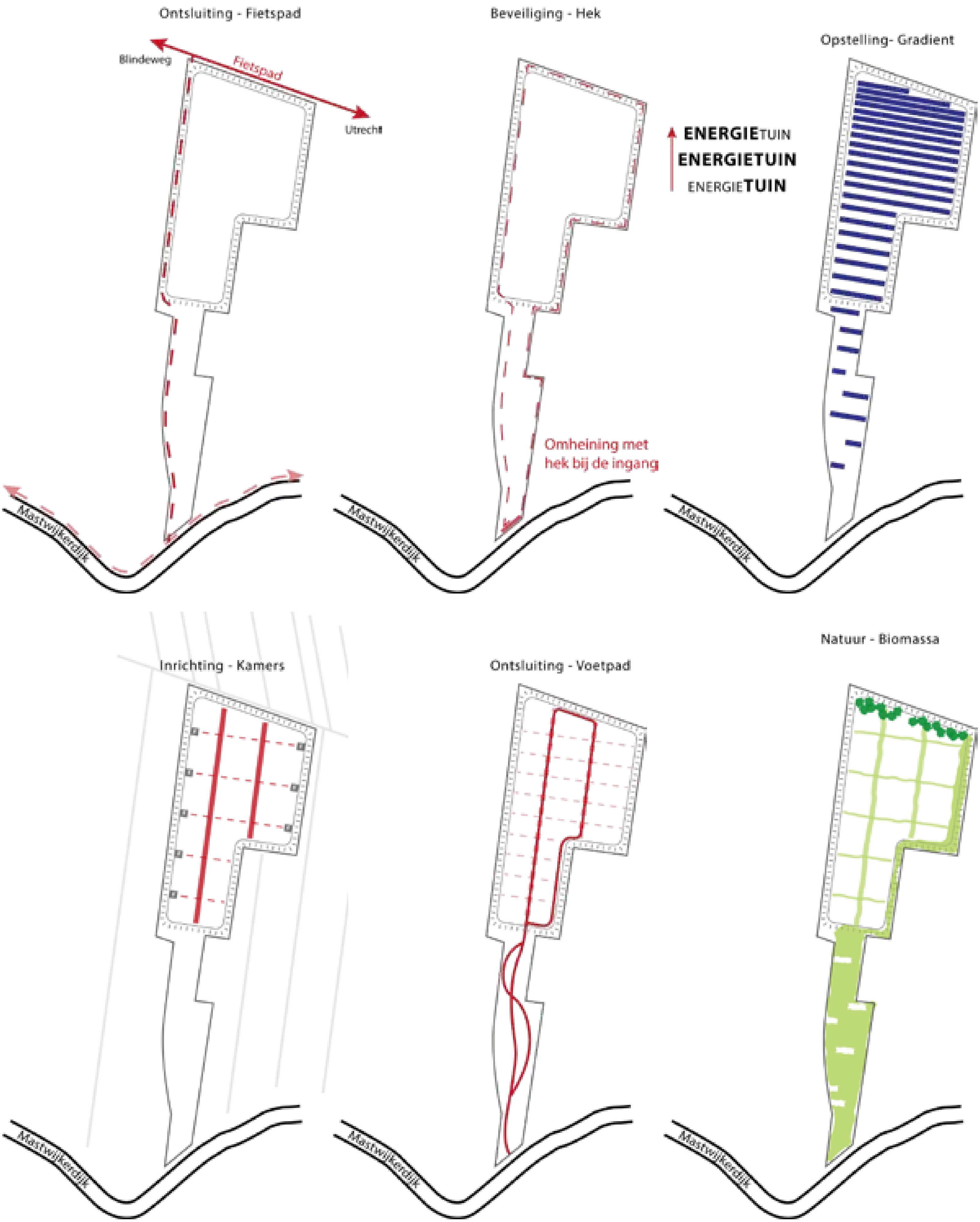
Section	Code	Simple descriptor	Operational descriptor
Provisioning	1.1.1.1	Any crops and fruits grown by humans for food	Planting of fruit trees
Provisioning	1.1.3.1	Livestock raised in housing and/or grazed outdoors	Sheep used to graze for maintenance
Regulation & Maintenance	2.1.2.3	Screening unsightly things	Hedgerows; Fruit trees
Regulation & Maintenance	2.2.2.1	Pollinating our fruit trees and other plants	Flower mixtures
Regulation & Maintenance	2.2.2.3	Providing habitats for wild plants and animals that can be useful to us	Hedgerows; fruit trees; flower meadows; previously below panels as well
Cultural	3.1.1.2	Watching plants and animals where they live; using nature to de-stress	Flower fields are adjacent to the existing unpaved roads
Cultural	3.1.2.2	Studying nature	Ecological experiments
Cultural	6.1.1.1	Things in the physical environment that we can experience actively or passively	Viewpoint

