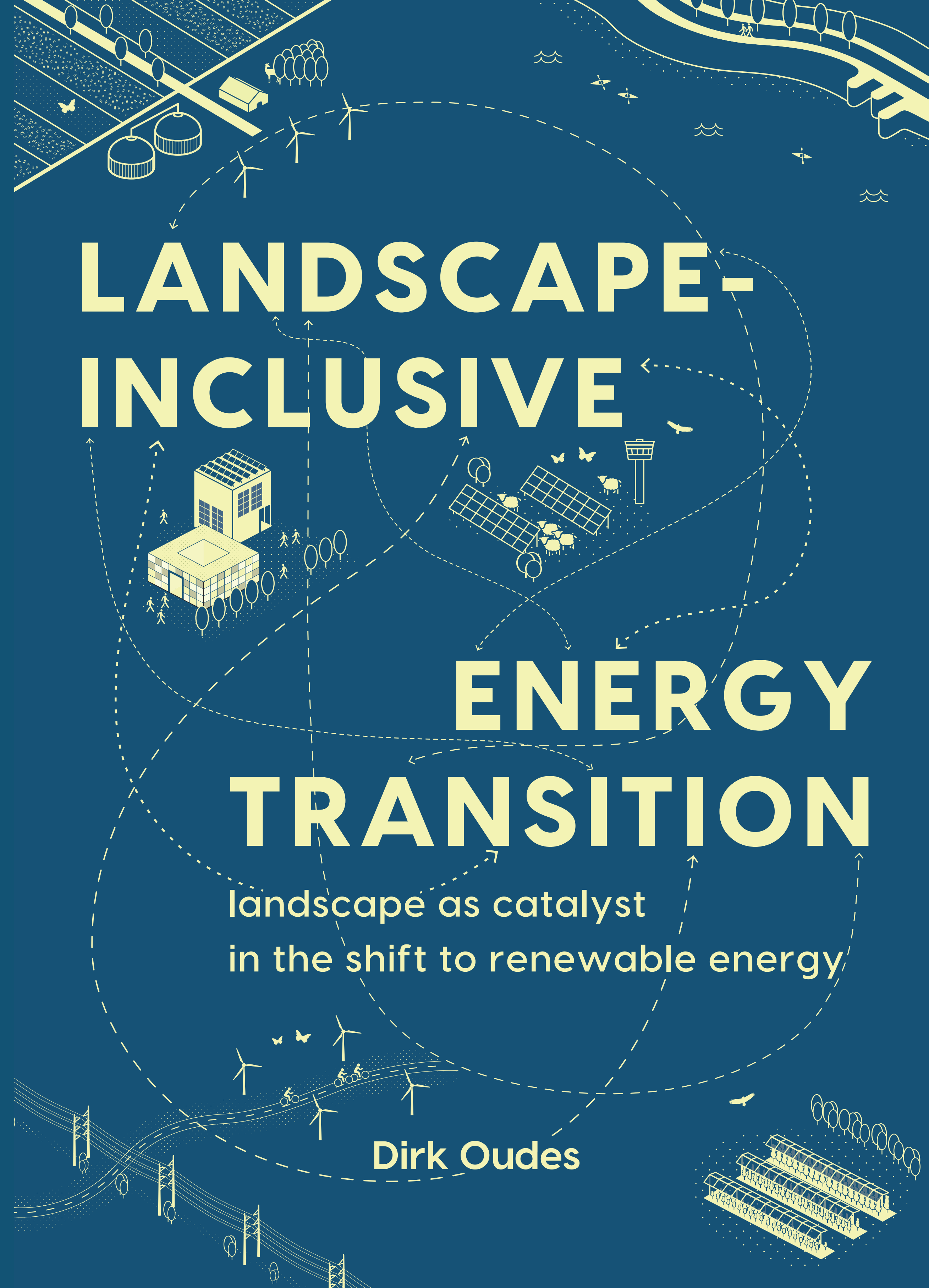
LANDSCAPE-INCLUSIVE ENERGY TRANSITION

landscape as catalyst in the shift to renewable energy



Dirk Oudes

Propositions

1. The term ‘landscape’ is not needed to make use of the potential of landscapes.
   (this thesis)

2. Solar parks are not parks.
   (this thesis)

3. Societal impact increases when society can impact scientific research.

4. Fieldtrips are indispensable for scientists working on topics related to landscape.

5. The coffee machine at the home office is for productivity, the coffee machine at the university is for creativity.

6. Professional experience prior to PhD research is both a blessing and a curse.

Propositions belonging to the thesis, entitled
Landscape-inclusive energy transition: landscape as catalyst in the shift to renewable energy

Dirk Oudes
Wageningen, 30 June 2022

LANDSCAPE-INCLUSIVE ENERGY TRANSITION

landscape as catalyst in the shift to renewable energy

Dirk Oudes

Thesis committee

Promotor
Dr S. Stremke
Associate professor Landscape Architecture and Spatial Planning (LSP)
Wageningen University & Research
Professor Landscape architecture
Amsterdam Academy of Architecture

Co-promotor (until September 2021)
Prof. Dr A. van den Brink
Emeritus professor Landscape Architecture and Spatial Planning (LSP)
Wageningen University & Research

Other members
Prof. Dr E.S. van Leeuwen, Wageningen University & Research
Prof. Dr K. Sherren, Dalhousie University, Canada
Prof. Dr S. Schöbel-Rutschmann, Technical University Munich, Germany
Prof. Dr W.C. Sinke, University of Amsterdam

This research was conducted under the auspices of the Graduate School for Socio-Economic and Natural Sciences of the Environment (SENSE).

LANDSCAPE-INCLUSIVE ENERGY TRANSITION

landscape as catalyst in the shift to renewable energy

Dirk Oudes

Thesis
submitted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus,
Prof. Dr A.P.J. Mol,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Thursday the 30th of June 2022
at 4 p.m. in the Omnia Auditorium.

Dirk Oudes

Landscape-inclusive energy transition
landscape as catalyst in the shift to renewable energy

258 pages.

PhD thesis, Wageningen University, Wageningen, the Netherlands (2022)

With references, with summary in English and Dutch

ISBN: 978-94-6447-148-9
DOI: https://doi.org/10.18174/566620

Contents

Local inhabitants take a walk in the public park next to Embalse de Canales, Andalucia, Spain. The public park is situated on the dam crest of a hydropower plant (source: author).

Chapter 1

Introduction

Introduction 1

Energy transition and landscape are often considered as zero-sum game: progress for the former equals (perceived) losses for the latter. Despite the clear benefits of mitigating climate change, the landscape changes invoked by renewable energy provision often leads to local opposition (Pasqualetti, 2011a; Roddis et al., 2020). In the years to come, renewable energy will continue to be a key driver in the change of landscapes where people live, work and recreate (Bridge, Bouzarovski, Bradshaw, & Eyre, 2013; Nadaï & van der Horst, 2010; Selman, 2010). To many agents of the energy transition landscape is therefore an 'obstacle' to be overcome to ensure energy targets are met. Southill Solar is a demonstration of the contrary where the 'obstacle' landscape became a 'catalyst' in the shift to renewable energy.

Southill Solar Landscape: evidence of socio-spatial innovation 1.1

Northwest of Oxford, United Kingdom, lies the Cotswolds, a designated area of outstanding natural beauty (AONB). This area is characterized by small 17th century villages and manor houses in a hilly landscape, consisting of medieval estates and ancient forest patches. In 2012, the local sustainability cooperative of the village Charlbury started a campaign to build a community solar power plant. The cooperative proposed to build on a large linear plot of grassland that undulates towards the river Evenlode. In the initial design, most of the site was covered with photovoltaic (PV) arrays in a low density. This design was rejected on grounds of negative visual impact on the AONB. The cooperative decided to resubmit the planning application. To address the issue of visual impact, the cooperative organized a so-called 'bring-your-brolly-day' (brolly is another term for umbrella). On this day, more than one hundred local citizens (on a population of less than 3.000) marked various layouts of the power plant with their umbrellas. Those umbrellas, note the symbolic association with climate change, represented the height of the proposed PV panels. Photographs from strategic locations made it possible to identify the visibility of each of the layouts (fig. 1.1).

Fig. 1.1. Bring your brolly day at Southill Solar in 2014. Local citizens standing on a line representing a potential layout of the proposed solar power plant (source: Southill Community Energy).

The community then decided to reduce the number of panels, favoring a lower visual impact over higher financial returns for the community. The well-supported, revised plan convinced the authorities to approve the project. Profits from this solar power plant are used for various local projects, for example improving energy efficiency of the community center. The cooperative did not only consider visual impact, they also aimed to improve the ecological conditions of the site. Over half of the project site has been dedicated to improve local biodiversity. The low grade agricultural land has been improved with nest boxes, a community fruit orchard and a field with sunflowers for wintering birds (fig. 1.2). The grassland beneath and adjacent to the PV panels have been seeded with different types of wildflower seeds to provide habitats for a variety of animals. Although this solar power plant is not accessible to the general public, local groups help with removal of weeds, harvesting and maintenance of the fruit trees and other land management activities.

Fig.1.2. Area providing winter foraging for birds at Southill Solar (source: author).

Southill Solar is an example of a renewable energy project where objectives of climate mitigation and economic profit have been balanced with landscape objectives, such as visibility and habitat improvement. The participatory approach won the yearly award of the Landscape Institute (chartered body of landscape profession in the United Kingdom) in the category local landscape planning (Landscape Institute, 2015). Today, Southill Solar is still an exception, in contrast with the mainstream practices of renewable energy projects. More often than not, landscape is used as an argument for opposing renewable energy projects and thus seems to represent an obstacle to the energy transition. This is hardly surprising, considering many development sites are selected for economic reasons without understanding the meaning the landscape holds for its inhabitants (Pasqualetti, 2011a). Involvement of local stakeholders through participation is often limited and too late (Devine-Wright, 2011b). Moreover, the great majority of sites with planning approval are transformed to monofunctional power plants with substantial impact on functions and values of landscape (Selman, 2010).

This thesis therefore explores whether 'landscape' can turn from perceived obstacle into a systemic catalyzer for the 21st century energy transition. To this end, this thesis aims to identify key tenets for a *landscape inclusive energy transition*, for advancing the energy transition while meeting societal considerations regarding landscape.

1.2 Energy transitions and landscape transformation

Southill Solar is representative of the global ambition to shift from fossil fuels to renewable energy sources (IRENA, 2022). In the last decades, concerns about the global climate have led to the signing of (inter)governmental agreements and the setting of national and regional targets for renewable energy. The objective of the Paris Agreement is to keep global temperature rise below 2ºC compared to pre-industrial levels and to pursue efforts to limit the increase to 1.5ºC (United Nations, 2015). Significant reduction of greenhouse gas (GHG) emissions are needed to reach these targets and renewable energy provision provides an important share of this reduction (IPCC, 2021). The European Union has defined targets for a share of 32% renewable energy in 2030 (European Parliament & European Council, 2018) and with the introduction of the Green Deal, a target of 55% GHG emission reduction by 2030 was set (European Commission, 2021). In the Netherlands, these targets led to the signing of the cross-sectoral, national climate agreement (Klimaatakkoord, 2019). Representatives from the built environment, industry, mobility, agriculture and land use, and the electricity sector agreed upon emission reduction targets for 2030. Emission reduction by means of renewable energy provision is, in the Netherlands, primarily operationalized on the regional level. Regional plans for energy provision involve local and provincial governments, grid operators, water boards, businesses, NGO's and energy cooperatives (Pistoni, 2020).

When energy targets are implemented on the regional and local scale, it becomes clear that the energy transition requires changes in how we build our homes, produce our foods, the fuels we use and how we behave in general. Energy transition therefore is not merely a technological or economic transition, but has social, cultural, environmental, political and spatial dimensions as well (Miller, Iles, & Jones, 2013; Pasqualetti, 2000; Sijmons, Hugtenburg, van Hoorn, & Feddes, 2014; Sovacool, 2014). Studies of the spatial dimension reveal the large number and scale of the required interventions (Denholm & Margolis, 2008; Van Zalk & Behrens, 2018), explained by the lower power density of renewable energy sources compared to fossil fuels (Smil, 2010). However, even countries with high population density such as the Netherlands can achieve the targets set in the Paris Agreement within the national borders (Sijmons et al., 2017).

Achieving the energy transition leads to transformations of familiar and cherished landscapes (Bridge et al., 2013; Selman, 2010; Wolsink, 2017). While landscape *change* is gradual and may even go unnoticed, *transformation* of landscape is more immediate and dramatic (Antrop, 2006; Selman, 2010). Landscape transformation is a two-fold process. On the one hand, renewable energy development transforms *physical* landscape patterns, for example when a hydropower plant requires a reservoir and thus alters the hydrological system of a river. On the other hand, renewable energy development also transforms how landscape users *interpret and experience* their environment. For some people, the creation of the reservoir gives them joy for taking a swim, yet others may lament the loss of houses due to the construction. These two sides of landscape are reflected in the definition of landscape in the European Landscape Convention: landscape is “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe, 2000, p. 2).

Landscape transformation prompted by energy development is not limited to the current transition. Throughout history, our energy demand has transformed existing landscapes and created new landscapes. Pasqualetti (2013) describes four stages: the organic economy, the mineral economy, the electricity economy and the sustainable economy. In each of these stages the energy demand of humans actively shapes landscapes, whether it concerns deforested landscapes to acquire firewood, open pit coal mines, nuclear power plants or wind energy landscapes.
Energy landscapes in this thesis are therefore defined as ‘observable landscapes that originate directly from the human development of energy resources’ (Pasqualetti & Stremke, 2018). Unless stated otherwise, energy landscape in this thesis refers to *renewable* energy landscape. The past energy transitions have all led to distinct energy landscapes, although energy has not always been the singular driver for landscape transformation. Instead, transformation was driven by multiple societal needs, for example land reclamation, peat extraction and urbanization (De Jong & Stremke, 2020). Energy landscapes thus reflect societal considerations and human value systems that change over time (Pasqualetti & Stremke, 2018; Thayer, 1994). In this thesis, societal considerations refer to the interests, values and concerns of local stakeholders and society at large with regard to landscape transformation. Similar to the past, the energy transition of the 21st century is interconnected with concerns such as human well-being, methods of production and consumption and food security, as expressed by the UN Sustainable Development Goals. These interconnections illustrate the missed opportunities to create synergies between energy provision and other societal challenges, as contemporary energy projects have a rather prominent sectoral focus (Delafield et al., 2021).

The current energy transition is and will continue to take place in familiar and mundane, 'lived landscapes' (Sherren, 2021). The term 'lived landscapes' refers to the places where people reside, work and move as part of their everyday lives. These landscapes are not 'blank slates', yet have specific physical characteristics and are interpreted and experienced differently by people (Calvert, Greer, & Maddison-MacFadyen, 2019; Nassauer, 2012). Especially in areas with high population density, the implications of landscape transformation caused by the energy transition may therefore be severe (Bridge et al., 2013). As a result, the energy transition requires a process where functions and values of landscape are negotiated between stakeholders such as inhabitants, decision-makers, experts, NGOs and developers (Bridge et al., 2013; Calvert et al., 2019; Pasqualetti, 2011a).

Environmental disciplines such as landscape architecture, urban design, and spatial planning play an active role in shaping energy landscapes (Pasqualetti & Stremke, 2018; Wissen Hayek et al., 2019). In environmental planning and design processes, stakeholders can express their different perspectives on the functions and values of the landscape and allows them to imagine, negotiate and decide about landscape transformation (Nassauer, 2012). Planning and design ranges from strategic 'conversations' with stakeholders on the energy transition on a regional level (Kempenaar, Puerari, Pleijte, & van Buuren, 2021) all the way to operational site design involving local stakeholders (Picchi, van Lierop, Geneletti, & Stremke, 2019).

Landscape as perceived obstacle to energy transition 1.3

The landscape transformation driven by energy transition does not go unnoticed (Pasqualetti, 2011a). Accordingly, landscape is a key arena for the energy transition where the interests, values and concerns of local stakeholders and society at large meet (Nadaï & van der Horst, 2010). This arena encompasses diverse stakeholders:

local inhabitants, energy cooperatives, NGOs, industry, grid operators, policy makers, decision makers and researchers. Many of these agents disregard or have a limited view on the concept of landscape. As a result, landscape is perceived as an 'obstacle' that needs to be overcome to meet renewable energy targets and mitigate climate change. The following sub-sections address the disregard of 'landscape' as well as two conventional views on 'landscape' and consequences for both the energy transition and the lived landscapes.

1.3.1 Disregarding landscape

The concept 'landscape' is disregarded in defining energy targets, selecting sites and designing renewable energy projects. Instead, the focus lies on technical and economic considerations such as technological performance and cost-efficiency (Pasqualetti, 2011a; Scognamiglio, 2016; Sovacool, 2014). The energy targets defined by local or supra-local governments too often disregard landscape, leading to development of energy projects without local support (Prados, 2010). Site selection for renewable energy development is mainly informed by energy potential and transportation costs while landscape considerations are largely absent (Bosch & Schwarz, 2019; Fast et al., 2016). Furthermore, sites are selected because existing urban or industrial developments make it easier to obtain planning approval (Cowell, 2010; Roddis, Carver, Dallimer, Norman, & Ziv, 2018). This may lead to technological clusters and raise questions on distributional justice as landscapes of some communities are targeted more than those of others (Balta-Ozkan, Watson, & Mocca, 2015). In the short or medium term, these opportunistic site selections may become problematic for the continuity of the energy transition as these 'easy' sites become scarce (Frantál et al., 2018; Roddis et al., 2020). This narrow focus on a specific site or technology, and thus the lack of insight in the suitability of other sites or alternative technologies, makes it difficult for local stakeholders to understand and ultimately come to terms with the planning approval of a renewable energy project (Roddis et al., 2020).

Disregarding 'landscape' also leads to implementation of single-purpose renewable energy projects that are optimized for electricity production. These projects lack attention for physical characteristics of landscape, as well as how stakeholders interpret and experience the landscape (Scognamiglio, 2016; Selman, 2010). Consequences of disregarding 'landscape' in renewable energy projects are, for example, fragmentation of the countryside (Chiabrando, Fabrizio, & Garnero, 2009), a loss of cultural heritage (Scognamiglio, 2016), a loss of space used for exercise and relaxation (Roddis et al., 2020), adverse impact on the aesthetic appreciation of the living environment (Ioannidis & Koutsoyiannis, 2020; Sánchez-Pantoja, Vidal, & Pastor, 2018), decreasing place attachment and initiating a loss of stewardship and care (Devine-Wright & Howes, 2010; Moore & Hackett, 2016).

The disregard of 'landscape' may ultimately lead to the rejection of planning applications because the use and appreciation of landscape by local stakeholders has been neglected by developers (Fontaine, 2020; Wolsink, 2017).

Considering landscape as 'scenery' 1.3.2

When 'landscape' is present in location finding and implementation of renewable energy projects, it is often considered as 'scenery' (e.g. Fernandez-Jimenez et al., 2015; Rodrigues, Montañés, & Fueyo, 2010). Consequently, landscape becomes the visual backdrop of a proposed energy technology, separating landscape and technology instead of considering them together as 'complete landscape' (Bevk & Golobič, 2020; Crowe, 1958; Wolsink, 2017).

If landscape is considered as 'scenery' exclusively, proposals for energy development are assessed on the effects of energy infrastructure on particular viewsheds (Salak, Lindberg, Kienast, & Hunziker, 2021). Outcomes of such assessments are not seldom resulting in the rejection of proposals or taking site-level interventions that focus on reducing visibility without considering the characteristics of the host landscape (Bevk & Golobič, 2020; Merida-Rodriguez, Lobon-Martin, & Perles-Rosello, 2015). With regard to the latter, Solarfeld Gänsdorf (Germany) is an example where an atypical hedgerow structure was introduced to reduce the visibility of the solar power plant. Although this intervention is effective in reducing visibility, it changed the character of the original, open agricultural landscape.

Moreover, recent studies refute the presumption that visibility of energy infrastructure is always perceived negatively (Firestone & Kirk, 2019; Russell & Firestone, 2021; Wolsink, 2017). Noticing existing energy infrastructure is actually a strong predictor of support for renewable energy (Sherren, Parkins, Owen, & Terashima, 2019).

Furthermore, landscape as 'scenery' reduces the relationship individuals have with their landscape to a singular – visual – phenomenon whereas landscape experience also comprises smell, touch, taste and hearing (Van Etteger, 2016). As 'scenery', landscape is mainly understood as a phenomenon that is visually perceived, yet this disregards the psychological bond people develop over time with a landscape, described as 'place attachment' (Scannell & Gifford, 2010). Place attachment has been studied to explain opposition of local stakeholders to landscape change (Devine-Wright, 2013), although studies also point to stakeholders becoming accustomed to landscape change over time (Sherren et al., 2016).

The overemphasis on the visual aspect of landscape in the energy transition has a polarizing effect on the discussion about site selection and design. Not seldom the landowner that profits from the exploitation of renewable energy is directly opposed by nearby inhabitants and frequent visitors arguing that their visual experience is adversely affected. Such conflicts raise questions on who's landscape it is, what landscape values are considered and how they are weighed (Bridge et al., 2013), but certainly point to a wider balancing of values than purely visual values (Van der Horst & Vermeylen, 2011). Conflicts originate from different landscape evaluations of 'insiders', people native to the landscape, and 'outsiders', people new to the landscape (Selman, 2006; Van der Horst & Vermeylen, 2011). 'Insiders' often emphasize functional aspects of landscape, while 'outsiders' often emphasize experiential aspects of landscape (Van der Horst & Vermeylen, 2011). Pursuing social acceptance requires land owners and those "with substantial place attachment as well as members of the broader community" to be invested in planning and design processes (Wolsink, 2017, p. 16).

Considering landscape to be in a 'stable state' 1.3.3

Landscape is in the energy transition frequently considered to be in a *stable-state*. This presupposes a sense of landscape permanence: the expectations of people that their landscape remains the same, followed by the threatening feeling when landscape change occurs or is proposed (Pasqualetti, 2000). Considering landscape to be in a 'stable state' relates to a more general attitude of our time – philosopher Roman Krznaric calls this the 'tyranny of the now' – the focus on the present at the expense of thinking about the future (Krznaric, 2021).

Looking back in the history of landscapes makes clear that landscapes change continuously, and that landscape permanence is an illusion. To illustrate, the Veluwe is now one of Europe's largest continuous nature areas, located at the center of the Netherlands. In 2016, the Veluwe was runner-up in the public election for the 'most beautiful nature area' in the Netherlands. Throughout history, however, this landscape continuously changed as a reflection of society's changing agricultural, industrial, energy and recreational needs (for more detailed information please see textbox 1.1).