Table A.3.1: Ecosystem services at Gänsdorf

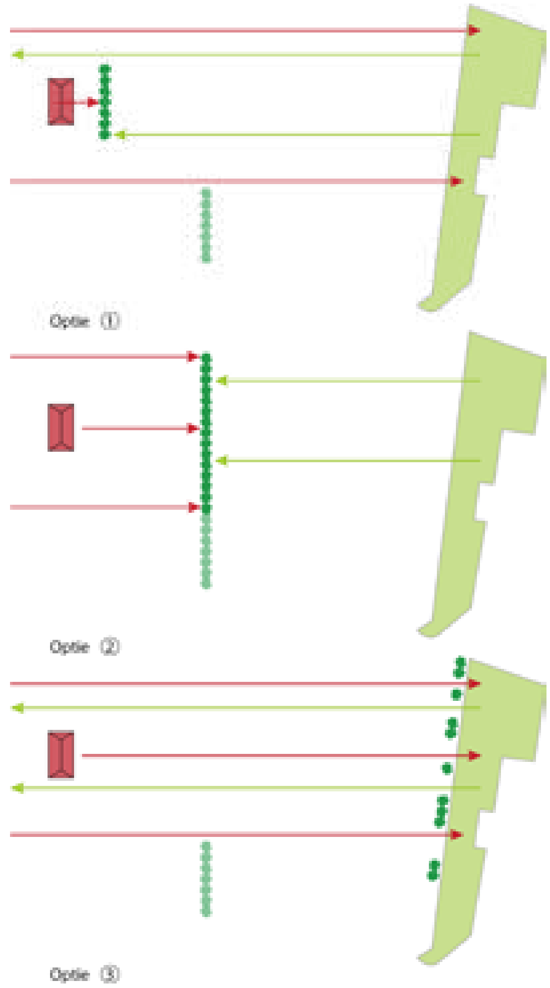


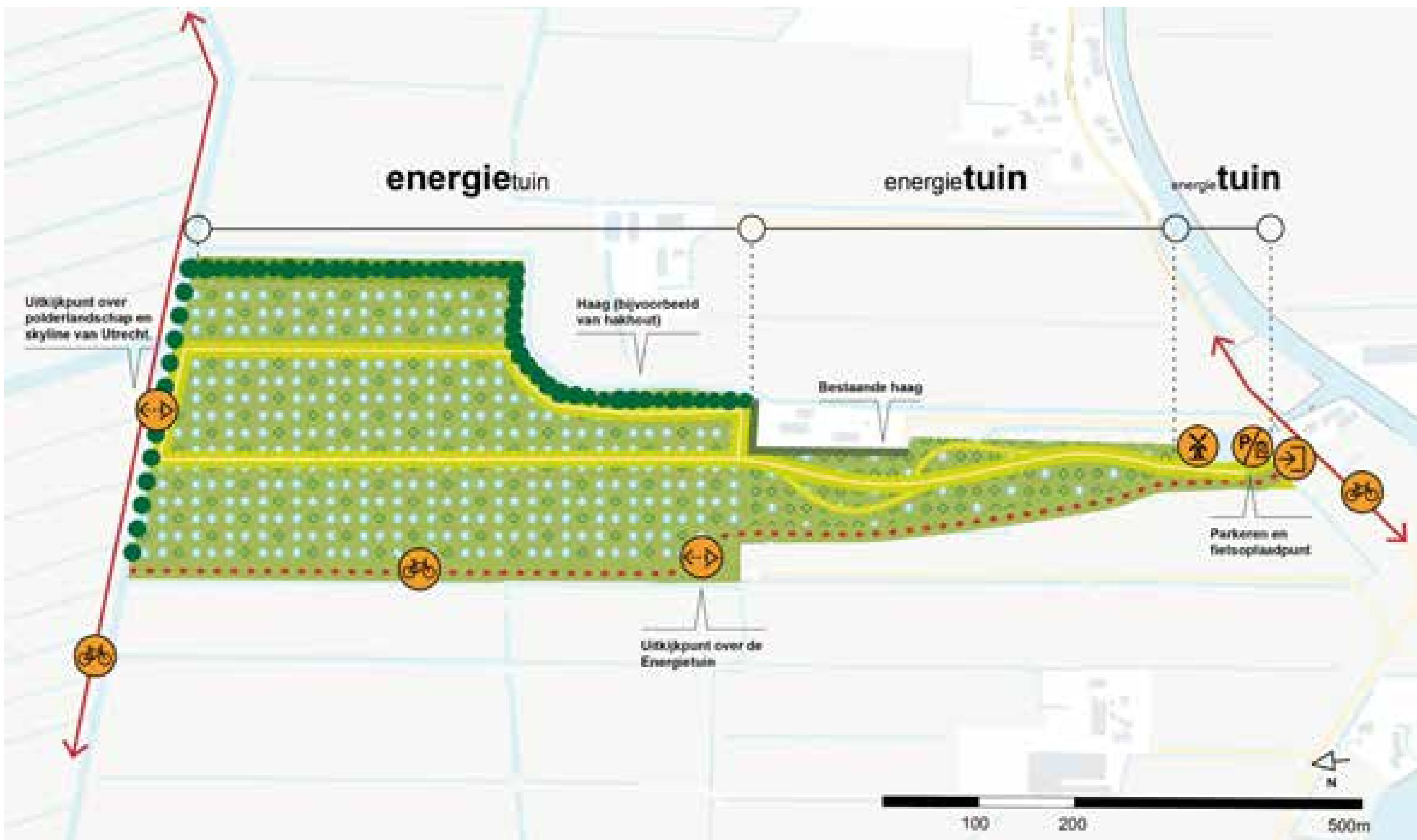
Appendix B - Design development

B.1 Phase A - Development of design principles and first spatial concept



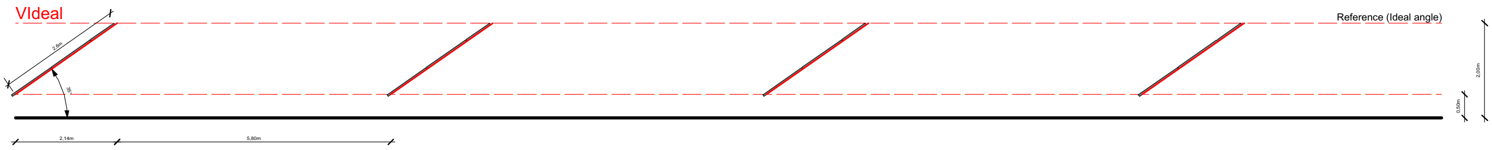

Voorzieningen
Uitkijk Polder
Uitkijktoren Energietuin
Banken
Historische molen
Informatie & Oplaadpunt
Mastwijkerdijk

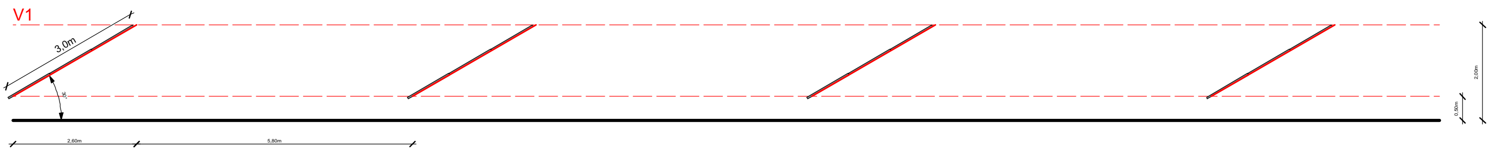

Optie 1
Optie 2
Optie 3

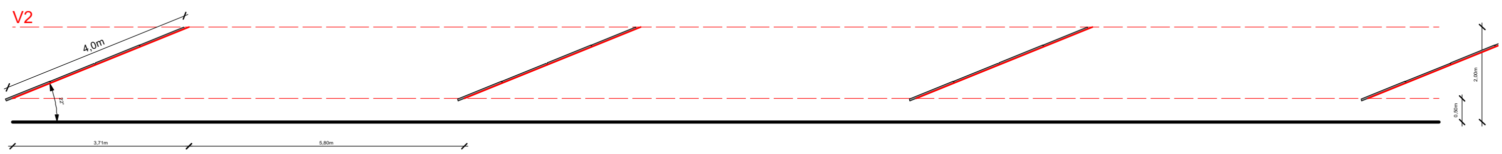

energietuin
energietuin
energietuin
Uitkijkpunt over polderlandschap en skyline van Utrecht.
Haag (bijvoorbeeld van hakhout)
Bestaande haag
Parkeren en fietsoplaadpunt
Uitkijkpunt over de Energietuin
N
100
200
500m

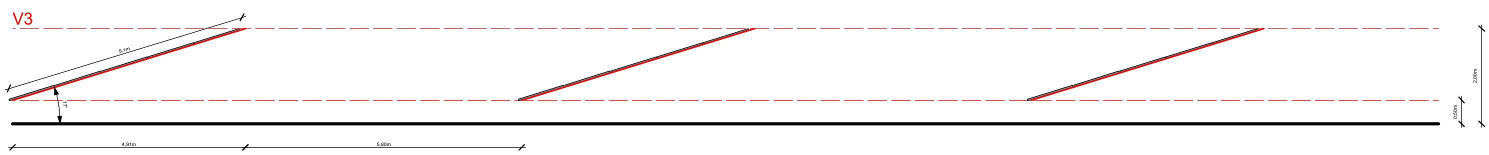
B.2 Phase B - Research on possible versions of PV characteristics / layout

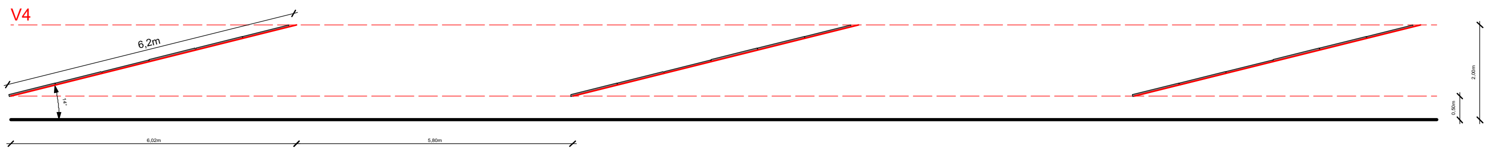
Calculations for 300Wp modules with 11MWp in total as requirement

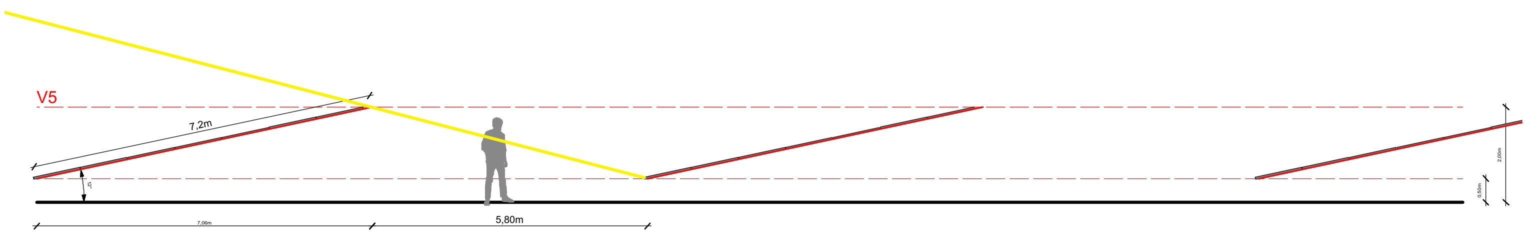


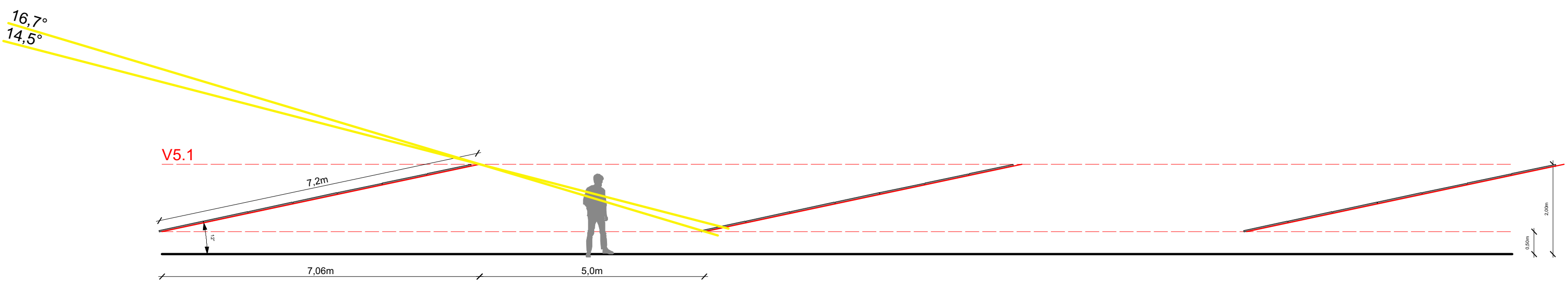


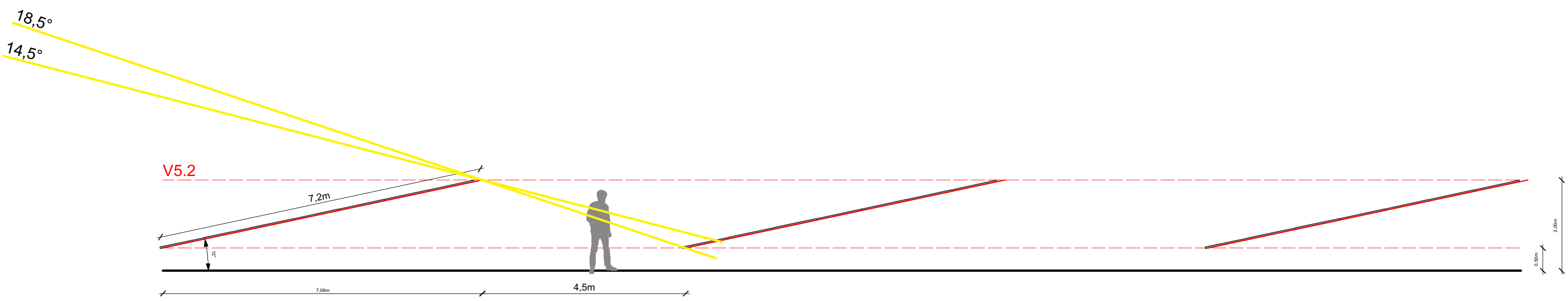


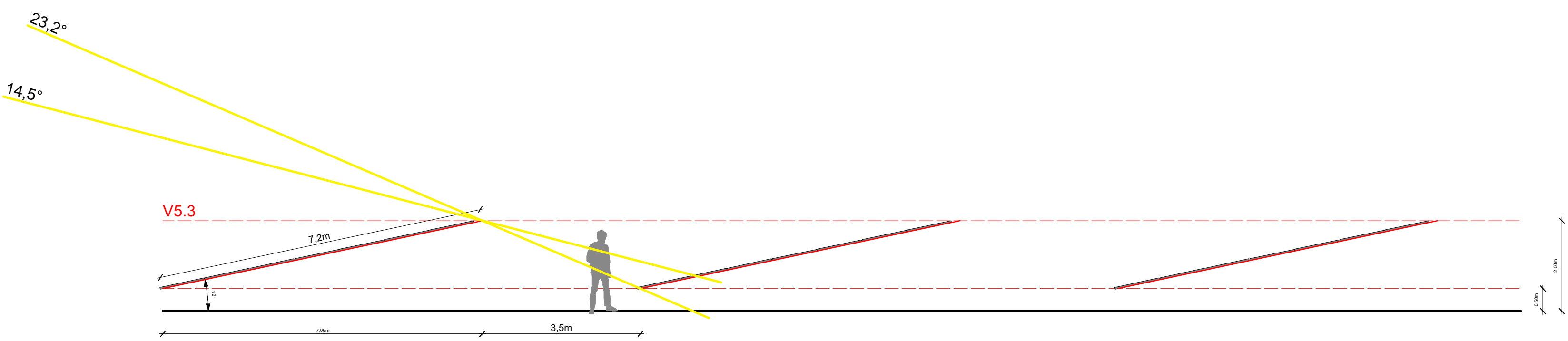



V4
6,2m


V5
7,2m
5,80m

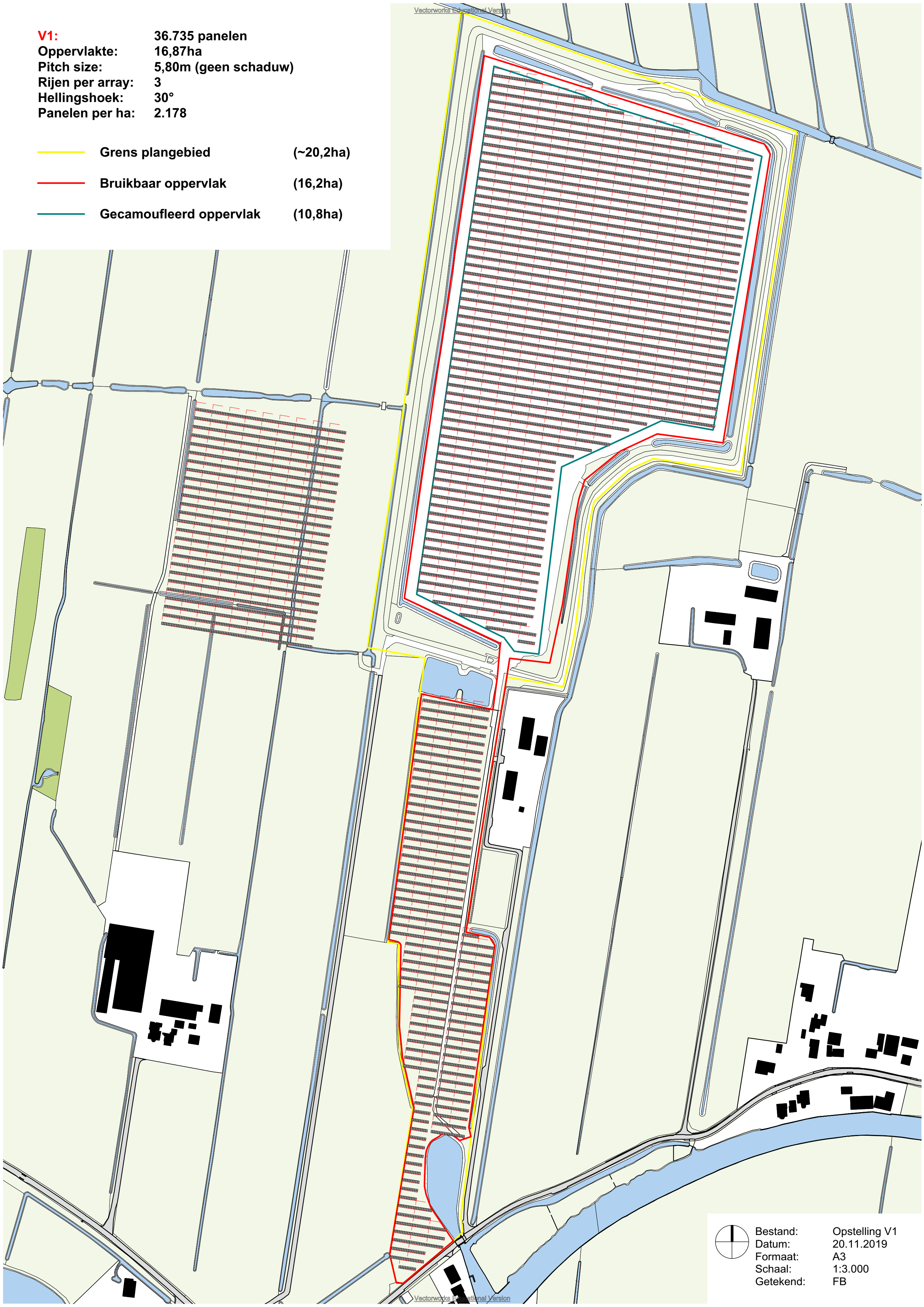

16,7°
14,5°
V5.1
7,2m
7,06m
5,0m


18,5°
14,5°
V5.2
7,2m
4,5m


23,2°
14,5°
V5.3
7,2m
3,5m