Still, the belief that the present landscape is in a stable, optimum state that needs to be conserved and protected against change is persistent (Sherren, 2021; Tress & Tress, 2001). This so-called 'climax thinking' is rooted in ecological equilibrium theory, where succession in a plant community ultimately leads to a stable state: the equilibrium (Sherren, 2021). While contemporary ecologist favor non-equilibrium thinking (Mori, 2011), climax thinking continues to

challenge proposed changes in our landscapes (Linnerud, Toney, Simonsen, & Holden, 2019).
The challenge of climax thinking is further explained by prospect theory, which states that people are systematically biased against change, because they tend to prefer avoiding losses compared to receiving equivalent gains (Kahneman, 2013). In renewable energy projects – according to this theory – people will give more weight to the negative aspects than to the positive aspects. As a result, the current state of the landscape remains unquestioned and is used as the reference point for any potential change.
Although unique landscapes are arguably worth preserving, overabundant protective designations significantly reduces available areas for renewable energy provision. The result of climax thinking is that challenges of today – such as the energy transition – are pushed to communities living somewhere else or in the future (Sherren, 2021).
Paradoxically, renewable energy developments are often wrapped in the promise of temporality (Windemer, 2019). The end-of-life stage of renewable energy technologies, such as wind turbines and PV panels, is often reached in 20-30 years. This fact is used by developers and/or governments to frame renewable energy projects as *temporary* without explicitly stating what will happen in the *landscape* once the end-of-life of the energy *technology* is reached. This is problematic because the temporal character of interventions is used to acquire building permits, while in reality energy infrastructure could be repowered or even left alone, creating sites with derelict energy infrastructure (Windemer & Cowell, 2021).

In much of todays' energy transition discourse, landscape is either *disregarded* or commonly understood as a *scenery* in a *stable-state* that is negatively impacted by renewable energy infrastructure. This limited 'conventional understanding' of landscape can be observed in the definition of energy targets at the (inter)national scale (e.g. the Dutch energy agreement, see Sociaal-Economische

Raad, 2013), to the mapping of energy potentials (e.g. Borgogno Mondino, Fabrizio, & Chiabrando, 2015; Cevallos-Sierra & Ramos-Martin, 2018) and the articulation of energy policies (e.g. cost-efficient subsidy schemes, RVO, 2022) all the way to the design of renewable energy projects (Ferrario & Castiglioni, 2017; Merida-Rodriguez et al., 2015; Thayer, 1994).

This situation leads to the somewhat prominent conception that landscape forms an 'obstacle' for the continuity of the energy transition. Landscape and the energy transition are predominantly considered as separate entities. Landscape – in the conventional understanding – only becomes part of the discussion when energy infrastructure is proposed in a specific area, which leads to many conflicts.

Textbox 1.1. Landscape dynamics of the Veluwe

The Veluwe is one of Europe's largest continuous nature areas, located at the center of the Netherlands. This push moraine complex is characterized by forest, heath and sand drift areas. In 2016 the Veluwe was runner-up in the election for the most beautiful nature area in the Netherlands. However, most voters might not be aware that the Veluwe actually has a long history of agricultural and industrial use that have caused this landscape to change dramatically through the centuries. In pre-historic times the Veluwe was an area with one of the highest population densities of the Netherlands. Multiple cycles of over-exploitation, population decline and re-cultivation changed the appearance of the Veluwe as a largely forested area and relatively open heath landscape. The industrial use of the Veluwe is evidenced by over 200 watermills that were located in the edges of the Veluwe, making use of the elevation difference. The water mills were used for processing copper and wool and producing paper. In addition, wood was processed in kilns to produce charcoal for harvesting iron ore that was found in the loam layers. At the start of the 20th century the 'wild' and uncultivated appearance of the Veluwe was qualified as 'despicable' by train travelers who could perceive the Veluwe on their journeys. This changed when people started to appreciate the 'unspoiled' life outside the city and areas such as the Veluwe were romanticized by painters and writers. Hotels, pensions and sanatoria emerged at the Veluwe. Currently the Veluwe is an important part of the Dutch ecological network: wildlife corridors have been constructed to provide connections across the highways, agricultural land has been redeveloped as nature areas and an industrial business park has been decommissioned to improve the connection between the Veluwe and fluvial plains of the river Rhine (Neefjes & Bleumink, 2021).

1.4 The dormant potential of landscape

In contrast to this conventional, limited understanding of landscape, scholars point to the potential of landscape as an integrative concept where "nature and culture, science and aesthetics, geography and history, humans and their environment at all scales and in all aspects meet" (Antrop & Van Eetvelde, 2017, p. 4). This integrative character makes landscape a complex but unique concept (textbox 1.2). Unique, because landscape synthesizes different functions and human perspectives in a particular geographical setting (Nassauer, 2012; Pinto-Correia & Kristensen, 2013). In the context of landscape transformation, this means that natural drivers on the one hand, and social-economic and cultural drivers on the other hand, meet in a specific landscape (Pinto-Correia & Kristensen, 2013). Through local decision-making processes of conflict and negotiation, stakeholders can express their expectations for the future landscape (Bosch & Schmidt, 2020; Bridge et al., 2013; Nadaï & van der Horst, 2010). The outcome of such a process may lead to landscape transformation and because different 'places' deal differently with the energy transition, landscape becomes a driver of "novelty and experimentation" (Bridge et al., 2013, p. 336).

1.4.1 Exploring the dormant potential of landscape

This dormant potential of landscape calls for a further exploration. As concept, 'landscape' has been in use for over 800 years and is shared by a wide range of disciplines (Antrop & Van Eetvelde, 2017; Vicenzotti, Jorgensen, Qviström, & Swaffield, 2016). The definition of landscape from the European Landscape Convention (p. 5) is widely used amongst these disciplines and clearly illustrates the duality of the concept: landscape includes both the meaning of 'land' or 'area' (object) as well as the interpretation and experience of that landscape (subject) (Antrop, 2006; Tress & Tress, 2001). Landscape as *object*, or physical construct, is shaped by natural processes and human activity. Biophysical characteristics such as substrate composition determine, for example, the location of geothermal reservoirs. Humans decide to drill the wells and build the power plants to convert the hot steam into electrical energy. Landscape is thus the "interface where nature and culture come together so obviously" (De Jonge, 2009, p. 43). Landscape as *subject* is a social construct. Different landscape users such as inhabitants, commuters or tourists, interpret and experience landscapes differently. Their interpretation and experience is not only dependent on their bodily movement, but also on social-cultural factors (e.g. education, norms, beliefs) which, in turn, explains why landscape users attach different values to landscapes (Jones, 1991; Kühne, Weber, & Berr, 2019; Selman, 2010). Many of these landscape values have, implicitly or explicitly, become part of planning regulations and laws (Bridge et al., 2013).

The interactions between natural processes and human activities changes landscapes over time (Antrop, 2005; Tress & Tress, 2001). Although societal needs have always shaped landscapes, contemporary drivers such as agricultural intensification, urbanization, climate adaptation and mitigation replaces gradual change with immediate transformation (Antrop, 2005; Bridge et al., 2013).
Even without changes in the physical landscape, interpretation and experience of landscape may change (Butler & Sarlöv-Herlin, 2019; Tress & Tress, 2001). In general, however, the 'social production of taste' tends to be rather slow, making it more difficult to accept change (Selman, 2010). This changing interpretation of landscape was illustrated by the Veluwe (textbox 1.1) and many other 'national parks' for that matter. The Veluwe was first considered as

threatening 'wild' land, yet later reinterpreted as 'unspoiled' land, valued for its experiential and natural qualities.

1.4.2 Recognizing the potential of landscape for the energy transition

Discourse on landscape took place long before the energy transition was recognized as the driver of landscape transformation that it is today (Nadaï & van der Horst, 2010). However, over the past years, the significance of landscape for the energy transition is increasingly recognized in academia and society. This relevance of 'landscape' for the energy transition, for example, gave rise to a multi-year EU funded collaboration between science and technology (COST action). Over 200 participants from 37 European countries collaborated in the RELY project on renewable energy and landscape quality (Roth et al., 2018).

In the Netherlands, the negotiations for the national climate agreement were supported by landscape experts and designers. The final agreement contained four spatial guidelines that referred to concepts such as multifunctional land use and landscape character (Klimaatakkoord, 2019). The Dutch energy sector is also becoming increasingly aware of the significance of landscape in the energy transition. To illustrate, the solar energy industry association 'Holland Solar' took the initiative to develop a code of conduct, which was co-signed by multiple landscape NGOs. This code of conduct explicitly acknowledges the value of landscape (Holland Solar, 2019). Moreover, it states to not only preserve existing but to improve landscape qualities. Collaborations between industrial parties, developers, NGOs, governments, designers, consultants and researchers have resulted in a 'national consortium' that aims to realize synergies between solar energy and landscape (Zon in Landschap, 2022). Provincial and regional governments – another key agent in the transition – are developing guidelines that aim to help developers, local governments and designers to take into account specific landscape characteristics when developing renewable energy projects (Van Vuurde et al., 2019). Local governments too, for example the municipality of Wageningen, are developing landscape specific policies for, among others, solar power plants (LoS Stadomland, 2020).

These developments make clear that stakeholders in the energy transition, particularly inhabitants, governments, cultural and environmental NGO's as well as other landscape users, have become aware of the current disregard of landscape in the energy transition discourse. Through research, code of conducts, policies and guidelines, and local debates, these stakeholders stress the need to feature 'landscape' more prominently in the energy transition. They propose and, at times demand that their considerations are taken into account during the planning and design of energy landscapes. As a result, their considerations are starting to affect the location and appearance of energy landscapes, for example the spatial extent of projects, the choice of wind turbines, the distance between PV arrays and the design of biogas or geothermal power plants.

Thus, depending on the considerations deemed relevant by decision makers in a certain place and time, physical landscapes emerge that are not merely optimized according to technological or economic parameters, but reflect physical landscape characteristics and societal considerations (Bridge et al., 2013; Nadaï & van der Horst, 2010). Including landscape in the energy transition discourse – according to Paul Selman's paper entitled *Learning to love the landscapes of carbon-neutrality* – can "display placeness and tell a story of human ingenuity, adaptation and wisdom that is intrinsically worthy of pride" (Selman, 2010).

Textbox 1.2. Alternatives to 'landscape'?

Landscape, admittedly, is a complex concept and this might raise the question if the concept should not be abandoned altogether, in favor of other terms that are better equipped to address the implications of the energy transition to people's surroundings.

Space for example, is a term that is often used interchangeably with landscape, especially in the context of 'spatial impact' or 'spatial dimensions' of the energy transition. Used like this illustrates the rather abstract meaning of space. Bridge et al. (2013) for example, 'unpack' the spatiality of the energy transition, amongst others, using the word *landscape*. Some disciplines use space primarily quantitative, which makes it a useful concept to compare spatial footprints of different energy technologies and illustrate the scale of the energy transition.

In line, Tuan (1977) argues that space is rather abstract and focuses on the physical surroundings, while *place* focuses on the meanings associated with space and is therefore human centered and personal (Tuan, 1977). Although *place* highlights the personal attachments of people to their surroundings, it has less emphasis on the natural and cultural, physical characteristics.

Environment is often used in a similarly abstract way, usually referring to the *natural* environment but is also used in other ways, for example *social environment* or *neighborhood environment*. Either way, environment refers to everything around an organism (e.g. human or plant) and usually does not convey the meanings that organism attaches to the environment.

Another candidate term is *land*, which is a closely related term that points towards a piece of terrain that is owned by someone (Antrop & Van Eetvelde, 2017). Land is thus relevant for the energy transition, because ownership of land is an important aspect in decision-making. However, 'land' largely lacks qualitative notions: "you can ask of land how much there is, but not what it is like" (Ingold, 1993, p. 153).

Territory it etymologically linked to land ('terra' means 'land') and refers to a delimited area governed by political or social power (Antrop & Van Eetvelde, 2017; Bridge et al., 2013). This is a useful term in the energy transition, because what happens in a territory is often governed by multiple levels of power (e.g. EU legislation and municipal laws). However, similar to land, the English term *territory* hardly conveys the interpretation and experience of individuals and groups of their surroundings. In other words, "interest groups dealing with the same territory of land see different landscapes." (Antrop & Van Eetvelde, 2017, p. 41).

Towards more inclusion of landscape in the energy transition - knowledge gaps and research aim 1.5

The concept of landscape thus encompasses much more than how it is currently used in much of the energy transition discourse. The limited, conventional understanding of landscape disrupts the continuity of the transition *and* has negative consequences for the quality of our landscapes.
As a result, both scholars and society at large start to call for an energy transition that includes 'landscape' more prominently in the processes of defining energy targets, designing energy projects and developing energy policies.

Existing research on landscape and renewable energy has been largely focusing on wind energy (e.g. Pasqualetti, Gipe, & Righter, 2002; Stremke & Schöbel, 2019; Thayer & Freeman, 1987), hydropower energy (e.g. Ferrario & Castiglioni, 2017; Frolova, 2010; Rodriguez, 2012) and high-voltage powerlines (e.g. Devine-Wright & Batel, 2013). Ground-mounted solar power plants, on the contrary, are a relatively new phenomenon and their interaction with landscape presents a rather unchartered research territory. The construction of solar power plants (SPP) has increased over the past decade (Comello, Reichelstein, & Sahoo, 2018). Discussions revolve around land use competition as well as environmental and visual impacts, which has started to give rise to dedicated SPP research (Denholm & Margolis, 2008; Hernandez et al., 2014; Ioannidis & Koutsoyiannis, 2020; Sánchez-Pantoja et al., 2018). This PhD thesis aims to contribute to this growing body of knowledge on solar power plants with a particular attention for landscape. In line with the depicted problems (section 1.3) *and* dormant potentials (section 1.4), the following four knowledge gaps have been identified:

The first knowledge gap concerns different types of solar power plants that arise under influence of societal considerations.

Different types of solar power plants are emerging that aim to achieve objectives in addition to electricity production such as food production, improving ecological qualities or enabling recreational activities (Dupraz et al., 2011; Randle-Boggis et al., 2020; Scognamiglio, 2016). Recent studies point in general terms to a range of multi-purpose solar power plants, yet lack the level of detail required for planning and design processes (Burke, 2018; Frantál et al., 2018; Hernandez et al., 2019). Although these studies highlight the potential of multi-purpose energy landscapes, a *comprehensive typology of solar power plants is missing* that can provide directions for an evidence based and transparent processes, from location finding to implementation and evaluation.

The second knowledge gap concerns the spatial properties of so-called 'solar landscapes'. While a solar power plant can have multiple purposes, key to the concept of 'solar landscapes' is the "design of solar power plants as landscape" (Scognamiglio, 2016, p. 638). This means re-configuring PV patterns and including agricultural or recreation functions in relationship to characteristics of the existing landscape, or creating new, distinct patterns. The concept of 'solar landscape' connects back with Sylvia Crowe who in the 1950s started to argue for designing 'complete landscapes', instead of mitigating inertia between technology and landscape (Crowe, 1958, p. 24). Some studies have presented single, theoretical cases (Semeraro, Pomes, Del Giudice, Negro, & Aretano, 2018; Stremke & Schöbel, 2019) or highlighted specific aspects such as ecological improvement or visibility (Apostol, Palmer, Pasqualetti, Smardon, & Sullivan, 2017; Randle-Boggis et al., 2020). There are however few studies that *systematically examine the spatial properties* of constructed solar landscapes.

The third knowledge gap relates to a more encompassing view on landscape transformation. Existing literature focuses mainly on visual impact mitigation of renewable energy technologies (Apostol, Palmer, et al., 2017; Sánchez-Pantoja et al., 2018). However,

landscape is more than just ‘scenery’: attention for visual perception needs to be complemented with a wider set of functional, experiential and temporal aspects of landscape transformation (Bevk & Golobič, 2020; Pasqualetti & Stremke, 2018; Wolsink, 2017). Moreover, evaluation of landscape transformation differs according to the considerations of (a certain group of) stakeholders (Antrop & Van Eetvelde, 2017; Van der Horst & Vermeylen, 2011).
Landscape quality is an analytical concept useful to examine different aspects of landscape transformations and associated societal considerations. The concept of landscape quality comprises functional, experiential and future aspects (Busscher, van den Brink, & Verweij, 2018; Hooimeijer, Kroon, & Luttik, 2001; F. Klijn, de Bruin, de Hoog, Jansen, & Sijmons, 2013). Although experiential aspects have been studied to some degree in the design of landscape transformations, it is unclear how *functional, experiential and future aspects of landscape quality can be addressed* in the energy transition.

Finally, the fourth knowledge gap concerns the disregard of ‘landscape’ in the definition of energy targets. These targets are often set without landscape knowledge and without stakeholders involvement (Prados, 2010). Energy potential mapping can inform energy target definition, yet often focus on a single technology (Borgogno Mondino et al., 2015) or a single aspect of landscape (e.g. visbility, Fernandez-Jimenez et al., 2015) and input data is limited to topographical, climatological and legislative data. There exists a clear knowledge gap on how *to include local landscape knowledge and societal considerations* in the definition of renewable energy targets.

Existing studies primarily focus on *energy technologies* instead of *energy landscapes*: technology and landscape are commonly considered to be separate entities. Studies focusing specifically on designing ‘complete landscapes’ as postulated above are still rare. While other scholars too advocate this, they have so far remained theoretical and without sufficient detail to inform the processes of defining energy targets, designing renewable energy projects and developing energy policies. This overall knowledge gap points to the need for what is in this PhD thesis referred to as *landscape inclusive energy transition*: an energy transition that embraces a comprehensive understanding of landscape beyond 'scenery' and 'stable state'. Despite the benefits of a landscape inclusive energy transition, it is unclear whether and how landscape can turn from a perceived obstacle into a systemic catalyzer for the 21st century energy transition.

This thesis therefore aims to identify key tenets for a *landscape inclusive energy transition*, for advancing the energy transition while meeting societal considerations regarding landscape. The use of the term *tenets* implies that this PhD thesis does not aspire to articulate fully established *axioms* or undisputable *dogmas*. Rather, this thesis provides new knowledge and directions for continued innovation in research, policy and practice, towards a more landscape inclusive energy transition.

To this end, this thesis is guided by the following four research questions, each one studied in an individual research module. Please note, the knowledge gaps (p. 13-14) related to the research questions below have been presented in reverse order.

1. How can spatially explicit, evidence-based and stakeholder-informed energy transition targets be defined?
2. How is landscape quality addressed in large-scale transformation projects and what is the role of design, governments and participation?
3. What are the visual, functional and temporal properties of frontrunner solar landscapes in Europe?
4. Which societal considerations materialize in Solar Power Plants and what types of multi-purpose SPP can be defined to support evidence-based and transparent planning and design of SPPs?

Research design 1.6

Worldview 1.6.1

This thesis is built upon a pragmatic worldview. This worldview acknowledges the existence of both a 'real' world and a 'socially constructed' world (Crotty, 1998) and its proponents are concerned with 'what works' and real-world problem solving (Creswell, 2009). In a pragmatic worldview, the researcher can use both quantitative and qualitative methods and it is therefore appropriate for planning and design research that deals with complex problems and the variety of interests involved with landscape (Lenzholzer, Duchhart, & van den Brink, 2017).

Mixed methods 1.6.2

On the level of this thesis, I use a mixed methods strategy that combines both qualitative and quantitative methods (Creswell, 2009). Examples of qualitative methods used are systematic literature review and interviews. Examples of quantitative methods used are energy potential mapping and a questionnaire. The used methods for each chapter are summarized below.

Furthermore, I use different data sources in this thesis: peer-reviewed and grey literature, project documentation, and geographic data, such as topographical maps, satellite imagery and wind speed maps. In addition, expert input, stakeholder input and field observations were used.

During the timespan of this PhD thesis, my own observations while working on commissioned projects, exploratory fieldwork and my conversations with policy and decision makers, energy experts and local inhabitants during workshops or lectures have helped me to understand the larger societal context of the energy transtion. In a way, they have enabled me to reflect upon the individual research modules and to compose both the introduction and discussion of this PhD thesis.

In chapter 2, defining energy targets based upon landscape knowledge and societal considerations was investigated using the single *case study* of Parkstad Limburg, a region in the south of the Netherlands. This case was selected because policy makers of this region were motivated to define evidence-based energy targets. Furthermore, geographic data was available for the whole region and civil servants and aldermen of the municipalities were willing to participate in the research project by means of *interviews* and *questionnaire*. *Energy potential mapping* served as an input to compute the potential renewable energy generation for different scenarios and determine year of energy neutrality. A full description of the methodological framework can be found in chapter 2.2.

In chapter 3, aspects of landscape quality in large-scale landscape transformation projects are analyzed using a *systematic review* of the literature on three cases. The cases were identified by means of an *email questionnaire* to experts. Peer-reviewed and grey literature were analyzed using a *qualitative content analysis* (Boréus & Bergström, 2017). A full description of the methods can be found in chapter 3.2.

In chapter 4, a *comparative analysis of multiple embedded cases* of solar landscapes is used to identify their visual, functional and temporal properties (Yin, 2009). *Expert consultation* was used to identify cases. For each of the cases, a *spatial analysis* (Frankl, 1968; Steenbergen, 2008) and a *document analysis* of project documentation was conducted. *Field observations* were used to verify the results of the spatial analysis. Individual case analysis were synthesized to identify similarities and differences across cases (Yin, 2009). A full description of the methods can be found in chapter 4.2.

Chapter 5 uses a *literature review* to identify the key societal considerations with regard to solar power plants. For the delineation of the typology, this chapter makes use of the same dataset of chapter 4, supplemented with additional cases. These additional cases are analyzed similar to the *comparative case analysis* of chapter 4. Multiple iterations of cross-case comparison and individual case reflection were used to develop the typology. Feedback from a *questionnaire* to case informants and expert *interviews* was used to inform these iterations and further supplement and elaborate the typology. A full description of the used methods can be found in chapter 5.2.

Research quality 1.6.3

Several strategies were employed to ensure research quality throughout the thesis. To start, methods such as energy potential mapping, systematic review and comparative case-analysis are data intensive methods. To deal with these large quantities of data, data *management strategies* were put in place in the early stages of research. Strategies involved clear file and folder names, folder structures, distinctions between raw and processed data and building templates to collect, organize and process data.

Furthermore, energy landscapes are often not (yet) captured in comprehensive databases or geographic datasets that allow convenient comparison and selection of cases based upon certain characteristics. To avoid a bias in case identification, namely those cases known to the involved researchers, case identification was accomplished by collaborating with a *diverse set of experts* and *extensive desk-studies* (chapter 3, 4 and 5).

For the embedded case studies, a *case study protocol* was developed and used to instruct the involved researchers and to ensure consistency and reliability of the individual case analysis. Similarly, an *interview protocol* was devised for the expert interviews in chapter 5, in collaboration with a methodological expert.

Data triangulation was used in the case studies to ensure the validity of the spatial analysis of solar power plants. Initial analysis was done using both satellite imagery and project documentation (including design and construction drawings) and verified during fieldwork. In some cases, verification was supported by informal conversations with the involved designer, developer or civil servant, because they supplied the project documentation or provided access to the site. Data analysis for each of the chapters involved one or more workshops that included the involved researchers and a knowledgeable colleague not involved in the actual research.

Moreover, preliminary findings have been presented on a regular basis to both professional and academic audiences. These presentations yielded relevant questions, additional insights, and confirmation of the then preliminary findings.

Finally, in addition to informal peer review, each of the following chapters (except the discussion and conclusion) has been submitted as individual papers to international scientific journals that employ rigorous *peer review*. The feedback of the reviewers have helped to improve the structure of the papers, the clarity of writing and the articulation of the findings. Chapter 2, 3 and 4 have been published in scientific journals. All publication details are provided at the start of the respective chapter. Chapter 5 has been – at the moment of writing – invited for resubmission following major revisions with another Q1 journal.