V1:	**36.735 panelen**
Oppervlakte:	**16,87ha**
Pitch size:	**5,80m (geen schaduw)**
Rijen per array:	**3**
Hellingshoek:	**30°**
Panelen per ha:	**2.178**

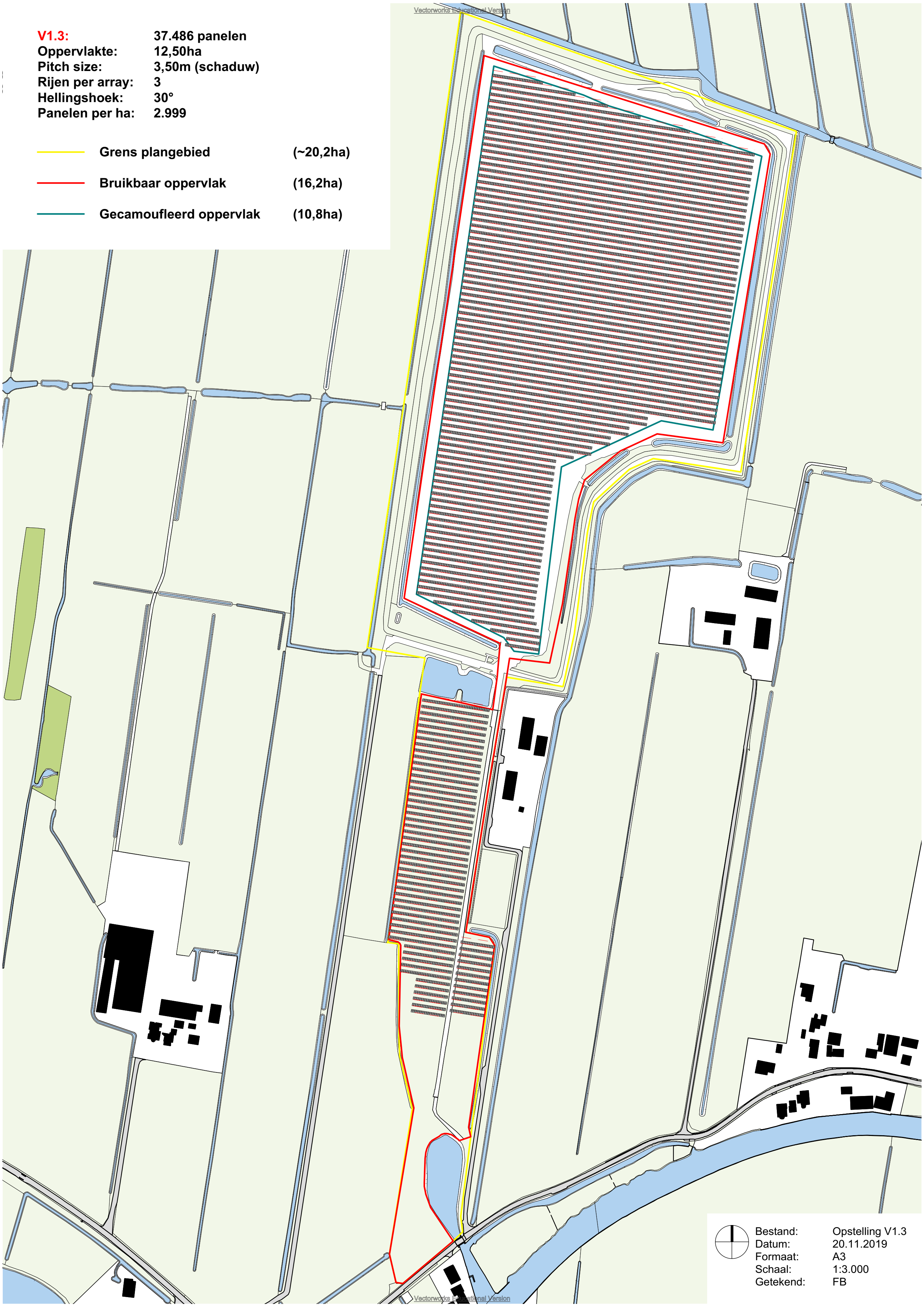
(yellow line)	**Grens plangebied**	**(~20,2ha)**
(red line)	**Bruikbaar oppervlak**	**(16,2ha)**
(teal line)	**Gecamoufleerd oppervlak**	**(10,8ha)**