1.7 Structure of the thesis

Following this introduction to the PhD thesis – chapter 2 presents an methodological framework to *define energy targets* including local landscape knowledge and stakeholder considerations. In chapter 3, the literature on three large-scale landscape transformation projects is systematically analyzed to understand how functional, experiential and future aspects of *landscape quality* can be addressed in the energy transition. Chapter 4 comprises a comparative analysis of 11 frontrunner *solar landscapes* in Europe and systematically examines the visual, functional and temporal properties of solar landscapes. Chapter 5 presents a *typology of multi-purpose solar power plants* that can provide directions for an evidence based and transparent processes, from location finding to implementation and evaluation. Chapter 6 discusses and concludes this thesis by presenting five tenets for a landscape inclusive energy transition.

The village Vijlen, just south of the region Parkstad Limburg, with windturbines located in Germany in the background (source: author).

Chapter 2

Spatial transition analysis: Spatially explicit and evidence-based targets for sustainable energy transition at the local and regional scale

Dirk Oudes
Sven Stremke

Landscape and Urban Planning 169, 1-11. 2018

Abstract

Climate change, depletion of fossil fuels, and economic concerns are among the main drivers of sustainable energy transition. Over the past decade, several regions with low population density have successfully transited towards renewable energy (for example Siena, Italy). In the Netherlands and other countries, more densely populated regions have drawn up ambitious targets for energy transition. Most of these transition targets lack empirical evidence with regard to spatio-technological feasibility. This lack of evidence may compromise energy transition if constraints are discovered posteriori and short-term milestones missed. To address this shortcoming, we propose an integrated approach. Spatial Transition Analysis (STA) can assist in defining spatially explicit and evidence-based targets for energy transition. STA combines quantitative modelling of energy potentials, qualitative spatial considerations for the siting of renewable energy technologies and comparative scenario development. The application of STA in a case-study (Parkstad Limburg, the Netherlands) revealed that the region has the potential to become energy neutral between 2035 and 2045. Examining and illustrating the different types of constraints as well as the possible choices between renewable energy technologies enabled stakeholders to start planning for energy transition and implementing first interventions. This shows that STA provides a solid framework to foster sustainable energy transition initiated by regional stakeholders and informed by local preferences.

Introduction 2.1

Climate change, depletion of fossil fuels and concerns about local economies are among the main drivers of sustainable energy transition (Bridge et al., 2013). This transition is not limited to the transformation of energy infrastructure, but involves transformations of “the broader social and economic assemblages that are built around energy production and consumption” (Miller et al., 2013, p. 135) and is being increasingly studied by social scientists, geographers, spatial planners, landscape architects and other environmental designers (e.g. Sijmons et al., 2014; Stremke & van den Dobbelsteen, 2013). The part of the physical environment affected by energy transition is commonly referred to as ‘energy landscape’ (Pasqualetti, 2013; Selman, 2010; Van der Horst & Vermeylen, 2011). In line with the European Landscape Convention, landscape refers to “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe, 2000, p. 2).

In Europe, several regions have successfully transitioned towards renewable energy, for example Siena, Italy (Casprini, 2013) and Samsø, Denmark (De Waal & Stremke, 2014) − all of which have a low population density. In the Netherlands and other countries, more densely populated regions have defined ambitious targets for energy transition, within a relatively short period of time. Examples in the Netherlands are Stedendriehoek (Pijlman & Bosman, 2014) and the cities Utrecht (Gemeente Utrecht, 2011) and Groningen (Gemeente Groningen, 2008) aiming to achieve 100% energy or carbon neutrality by 2030 or even 2025. Energy neutrality refers to “the extent to which a district [...] can supply itself with sustainable energy generated within the boundaries of that district” (Jablonska et al., 2011, p. 1). Regions are often unaware whether spatial characteristics of the region are suitable to achieve energy neutrality (e.g. “Energietransitienota Duurzame Energie Achterhoek (2015),” 2015; Pijlman & Bosman, 2014). Next, transition targets are often based on little evidence regarding technological feasibility. Furthermore, many targets are conceived without involving stakeholders. Considerations of stakeholders with regard to the way the energy transition should take place are not taken into account. Such bold and superimposed transition targets may compromise energy transition if constraints are discovered posteriori and short-term milestones are missed. To illustrate, the target of the municipality Groningen (the Netherlands) has already been adjusted from 2025 to 2035 (Gemeente Groningen, 2011).

The urgent need to define realistic long-term transition targets and to take action was stressed again by the 2015 Paris Climate Agreement. In the Netherlands, the Dutch NGO Urgenda, together with 900 citizens, successfully filed the so-called Climate Case against the Dutch government (Urgenda, 2015). Energy transition has become a key challenge and (inter)national agreements need to be turned into regional and local targets.

To the best knowledge of the authors of this paper, no methodological framework exists that can help define energy transition targets that are spatially explicit, evidence-based, and informed by qualitative stakeholder considerations. The objective of this paper is, therefore, to close this knowledge gap, to present and discuss an integrated approach – Spatial Transition Analysis (STA) – that can be used to define targets for regional and local energy transition. To address the shortcomings of current practice, STA ought to be spatially explicit, evidence-based with regard to renewable energy technologies (RET), and inclusive of stakeholder values and preferences.

Several concepts, methods and approaches have provided building blocks for the research presented in this paper. Departing from the concept of 'energy landscape', (Stremke, 2015) introduced a conceptual framework for the planning and design of sustainable energy transition. He stresses that four dimensions (or types) of criteria should be addressed in the planning and design of sustainable energy landscapes, namely environmental, socio-cultural, economic and technical criteria. This typology will be revisited later in the paper.

Energy Potential Mapping (EPM) offers another building block for energy landscape research. This method is used to map and quantify technical energy potentials (Van den Dobbelsteen, Broersma, & Stremke, 2011). Wang, Mwirigi M'Ikiugu, and Kinoshita (2014) include biophysical and technical constraints that adversely affect renewable energy potentials. Stakeholder preference with regard to renewable energy technologies – another key constraint – is missing however.

Strategic planning and design provided the theoretical foundations of the research presented in this paper (see for example Albrechts, 2004). The Five Step Approach is a methodological framework for strategic design that has been applied to envision regional energy landscapes (Stremke, Koh, Neven, & Boekel, 2012). For this, three modes of change, namely current projected trends, critical uncertainties and intended change are integrated in a design process that explores alternative pathways for the realization of transition targets (Stremke, van Kann, & Koh, 2012). In this paper the focus is on how such targets can be determined.

Advanced methods such as trade-off analysis (for example Burgess et al., 2012; Howard et al., 2013) and multi-criteria decision analysis (for example A. Grêt-Regamey & Wissen-Hayek, 2013) are complex and require vast amounts of data and resources. They can play an important role after transition targets have been defined and alternative interventions explored.

For the research presented here, literature studies and a case study (Yin, 2009) have been conducted. Insights from other closely related projects in the Netherlands, Germany, Austria and Denmark have been incorporated (for example De Waal & Stremke, 2014). A case study was carried out in the Parkstad Limburg region (The Netherlands). The area selected consists of an agglomeration of three mid-sized cities and five rural municipalities. The research process was iterative in character and conducted in close collaboration with the regional and local initiators of energy transition as well as other stakeholders.

The second section of this paper delineates the methodological framework that can be employed to define energy targets. The third section illustrates these steps making use of materials and results from the Parkstad Limburg Energy Transition (PALET) project. Finally, the approach and the results are discussed in section four and conclusions drawn in section five.

2.2 Methodological framework for spatial transition analysis (STA)

This section gives a brief description of the methods and techniques needed to define energy targets at the regional or local level. The overall methodological framework and the links between the different steps are illustrated in figure 2.1. The aim, execution, input and output of each of the seven STA steps are addressed in the following sub-sections.

2.2.1 Interviews

One of the aims of conducting interviews with local stakeholders is to gather spatially explicit data on potentials, constraints and the existing supply of renewable energy sources. Another aim is to collect information on stakeholder preference and aversion regarding RET. The output may consist of local (GIS) data, municipal development plans, annotated topographical maps as well as documents listing preference and aversion to RET.

2.2.2 Questionnaire

The aim of the questionnaire was to discover the significance of certain criteria for sustainable energy transition, as perceived by the stakeholders. Their preferences are operationalized in Step Four and inform the scenario development in Step Six. Departing from a long-list of 40+ sustainability criteria (Stremke, 2015), sixteen criteria applicable for energy transition in Parkstad Limburg were selected for the PALET questionnaire. Respondents were civil servants and aldermen from the eight municipalities and the regional government. They were asked to rate each criterion on a scale of 1 (not important) to 5 (important).

Selection of renewable energy sources and technologies 2.2.3

The aim of Step Three is to determine potential renewable energy sources and technologies for the transition. In order to develop a robust energy system, multiple sources and alternative technologies for each source are to be included (Stremke & Koh, 2011). Given the aim of the research – to define an evidence based target – only proven energy technologies are included and sufficient data on renewable energy potentials of these technologies must be available.

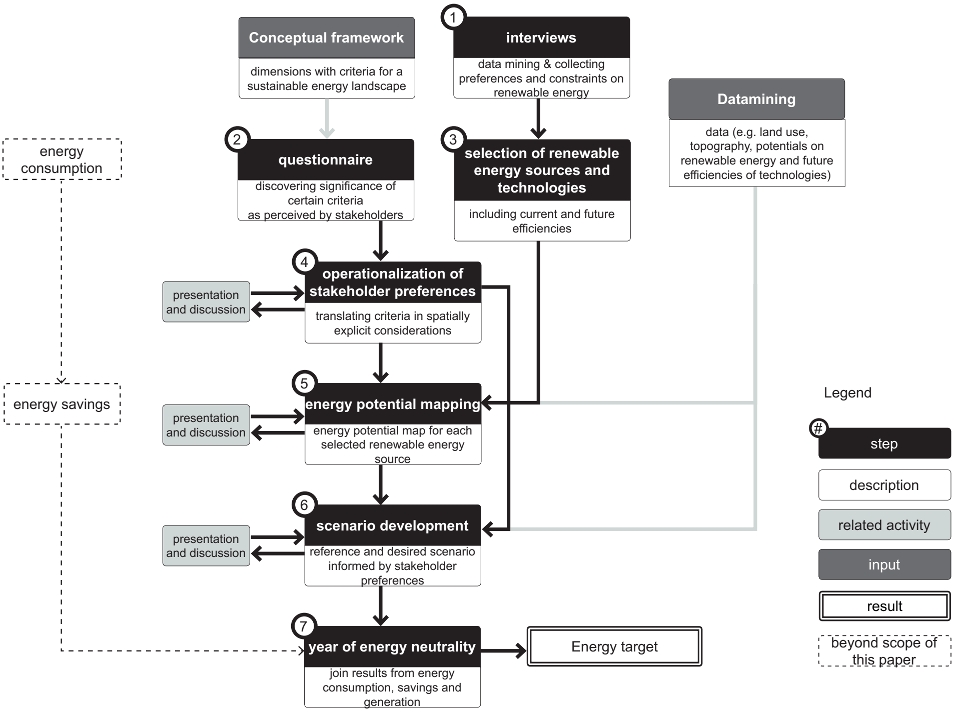


Fig. 2.1. Methodological framework for Spatial Transition Analysis (STA), revealing the sequence of and links between the seven steps needed to define energy transition targets.

For PALET, a preliminary analysis of existing data on renewable energy sources was conducted and proven technologies listed. For example, the number of solar hours per year and spatial data on building typology to determine the potential of photovoltaic (PV) panels on rooftops. A definitive selection of renewable energy sources and technologies was made in collaboration with technology experts and key stakeholders. Data and spatial information were included in the mapping study (Step Five). Current and expected efficiencies of renewable energy technologies were derived from literature available. The output of Step Three is a list of technologies and efficiencies clustered according to energy sources.

2.2.4 Operationalization of stakeholder preferences

The aim of Step Four is to operationalize qualitative sustainability criteria, making them spatially explicit. The conceptual framework for the development of sustainable energy landscapes can help here (fig. 2.2). For each study, criteria have to be defined and prioritized by stakeholders in collaboration with experts. In order to develop a sustainable energy landscape and prevent land use competition, stakeholders might want to limit the area made available for PV farms. Data used in completing this step is the result of the interviews (Step One) and the questionnaire (Step Two), as well as notes from discussions and literature. The output is a list of spatially explicit considerations to be used as input for the process of mapping energy potential (Step Five) and scenario development (Step Six). An example is presented in Section 3.4.

2.2.5 Energy potential mapping

The aim of Step Five is to map renewable energy potentials and constraints. These are differentiated according to land use categories. In PALET, these included residential area, public services, commercial services as well as areas being used for industry and transport, for example. Using the GIS software ArcGIS, each potential and constraint is defined as layer, edited, organized and visualised. GIS datasets may contain general topographical information about

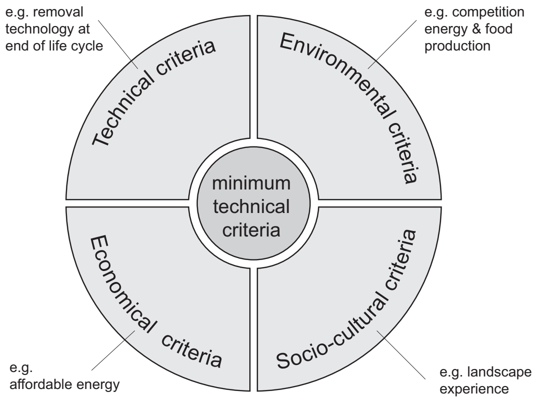


Fig. 2.2. Conceptual framework for the planning and design of sustainable energy landscapes (Stremke, 2015).

land use and relief for example and constraints to renewable energy technologies, such as soil protection areas and Natura 2000 areas. Additional data, such as the locations of fallow land and sound barriers, came from the interviews (Step One). Data on numerical potentials of renewable sources, for example, solar irradiation and wind speed 100 m above ground level were inserted into the GIS. The output of Step Five is a GIS model and a map for each renewable energy source, containing specific information about the potentials and constraints of the preselected energy technologies.

Scenario development 2.2.6

The aim of Step Six is to compute the potential for renewable energy generation in petajoules (PJ) and to indicate the relative effects of each constraint. To do this, two scenarios are developed: a 'reference scenario' which incorporates technical constraints only and a 'desired scenario' based on stakeholder preferences and expert knowledge (see fig. 2.3). The former scenario establishes a reference, which is the maximum technical potential for renewable energy generation (Blaschke, Biberacher, Gadocha, & Schardinger, 2013). The latter scenario reveals the effects of stakeholder preferences and provides a realistic image of renewable

energy potentials. Information from interviews (Step One) and questionnaire (Step Two) along with spatial explicit considerations (Step Four) make the input for scenario development.
In PALET, flowcharts were used to reveal the relationships between potentials and constraints of each selected RET. They provided the basis for the creation of the scenarios and calculations. Spreadsheet software (Microsoft Excel) was used to organize and calculate the amount of renewable energy provision. The output of Step Six is an overview of renewable energy provision organized by source and technology. This is communicated through flowcharts, tables, textual description, bar charts and infographics.

2.2.7 Year of energy neutrality

The aim of Step Seven is to link the results of the renewable energy study (as presented in this paper) with the current energy consumption and potential energy savings. Together, they make it possible to determine the possible year of energy neutrality. Implementation time may differ per renewable energy technology, ranging from one or two years for solar panels up to ten years for large wind parks in the Netherlands (Hekkenberg & Lensink, 2013). Taking this into account, an s-curve that is typical for technology diffusion (i.e. take-off, acceleration and stabilization phase) was applied in PALET to estimate the year of energy neutrality. When local renewable energy provision exceeds local energy consumption, energy neutrality is achieved. Data used in this step are the results from Step Six (desired scenario) and from the energy savings study. The outcome of Step Seven is an indication of the potential year of energy neutrality for a study area.

2

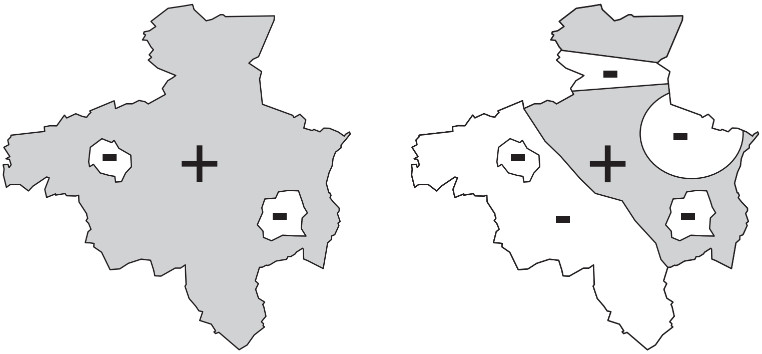


Fig. 2.3. Conceptual visualization of the differences between 'reference scenario' (left) and 'desired scenario' (right). In this figure the plus symbol represents the potential area for renewable energy, while the minus symbol represents the constraints. In the 'reference scenario' only technical constraints are incorporated, while the 'desired scenario' shows the effects of stakeholder preferences and provides a more realistic image of renewable energy potentials.

Fig. 2.4. Geographical location of Parkstad Limburg in the south of the Netherlands (above left) and map of the eight municipalities that together constitute the region.

2.3 Case study Parkstad Limburg

Our case study – Parkstad Limburg – is a region in the south of the Netherlands (fig. 2.4) consisting of eight municipalities. It is an agglomeration of three mid-sized cities and five rural municipalities. It has a surface area of 211 km^2 and some 255.000 inhabitants (1208 inhabitants/km^2). Compared to the rest of the Netherlands, it has an atypical landscape, consisting of large plateaus and wide river valleys. Parkstad Limburg is experiencing demographic shrinkage (CBS, 2010) and declining employment opportunities (CBS, 2009). The PALET project was commissioned by the regional government and executed by three parties. Zuyd University studied the current energy demand and potential energy savings, H+N+S landscape architects coordinated the project, while the authors of this paper examined the renewable energy potentials. A group of representatives from the municipal and regional authorities informed the project and reflected on the process. The research was conducted in the first half of 2014. With regards to the four key elements of successful transitions (Loorbach & Rotmans, 2010), the project contributed to the creation of a transition arena, as well as to the establishment of a shared transition agenda in Parkstad Limburg. Note that implementation and monitoring are part of ongoing follow-up projects that are beyond the scope of this paper.
Section Three illustrates the application of STA in the Parkstad Limburg region. The sequence of sub-sections corresponds with that of Section Two. Solar energy technologies that convert solar irradiation into electricity and heat are used to exemplify the STA approach.

2.3.1 Interviews

The interviews were semi-structured and involved eighteen representatives from the eight municipalities and the regional government. Interviewees were asked about the current status-quo and ideas for energy transition in each municipality. The interviewees offered spatial data with different levels of detail, for example CAD drawings of fallow terrains and strategic visions. They reported that selected policy constraints for renewable energy were available in GIS format for the entire province – a consistent data set for all municipalities. Interviewees also suggested various ideas for siting renewable energy technologies, for example, the construction of PV panels on sound barriers of a new highway. The interviews revealed many relevant insights. Some of the data, however, turned out to be too detailed for research on the regional energy target but were used in subsequent projects.

Table 2.1. Overview of results from the PALET questionnaire: the four dimensions of sustainability, criteria and scores (bandwidth and average; 1 indicating 'not important' and 5 'important').

Dimension	Criterion questionnaire	Lowest score	Highest score	Average score
Technical	Make use of renewable energy sources	4	5	4.8
	Employ locally available energy	2	5	4.4
	Aim for a diversified energy system	1	5	4.2
	Aim for a self-sufficient energy landscape	3	5	4.5
Environmental	Reduction of harmful emissions	3	5	4.4
	Do not compete with food production	3	5	4.3
	Preserve/improve biodiversity	4	5	4.6
	Preserve other ecosystem services	3	5	4.8
Socio-cultural	Attractive landscape	3	5	4.7
	Preserve sites with cultural heritage value	2	5	4.6
	Maintain (or improve) potentials for recreation and ecotourism	1	5	3.7
Economical	Access to affordable energy	2	5	4.1
	Minimize land-use competition	1	5	3.9
	Create local and regional jobs	4	5	4.6
	Maintain/improve secure energy supply	2	5	4.4
	Economic feasibility	2	5	4.6

2.3.2 Questionnaire

A total of 39 people responded to the questionnaire, among whom were civil servants and alder(wo)men. The results of the questionnaire are depicted in table 2.1. The 'use of renewable energy sources', 'economic feasibility' and the 'preservation of cultural heritage sites' were considered important criteria that should be taken into account for the sustainable energy transition in this region. Other criteria such as 'minimize land use competition' and 'maintain potentials for recreation and ecotourism' were considered important to some extent. The relatively high average of criteria indicates a desire to develop a sustainable energy landscape, even though some respondents considered particular criteria less important than others. Clearly, there is consensus and a positive attitude towards the use of locally available renewable energy sources. Landscapes with high scenic values should be considered carefully during the transition.

2.3.3 Selection of renewable energy sources and technologies

Five renewable energy sources were studied in detail for the Parkstad Limburg region: solar, wind, heat-cold storage, hydropower and biomass. Deep geothermal energy was excluded for two reasons: a lack of reliable data on geothermal potential and the very low potential indicated in the few references that were available. For each of the five energy sources, renewable energy technologies were selected (table 2.2). For solar energy, For solar energy, the technologies were PV panels, solar thermal collectors and asphalt solar collectors. For each technology, efficiencies and their expected increase in efficiency were derived from literature (table 2.3). To calculate the future efficiencies of PV cells, estimationsfor the three most prominent techniques were averaged. If solid indicators for future efficiencies were absent, the current efficiency was used.

Table 2.2. Overview of renewable energy sources and technologies that were selected for PALET. For biomass, types of biomass are described instead of technologies.

Renewable energy source (RES)	Renewable energy technology (RET)
Solar energy	Photo-voltaic (PV) panels Solar thermal collector Asphalt solar collector
Wind energy	Wind turbine Small building-integrated wind turbine
Heat-cold storage	Open system Closed system Mijnwater 2.0 (heat-cold exchange by means of local old mineshafts)
Hydropower	Small hydropower system
Biomass	Waste gas Manure Verge clippings Woody biomass Straw Energy crop

Table 2.3. Overview of conversion efficiencies for selected solar energy technologies. Source: NREL (2013) and Mehalic (2009).

Current and future efficiencies	2014	2020	2030	2040	2050
Photovoltaic panels	15%	18%	22%	27%	30%
Solar thermal collectors	35%	39%	45%	51%	56%
Asphalt solar collectors	25%	25%	25%	25%	25%

2.3.4 Operationalization of stakeholder preferences

For solar energy, the physical potentials and constraints, technical requirements and stakeholder preferences were made spatially explicit. A complete overview of constraints that limit the potential of renewable energy generation can be found in appendix A. For PV farms on agricultural land, for example, constraints are (1) unfit shape of terrain, (2) parcels with northern orientation, (3) parcels with steep slope, (4) competition with food production and (5) parcels within protected landscape. The importance of food production to the stakeholders and experts resulted in the exclusion of 90% of agricultural land from being used as PV farms. The remainder might become available due to continuous improvements in agricultural practice in the Netherlands (computed on the basis of historical trends). The high importance of the socio-cultural criterion aesthetic value/landscape experience affects the potential for placing PV panels and solar thermal collectors. Half of the settlements with heritage status – the most visible part – and all cultural heritage buildings were excluded. Because of the importance of the socio-cultural criterion recreation and ecotourism, lakes used for leisure purposes were exempt from floating PV farms. Note that not all criteria studied in the questionnaire resulted in spatially explicit constraints. Some questions simply served to facilitate an understanding of the motivation for energy transition in the region.

During this phase of the research, four types of constraints that would affect the introduction of renewable energy technologies were identified; they can be classified as following:

- Physical constraints that inhibit the implementation of a specific technology, for example, northern orientation of slopes inhibiting the installation of PV farms.
- Exogenous policy constraints that are dictated from outside the region, formalized in legislation and therefore difficult to change for regional stakeholders. For example, low flying zones for air traffic which prohibit the installation of large wind turbines.

— Endogenous policy constraints that are formalized in regional or local legislation. The responsible legal bodies within the study area can change constraints such as the heritage status of certain settlements.
— Normative constraints that are not (yet) formalized in legislation, but reflect the sentiment or negative attitude of regional stakeholders towards certain RET or RET locations.

The number and type of constraints differ per technology. PV farms in Parkstad Limburg, for example, are affected by five constraints – three physical and two normative (fig. 2.5). Placing the different constraints within the conceptual diagram for sustainable energy landscapes enables stakeholders to better understand the number and types of constraints for each technology.

Questionnaire 2.3.5

A total of 39 people responded to the questionnaire, among whom were civil servants and alder(wo)men. The results of the questionnaire are depicted in table 2.1. The 'use of renewable energy sources', 'economic feasibility' and the 'preservation of cultural heritage sites' were considered important criteria that should be taken into account for the sustainable energy transition in this region. Other criteria such as 'minimize land use competition' and 'maintain potentials for recreation and ecotourism' were considered important to some extent. The relatively high average of criteria indicates a desire to develop a sustainable energy landscape, even though some respondents considered particular criteria less important than others. Clearly, there is consensus and a positive attitude towards the use of locally available renewable energy sources. Landscapes with high scenic values should be considered carefully during the transition.

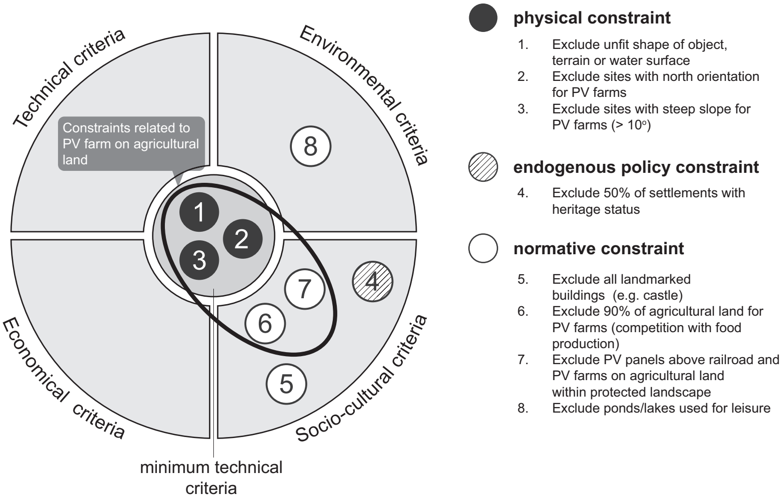


Fig. 2.5. Overview of constraints for selected solar energy technologies. The figure reveals how a set of specific constraints to renewable energy technologies can be linked to the dimensions of sustainability. The black outline indicates the constraints related to the technology PV farm.

2.3.6 Energy potential mapping

For solar and wind energy, heat-cold storage, hydropower and biomass, the potentials and constraints were illustrated in one map each (1:25.000). Figure 2.6 shows the map that was created for solar energy. This map indicates that the entire region falls within a zone of 1450–1500 h of sunshine per year. Roofs of residential, public and commercial buildings and industrial plants are suitable for both PV panels and solar thermal collectors. The map depicts settlements with heritage status as well as landmarked buildings. Open water offers potential for floating PV farms, except where lakes are being used for leisure purposes. In general, agricultural land can host PV farms, so can sand mining areas and landfill sites. Note that a 10% rule for agricultural land is applied. The National Landscape South-Limburg – a large part of the region – is not suited for PV farms. The Northern part of the region contains large areas of forest, which are also excluded. In the medium to long-term,

2

asphalt solar collectors can be integrated into the roads. PV panels can be integrated in new road structures, above railways and in (a portion of) the vertical surface of sound barriers along the highway that is being constructed.

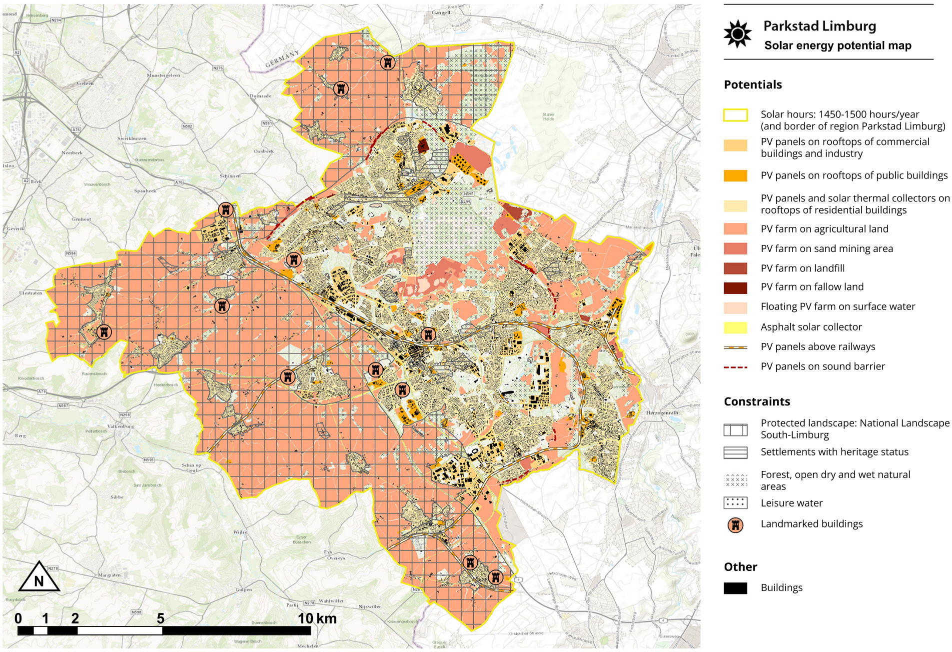


Fig. 2.6. Solar energy potential map of Parkstad Limburg.

Scenario development 2.3.7

In the reference scenario, the total renewable energy potential is 69 PJ. In the desired scenario, the renewable energy potential amounts to 20 PJ. The flowcharts in appendix B and C show the solar energy potentials and constraints that were included in the reference and desired scenario respectively. The large difference in solar energy potential between the two scenarios is mainly the result of the fact that 90% of the agricultural land is excluded for PV farms in the desired scenario. Appendix A shows how each constraint affects the overall provision of solar energy in the desired scenario.

2.3.8 Year of energy neutrality

The energy consumption in Parkstad Limburg was 30 PJ in 2012 while the potential energy savings amount to 16 PJ (Bongers, Broers, Janssen, Kimman, & Weusten, 2014). Combining the results of both studies, the year of potential energy neutrality has been estimated anytime between 2035 and 2045 (desired scenario), making use of nonlinear technology diffusion rates. Societal and economic developments as well as other factors such as technological breakthroughs will influence the energy transition and prohibit the prediction of a specific year of energy neutrality.

The renewable energy portfolio of Parkstad Limburg in the desired scenario consists largely of solar energy (51.5%) and heat-cold storage (40.7%). Wind energy (5.6%) is very limited due to policy and normative constraints. Biomass (2%) contributes relatively little and consists of second-generation biomass only. Yet, even in the reference scenario, the use of energy crops on arable land only doubles the biomass potential (4%). Hydropower (0.2%) has a very low potential in Parkstad Limburg because height differences are small.

Regional energy potentials exceed the expected demand for electricity by 19% and heat for 85%. More and more transport will make use of renewable electricity but the region is unable to generate the remaining demand of fossil fuel for transport. The required import of fossil fuels would need to be compensated by export of renewable electricity as is being done, for example on Samsø, Denmark.

To some extent, the renewable energy portfolio is flexible with regard to technologies. For example, PV farms could substitute wind turbines. This flexibility is important for stakeholders as it enables them to deal with changing societal preferences as well as technological advancements. Slower deployment of renewable energy technologies and/or implementation of energy saving measures would push back the year of energy-neutrality in Parkstad Limburg and other places where STA is employed to establish spatially explicit and evidence-based targets for energy transition.

Discussion 2.4

In this section, we will discuss data, spatial extent and stakeholder interaction of the case study. We will then look at the similarities and differences between STA and other spatial approaches to sustainable energy transition.

Data and level of detail 2.4.1

Researching the spatially explicit potentials for multiple renewable energy sources and technologies in a region of more than 200 km^2 requires a large amount of reliable data. This dependency on accurate and up-to-date GIS data, for example, can become an issue in countries where such data is incomplete or unavailable. Furthermore, the research is based on scientific literature with regards to the future efficiencies of energy technologies. Therefore, the potential year of energy self-sufficiency should be considered an estimate rather than a fact. Additional data such as demographic trends can strengthen the evidence-based character of STA studies.

Thanks to the iterative research process, two scenarios turned out to be sufficient for PALET. Depending on the characteristics of the physical environment and stakeholder preferences, more scenarios (i.e. different sets of constraints) might be needed in other STAs. Dynamic GIS models enable quick exploration of additional scenarios. The dynamic GIS model that was created for PALET is being used in the follow-up projects. PALET 2.0 provides insights into the potential for energy saving and renewable energy generation for each municipality individually. The model is also being used in PALET 3.0 to determine short-term targets and support mutual agreements between the eight municipalities.

Spatial extent and energy neutrality 2.4.2

The spatial extent of PALET was determined on the basis of existing collaborations between the eight municipalities. This is certainly beneficial for the management of the energy transition process as the different administrations were used to joining forces. However, this spatial delineation remains somewhat arbitrary since the collaboration with other regions may provide additional value in the light of energy transition. Electricity exchange, for example, could help to deal with the intermittent character of wind and solar energy. It remains to stress that energy neutral regions, as opposed to autarkic regions, are well connected with other regions in order to create robust energy systems.

2.4.3 Stakeholders, interaction and preferences

The excellent interaction with commissioners and representatives from the municipalities enabled the PALET research process to proceed smoothly. This may not be the case in all regions, while we see it as a prerequisite of any similar study. Others have argued rightfully about the importance of capacity building in fostering energy transition (see for example Trutnevyte, Stauffacher, & Scholz, 2011). Stakeholders learn about energy, technologies and get to know others involved in the transition. Projects such as PALET are important for researchers too, because they allow the testing of theoretical concepts and frameworks. Due to limited time, the questionnaire was only distributed to alder (wo)men and civil servants. For more inclusive results, inhabitants, entrepreneurs and non-governmental organisations need to participate. In Parkstad Limburg, this is being addressed in follow-up projects. The translation of qualitative results from stakeholder inquiry towards quantitative scenarios required different degrees of interpretation. The outcome of the questionnaire directly affected some choices during the scenario development, for example the protection of scenic landscape. More specific and elaborated questionnaires may be beneficial for future projects.

Some of the constraints that play a role in the STA can be considered flexible in the medium to long term. Responsibilities for present-day exogenous policy constraints, for example, may be delegated to local governments in the future, as a consequence of decentralisation. Furthermore, constraints that are currently normative in character could become part of local or regional policies once there is a consensus among stakeholders. In addition, attitudes towards renewable energy technologies may change in time due to new insights, changing value systems or other factors (ETSU, 1993). Therefore, it is suggested to monitor developments throughout the transition and adjust measures where needed.

2.4.4 Similarities and differences between STA and other approaches

This paper shows how a target for energy transition can be established by researching the potentials for renewable energy provision and energy savings. Qualitative considerations of stakeholders and experts are included in the STA, together with the particular bio-physical characteristics of Parkstad Limburg. In doing so STA expands on the work of (Wang et al., 2014) who studied the potential degree of self-sufficiency without stakeholder preferences. Blaschke et al. (2013) too uses GIS maps and distinguishes between 'technical' and 'realistic' potentials. The latter, however, is solely based on expert judgement and not informed by stakeholder preferences. Similar to van den Dobbelsteen et al. (2011), STA illustrates renewable energy potentials through maps. The dynamic GIS model and inclusion of stakeholder preference are two differentiating characteristics of STA. Other research such as the visual assessment of potential interventions (for example A. Grêt-Regamey & Wissen-Hayek, 2013) can be carried out once the energy transition target has been established. In Parkstad Limburg, the STA was conducted in a relatively short amount of time and at an early phase of the regional energy transition. As a matter of fact, it marked the start of the planning process. The research provided the foundations for a joint political ambition (the target) while contributing to capacity building in the region. If reliable (GIS) data is available and active stakeholder participation incorporated, STA may prove to be beneficial to support the energy transition process in other countries.

2.5 Conclusions

The main objective of the research presented in this paper was to advance the study of spatially explicit and evidence-based targets for sustainable energy transition at the regional and local scale. This paper focuses on the study of renewable energy potentials informed by qualitative stakeholder considerations. The potentials for energy savings should be studied in parallel (see for example Bongers et al., 2014).

The proposed methodological framework – Spatial Transition Analysis (STA) – employs quantitative techniques to model renewable energy potentials, takes qualitative considerations into account and unravels the variables that influence both the transition target and the time needed to reach energy neutrality. In doing so, STA allows for the exploration of alternative transition paths.

The paper illustrates that Parkstad Limburg has the potential to become energy neutral anytime between 2035 and 2045. This finding is of great value to the stakeholders; short-term actions have been initiated and medium to long-term actions discussed actively. Moreover, findings are expected to facilitate the evaluation of existing policies or even the design of new policies. Empirical data, scenarios and dynamic models reveal the direct relationships between the local landscape characteristics, stakeholder values and renewable energy potentials. In addition, STA can help to explicate how particular sustainability criteria and associated stakeholder preferences may influence the choice and location of renewable energy technologies. This enables stakeholders to start planning for energy transition and implementing first interventions. STA therefore provides a solid approach fostering a sustainable energy transition, initiated by regional stakeholders and informed by local preferences.

As opposed to current mainstream practice, STA aids a thorough understanding of qualitative aspects at an early stage of energy transition process, without limiting the discussion to a small number of economically interesting technologies. Opposition towards certain renewable energy technologies is expected to be less fierce when qualitative aspects have been considered at an early stage. Continuous research in Parkstad Limburg will, among others, allow the examination of this assertion. The (region-specific) trade-offs between qualitative considerations and economic aspects, for example pay-back time, deserve further attention. However, what has already become clear through the research in Parkstad Limburg is that more qualitative considerations are likely to increase the financial costs of the transition. Constructing fewer wind turbines, for example, can help to maintain landscape scenery while alternative technologies are more cost intensive.

Close collaboration with social scientists is needed to further strengthen stakeholder interaction. This applies to energy transition in general and spatially explicit approaches such as STA in particular. Further research is needed on the role of landscape architects and other environmental designers in energy transition processes. Creative inquiry into alternative futures – a key contribution of environmental designers to energy transition – may be fostered by scenario design (e.g. Weller, 2008) and research through design approaches (e.g. Lenzholzer, Duchhart, & Koh, 2013).

For transitions at a regional level, such as Parkstad Limburg, it is important to acknowledge and connect with already existing local initiatives and to foster the emergence of a transition community consisting of citizens, entrepreneurs and other (semi-public) organisations. Initiatives such as PALET can provide inspiration and serve as a reference to others – a region-specific knowledge base that empowers local initiatives while addressing global challenges.

Acknowledgments

The authors like to thank the representatives of Parkstad Limburg for their enthusiasm and learning attitude with regard to sustainable energy transition. Next, we would like to thank the project partners Zuyd University, H+N+S landscape architects and Siebe Broersma from TU Delft. We also like to thank Renée de Waal for reviewing the first manuscript. Last but not least, we thank the anonymous peers for reviewing the manuscript.

Smoke of a nearby fire reveals the light beams of the heliostats (mirrors on the ground) to the central tower of concentrated solar power plant (CSP) Gemasolar, near Seville, Spain (source: author).

Chapter 3

Climate adaptation, urban regeneration and brownfield reclamation: a literature review on landscape quality in large-scale transformation projects

Dirk Oudes
Sven Stremke

Landscape Research, 45(7), 905–919. 2020

Abstract

The transition to renewable energy is a powerful driver for large-scale landscape transformation. Environmental design is increasingly concerned with this transition, but little is known about purposefully designed renewable energy landscapes. To improve the design of large-scale energy landscapes we reviewed the literature on three innovative large-scale landscape transformations: Room for the River Nijmegen-Lent (The Netherlands), Queen Elizabeth Olympic Park (UK) and Freshkills Park (USA). We analysed 61 papers on landscape quality and the role of design, governments and participation. Concerning landscape quality, literature reports on functionality and certain aspects of experience rather than firmness (future values) of the transformation. While designers played an important role in large-scale landscape transformations, local governments seem not to be in control of the decision-making and participation was limited. The three cases illustrate how executed projects influence the discourse on landscape transformation and provide valuable insights for the design of renewable energy landscapes.

Introduction 3.1

Changing societal demands and values often result in the transformation of landscapes (Antrop, 2005). Landscape is here defined as “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe, 2000, p. 2). Landscape transformation involves a change in the dominant land use and the visual appearance of the landscape. Environmental design disciplines are active in an increasing number of landscape transformations. These disciplines, such as landscape architecture, urban design, spatial planning and architecture are concerned with the conscious shaping of the environment. Examples of designed transformations are the remediation of post-industrial landscapes (e.g. Landscape Park Duisburg Nord in Germany), urban regeneration (e.g. Madrid RIO in Spain) and large-scale climate adaptation (e.g. Rebuild by Design programme in the USA). These examples illustrate that landscape transformation can improve the quality of the living environment (Antrop, 2005; Bélanger, 2009).

A key driver of landscape transformation nowadays, is the transition to renewable energy (Bridge et al., 2013; Nadaï & van der Horst, 2010). This transition requires substantial interventions in the landscape. The renewable energy target for The Netherlands in 2030, for example, equals approximately 3000 additional wind turbines.
These targets will necessitate large-scale landscape transformations in denser populated areas (for the Dutch situation see Sijmons et al., 2017). Up until now, energy transition in denser populated areas is somewhat limited to small-scale renewable energy interventions (e.g. groups of wind turbines in business areas), while large-scale interventions are often located in remote areas (e.g. utility scale solar fields or wind parks in the USA and Spain).

Renewable energy interventions in denser populated areas prove to be controversial, because the resulting landscape transformations, alter landscape values of local stakeholders (Selman, 2010; Wolsink, 2007b). In several countries, because of this controversy, environmental design is increasingly engaged with renewable energy landscapes (A. Van den Brink & Bruns, 2012), although this is a relatively new topic for environmental design (Stremke & van den Dobbelsteen, 2013). Environmental designers can use landscape quality as a conceptual tool to address landscape values in the design of landscape transformations. In this paper, we consider landscape quality to consist of the following three criteria: functional, experiential and future values (Hooimeijer et al., 2001). The design of large-scale landscape transformation for renewable energy, similar to other landscape transformations, will benefit from a more encompassing approach to landscape quality.

General environmental design approaches and environmental design processes are widely discussed in literature (e.g. Sijmons, 1990; Steinitz, 1990). Others have built on this existing body of knowledge to advance environmental design processes for energy transition at the regional scale (Oudes & Stremke, 2018; Stremke, van Kann, et al., 2012). Large-scale interventions are featured in these studies from a *strategic* planning and design perspective, which involves long term processes of change and vision development (Kempenaar & van den Brink, 2018). Publications on the *operational* design of renewable energy landscapes, where the change in landscape quality becomes tangible (Wolsink, 2017), tend to focus on experience and preserving scenic values – a single aspect of landscape quality (e.g. Apostol, Palmer, et al., 2017). Little is known about the other two aspects of landscape quality and the operational design of large-scale landscape transformations for renewable energy transition. The resulting main research question is: *How is landscape quality addressed in large-scale transformation projects and what is the role of design, governments and participation?*

Because little has been published on designed large-scale renewable energy landscapes, we adopted a wider perspective and systematically reviewed the literature on three designed large-scale, constructed landscape transformations: Queen Elizabeth Olympic Park (London, UK), Room for the River Nijmegen-Lent (Nijmegen, the Netherlands) and Freshkills Park (New York City, USA). For ease of reading, we refer to the first project as 'Olympic Park' and the second as 'Nijmegen-Lent'.

The second section of this paper explains the selection of cases, describes the literature retrieval and analysis, and introduces the three cases. The third section introduces the key concepts underlying the research. The fourth section presents the results, organised according to the key aspects in the research question: landscape quality and the role of governments, design and participation. The research is discussed and conclusions presented in sections five and six respectively.

Method and materials 3.2

We used a case based approach to identify literature on the design of large-scale landscape transformations. Experts provided a large number of cases, which we subsequently reduced by means of a desk-study. A preliminary database search informed the final selection of cases, followed by a qualitative analysis of the case literature.

Case selection, literature retrieval and data analysis 3.2.1

Our systematic review of cases of landscape transformation aimed to "comprehensively identify, appraise and synthesise all the relevant studies on a given topic" (Petticrew & Roberts, 2008, p. 19). In an email questionnaire we asked international experts in the field of environmental design to provide us with suitable cases of landscape transformation. The cases had to (1) show transformation of landscape function and character, (2) be large in scale, (3) be completed or under construction, and (4) involve environmental designers. A total of 18 experts (72%) responded to the questionnaire, yielding 75 unique cases (see supplementary material). In a desk study, we reduced the long list to 16 cases. The existence of peer-reviewed literature was a condition for case selection, to maintain scientific rigour. A preliminary literature search revealed peer-reviewed papers for 8 of the 16 shortlisted cases; the few cases related to renewable energy transition had to be excluded.

For each of the eight remaining cases we performed a database search for peer-reviewed and grey literature in Scopus, Avery Index, CAB Abstracts and Google Scholar. The search query combined the concepts design, planning and architecture with (alternatives of) the case name. The level of detail in the literature ranges from in-depth accounts of the transformation process by researchers, for example by interviewing designers and stakeholders, to essays that position the cases in a wider societal or academic context, to papers written by authors immersed in the transformation process. We included literature dated from the initiation of the transformation project until autumn 2018.

We first screened the titles and abstracts, followed by full texts, and we identified additional literature by tracking references. We excluded literature that did not examine environmental design in relation to the transformation project. The three cases with most literature were selected: Olympic Park, Nijmegen-Lent and Freshkills Park. We analysed 61 articles: 19 on Olympic Park, 17 on Nijmegen-Lent and 25 on Freshkills Park. A graphic overview of the literature selection process for the three selected cases can be found in figure 3.1.