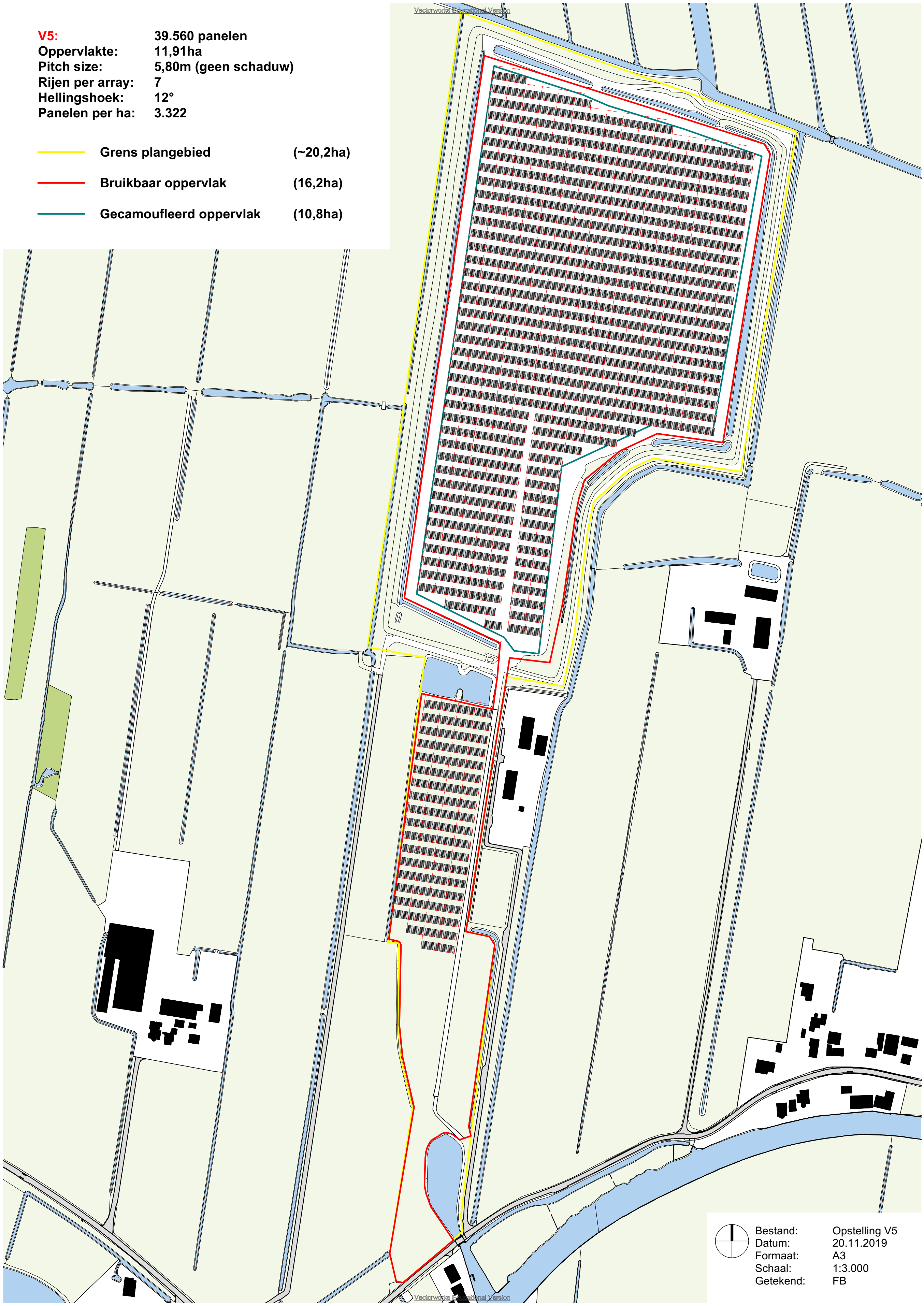
Bestand:	Opstelling V1
Datum:	20.11.2019
Formaat:	A3
Schaal:	1:3.000
Getekend:	FB

V1.3:	**37.486 panelen**
Oppervlakte:	**12,50ha**
Pitch size:	**3,50m (schaduw)**
Rijen per array:	**3**
Hellingshoek:	**30°**
Panelen per ha:	**2.999**

(yellow line)	**Grens plangebied**	**(~20,2ha)**
(red line)	**Bruikbaar oppervlak**	**(16,2ha)**
(teal line)	**Gecamoufleerd oppervlak**	**(10,8ha)**

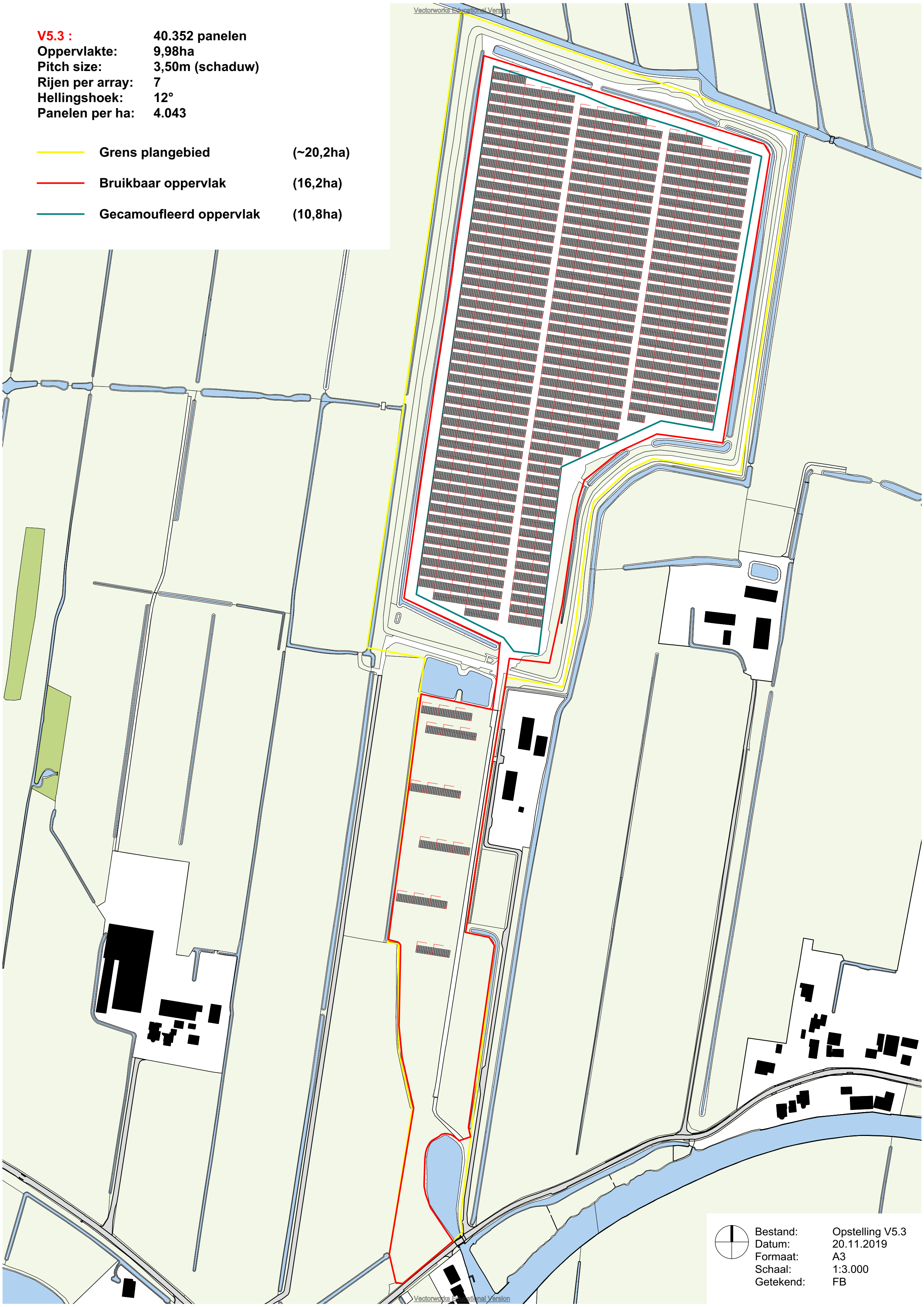


Bestand:	Opstelling V1.3
Datum:	20.11.2019
Formaat:	A3
Schaal:	1:3.000
Getekend:	FB


V5: 39.560 panelen
Oppervlakte: 11,91ha
Pitch size: 5,80m (geen schaduw)
Rijen per array: 7
Hellingshoek: 12°
Panelen per ha: 3.322
Grens plangebied (~20,2ha)
Bruikbaar oppervlak (16,2ha)
Gecamoufleerd oppervlak (10,8ha)
Vectorworks Educational Version
Bestand: Opstelling V5
Datum: 20.11.2019
Formaat: A3
Schaal: 1:3.000
Getekend: FB

V5.3 :	40.352 panelen
Oppervlakte:	9,98ha
Pitch size:	3,50m (schaduw)
Rijen per array:	7
Hellingshoek:	12°
Panelen per ha:	4.043

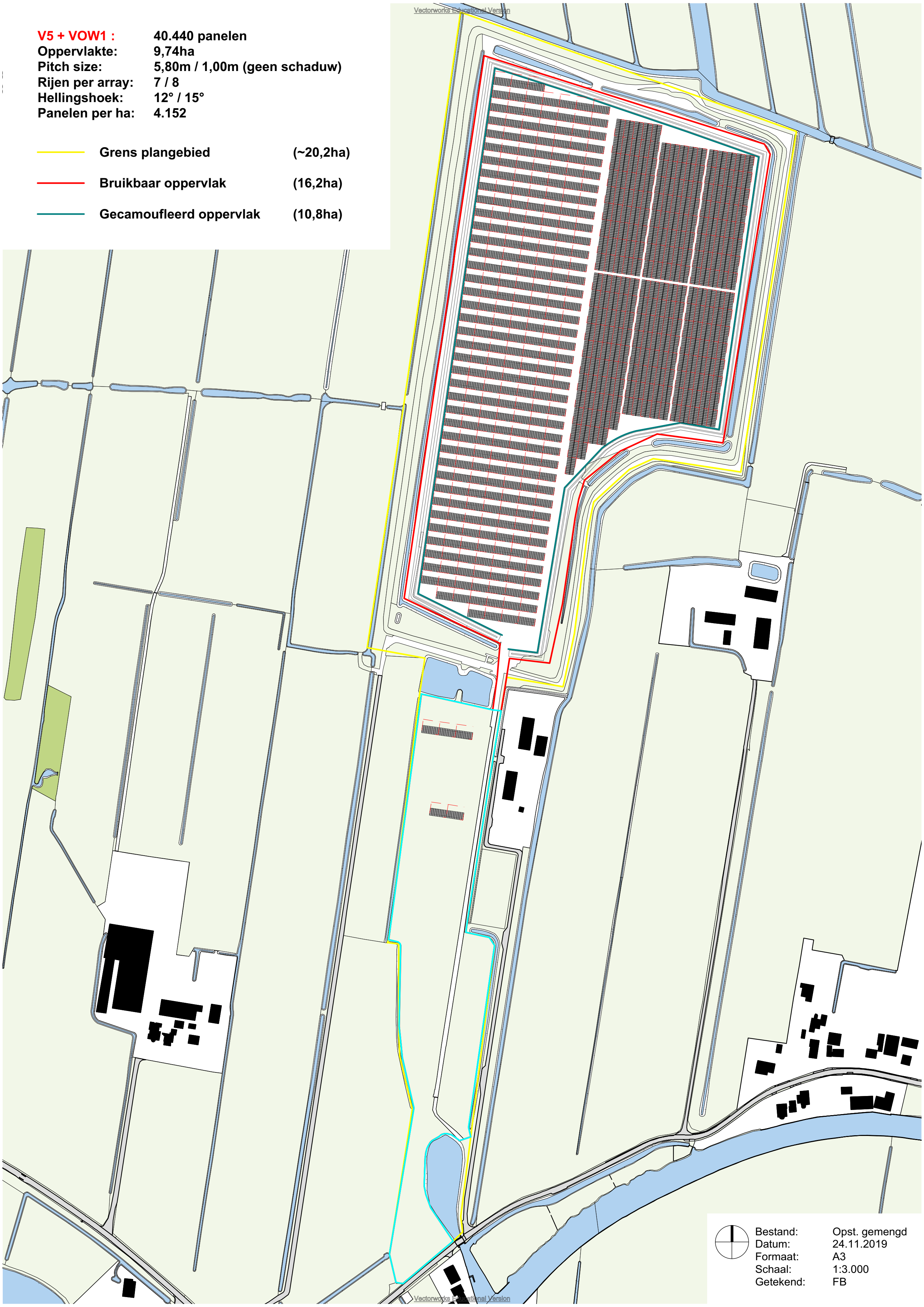
(yellow line)	Grens plangebied	(~20,2ha)
(red line)	Bruikbaar oppervlak	(16,2ha)
(teal line)	Gecamoufleerd oppervlak	(10,8ha)



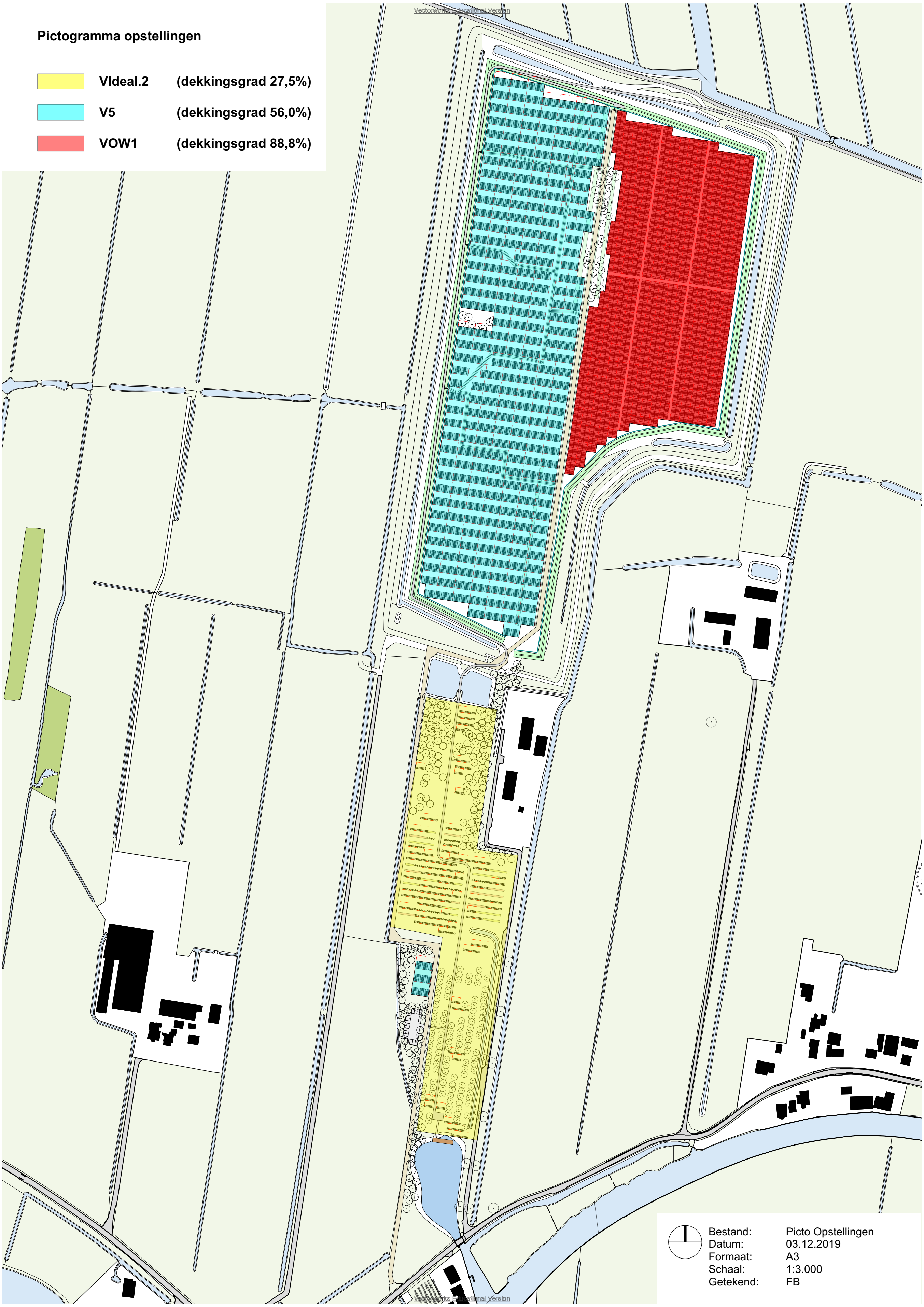
Bestand:	Opstelling V5.3
Datum:	20.11.2019
Formaat:	A3
Schaal:	1:3.000
Getekend:	FB