The conclusions drawn in this paper are the authors' interpretation of documented reflections of other researchers about landscape transformation. We performed a qualitative content analysis to systematically describe the meaning of qualitative data (Boréus &

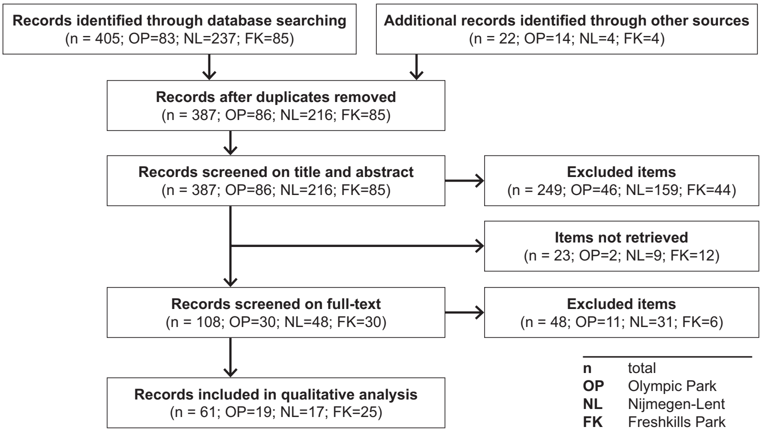
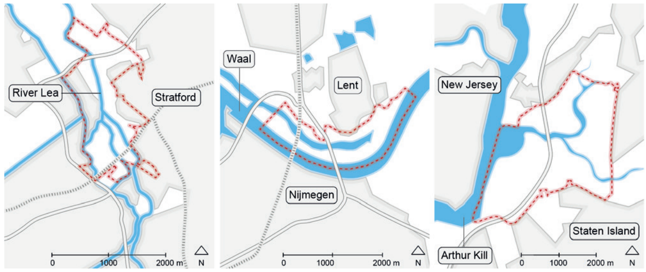


Fig. 3.1. Flow diagram of the literature selection process.

Bergström, 2017). We combined both inductive and deductive coding to identify four key aspects relevant to landscape transformations: landscape quality, governments, design and participation. Other aspects, such as project and programme management and legal procedures, may also affect landscape quality in transformation processes but are beyond the scope of this review.

Basic information on the three cases 3.2.2

The 2012 Olympic Games served as a catalyst to regenerate a part of East-London giving rise to the Olympic Park. Nijmegen-Lent is a Dutch climate adaptation project involving the creation of a river bypass and the relocation of a dike to increase discharge capacity of the river Waal. Freshkills Park concerns the transformation of the largest landfill of the United States into a public park. The key characteristics of the three cases are summarised in figure 3.2.



	Olympic Park	Nijmegen-Lent	Freshkills Park
Location	Lower Lea Valley in East London, United Kingdom.	Nijmegen, East of the Netherlands.	Staten Island, New York City, United States of America.
Size	230 hectare.	250 hectare.	890 hectare.
Timespan	2005 (Olympic bid) – 2014 (opening park).	2000 (announcement) – 2015 (construction).	2006 (masterplan) - present
Incentive	2012 Olympic Games.	National flood risk management program Room for the River consisting of 30+ indiviudual projects.	Closure of landfill.
Aim	Support Olympic Games and urban regeneration of East London (including jobs and houses).	Integrate flood protection measures with urban development, recreation and road infrastructure.	Reclamation of landfill as public park.
Main spatial interventions	Urban and public park development. Relocation of 250 businesses, 1500 residents and wildlife.	Creation of a river bypass and dike relocation. Demolition of 50 houses.	Capping of landfill and transformation to public park through ecological renewal.
Costs & funding (estimate)	Over 8000m pounds (approx. 9000m euros), funded by national and local government, and the National Lottery Fund.	Approx. 340m euros, primarily funded by national government.	650m dollars (570m euros), partially funded by city of New York.

Fig. 3.2. Key characteristics of the three cases.

3.3 Conceptual framework

The present review on landscape quality in large-scale landscape transformations aims to inform the design of large-scale renewable energy landscapes. In literature on energy landscapes, amongst others, three aspects are considered to be of critical importance: governments (Leibenath & Lintz, 2018), design (Stremke & van den Dobbelsteen, 2013) and participation (Devine-Wright, 2011a). We found the same aspects in the literature on the three aforementioned large-scale landscape transformation projects.

In each case, governmental bodies (in a multi-level governance constellation) proposed a landscape transformation and employed design to give form to the intended change. Local stakeholders were involved to various degrees. All four research components – landscape quality, governments, design and participation are introduced below.

Landscape quality 3.3.1

The key features of the landscape quality concept are presented as design criteria and are based on the Vitruvius triplet: utilitas, venustas and firmitas (Vitruvius, n.d.). 'Utilitas', or functionality, is translated as *use value*; 'venustas', or beauty/attractiveness, is translated as *experiential value*; and 'firmitas', or firmness, is translated as *future value* (Hooimeijer et al., 2001). Daniel (2001) states that landscape quality "arises from the relationship between properties of the landscape and the effects of those properties on human viewers" (p. 268). Much of the recent research focuses on the experiential component of landscape quality: *venustas* (e.g. Dramstad, Tveit, Fjellstad, & Fry, 2006; Vizzari, 2011).

We used the analytical framework for landscape quality by Hooimeijer et al. (2001), who relate each of the three aforementioned design criteria to four societal interests: *economic*, *social*, *ecological* and *cultural*. This framework enables each design criterion to be examined from the perspective of specific societal interests (fig. 3.3). As a result, landscape quality is specified by aspects that

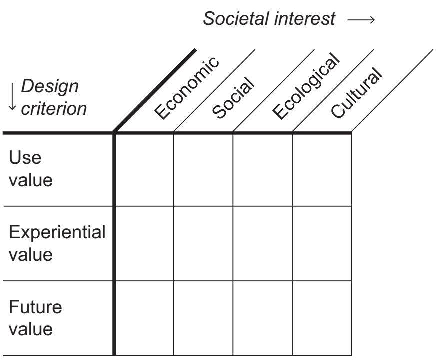


Fig. 3.3. Landscape quality framework: aspects of landscape quality are at the intersection of design criteria and societal interests.

relate to both design criterion and societal interest. Hooimeijer et al. (2001) mention several aspects. Aspects of landscape quality from an economic perspective for example, include connectivity and adaptivity to new uses. Aspects of social interest include improving social justice through spatial design and equal access to essential resources. The ecological perspective includes aspects such as contamination and future supply of resources. Aspects of cultural interest include beauty, identity/character and cultural heritage values.

3.3.2 Governments

Political considerations, economic development and environmental concerns have fueled a reorganisation of government in much of the Western world (Albrechts, Healey, & Kunzmann, 2003). Government decentralization has led to increased planning responsibilities of local authorities, and involvement of economic parties and civil society in decision-making (Healey, Khakee, Motte, & Needham, 1999). This trend is reflected in the literature on all three cases. We found that interactions between multiple tiers of government featured prominently in the cases. Interactions with non-state actors reported in the literature were mainly concerned with the participation of local stakeholders (see section 3.3.4). During the literature analysis, we considered the roles of government at the local, mid-level, national and supranational levels as well as the interaction between these levels.

3.3.3 Design

Design is both an activity, or process, and a product, such as a masterplan. We based our analysis of the design aspect in the cases on the ‘framework for theory’ by Steinitz (1990), as simplified by Stiles (1994), as it encompasses “all the design/planning issues which necessarily have to be addressed in the work undertaken by the landscape profession” (Stiles, 1994, p. 141). Stiles (1994) identifies three parts to the design process: (1) resource description, (2) initiation of change and (3) evaluation of the (changed) landscape resources. Resource description encompasses the analysis and representation of the existing landscape, its mechanisms and interrelationships. The initiation of change contains the projected changes and proposed interventions. The final part concerns who evaluates the design, how, and the criteria used. For the analysis of design in the transformation projects, we were particularly interested in the design process (e.g. activities, methods, products) and in the role of design in the transformation process.

Participation 3.3.4

As landscape transformations, by definition, alter the living environment of local stakeholders, we studied the participation strategies employed in the three transformation projects. We used the 'participation ladder' (Arnstein, 1969), which clusters eight participatory strategies in three categories, to identify and organise the strategies that were used to engage local stakeholders in the transformation project. The strategies citizen control, delegated power and partnership are considered as forms of 'citizen power'; placation, consultation and informing as degrees of 'tokenism'; and therapy and manipulation as 'non-participation'. In addition to the participatory strategies by which other actors involve local stakeholders, we identified strategies employed by local stakeholders *themselves* resisting the transformation process.

Results 3.4

We first present the reported effects of the transformation projects on landscape quality (3.4.1). We then report on the role of governments (3.4.2), followed by design (3.4.3) and participation (3.4.4). As this paper progresses, the results build on findings presented earlier in the section. Detailed qualitative descriptions supporting the results can be found in the supplementary material.

3.4.1 Landscape quality

For all three projects, reported effects of the transformation on the landscape can be related to all design criteria – most attention is given to *use value* and *experiential value* (fig. 3.4). Within *use value*, cultural interests are underrepresented. Within *experiential value*, social and cultural interests are highly represented. Within *future value*, social interests are underrepresented. The reported aspects of landscape quality reflect a distinctive focus of each transformation case, across several, but not all societal interests. For Olympic Park this concerns social housing and economic profits from urban development in relation to the investments made for the Olympic Games. For Nijmegen-Lent this concerns the combination of flood protection with urban development and the creation of a riverpark. For Freshkills Park this concerns the ecological remediation of the former landfill to a park. The diversity of landscape quality aspects shows that besides the main objective of each project, multiple purposes or co-benefits related to existing local issues or future demands are addressed in the transformation. In the following, we will present the reported effects according to the four societal interests, starting with *economic interest*.

Societal interest ⟶

↓ *Design criterion*	Olympic Park				Nijmegen-Lent				Freshkills Park			
	Economic	Social	Ecological	Cultural	Economic	Social	Ecological	Cultural	Economic	Social	Ecological	Cultural
Use value	12	11	3	3	3	3	6	1	1	0	5	4
Experiential value	6	13	2	9	0	0	0	7	0	1	5	1
Future value	7	1	5	0	4	0	3	1	0	1	5	8

Fig. 3.4. Mentioning of effects of the transformation on landscape quality across the design criteria and societal interests: often (dark grey), occasionally (light grey) and seldom or never (white) relative to the individual case, including absolute numbers of mentioning.

In all projects, an important aspect of landscape quality with respect to *economic interest* is the connection with the wider geographical area. Furthermore, *economic future values* (bottom left cell for each case) reflect the potential of the area to accommodate future (urban) developments. Aspects of social injustice feature prominently in the literature on *social interest*. While amenities such as a public park are mentioned as positive effects, many reported negative effects concern the accessibility of these amenities to various groups, especially in Olympic Park (Davis & Thornley, 2010; Waters, 2016).
Positively formulated aspects of landscape quality, such as water safety, wildlife and habitat creation, relate to the *ecological interest*. A central item is the reintroduction or restoration of natural functions and values, both as patches and as green infrastructure. The future values address themes such as renewable energy provision, circular economy and climate adaptation.

The *cultural interest* of landscape quality is reflected in all three projects through both 'traditional' *experiential values* such the aesthetic experience of landscape features as well as symbolic future values, such as Freshkills Park as representation of sustainability (Hutchinson, 2015). Olympic Park and Nijmegen-Lent revolve mainly on experiential value and Freshkills Park on future values.

Few trade-offs between aspects of landscape quality are reported. Most of them are influenced by economic forces, such as in the case of Olympic Park, the decreasing amount of social housing as a consequence of the need to recoup investments (Hoolachan, 2017) and the cancelling of renewable energy projects (Smith, 2014b) as well as a leisure centre (Shirai, 2014) for cost reasons.

The literature reveals that landscape quality operates on different scale levels, with both beneficial and adverse effects. In Nijmegen-Lent, landscape quality objectives explicitly included urban aspects, which allowed the national flood risk management programme to tie in with local issues, or a "layering of different demands on the same site" (Redeker, 2018, p. 317). This has even raised water safety levels above those technically required (Heeres, van Dijk, Arts, & Tillema, 2017) resulting in the cancelling of several other flood risk measures (Havinga & der Nederlanden, 2018). For Olympic Park, on the other hand, Hoolachan (2017) stresses the tensions between different government views of sustainability. The priority for economic sustainability at the national level has had adverse effects on social sustainability at the local level, such as the displacing of existing communities.

3.4.2 Governments

During the bid phase for Olympic Park, a patchwork of existing local partnerships collaboratively developed a regeneration strategy (Owens, 2012). The increasing pressure to deliver the site for the Olympic Games gave way to a more top-down process (Davis, 2011; Owens, 2012; Smith, 2014a). The main control over the project lay with a mid-level dedicated planning agency, to which the local boroughs had delegated their planning powers (Davis, 2011; Shirai, 2014). The individual boroughs were participating in the decision-making process through various boards.

The planned location for the flood risk management measures of Nijmegen-Lent was previously earmarked for urban development by the municipality. The national and local governments negotiated to resolve this conflict and empowered the local government to take the lead in the transformation (Heeres et al., 2017), supported by the provincial government (Winnubst, 2011). Next to flood risk management, landscape quality was a second objective of the programme, supported by nationwide descriptions of landscape characteristics (Busscher et al., 2018). The national government coordinated the Room for the River programme, with strict constraints on the required hydrological effects for each individual project (F. Klijn et al., 2013). Quality control mechanisms were supervised by an independent multidisciplinary Quality team (F. Klijn et al., 2013). This 'Q-team' made unsolicited recommendations and was unconstrained by formal governmental or institutional opinions on landscape quality (Heeres et al., 2017; F. Klijn et al., 2013). One effect of the Q-team was the employment of landscape architects to accommodate the standards set by the Q-team and consequently raising landscape quality (Redeker, 2018).

The Freshkhills Park project is being run by the New York City Department of Parks and Recreation, while the local Staten Island administration has little influence on the decision making (Hutchinson, 2015). NYC Parks actively employs the experiential value of the site to engage communities and to raise both interest and funds for the three development phases (Hutchinson, 2015).

Design 3.4.3

Design process: resource description, initiation of change, evaluation 3.4.3.1

Within *resource description*, the literature on the Olympic Park project reports a lack of in-depth understanding of the local social topography and how residents experience their landscape (Davis, 2011; Davis & Thornley, 2010; Evans, 2014). This explains many of the reported negative effects on landscape quality from a societal perspective (3.4.1). Environmental design reportedly plays an important role in this process, as representing and visualising the Lower Lea Valley as a deprived site is used to justify the large public expenses (Davis, 2011).

Within the *initiation of change*, the integration of the existing landscape into the design is an aspect of landscape quality to be addressed. The clearing of the Olympic Park site (most houses and businesses were relocated and the entire area was remediated) is framed by scholars and stakeholders alike as a 'tabula rasa' approach (Davis, 2011; Waters, 2016). This made it difficult for the designers to "provide a sense of the future 'character' or 'identity' of legacy for local stakeholders" (Davis, 2011). Regarding Freshkills

Park, Pollak (2007, p. 89) argues that for transformations of such scale, the perspective of a “stable whole” is an illusion and that the identity of the site is dynamic and heterogenic.

Another theme is the use of representations, products of the design process. Representations are reported to be subject to political control in Olympic Park (Davis, 2011) and to obscure negative effects in Freshkills Park (May, 2008). However, in Nijmegen-Lent, designs and drawings were reportedly helpful in understanding concepts such as landscape quality (Nikologianni, Moore, & Larkham, 2017) and stakeholders in being open to new ideas in a collaborative process (Heeres et al., 2017).

The three projects comprise a variety of formal and informal *evaluations of design proposals*; with different degrees of success. On Olympic Park, the objective of the Legacy Masterplan Framework (LMF) was to guide development after the Olympic Games and it formed the basis for other spatial visons. Davis (Davis, 2011) stresses the absence of alternative scenarios in the LMF, as well as the absence of clear evaluation criteria for the proposed spatial scenario. For Freshkills Park, Hutchinson (2015) reports on the lack of investigated alternative options to a park. The literature on Nijmegen-Lent reports that alternative designs were evaluated but that design criteria were either disputed (Winnubst, 2011) or unknown to the inhabitants (Cuppen & Winnubst, 2008). In addition, literature suggests that the final decision was based on the firmness (i.e. *future value*) of the proposed intervention (Cuppen & Winnubst, 2008; Winnubst, 2011).

3.4.3.2 Role of design in the transformation process

Designs for Olympic Park reportedly had an important function in the initial visioning process for the Olympics (Evans, 2014) as a quality control framework for the inevitable changes during the transformation process (Nimmo, Frost, Shaw, & McNevin, 2011) and in projecting value and need with regard to the urban legacy

(Davis, 2011). Despite the strong design-led approach (Neal, 2011), the actual catalyst effect of the urban regeneration was highly dependent on the political and economic context (Davis, 2011).

The design process for Nijmegen-Lent was controlled by the designers (Heeres et al., 2017), who worked in tandem with the process manager (Hulsker, Wienhoven, van Diest, & Buijs, 2011). Experienced designers in the role of lead designer and as part of the Q-team functioned as links between the technical design and the integrative spatial design. An overall collaborative approach to design is reported, which resulted in shared solutions and the support by engaged inhabitants (Heeres et al., 2017).

The design competition for Freshkills Park served as an impetus for the transformation, which suggests that in this project a similar importance is attributed to designers. Environmental designers led an large multidisciplinary team and their work is mentioned as one of the key drivers guiding the shape of the park (Hutchinson, 2015). However, May (2008) states that design is being used to recast the image of Freshkills Park in “the collective memory of a population”, with the result that the “horrible realities of our Modern American lifestyles” are ignored (May, 2008, p. 103). Hutchinson identifies several ‘contingencies’ or events that altered the original vision for Freshkills Park, such as the terrorist attack of 9/11, pressure from the Staten Island administration, and Superstorm Sandy. These contingencies “changed the ideas of what a park should be” (Hutchinson, 2015, p. 169): a new range of values, roles and functions are now associated with parks.

Participation 3.4.4

Participatory strategies 3.4.4.1

Participatory strategies have been identified in all three projects and literature primarily discusses the involvement of inhabitants. The higher-level participatory strategies *citizen control*, *delegated*

power and *partnership*, according to the literature, have not been applied in any of the three cases.
In the Olympic Park literature, we identified *consultation* and *informing strategies*. The criticism regarding *consultation* relates to the extent to which local citizens could exert genuine influence. Although the scale and complexity of this project is considered too big for consensus building (Davis, 2011; Evans, 2014), the *consultation strategies* employed are criticised for not aiming to influence the design outcome but to 'instil' ownership (Davis, 2011). In Arnstein's categorisation this could be considered a form of *therapy*. The workshops for the draft version of the LMF were attended by 10 to 40 people, which "represented a tiny fraction of the population of each of the boroughs" (Davis, 2011).
The participation strategies identified for Nijmegen-Lent are *placation*, *consultation* and *informing*. Inhabitants joined advisory boards (*placation*) and formal (Winnubst, 2011) and informal *consultation* events were organised (Heeres et al., 2017). *Informing strategies* are also reported (Rijke, van Herk, Zevenbergen, & Ashley, 2012). In the phase of the environmental impact assessment, the participatory process was subordinate to the political process (Cuppen & Winnubst, 2008).
Similarly, the literature on Freshkills Park reports *placation*, *consultation* and *informing*. *Consultation* resulted in "consensus building in the community and ultimately encouraged support for the reclamation" (De Sousa & D'Souza, 2011) and the inclusion of public preferences in the masterplan (Sugarman, 2009).

3.4.4.2 Participation and design

In Nijmegen-Lent, environmental designers invested in building professional relationships with inhabitants (by means of e.g. excursions), which enabled a mutual exchange of thoughts on important issues. Overall, participation is reported to have had a positive effect on the landscape quality (Hulsker et al., 2011) and possibly contributed to the realisation of the project within the envisioned timeframe (Heeres et al., 2017).

Public meetings on Freshkills Park revealed community preferences, including renewable energy provision, an educational programme (De Sousa & D'Souza, 2011) and the parks infrastructure (Hutchinson, 2015). Some of those functions, it has been argued, may have otherwise been introduced by governmental authorities (Hutchinson, 2015).

The design for Olympic Park was primarily influenced by well-organised specific interest groups (Davis, 2011). The resulting changes did not necessarily reflect a shared vision. In general, it was not made clear how the output of the consultation events could influence the design and there appeared to be no difference attributed to individual or shared views. More specifically, a structured analysis or evaluation of the outcomes of consultation was absent, allowing the environmental designers to 'cherry-pick' (Davis, 2011).

Indication of resistance 3.4.4.3

In addition to these participation strategies, we found evidence of confrontation between inhabitants and governments. Inhabitants were reportedly pro-active in demanding a role in the planning process for Nijmegen-Lent, in response to the initial plan to demolish 50 houses (Winnubst, 2011). This confrontational approach was fueled by local attitudes to government based on the previous experience of the annexation of the small town of Lent by the city of Nijmegen (Redeker, 2018; Winnubst, 2011). Opposition to Freshkills Park has to do with the landfill itself and the suitability of the site as a park (Hutchinson, 2015). Resistance to Olympic Park focused on the relocation of existing land uses, such as allotments and cycling facilities. Opposition was also fueled by an evaluation of the existing landscape that was not shared by local stakeholders (Davis, 2011) and the radical changes to the landscape for inhabitants (Hoolachan, 2017).

3.5 Discussion

3.5.1 Design of large-scale landscape transformations

The literature on the three projects points to a central and integrative role of design. However, we expected certain topics related to *design* and *designing* to be discussed more extensively in the literature on large-scale landscape transformations. Firstly, literature only incidentally referred to the use of evidence-based scenarios or alternative futures to facilitate the *initiation of change* (3.3.3). Contrastingly, an increasing number of scholars are concerned with methods to generate alternative futures, supported by scientific knowledge (e.g. Hoversten & Swaffield, 2019; van den Brink & Bruns, 2012). This suggests a gap between current scholarly thinking and design practice. Secondly, the reviewed literature stresses that criteria to *evaluate* design(s) are either absent, unknown to, or disputed by local stakeholders. Stremke (2015, p.7) argues that for the design of energy landscapes “criteria have to be selected, made explicit, and prioritised by stakeholders and experts”. The literature on the three landscape transformations reveals no attempts to accomplish such systematic and transparent evaluation. Thirdly, the recurring attention for co-benefits in all three projects, suggests *multifunctionality* as a consistent and sustained objective in large-scale landscape transformations. Recent research suggests that multifunctionality is also a characteristic of certain types of energy landscapes: landscapes with wind turbines are an example of so-called ‘component energy landscapes’ that feature concurrent land uses. ‘Entity energy landscapes’ such as surface coal mines, on the contrary, are characterised by a mono-functional land use and sharp physical boundaries (Pasqualetti & Stremke, 2018). Our three cases, however, are large, distinct landscape entities that comprise multiple land uses. This opens up the possibility of future large-scale renewable energy landscapes that may embody the spatial expanse and physical boundaries of *entity* energy landscapes and yet permit the multifunctionality of *component* energy landscapes. This would enable a scaling up of the energy transition in some landscapes, while allowing the integration of other functions and, not unimportantly, ease the preservation of landscapes with cultural or natural values elsewhere.

Governance levels and interaction 3.5.2

The results of this review align with the rise of the mid-level governance level, as it “seems to offer a functional area within which the interactions of economic relations, environmental systems and daily life time-space patterns can be better understood than at a higher or lower level of government” (Healey, 2007, p. 23). The exception is the Nijmegen-Lent case, which the literature shows, revolved primarily around the interaction between local and national government. The strong influence of the national government in this case can be explained by the need to coordinate more than 30 flood risk management projects across the country.

Participation versus co-creation 3.5.3

Participatory strategies have been employed with varying degrees of success. The literature suggests that participation was used mainly in a one-way fashion, rather than to encourage active engagement in the design process. Literature also reports the use of rather conventional methods, such as public meetings, workshops and site visits. Advanced approaches to engage stakeholders, such as web-based decision support tools (e.g. Grêt-Regamey et al., 2017) or participatory mapping (e.g. Stremke & Picchi, 2017), are not mentioned. Quite the contrary has been described: during consultation events on Olympic Park, for example, participants were presented with three dimensional puzzle pieces which only fitted in one place, challenging them to find “the right place, rather than [...] identify creative alternatives” (Davis, 2011).

3.6 Conclusions

3.6.1 General conclusions

This study set out to investigate large-scale landscape transformation projects to advance the environmental design of renewable energy landscapes, by examining the following research question: *How is landscape quality addressed in large-scale transformation projects and what is the role of design, governments and participation?*

Literature showed that landscape quality is addressed in all three cases by the design criteria *functionality* (use value), *experience* (experiential value), and *firmness* (future value), of which the latter receives the least attention. Literature attributes many beneficial aspects of landscape quality to the projects. These aspects can be distinguished as *economic*, *social*, *ecological* and *cultural* interests, but not all interests are mentioned equally in the literature. Each project has a distinctive focus within the larger realm of landscape quality. Adverse effects were scarcely reported as trade-offs with other qualitative aspects, but were linked to aspects outside the realm of landscape quality, such as economic costs or political context.

The role of mid-level governments was to control the transformation, resulting in an advisory role of local governments. Which government body is in control and how it asserts power is not necessarily fixed throughout the transformation process. Environmental designers played an important role in analysing the existing site and developing designs for the landscape. Nevertheless, the literature shows that important decisions were made *before* environmental designers have been involved. Also, external events and conditions led to changes in the design, or to alterations of functions and values ascribed to the transformation.
The role of participation in the transformation projects was limited and participation strategies were somewhat limited to consultation and informing. While literature indicates that inclusion

of local issues or preferences, potentially informed by participatory strategies, results in synergies and support for the transformation, poor integration of participation in the design process endangers genuine influence of local stakeholders. Regardless of the levels of government involved, the type of design process and participation strategies, all three cases feature some resistance to the large-scale landscape transformation.

3.6.2 New knowledge contributing to renewable energy transition

This review resulted in insights not only for large-scale landscape transformation projects, but also for renewable energy transition. Where the three studied cases show consideration of all three landscape quality criteria, primarily *functionality* and *experience* are addressed in energy landscape debates. The cases incorporate multiple functions, but this is not yet common practice for energy landscapes (see for solar energy e.g. Scognamiglio, 2016). Aspects of *firmness*, or the future value of energy landscapes, are for example reversibility and recycling of energy landscapes. Although energy landscape literature stresses the importance of this criterion (Pasqualetti & Stremke, 2018), we are not aware of it being substantially incorporated in renewable energy projects yet.

The review showed that the large-scale character of the landscape transformation complicates the development of a new and yet meaningful landscape character. Distinctive for the transition to renewable energy (as opposed to the three cases) is that standardised technological and currently unfamiliar objects are introduced into the landscape. Introduction of energy technologies, such as wind turbines and photovoltaic (PV) panels, will therefore require additional and concerted efforts to avoid a further 'erosion' of landscape diversity at the larger scale. Inclusion of local issues and stakeholder preferences, as mentioned in the general conclusions, can contribute to maintain and strengthen landscape diversity.

In all three cases we found that governments influence how large-scale landscape transformations are evaluated. Similarly, governments are in a position to determine qualitative criteria for energy landscapes and evaluate projects on characteristics other than mere quantities of renewable energy provision (e.g. landscape quality in the Dutch Climate Agreement, Klimaatakkoord, 2019). The use of qualitative criteria will necessitate a further specification of what is meant by 'landscape quality' and 'sustainability'. Specification of criteria can prevent different interpretations on, for example, different spatial scales. A first step in this direction could be to formally include landscape quality as an objective in energy projects and to coordinate quality control at both national and local levels, as reported in the literature on Nijmegen-Lent. One of the prerequisites for such an endeavour is to have solid and comprehensive understanding of the current landscape characteristics.

The three cases illustrate how executed large-scale landscape transformation projects influence the discourse on landscape transformation. Without downplaying the potential adverse effects of large-scale landscape transformations, the discourse on large-scale renewable energy landscapes (and beyond) will benefit from the continued study of and reflection on projects that embrace renewable energy *and* landscape quality.

Acknowledgements
The authors like to thank the scholars and experts that provided us with an extensive overview of large-scale landscape transformation projects. Furthermore, we thank the anonymous peers for reviewing the manuscript.

Entrance of the publicly accessible solar park 'de Kwekerij', in Gelderland, the Netherlands (source: author).

Chapter 4

Next generation solar power plants? A comparative analysis of frontrunner solar landscapes in Europe

Dirk Oudes
Sven Stremke

Renewable & Sustainable Energy Reviews, 145. 2021

Abstract

Solar power plants transform the existing landscape. This landscape change raises concerns about *visual impact*, land use competition and the *end-of-life stage* of solar power plants. Existing research stresses the need to address these concerns, arguing for a combined spatial arrangement of solar power plant and landscape: solar landscape. Solar landscapes share the aim to achieve other benefits (e.g. reducing visibility, habitat creation) in addition to electricity generation, yet empirical evidence on solar landscapes is scarce. This comparative analysis of 11 frontrunner cases aims to contribute to the understanding of solar landscapes, by studying the spatial properties *visibility*, *multifunctionality* and *temporality*. Visibility is reduced in all cases. In five cases, however, visibility is partly enhanced in combination with recreational amenities. Between 6 and 14 provisioning, regulating and cultural functions were found in the cases. Functions were located beneath arrays, between arrays and adjacent to photovoltaic patches. Temporal considerations were identified in most cases, yet only two cases introduced new landscape features to enhance future use of the sites after decommissioning. Across cases, this case study shows how contemporary concerns about solar power plants, such as visual impact, land use competition and the end-of-life stage are addressed. Although the cases altogether present a portfolio of measures responding to societal concerns, the full potential of the three key properties is yet to be explored. Furthermore, this comparative analysis highlights the need to address emerging trade-offs between spatial properties and to discern between different types of solar landscapes. The used analytical framework may supplement the assessment of solar power plants to examine not only *negative*, but also *positive* impacts.

Introduction 4.1

Solar power plants (SPP) have been constructed at an increasing rate over the past decades (Comello et al., 2018). These power plants, consisting of ground-mounted photovoltaic (PV) arrays and electrical infrastructure, transform the landscape (Carullo, Russo, Riguccio, & Tomaselli, 2013; Ioannidis & Koutsoyiannis, 2020; Pasqualetti & Stremke, 2018; Picchi et al., 2019; Scognamiglio, 2016; Selman, 2010). Landscape is here defined as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000). SPP not only transform existing landscape patterns, that is the size, shape, arrangement and distribution of individual landscape elements (Farina, 2006), but also how the landscape is perceived by inhabitants and other landscape users (Bevk & Golobič, 2020; Delicado, Figueiredo, & Silva, 2016).

These landscape transformations raise societal concerns about visual impact, land use competition and the end-of-life stage. Visual impact is a key concern with respect to SPPs (Apostol, Palmer, et al., 2017; Scognamiglio, 2016; Wolsink, 2017). SPPs can have visual impact due to their scale, color, pattern and artificiality (Merida-Rodriguez et al., 2015; Sánchez-Pantoja et al., 2018; Scognamiglio, 2016; Torres-Sibille, Cloquell-Ballester, Cloquell-Ballester, & Artacho Ramírez, 2009) and, as a consequence, influence perception adversely (Bevk & Golobič, 2020). Furthermore, SPPs require land previously occupied by other uses and therefore increase land use pressure. SPPs can, for example, result in the loss of agricultural land (Chiabrando et al., 2009; Tsoutsos, Frantzeskaki, & Gekas, 2005) and also affect habitats, as vegetation is degraded or removed (Chiabrando et al., 2009; Hernandez et al., 2014; Turney & Fthenakis, 2011) and soil is moved or covered (Tsoutsos et al., 2005). These land use changes can be substantial in a short period of time (Poggi, Firmino, & Amado, 2018) and require recovery time for vegetation and soil (Turney & Fthenakis, 2011). The common life-span of SPP is 20-30 years, due to the life expectancy of the modules (Fthenakis &

Kim, 2009). Concerns about the end-of-life stage of SPPs are whether decommissioning will take place (Windemer, 2019) and if so, what the state of the resulting landscape will be (Semeraro et al., 2018). All these three groups of concerns have a clear spatial dimension and can result in negative responses of local inhabitants and other landscape users towards SPP (Bevk & Golobič, 2020; Roddis et al., 2020; Scognamiglio, 2016; Wolsink, 2017). Consequently, these responses may threaten the progress of the energy transition (Batel, Devine-Wright, & Tangeland, 2013; Wüstenhagen, Wolsink, & Bürer, 2007).

Existing research points to the need of SPP to address societal concerns, by attending to three key properties: visibility, multifunctionality and temporality. *Visibility* refers to whether an SPP is observable by landscape users from a certain location (Apostol, Palmer, et al., 2017; Fernandez-Jimenez et al., 2015). Visibility can be changed, for example, by using vegetation for screening or adjusting the size of the SPP to the characteristics of the host landscape (Bevk & Golobič, 2020; Scognamiglio, 2016; Stremke & Schöbel, 2019). *Multifunctionality* refers to the capacity of a certain area of land to serve multiple purposes and fulfill several needs at the same time (Brandt & Vejre, 2004; Lovell & Johnston, 2009; Selman, 2009). Electricity generation in SPP can be combined, for example, with ecological restoration (Hernandez et al., 2019; Moore-O'Leary et al., 2017; Randle-Boggis et al., 2020; Semeraro et al., 2018) and outdoor education (Scognamiglio, 2016; Semeraro et al., 2018). *Temporality* is a relatively new, emerging topic in energy landscape research and refers to the dynamic character of SPP (Pasqualetti & Stremke, 2018; Windemer, 2019). Elements introduced during the SPP construction have the potential to enhance the future landscape or inhibit certain developments after decommissioning of the solar infrastructure (Pasqualetti & Stremke, 2018; Semeraro et al., 2018). Temporality is also relevant in the context of recycling energy landscapes: renewable energy technologies are introduced at sites formerly used for conventional energies. In Nijmegen in

the Netherlands, for example, an SPP is built on a site previously occupied by a coal-fired power plant.
Others have recently introduced the concept of ‘photovoltaic landscape’ or ‘solar landscape’ that encompasses a joint approach between SPP and landscape (Lobaccaro et al., 2019; Scognamiglio, 2016). This approach involves a combined spatial arrangement of SPP and landscape where solar infrastructure is adapted (e.g. height of arrays, distance between arrays) and ‘landscape features’ are included (e.g. hedgerows, wildflower meadows). While contemporary spatial arrangements of SPPs are optimized for energy and/or economic benefits, spatial arrangements of solar landscapes aim to achieve other benefits (e.g. reducing visibility, habitat creation) in addition to electricity generation (Apostol, Palmer, et al., 2017; Merida-Rodriguez et al., 2015; Semeraro et al., 2018; Stremke & Schöbel, 2019). For this paper, we make use of and build upon the novel concept of solar landscapes to examine SPPs that pay attention to visibility, multifunctionality and temporality.
However, few studies have investigated the visual, functional and temporal properties of constructed cases of solar landscapes. Lobaccaro et al. (2019) is the only study that examines spatial properties of built solar landscapes. They partly address visibility and multifunctionality and do not discuss temporality. Anyhow, most studies overlook the spatial arrangement of SPP and landscape (Armstrong, Ostle, & Whitaker, 2016; Chiabrando, Fabrizio, & Garnero, 2011; Torres-Sibille et al., 2009), focus on a single property (Apostol, McCarty, & Sullivan, 2017; Merida-Rodriguez et al., 2015; Randle-Boggis et al., 2020), or present theoretical discussions on what solar landscapes *can* be or *should* be (Hernandez et al., 2019; Scognamiglio, 2016; Stremke & Schöbel, 2019), but not on what solar landscapes *are*. The following research question is central to this paper: *what are the visual, functional and temporal properties of frontrunner solar landscapes in Europe?*

This research aims to contribute to the growing body of knowledge on solar landscapes by analyzing and comparing the spatial

4

properties of constructed solar landscapes in Europe. This study used expert consultation and desk-study to identify so-called 'frontrunner' SPPs. Insights in the innovative properties of these frontrunner cases constitute a vital contribution to the debate on how societal concerns about SPP can be resolved. Due to the novelty of the topic, an analytical framework was developed for the case study, based on a literature review. This framework focusing on visibility, multifunctionality and temporality of SPP may also enrich environmental impact assessments and multi-criteria decision analyses of SPP in response to prominent societal concerns. Furthermore, a better understanding of frontrunner cases, in combination with the cultivation of solar landscape vocabulary, is believed to support policy and decision makers, SPP developers, designers and other stakeholders to conceive solar landscapes supported by landscape users (Bevk & Golobič, 2020; De Marco et al., 2014; Scognamiglio, 2016).

The second section of this paper presents the methods and materials. The framework for the case analysis is presented in section three. The results and discussion section first presents the solar infrastructure and landscape feature properties, followed by visibility, multifunctionality and temporality. The paper is concluded in section five.

4.2 Methods and materials

4.2.1 Case-study approach

This study examines the spatial properties of built solar landscapes. We adopted a case-study approach in our research, as this allows for the description of a contemporary phenomenon in its spatial context (Yin, 2009). We used a multiple embedded case design to document and compare a high variety of spatial properties across all cases (Yin, 2009).

Case selection 4.2.2

Our research focuses on the Netherlands, the United Kingdom, Germany and Italy, as these countries have shown increasing attention for solar landscapes. In addition, the travel distance and language of these countries allowed us to study the cases within the time and resource provided. We aimed to study cases of SPP that were recognized for being at the front of addressing societal concerns and providing functions additional to electricity generation. We identified so-called 'frontrunner cases' through recognition in the form of awards granted, for example by solar industry, and expert judgement. We reached out to photovoltaic and environmental design experts using personal contacts and approaching photovoltaic developer and environmental design associations[1]. We asked the experts to provide us with the names of SPPs that provided benefits besides to electricity generation, such as ecological restoration, recreation or aesthetics.

The expert contact and the desk study on SPP awards resulted in a longlist of over 30 cases. A quick-scan was used to identify their main spatial properties. Based on the quick-scan, we selected cases that complied to two criteria that are key to solar landscapes. First, the case needed to demonstrate a combined spatial arrangement of SPP and landscape. Second, the case needed to include new landscape features in addition to solar infrastructure, for example water retention areas, opportunities for recreation or habitat patches. For each case, these criteria were evaluated using design maps or project documentation and confirmed by satellite imagery or field visits. We diversified according to spatial properties, as well as landscape type and project scale; variety in the latter two are expected to increase the variety of spatial properties (Apostol, Palmer, et al., 2017; Stremke & Schöbel, 2019). Ultimately, 11 cases were selected (fig. 4.1 and table 4.1).

[1] Associations in Germany: German Solar Association (BSW) and German Association of Landscape Architects (BDLA). The Netherlands: Holland Solar, Netherlands association for garden- and landscape architecture (NVTL) and Dutch association of urban designers and planners (BNSP). Italy: Italian Association of Landscape Architecture (AIAPP). United Kingdom: Solar Trade Association and Landscape Institute.

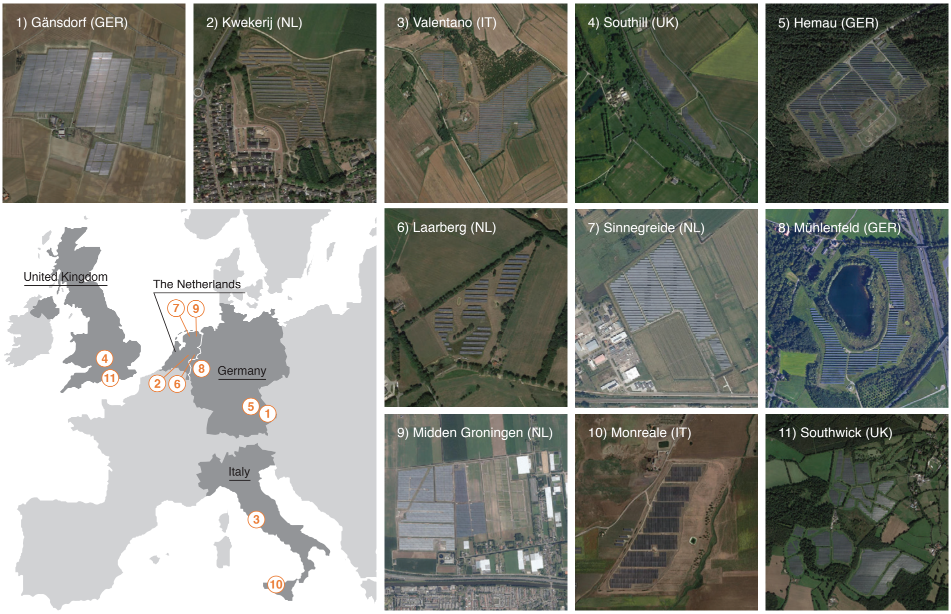


Fig. 4.1. The 11 selected cases. Scale of the images varies, see table 4.1 for actual size of the cases (source satellite imagery: Google Earth and Kadaster).

Table 4.1. General information on the 11 cases.

	GENERAL			SOLAR INFRASTRUCTURE			
Cases	Latitude	Year of construction	Country	Power (MWp)	Size (ha)	Energy density (MWp/ha)	Land Area Occupation Ratio (LAOR)
1. Gänsdorf	48'48'12	2009	Germany	54,0	180,9	0,30	22%
2. Kwekerij	52'03'24	2016	Netherlands	2,0	7,1	0,28	16%
3. Valentano	42'35'19	2011	Italy	6,0	17,6	0,34	23%
4. Southill	51'51'31	2016	United Kingdom	4,5	18,1	0,25	16%
5. Hemau	49'02'10	2002	Germany	4,0	18,0	0,22	20%
6. Laarberg	52'06'43	2018	Netherlands	2,2	6,4	0,35	21%
7. Sinnegreide	53'26'04	2018	Netherlands	11,8	12,0	0,98	53%
8. Mühlenfeld	51'27'51	2013	Germany	3,5	24,4	0,14	10%
9. Midden-Groningen	53'10'48	2019	Netherlands	103,0	121,2	0,85	61%
10. Monreale	37'52'07	2010	Italy	5,0	28,0	0,18	13%
11. Southwick	50'52'50	2015	United Kingdom	48,0	83,4	0,58	35%

Research process 4.2.3

For each case, we performed a spatial analysis (Frankl, 1968; Steenbergen, 2008) and studied accompanying project documentation. The spatial and document analysis was subsequently verified by field observations. To start, the spatial analysis was conducted using a case-study protocol, to strengthen consistency of the analysis by the multiple researchers involved (Yin, 2009). This protocol was tested and further refined by analyzing two contrasting cases. The properties that were used to guide the spatial analysis are presented in section 4.3. Results of the analysis were presented in maps, text and tables. Data used for the mapping were design maps as well as recent and historical satellite imagery.
Next, project documentation was used to confirm and specify the spatial arrangement of SPP and landscape. The document analysis was mainly based on project reports and websites that were collected until June 2020. This data was occasionally complemented

		HOST LANDSCAPE	
	Technology	Landscape type	Previous land use
	Fixed tilt	Open agricultural	Agriculture: highly productive arable land
	Fixed tilt	Semi-open bocage landscape	Agriculture: low grade, tree nursery
	Fixed tilt	Open agricultural	Agriculture: highly productive arable land
	Fixed tilt	Semi-enclosed valley side farmland	Agriculture: extensive, low grade
	Fixed tilt	Enclosed, agricultural landscape with large evergreen forests	Brownfield: military ammunition depot within production forest
	Fixed tilt	Semi-open bocage landscape	Agriculture: intensive grassland and corn production
	Fixed tilt	Open agricultural	Agriculture: grassland
	Fixed tilt	Semi-open bocage landscape	Brownfield: gravel mining and nature development
	Fixed tilt	Open peat landscape	Agriculture: arable and grassland
	Single-axis tracker	Undulated open agricultural landscape	Agriculture : extensive, wheat and olive groves
	Fixed tilt	Enclosed, mixed farmland/woodland	Agriculture: arable and grassland

by insights from case informants. Finally, intermediate results of spatial and document analysis were enhanced and verified by field observations that took place from May until October 2019.

The results of the individual cases were synthesized to identify similarities and differences across cases (Yin, 2009). Maps, textual descriptions and numerical date were aggregated using tables and examined along the categories of the framework for case analysis (section 4.3). Aggregating the data of all cases helped to profile the individual cases, specify the framework for case analysis and subsequently enhance the cross-case synthesis in an iterative manner.

4.3 Framework for case analysis

The framework for case analysis was developed deductively (drawing from literature) and inductively (drawing from the cases) through multiple iterations of application and reflection. The framework was used to analyze the spatial properties of the embedded cases. The larger host landscape was analyzed as well, as this forms the backdrop for the spatial properties. Solar infrastructure and landscape features refer to physical changes in the landscape that can, to some extent, be examined independently (e.g. Armstrong et al., 2016; Massi Pavan, Mellit, & De Pieri, 2011). Contrastingly, *visibility*, *multifunctionality* and *temporality* are *emergent* properties: properties of the whole revealed by interactions between individual characteristics (Barrett, Farina, & Barrett, 2009; J. A. Klijn, 1995). These properties of solar landscapes were analyzed by jointly examining *solar infrastructure* and *landscape features* (Lobaccaro et al., 2019; Scognamiglio, 2016) (fig. 4.2). This section first introduces the solar infrastructure and landscape feature properties (4.3.1), followed by the procedure for the study of emergent properties visibility, multifunctionality and temporality (4.3.2).

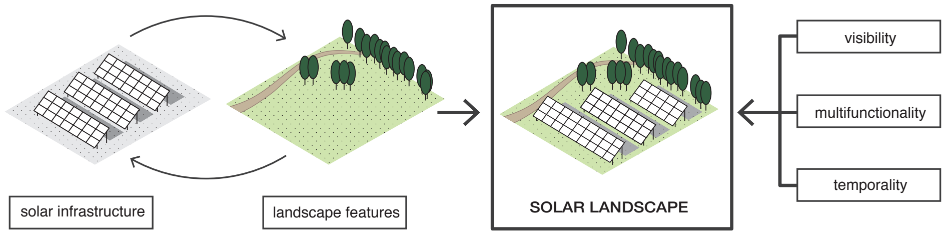


Fig. 4.2. Solar infrastructure and landscape feature properties refer to physical changes that can be examined independently. Visibility, multifunctionality and temporality are emergent properties of the solar landscape as a whole.

Solar infrastructure and landscape features 4.3.1

The spatial analysis started by identifying landscape type and previous land use function. These properties of the host landscape informed the subsequent analysis of solar infrastructure and landscape features.