V5 + VOW1 : 40.440 panelen
Oppervlakte: 9,74ha
Pitch size: 5,80m / 1,00m (geen schaduw)
Rijen per array: 7 / 8
Hellingshoek: 12° / 15°
Panelen per ha: 4.152

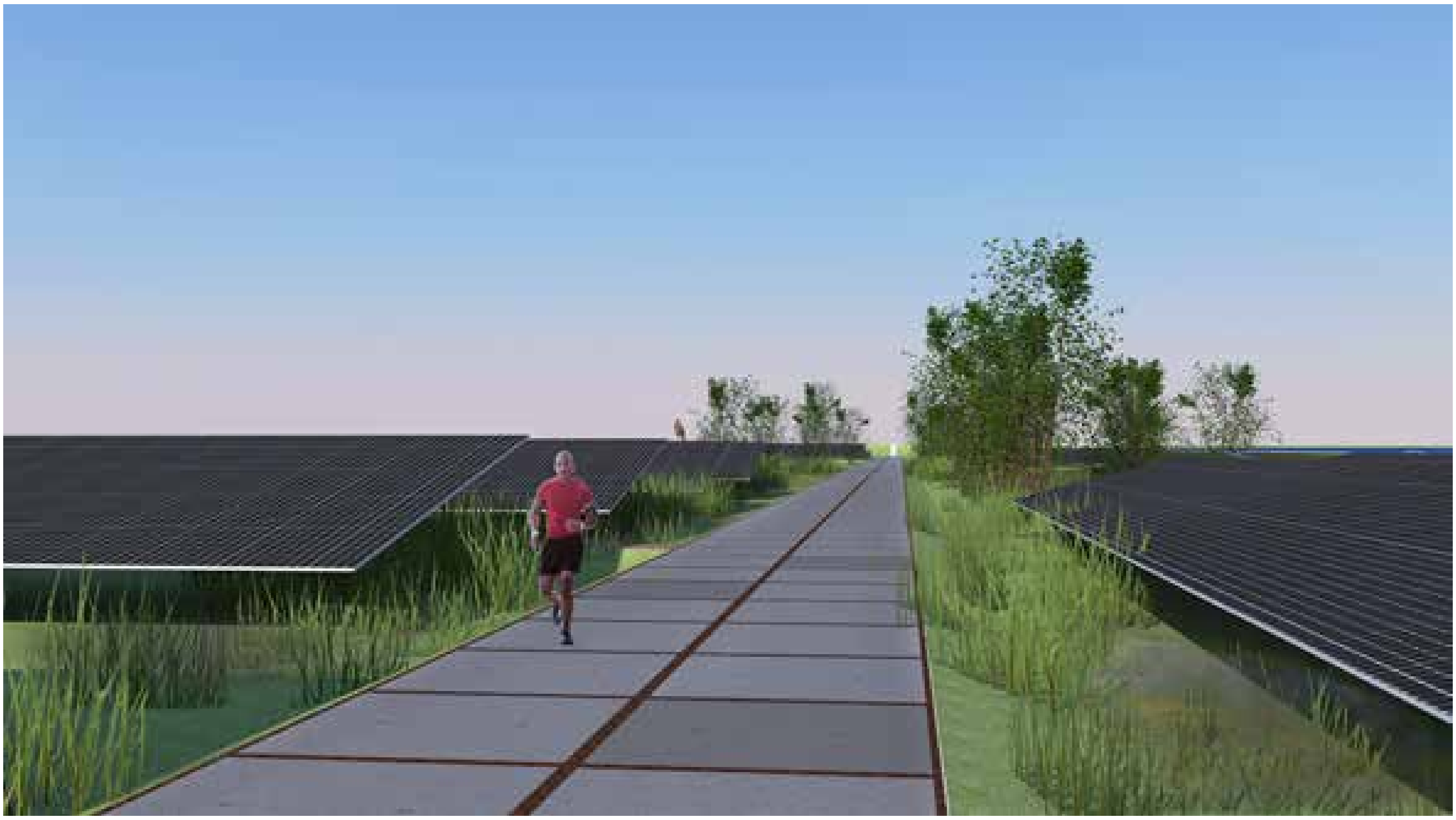
(gele lijn)	**Grens plangebied**	**(~20,2ha)**
(rode lijn)	**Bruikbaar oppervlak**	**(16,2ha)**
(groene lijn)	**Gecamoufleerd oppervlak**	**(10,8ha)**



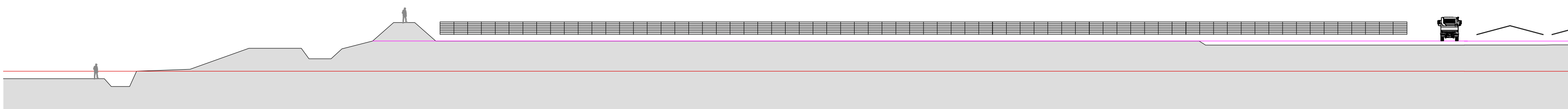
Bestand: Opst. gemengd
Datum: 24.11.2019
Formaat: A3
Schaal: 1:3.000
Getekend: FB


Pictogramma opstellingen
VIdeal.2 (dekkingsgrad 27,5%)
V5 (dekkingsgrad 56,0%)
VOW1 (dekkingsgrad 88,8%)
Bestand: Picto Opstellingen
Datum: 03.12.2019
Formaat: A3
Schaal: 1:3.000
Getekend: FB

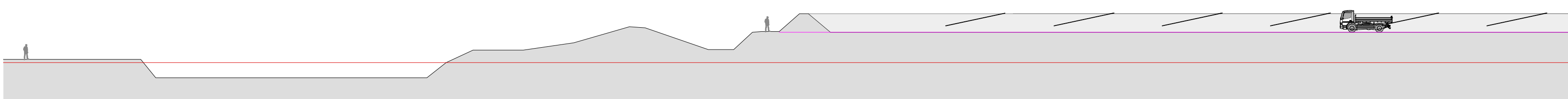
B.3 Phase C - Design for complete parcel, including visuals and sections for communication towards residents

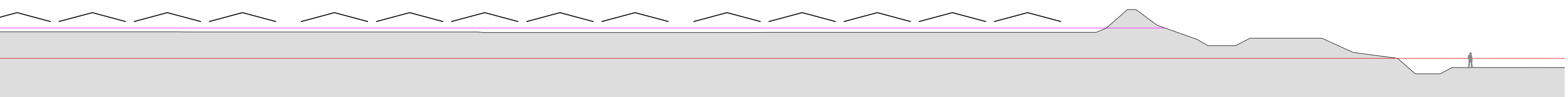


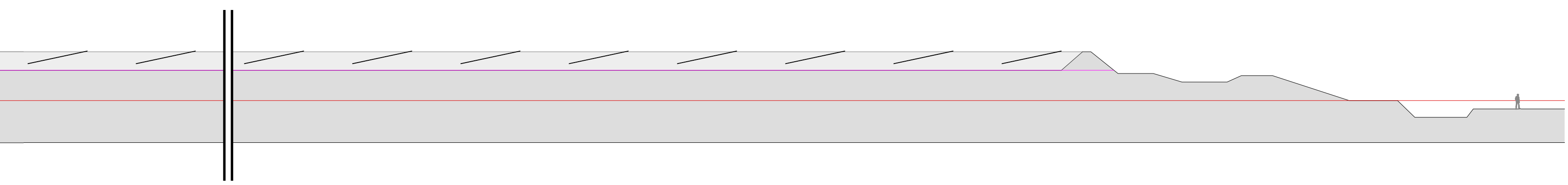
Section West - East (elevated part)



Section South - North (elevated part)