Solar infrastructure of SPP is discussed extensively in the literature (Merida-Rodriguez et al., 2015; e.g. Scognamiglio, 2016; Stremke & Schöbel, 2019). We created an overview of properties found in literature and specified these with the findings of the case analysis. For solar infrastructure, the spatial properties are grouped in three nested levels: the *system* as a whole, the *patch* as distinct group of arrays, and the *array* as specific object (table 4.2).

Literature reports on both potential and realized landscape features of SPP (Hernandez et al., 2014; Lobaccaro et al., 2019; Moore-O'Leary et al., 2017; Scognamiglio, 2016). We used the main categories identified in the literature to group the individual features found in the cases (table 4.2), namely ecological, recreational and educational, agricultural and water retention features.

Table 4.2. Framework for the analysis of the host landscape, solar infrastructure and landscape features.

Category	Sub-category	Property	Description	Literature
Host landscape		Landscape type	Open/enclosed, parcellation/ plot sizes, existing landscape infrastructure/features, urban settlements.	(Lobaccaro et al., 2019; Scognamiglio, 2016)
		Previous land use	Previous land use(s) at the site	(Hastik et al., 2015; Turney & Fthenakis, 2011)
Solar infrastructure	System	Layout	The number, size and position of the patches as part of the solar system.	(Bevk & Golobič, 2020; Stremke & Schöbel, 2019)
		Response to parcellation	The response of the system layout to the original parcellation.	(Stremke & Schöbel, 2019)
	Patch	Configuration	Size, position and alignment of the of patch within parcellation.	(Bevk & Golobič, 2020; Lobaccaro et al., 2019; Merida-Rodriguez et al., 2015; Scognamiglio, 2016; Stremke & Schöbel, 2019)
		Density	Density of the array within a patch. Indicator is the ground-coverage-ratio (GCR), which is the array length (L) divided by the row-to-row pitch (R)	(Bevk & Golobič, 2020; Doubleday, Choi, Maksimovic, Deline, & Olalla, 2016; Scognamiglio, 2016)
	Array	Orientation	Orientation or azimuth of the arrays. Traditional orientation (east-west or north-south) results in a stripes pattern, but other types of patterns are possible if the azimuth is varied.	(Scognamiglio, 2016; Stremke & Schöbel, 2019)
		Dimensions	Dimension of array, determined by: tilt of modules, total height of the array from the ground; length (l) of array; width of array; layout of array (orientation of modules and number of rows);	(Lobaccaro et al., 2019)
		Concurrence	Presence of multiple PV technologies or types of modules in a single case	(Torres-Sibille et al., 2009)
		Materials	Color of modules, materials used in supporting structure.	(Haurant, Oberti, & Muselli, 2011; Merida-Rodriguez et al., 2015; Stremke & Schöbel, 2019)

Category	Sub-category	Property	Description	Literature
Landscape features	Ecological	Feature	Features that support ecological functions, for example patches of wildflowers or hedgerows.	(Hernandez et al., 2019; Lovell & Johnston, 2009; Moore-O'Leary et al., 2017; Semeraro et al., 2018)
	Recreational and educational	Feature	Features that support recreational and education functions, such as community gathering spaces and outdoor classrooms.	(Lobaccaro et al., 2019; Scognamiglio, 2016; Semeraro et al., 2018)
	Agricultural	Feature	Features that support agricultural functions, such as grazing or orchards.	(Hernandez et al., 2019; Scognamiglio, 2016; Semeraro et al., 2018)
	Water management	Feature	Features that support hydrological functions, such as water retention areas.	(Hernandez et al., 2019; Lovell & Johnston, 2009; Moore-O'Leary et al., 2017)

Emergent properties of solar landscape 4.3.2

Visibility 4.3.2.1

The combined spatial arrangement of SPP and landscape affects the visibility of the solar infrastructure (Apostol, McCarty, et al., 2017; Kapetanakis, Kolokotsa, & Maria, 2014; Merida-Rodriguez et al., 2015; Stremke & Schöbel, 2019). To investigate this relationship, first the existing and new landscape features at the edge of the solar landscapes were analyzed. The edge is defined as the space between solar infrastructure and the project boundary (fig. 4.3a). Second, the part of the solar infrastructure visible to on-road observers was analyzed (Fernandez-Jimenez et al., 2015) and subsequently expressed in the degree of visibility. The degree of visibility is the part of the outer edge of the solar infrastructure visible to observers, as seen from the first line of observation (fig. 4.3a). The first line of observation is the set of roads or paths closest to the edge of the case. We distinguish between visible, partly visible and invisible, based on visibility levels as presented in (Apostol, Palmer, et al., 2017). Visibility from a larger distance and for on-site observers (Fernandez-Jimenez et al., 2015; Stremke & Schöbel, 2019) was examined during the field observations but not included here to allow a comprehensive comparison of the 11 embedded cases.

4.3.2.2 Multifunctionality

Solar landscapes provide multiple services and functions (Haines-Young & Potschin, 2012; Picchi et al., 2019; Scognamiglio, 2016). We use the term function as it indicates a capacity to deliver a certain service. In this research, we aimed to *identify* deliberately added functions with a certain expected service. The quantification and assessment of services is beyond the scope of this comparative analysis of 11 frontrunner cases. The Common International Classification of Ecosystem Services (CICES) was used to systematically identify and describe functions (Haines-Young & Potschin, 2018). For each case, a list of deliberately added functions was identified in project documentation and subsequently verified during field observations. These lists were discussed and adjusted during multiple workshops among involved researchers to ensure cross-case consistency. Using CICES, we analyzed the presence and number of functions identified in the cases. Three types of multifunctionality were identified: *array multifunctionality* (beneath arrays), *patch multifunctionality* (on patch area and not underneath arrays) and *adjacent multifunctionality* (next to patches) (fig. 4.3b).

4.3.2.3 Temporality

Landscapes change through time, largely driven by societal demands and expressing changing societal values (Antrop, 2005). The demand for renewable energy results in the introduction of energy technologies that transform landscapes within a relatively short period of time; this is why the development of SPP is considered dynamic. The life-span of SPPs is relatively short (20-30 years) compared to other, more permanent energy technologies, such as nuclear power plants (Pasqualetti & Stremke, 2018). Others have studied the *construction* and *operation/maintenance* stages of SPP (Guerin, 2017b, 2017a). This study adopted a wider temporal perspective and focused on the former state of the host landscape (i.e. *before* construction), the case during operation and maintenance stage and the decommissioning stage (fig. 4.4). Project documentation was used to identify if and how temporality was considered in these three stages: (1) inclusion of existing features of the host landscape in the case, (2) active management of landscape features during operation and maintenance stage and (3) plans for the decommissioning stage.

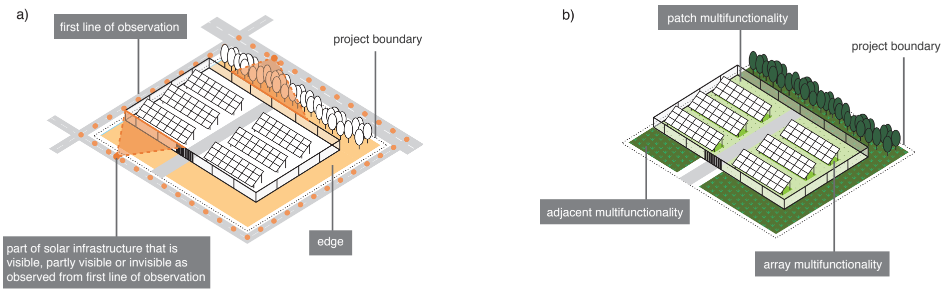


Fig. 4.3. a) Visibility of the solar infrastructure is expressed by the ratio of the outer edge of the solar infrastructure that is visible, partly visible or invisible (based on visibility levels as presented in (Apostol, Palmer, et al., 2017)). b) Multifunctionality beneath the arrays (array multifunctionality), on the patch area (patch multifunctionality) and next to patches (adjacent multifunctionality).

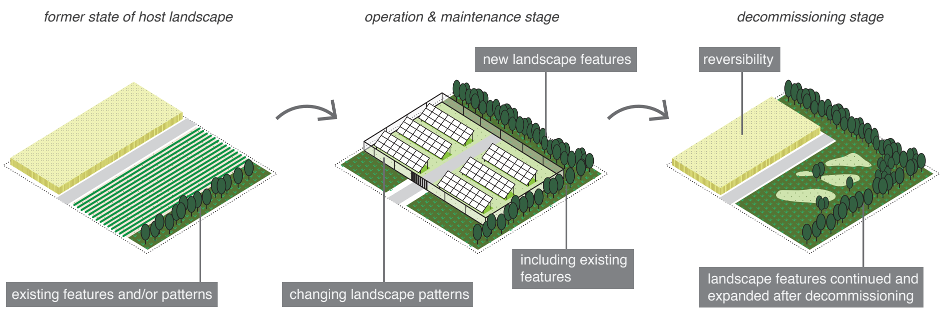


Fig. 4.4. Temporal properties: former state of the host landscape, case during operation/maintenance stage and decommissioning stage.

4.4 Results & discussion

The results are presented and discussed in three parts. The first two parts present the solar infrastructure (4.4.1) and landscape feature (4.4.2) properties. The third part (4.4.3) takes the perspective of the solar landscape as a whole and discusses the visibility, multifunctionality and temporality of the examined cases.

4.4.1 Solar infrastructure

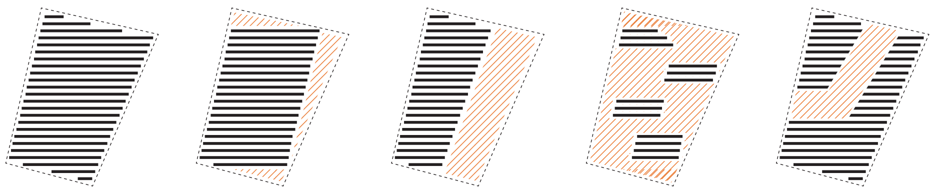
4.4.1.1 System layout and host landscape pattern

We found that the way the system layout responded to the host landscape differed between cases with a former agricultural use and those with a brownfield use. In the nine cases with a former agricultural use, the system size and plot size were key factors in the way the system layout responded to the pattern of the host landscape. In only one case the system was entirely located within a single plot (Monreale). In the other eight cases, solar infrastructure was distributed over multiple plots, whether the cases were small (e.g. Sinnegreide, 12 ha) or large (e.g. Gänsdorf, 181 ha). In these multiple plot cases, the plots of the host landscape either remained (almost) completely intact (five cases) or were aggregated into a single larger plot (three cases). For some cases, although parcellation remained intact, the individual plots are potentially not always recognized as such by observers. Recognition of individual plots can occur if there is high vegetation along the plot border and / or a field margin: a zone between plot border and PV patch.
In the two cases with a former brownfield use, the system layout was adjusted to site specific elements of the previous land use function, for example a gravel mining pit in Mühlenfeld.

4.4.1.2 Patch configuration and density

The system layout consists of multiple PV patches that are each configured within a specific plot. Five different types of patch configurations were found (fig. 4.5). Most cases consisted of a single configuration. In the *responsive configuration*, the size of the PV patch predominantly matched the plot size. For example, in Sinnegreide, PV arrays with various widths were used to cover the entire plot; the original parcellation remained intact. Contrastingly, in the *irresponsive configuration*, the patch shape was mainly self-referential, which, dependent on the plot shape, can result in left-over spaces. In Gänsdorf, constructed in 2009, the limited flexibility in array width of that time can have contributed to this configuration.

In the *split configuration*, the patch responded to the shape of the plot, yet only partially covered the plot area (25-50%). This partial coverage resulted in a perceived split of the original plot. In Southill for example, only the south-western part of the plot was used for arrays, the remainder of the plot consisted of landscape features. The fixed size of the single-axis tracker system employed in Monreale seems to have resulted in roughly equal patch sizes.



Type of patch configuration	**RESPONSIVE** Shape of patch mimics shape of plot and PV patch largely covers size of plot. Original parcellation structure, both shape and size remain recognizable. Potentially high variation in array length.	**IRRESPONSIVE** Patch shape is self-referential, variation in array length is kept to a minimum. Large part of plot is covered by PV patch. Potentially results in left-over spaces within the plot.	**SPLIT** Shape of PV patch matches shape of plot, but a substantial part of plot is not covered by the PV patch. Result is a split of the plot and an area next to the patch that has a different function.	**ISLANDS** Small part of plot is covered by PV arrays. The shape is independent from existing parcellation.	**INCIDENTAL** Local circumstances (such as underground infrastructure or build elements) prevent presence of arrays.
Alignment (of patch to plot)	Plot border	(partially) self-referential	Plot border (sometimes partially self-referential)	Self-referential	To site specific elements
Coverage (of plot by patch)	Very high (65-90%)	High (50-75%)	Low (25-50%)	Low (35-40%)	Dependent on local circumstances.
Cases	Sinnegreide Midden-Groningen Southwick	Gänsdorf Valentano	Southill Monreale [Sinnegreide]	Kwekerij Laarberg	Hemau Mühlenfeld [Southill] [Midden-Groningen] [Southwick]

Fig. 4.5. Five types of patch configurations. Main determinants for the patch configurations are alignment to plot and coverage of the plot by the PV patch. Case names between brackets indicate a certain configuration was identified, but it was secondary to another, primary configuration.

In the *islands configuration*, a single patch was divided into sub-patches and the patch shape was almost entirely self-referential. The plot was only for a small part (30-45%) covered by arrays. In the Kwekerij and Laarberg for example, this configuration resulted in multiple small PV patches dispersed across the plot. These configurations corroborate the proposals for patch variations by Scognamiglio (2016). The irresponsive, split and island configuration increase the spatial heterogeneity of the landscape, dependent on the previous land-use. In a host landscape with monofunctional agricultural plots, these configurations increase the variety of functions within a single plot, countering agricultural upscaling often seen in the countryside (Tscharntke, Klein, Kruess, Steffan-Dewenter, & Thies, 2005). However, some of these configurations are less aligned with landscape parcellation and recent research has shown this can negatively influence perception (Bevk & Golobič, 2020).

For brownfield cases, the patch configuration coincided with the strategy for the system layout: site specific elements determined the configuration. In the case of Hemau for example, the patch was shaped around the existing (elevated) bunkers and identified hotspots for biodiversity were also excluded for electricity generation. This fifth, *incidental configuration*, was also found in other cases in addition to another, primary configuration. In these cases, elements were highlighted that otherwise remained invisible, for example underground infrastructure became visible as a blank space between arrays.

The *patch density* is determined by the width of the array and the row-to-row-pitch, expressed by the ground-coverage-ratio (Doubleday et al., 2016) and ranged for the cases between 0,35 and 0,84 (table 4.3). Existing research points to two consequences of patch density: visual impact and impact on land use (Bevk & Golobič, 2020; Scognamiglio, 2016).

Potential visibility affected patch density in three cases: the Kwekerij, Sinnegreide and Southwick. In these cases a lower, secondary ground-coverage-ratio (GCR) was found where a high visibility of the solar system was expected. For Southwick though, we could not confirm a causal relationship. Although Scognamiglio (2016) stresses that a low patch density is pivotal to increase multifunctionality, no relationship between multifunctionality and patch density was found (see also 4.4.3.2). Cases with multifunctionality beneath arrays or on the patch area had a GCR ranging from 0,35 to 0,73, covering almost the entire spectrum of GCR found in the cases.

Table 4.3. Patch density of the cases expressed by the ground-coverage-ratio (GCR). In three cases, two different array types were found, resulting in two values for the GCR. The GCR is calculated by dividing the array length (L) by the row-to-row pitch (R) (Doubleday et al., 2016).

Cases	GCR of primary array type (L/R)	GCR or secondary array type (L/R)	Location of secondary array type
1. Gänsdorf	0,45	n/a	
2. Kwekerij	0,44	0,41	Most visible patches for nearby inhabitants.
3. Valentano	0,49	n/a	
4. Southill	0,63	n/a	
5. Hemau	0,35	n/a	
6. Laarberg	0,52	n/a	
7. Sinnegreide	0,84	0,69	Most visible patch near road.
8. Mühlenfeld	0,44	n/a	
9. Midden-Groningen	0,73	n/a	
10. Monreale	0,40	n/a	
11. Southwick	0,63	0,57	Most visible patch in west compartment.

4.4.1.3 Array orientation, dimensions and materials

On the level of arrays, we found that in all cases the *orientation* of the PV arrays was optimized for maximum solar energy generation. This optimization was for 10 cases east-west oriented arrays facing south, and for one case with a single-axis tracker north-south oriented arrays (table 4.4, see also table 4.1). In other words, the type of pattern was the same for all the cases: parallel stripes (Scognamiglio, 2016). To relinquish energy optimization and vary the azimuth is considered a key feature of solar landscapes. A variable azimuth can improve ecological performance or allow the solar infrastructure to align with the landscape pattern (Bevk & Golobič, 2020; Merida-Rodriguez et al., 2015; Scognamiglio, 2016) that, in turn, can result in new patch configurations. In addition, non-optimal azimuth angles reduce peak loads on the electricity grid and allow for a more flexible integration into the landscape (Comello et al., 2018; Freitas & Brito, 2019). If business models can incorporate these benefits, non-optimal azimuth angles can also result in an improved alignment of array and landscape pattern.[2] The *dimension* of the arrays is specific to each case, although the height was variable in three cases (table 4.4). In two cases (the Kwekerij and Sinnegreide), arrays were found with two different heights. Arrays with a lower height were closest to where most observers were expected (see also table GCR). In Monreale the difference in height of the arrays was caused by partial ground levelling.

The *color* of the arrays in the cases was the blue commonly seen in SPP. However, the rapid development of colored modules in the built environment may also permeate to solar landscapes (Tsai & Tsai, 2020). Only in Hemau, modules were three different shades of blue, as at the time of construction (2002) suppliers were not able to deliver the requested amount of modules from a single type of module. Consequently, Hemau is also the only case

[2] A recent example in the Netherlands is the project 'Energy garden' Assen-Zuid: https://www.nmfdrenthe.nl/wij-werken-aan/energieneutraal-drenthe/energietuin-assen-zuid/ (in Dutch)

where *concurrence* was identified. The same applies for the type of *supporting structure* used: all cases except Hemau used metal structures, while Hemau used a wooden structure.

Table 4.4. Array orientation, height, materials and concurrence.

	Array orientation		Array height	Array materials		Concurrence
Cases	Adjustment to plot	Optimum for solar energy generation	Consistent / variable	Color modules	Supporting structures	
1. Gänsdorf		x	consistent	Blue	Metal	no
2. Kwekerij		x	variable	Blue	Metal	no
3. Valentano		x	consistent	Blue	Metal	no
4. Southill		x	consistent	Blue	Metal	no
5. Hemau		x	consistent	Blue (three shades)	Wood	Yes, three types of modules and array types
6. Laarberg		x	consistent	Blue	Metal	no
7. Sinnegreide		x	variable	Blue	Metal	no
8. Mühlenfeld		x	consistent	Blue	Metal	no
9. Midden-Groningen		x	consistent	Blue	Metal	no
10. Monreale		x	variable	Blue	Metal	no
11. Southwick		x	consistent	Blue	Metal	no

Reflections on solar infrastructure across frontrunner SPPs 4.4.1.4

Southwick illustrates that combining solar infrastructure with landscape occurs at multiple scales: on the system level, the size of the existing plots determined the system layout; on the patch level, individual patches matched the shape of the plots. Even more, the existing parcellation remained visually recognizable as existing hedgerows with a sufficient zone around them were incorporated in the design. This spatial arrangement required additional space, resulting in the trade-off of a decreased maximum amount of arrays (lower LAOR value).

4.4.2 Landscape features

4.4.2.1 Ecological features

Several ecological features were found in the cases: patches of dry or wet vegetation, vegetative buffers, structures for roosting, nesting and hibernating, wildlife permeable fencing and some cases incorporated existing vegetation into the system layout (table 4.5).

Vegetative patches were identified in all cases, for example wildflower fields or shrubs. Vegetative buffers were found in seven cases, often combined with screening function at the edge of the case (see also 4.4.3.1). Buffers were for example hedgerows, tree rows or reed zones. In one case, Hemau, an existing monoculture forest patch was removed to avoid shadow on the arrays. The presence of vegetative patches and buffers in the cases reflects the growing evidence that SPP contribute to local biodiversity of (Moore-O'Leary et al., 2017; Randle-Boggis et al., 2020; Semeraro et al., 2018; Sinha, Hoffman, Sakers, & Althouse, 2018). Several similarities in ecological features were found, independent of landscape type: hedgerows, orchards and flower fields were found in many cases. Landscape features dependent on landscape type and other contextual characteristics become especially important when SPP become a more familiar phenomenon in the landscape (Oudes & Stremke, 2020). In five cases, built structures for roosting, nesting and hibernating, such as beehives or insect hotels, were identified. In ten cases wildlife permeable fencing was realized by either lifting the fence or by the addition of small mammal gates. These findings show that in most cases landscape fragmentation is addressed (Hernandez et al., 2014; Lobaccaro et al., 2019). In five cases existing vegetation was retained, such as hedgerows or solitary trees, while it is not uncommon that existing vegetation is removed (Chiabrando et al., 2009; Hernandez et al., 2014). In retaining vegetation, these cases address the loss of identity elements, or fragmentation of the countryside (Chiabrando et al., 2009).

Table 4.5. Ecological features found in the cases (x = new; [x] = enhanced, not completely new; (-) = removal).

	Ecological features						
Cases	**Total**	Patch of dry vegetation	Patch of wet vegetation	Vegetative buffer	Built structures for roosting, nesting and hibernating	Wildlife permeable fencing	Retaining existing vegetation
1. Gänsdorf	**3**	x		x	x		
2. Kwekerij	**5**	x	x	x	x	x	yes
3. Valentano	**4**	x		x		x	
4. Southill	**3 / [1]**	x		[x]	x	x	yes
5. Hemau	**3 / (1)**	x / (-)	x			x	
6. Laarberg	**5 / [1]**	x	x	[x]	x	x	yes
7. Sinnegreide	**3**	x		x		x	
8. Mühlenfeld	**3**	x	x			x	yes
9. Midden-Groningen	**3**	x		x		x	
10. Monreale	**3**	x		x		x	
11. Southwick	**5 / [1]**		x	x / [x]	x	x	yes
Total		**10 /(1)**	**5**	**7 / [3]**	**5**	**10**	**5**

Recreational and educational features 4.4.2.2

Recreational and/or educational features were identified in 9 of the 11 cases, confirming the potential suggested in earlier research (Scognamiglio, 2016; Semeraro et al., 2018). All recreational and educational features were located next to a PV patch, and not beneath or between the arrays as has been identified in the Solar Strand, USA (Scognamiglio, 2016). Recreational and educational features were for example lookouts, benches and information panels. The Kwekerij, Laarberg and Mühlenfeld seemed to actively enable recreation by adding multiple recreational facilities and connecting the case to a local recreational network. The other cases seemed to be addressing occasional or accidental on-site observers.

Recreational features were absent in Midden-Groningen, Monreale and Southill.

In the large-scale cases Gänsdorf, Midden-Groningen and Southwick, the space between the patches was occasionally publicly accessible (table 4.6). In Gänsdorf and Midden-Groningen, this access was the consequence of practical considerations (land ownership and maintenance respectively), while in Southwick the patch shape was deliberately adjusted to maintain an existing path. Across cases, no roads or paths formerly accessible were removed or cut-off. Moreover, in the Kwekerij a path network was created between the patches and access within the fence is possible on a daily basis. This study shows that solar landscapes are able to maintain or increase landscape connectivity (Antrop, 2000).