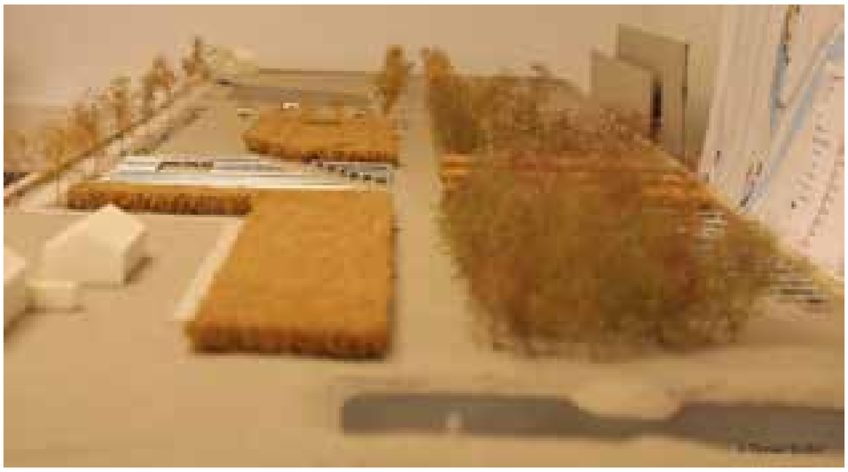
B.4 Phase D - More thrilling design for southern part, including vistas, biomass, and more exciting placing of PV system

Communication by physical model

Tweede conceptontwerp Energietuin Mastwijk (zuid) 12.02.2020

Naar aanleiding van de bewonersavond van 10 dec'19 en overleg tussen NMU, Afval-/Energiezorg en WUR is het conceptontwerp voor het zuidelijk deel van de Energietuin Mastwijk doorontwikkeld. Hieronder een beschrijving van de belangrijkste ingrediënten en aanpassingen ten aanzien van het eerste conceptontwerp.

Er zijn meerdere zicht-/loopassen door het zuidelijke deel toegevoegd, waarvan één centrale die de oorspronkelijke cope-verkaveling volgt. Het begin van de as functioneert als oprijlaan naar de parkeerplaats die mogelijk op het tot nu toe ingetekende plek blijft zitten. De rest van de zichtas is niet toegankelijk voor voertuigen (behalve voor onderhoud).
Aan de noordkant van deze zichtas, dus op de helling van de afvalberg, zal het kunstwerk te zien zijn. Vanaf de berg ziet de bezoeker een nieuw toegevoegde bomenlaan in het zuidelijke deel, waar het op de Mastwijkerdijk uitkomt.

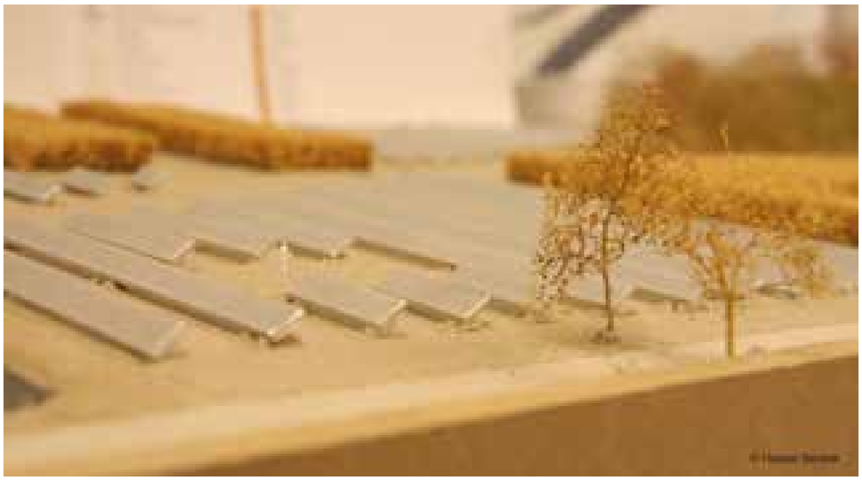


Centrale zichtas gezien vanuit afvalberg

Op basis van het gesprek tussen NMU, Afval-/Energiezorg en landschapsontwerpers van de WUR op 4 februari 2020 is ervoor gekozen om de bestaande wilgenbosjes zowel in het noordelijke als ook het zuidelijke deel te behouden. Hierdoor verandert in het zuiden zowel de massa bomen, dit wordt meer, als ook het aantal zonnepanelen, dit wordt verhoogd (0,2-0,5MWp) om ruimte in het noordelijke deel te verschaffen.
Verder zijn er vakken met een dicht energiegewas toegevoegd, bijvoorbeeld Miscanthus giganteus met een hoogte van drie tot vier meter, wat als zichtscheiding werkt en de ervaring van de Energietuin spannender maakt.

Miscanthus giganteus velden in park Schloss Dyck (Duitsland)

Door meerjarig maaibeleid en short rotation kunnen interessante patronen ontstaan en blijft er altijd een zicht- en geluidsbescherming staan voor de omwonenden. Binnen de patches van zonnepanelen en het energiegewas zijn kleine plekken vrijgehouden, die door een verhoging als uitkijkpunt kunnen fungeren. Bij rondleidingen of excursies kunnen deze plekken ook als verzamelpunt gebruikt worden om toelichtingen te geven in het zuidelijke deel van het terrein. De verhoging maakt het daarbij mogelijk om over de panelen en het energiegewas heen te kijken en te oriënteren.

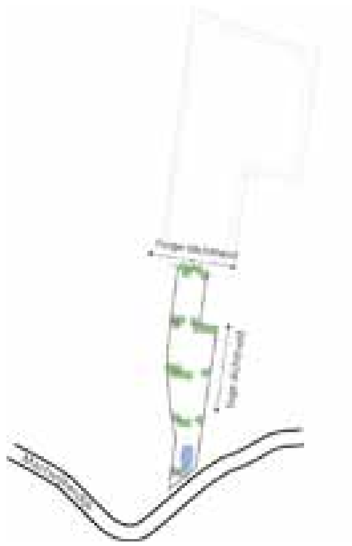


Verhoogde uitkijkpunt binnen een patch zonnepanelen

Losse blokken van zonnepanelen in de bomentuin

Het principe van toenemende dichtheid panelen richting de noordkant van het terrein is ook in het zuidelijke deel voortgezet, met losse blokken panelen in de bomentuin bij het toekomstige aanlegpunt. Halverwege het zuidelijke deel worden deze tot (lage) rijen zonnepanelen, vergelijkbaar met de opstelling in het voorste gedeelte van 'De Kwekerij' (Hengelo).

Om de openheid van de polder niet te kwetsen met het ontwerp van de Energietuin en deze toch spannend te kunnen invullen, is een aanvullend principe toegepast.
Op de centrale zichtas na, volgen de vegetatie en de panelen strikte oost-west lijnen, waardoor het gebied vanuit binnen heel dicht eruit ziet. maar van de oost en westkant op de meeste plekken doorzien kan worden.
Zo blijven bezoekers bijvoorbeeld vanaf de Mastwijkerdijk in beide richtingen in de open polder kijken.
Bij het aanlegpunt en de bomentuin is het bovendien de bedoeling om een kleine paviljoen te plaatsen die als informatie- en oplaadpunt dient en schutting bied tegen regen.



Saturatie zuidelijk deel

In dit ontwerp is ervan uitgegaan dat het mogelijk blijft om het achterste deel van het terrein te onderhouden via het bestaande onderhoudspad ten westen. Dat pad is ook aangehouden als doorgangsroute voor fietsers/wandelaars als de Energietuin (in de nacht) is afgesloten.

Not just another solarfield - Appendix C

Appendix C

File: Graphicplan EnergyGarder Mastwijk
Date: 18.05.2020
Format: A0+ (841*1300)
Scale: 1:1.000
Drawn: FB

Legend:

- Trees existing
- Trees new (solo/multiple stems)
- Shrubs
- Landing stage
- Bicycle path (Ijsselsteentjes)
- Maintenance road (Stelcon plates /gravel)
- Foot trail (unpaved)