Table 4.6. Recreational and educational features and accessibility in the cases.

	Recreational and educational features												**Accessibility**		
Cases	**Total**	Lookout	Information panel	Benches	Picnic tables	Community gathering site	Playground features	Car parking	Bicycle parking	Charging point electric bicycles	Walking path	Node in local recreational network	No access	Access between patches	Access within fence
1. Gänsdorf	**1**	x												x	
2. Kwekerij	**9**	x	x	x	x	x	x	x			x	x			x
3. Valentano	**1**										x		x		
4. Southill	**1**		x										x		
5. Hemau	**1**		x										x		
6. Laarberg	**4**		x		x					x		x	x		
7. Sinnegreide	**2**				x				x				x		
8. Mühlenfeld	**5**	x	x	x					x			x	x		
9. Midden-Groningen	**0**													x	
10. Monreale	**0**												x		
11. Southwick	**2**										x	x		x	
Total		**3**	**5**	**2**	**3**	**1**	**1**	**1**	**2**	**1**	**3**	**4**	**7**	**3**	**1**

Agricultural features 4.4.2.3

Nine cases included agricultural features, ranging from small fruit tree orchards to substantial olive groves. This high presence of agricultural features may point to addressing the loss of agricultural land (Chiabrando et al., 2009). In Monreale, a large olive grove was located next to the solar system, and the left-over spaces within the solar system were planted with olive and almond trees. In Gänsdorf, the case comprised a part of the former arable land. In three cases (Laarberg, Hemau and Midden-Groningen) sheep were kept inside for grazing. In five cases (Gänsdorf, the Kwekerij, Southill, Laarberg and Sinnegreide) small-scale agriculture targeting the local community (fruit orchards, vegetable gardens) was identified.

Water management features 4.4.2.4

Local water management was found in five of the cases. This study identified water retention areas, in addition to techniques of water recuperation (Lobaccaro et al., 2019). Water retention areas were part of two cases (Laarberg and the Kwekerij). In Laarberg, water run-off from a (future) business area can be stored beneath PV arrays, and the solar infrastructure was adjusted to allow for temporary flooding (above-ground cables). In Monreale, rain water recuperated from the PV patches, was stored in a basin to be used for the adjacent olive grove. In two other cases (Sinnegreide and Valentano) waterways were enhanced or recovered.

Reflections on landscape features across frontrunner SPPs 4.4.2.5

Laarberg includes multiple categories of landscape features: ecological, recreational, agricultural and water retention features have been combined with electricity generation on only 6,4 ha. Southill, on the contrary, displays focus on a single category: ecological restauration is central and to this end human access is limited.

Furthermore, in Southill and Hemau spaces suitable for electricity generation have been deliberately kept free to achieve ecological objectives. In other words, spatial arrangement of solar infrastructure is adjusted and even sub-optimal to accommodate other objectives. The Kwekerij and Gänsdorf are examples of synergy between functions: recreational and ecological values are increased by locating strips of wildflowers next to roads and pathways.

4.4.3 Solar landscape

Three emergent properties that arise from the combined spatial arrangement of SPP and landscape – in this paper and elsewhere conceptualized as solar landscape – are presented in this section: *visibility*, *multifunctionality* and *temporality*.

4.4.3.1 Visibility

This section presents the visibility of the solar infrastructure based on an analysis of the existing and new landscape features at the edge of the solar landscape.

The edge

The edge of the cases consisted of existing eye-level vegetation (appendix D) and new edge measures (appendix E), and in each case the solar infrastructure was completely surrounded by a fence. Existing eye-level vegetation, such as forest patches or hedgerows, were found in eight cases, with five cases consisting of over 60% existing eye-level vegetation along the edge. New edge measures consisted of landscape features, for example hedgerows or a reed zone. Three types of measures were applied in the cases: removal of existing landscape features, enhancing existing landscape features and new landscape features (appendix E).

Reducing visibility of solar infrastructure

In all cases, the visibility was deliberately reduced, either through siting within existing vegetation or through new edge measures with screening function (Apostol, McCarty, et al., 2017; Merida-Rodriguez et al., 2015). The highest ratio of a visible edge in a single case was 30% (Mühlenfeld). Contrastingly, in three cases clear views on the solar system were almost absent (fig. 4.6).

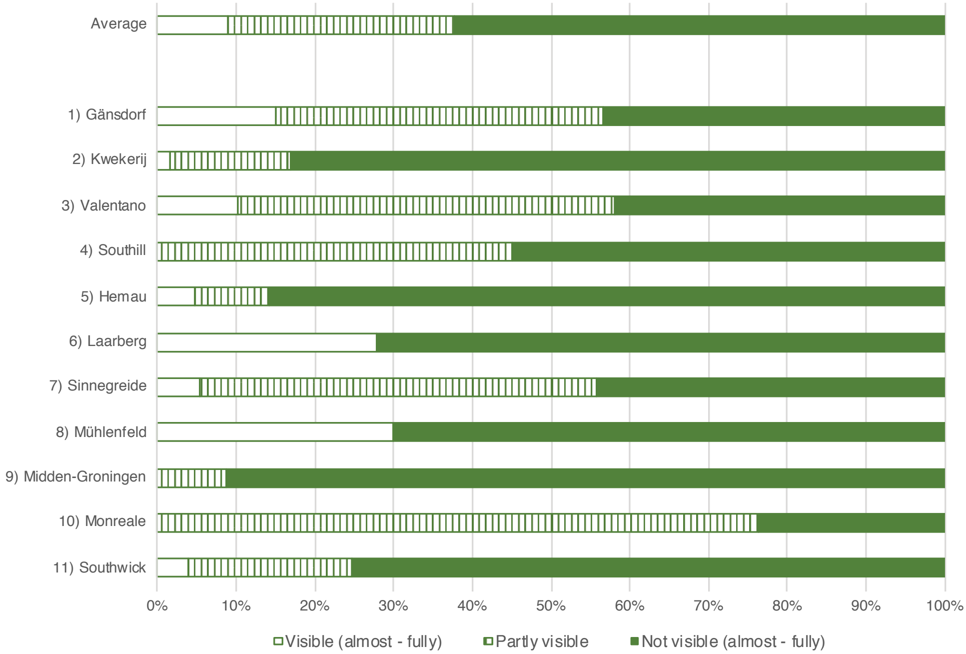


Fig. 4.6. Visibility of the solar infrastructure as observed from road infrastructure closest to the case, the first line of observation.

Southwick, Laarberg, Mühlenfeld, Hemau and Southill combined low visibility with few new landscape features and many existing landscape features. Existing vegetation, sometimes enhanced, was used for screening purposes. This combination supports the notion that careful site selection is an important aspect to achieve low visibility without the need for many new edge measures (Apostol, McCarty, et al., 2017; Stremke & Schöbel, 2019). Patch configuration also influenced visibility. In Southill for example, positioning the patch into the lower lying part of the plot reduced the visibility from higher located roads (Apostol, McCarty, et al., 2017; Fernandez-Jimenez et al., 2015; Merida-Rodriguez et al., 2015).

Monreale, Midden-Groningen, Sinnegreide, Valentano and Gänsdorf combined a low amount of existing eye-level vegetation along the edge (< 11%) with a high degree of new screening features (85-100%). Introduction of eye-level vegetation that is not typically found in open landscapes may have an adverse effect on the landscape character (Apostol, McCarty, et al., 2017; Bevk & Golobič, 2020; Merida-Rodriguez et al., 2015). In some cases, screening measures provided other functions as well. For example, in Gänsdorf an orchard was planted to reduce visibility from the road and at the same time produce fruit.

Enhancing visibility of the solar infrastructure

The overall reduction of visibility was contrasted by measures that deliberately *enhanced* visibility. In Gänsdorf, the Kwekerij, Mühlenfeld , Sinnegreide and Laarberg, features were added that provided visitors with a clear view of the solar system (fig. 4.7). In the first three cases, the solar infrastructure can be seen from a lookout, while the latter two cases feature an area at the edge of the case that provided amenities for visitors to stay for a short period of time. These five cases showed a combination of two strategies with respect to visibility: in general, visibility is reduced, but at a specific point visibility of the solar infrastructure is enhanced. The latter strategy seems to reflect "embracing visibility of energy facilities", which can be part of a place branding approach (Frantál et al., 2018, p. 92). This research shows that the cases addressed visibility (Apostol, Palmer, et al., 2017; Bevk & Golobič, 2020; Carullo et al., 2013; Chiabrando et al., 2009; Torres-Sibille et al., 2009; Tsoutsos et

Fig. 4.7. Measures enhancing visibility: lookout in Gänsdorf (a), Mühlenfeld (b, picture by Florian Becker) and the Kwekerij (c), and benches near a clear view to the solar infrastructure in Laarberg (d, picture by Coos van Ginkel) and Sinnegreide (e). All pictures by authors unless otherwise indicated.

al., 2005), and at the same time aimed to reframe visibility from a mainly *negative impact* into a potential *positive impact*.

Multifunctionality 4.4.3.2

4

Solar landscapes that provide functions additional to electricity generation can be considered multifunctional. In this section, we further detail the *multifunctionality* of the cases by examining the presence and number of functions, as well as three types of multifunctionality. The section is concluded with reflections on the assessment of multifunctionality.

Presence and number of functions

The studied cases provide a multitude of different functions. Of the 65 functions in the CICES model of ecosystem services, 18 were found in the cases (appendix F). The function *Providing habitats for wild plants and animals* (2.2.2.3), was the only function identified in all cases, besides *Solar power* (4.3.2.4). Two other functions were identified in nine out of eleven cases: *Pollinating our fruit trees and other plants* (2.2.2.1) and *Screening unsightly things* (2.1.2.3). Small-scale agricultural functions, such as grazing sheep (1.1.1.3), food production (1.1.1.1) were found in nine cases. These functions confirm that the cases aim to mitigate impacts of SPP identified in earlier research, such as habitat destruction and fragmentation, decrease of wildlife and biodiversity (Hernandez et al., 2014; Lovich & Ennen, 2011; Turney & Fthenakis, 2011) and land use impact or loss of productive land (Hastik et al., 2015; Horner & Clark, 2013; Tsoutsos et al., 2005; Turney & Fthenakis, 2011).

From the 18 identified functions, four were provisioning, seven regulating and seven were cultural functions. All three types of functions were found in all cases. The total number of functions ranged from 6 to 14 (fig. 4.8).

No clear relationship was found between the number of functions and the land area occupation ratio (LAOR, table 4.1) (Scognamiglio, 2016). Cases with a high LAOR (highest ratio found was 61%) still

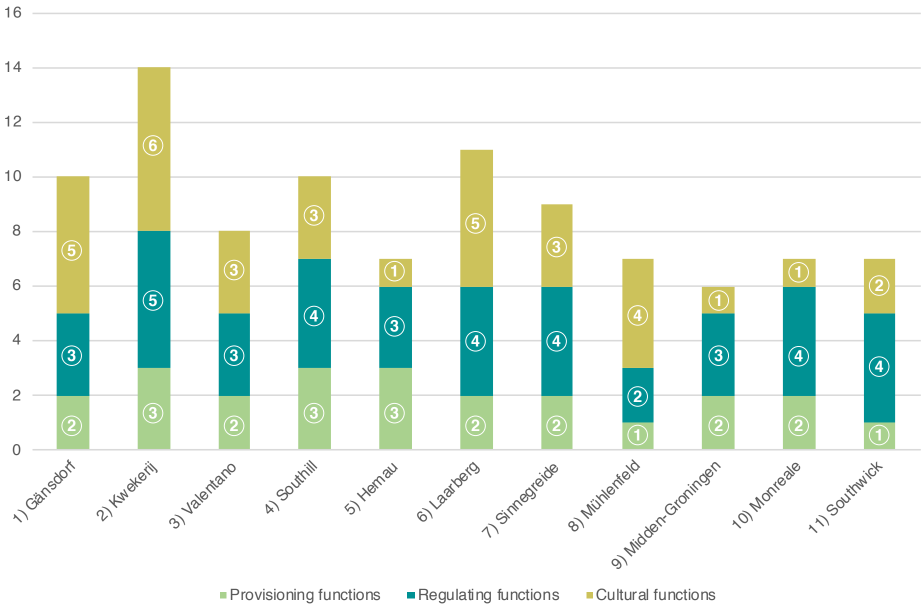


Fig. 4.8. The number of functions in each case, divided over provisioning, regulating and cultural functions.

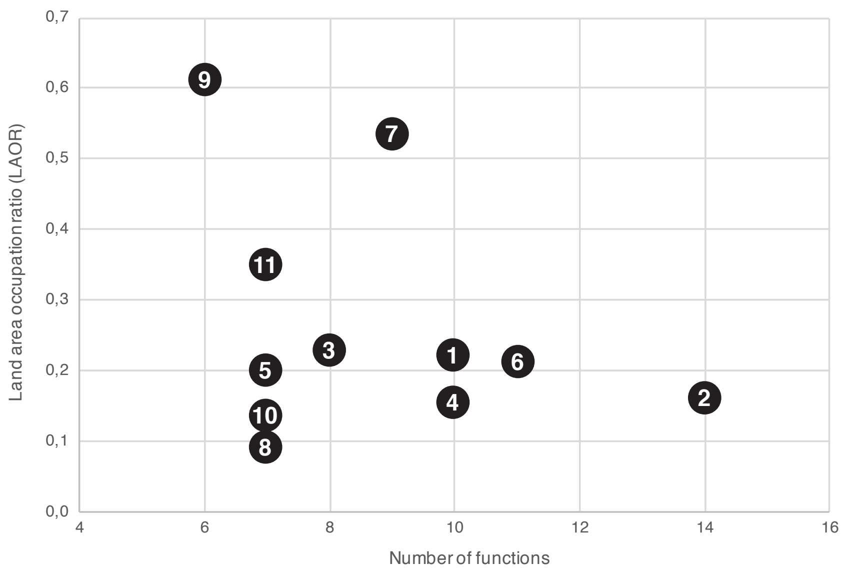


Fig. 4.9. The number of functions compared to the land use energy intensity, expressed by Land Area Occupation Ratio. 1=Gänsdorf; 2=Kwekerij; 3=Valentano; 4=Southill; 5=Hemau; 6=Laarberg; 7=Sinnegreide; 8=Mühlenfeld; 9=Midden-Groningen; 10=Monreale; 11=Southwick.

supported multiple functions, although these cases represented the lower end of the range of functions (fig. 4.9).

Three types: array, patch and adjacent multifunctionality

Functions were located beneath arrays (array multifunctionality), on the patch area (patch multifunctionality) and adjacent to patches (adjacent multifunctionality) (fig. 4.10). Array and patch multifunctionality allow for interactivity between functions (e.g. sheep finding shade under arrays) and were identified in 8 out of 11 cases (fig. 4.11). Adjacent multifunctionality was identified in all cases and was often a form of multiple land use or co-location with little interaction with the solar infrastructure (Brandt & Vejre, 2004; Selman, 2009). These findings are in line with, and further specify earlier research on solar landscapes; earlier research identified multifunctionality applied to solar infrastructure and as multiple land use within the project boundary (Lobaccaro et al., 2019).

On average, the cases contained 28,9% adjacent multifunctionality, 19,8% patch multifunctionality and 11,6% array multifunctionality, totaling to 60,4% (fig. 4.11). In seven cases, over 70% of the land surface was allotted to multifunctionality. In three of these cases (Valentano, Hemau and Midden-Groningen), this high share is for a large part caused by harvesting the meadow beneath and

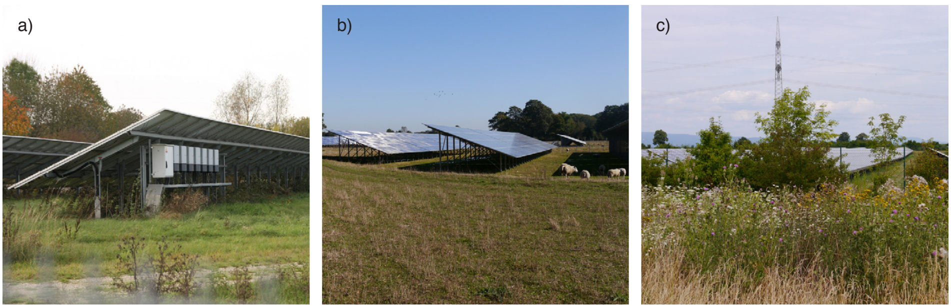


Fig. 4.10. a) array multifunctionality in Mühlenfeld (picture by Florian Becker): shade tolerating vegetation and inverters beneath arrays; b) patch multifunctionality in Laarberg: sheep grazing on the lowered patch area that also functions as water retention area; c) adjacent multifunctionality in Gänsdorf: hedgerow and wildflower field developed next to the PV patch.

between the arrays by or for livestock. Specifically for Midden-Groningen, multifunctionality is arranged as a sharp spatial distinction between the high-density PV patches and livestock (array and patch multifunctionality), and ecological features in the edge (adjacent multifunctionality). The large share of multifunctionality in the other four cases is explained by a diverse set of features: wildflower fields, recreational amenities and water retention (the Kwekerij), livestock grazing and water retention (Laarberg), fields of wildflowers and fine grasses (Southill) and an olive grove and wet ecological corridor (Monreale). The cases with high shares of array and patch multifunctionality indicate the potential to increase multifunctionality without adversely affecting land used for electricity generation. High shares of adjacent multifunctionality were found in Monreale, Southill, the Kwekerij, Valentano, Laarberg and Hemau. With adjacent multifunctionality, however, land otherwise available for electricity generation is used for other functions. This latter type of multifunctionality therefore reduces the overall land use energy intensity of the solar landscape (Scognamiglio, 2016).

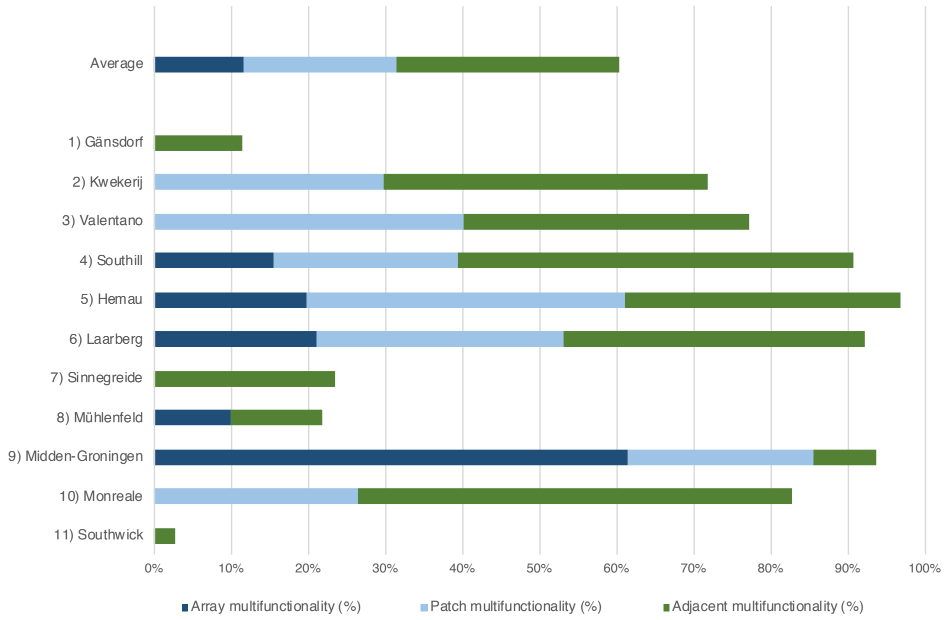


Fig. 4.11. Shares of land surface allotted to array, patch and adjacent multifunctionality.

Assessment of multifunctionality

The number of functions and the land surface allocated to multifunctionality are useful indicators to compare SPP on multifunctionality, yet they do not assess functions. Assessment of ecosystem functions and services needs to provide insight in their effectiveness, management (Randle-Boggis et al., 2020) and comparison to the baseline situation (Hastik et al., 2015). Such an assessment requires integrated approaches that make use of a mix of methods and tools on multiple scales of analysis (Picchi et al., 2019). Without advancing such assessment methods for solar landscapes, cases may emerge that bear the promise of multifunctionality, but only deliver minor provisioning, regulating or cultural benefits. Current assessments of SPP often make use of performance indicators based on installed capacity or electricity generation (Horner & Clark, 2013; Martín-Chivelet, 2016). Using these indicators, most of the cases in this study will be outperformed by SPP that are optimized for electricity generation. These assessments and their associated indicators will need to be supplemented by other indicators that capture multifunctionality.

4.4.3.3 Temporality

Temporality in the cases was addressed in 8 out of 11 cases by attention for landscape elements and patterns present in the host landscape, active management during operation and maintenance stage and landscape plans for the decommissioning stage.

In five cases, landscape elements and patterns that were part of the *former state of the host landscape* were included in operation and maintenance stage, with the potential to extend into decommissioning stage. These efforts can result in 'remnants of the past' and carry symbolic and historical value (Antrop, 2005). Elements were often vegetation, such as hedgerows or trees, but also former military bunkers were preserved (Hemau). In two cases (Gänsdorf and Midden-Groningen) existing parcellation was explicitly considered to maintain landscape character during the operation and maintenance stage.

Active management of landscape features during *operation and maintenance stage* was identified in four cases (Gänsdorf, the Kwekerij, Southill and Hemau). In these cases, monitoring and evaluation was organized, and consequently enabled decision-making based on changing monitoring results and contextual circumstances. A distinctive example is the Kwekerij, where changing demands by local stakeholders resulted in the addition of a vegetable garden in a later stage. On the contrary, other cases indicate a lack of active management and appeared not to be resilient to changing circumstances. In Monreale for example, the olive grove adjacent to the solar system is currently in a poor state. This olive grove was supposed to be used for local olive oil production, but it seems it was not well embedded in the local socio-economic context. In Southwick, original plans involved wildflower fields, grazing sheep and bat boxes. These plans, partially executed, appear to have been abandoned following a change in the ownership of the SPP.

Plans for the *decommissioning stage* were mentioned in six cases, mostly involving reversibility (Pasqualetti & Stremke, 2018). Three cases (Southill, Midden-Groningen and Southwick) plan to reverse the site into the former state of the landscape, although it is not always clear if this concerns removal of both solar infrastructure and landscape features. In Gänsdorf, rather than decommissioning, the plan is to continue combining electricity generation with habitat creation and agriculture by means of agrivoltaïcs. If executed, this plan will result in the recycling of the existing energy landscape (Pasqualetti & Stremke, 2018). In the Kwekerij and Monreale, landscape features in operation and maintenance stage supported the plans for the decommissioning stage. In the Kwekerij, local inhabitants benefit from the park function in operation and maintenance stage, and a larger park will be available to them once the solar infrastructure will be dismantled. In Monreale, cultivation of herbs between the arrays is supposed to increase soil quality for agricultural use in the decommissioning stage. Concluding, while in eight cases the temporal character of the cases was considered, only two cases used landscape features to enhance future use of the sites, beyond site restoration (Sinha et al., 2018). Thus, in most cases use of landscape features in decommissioning stage is not explicitly considered, which in turn might adversely affect their continuation (Semeraro et al., 2018). This unclarity of the decommissioning stage has already been identified for wind energy and can potentially result in repowering or abandonment of renewable energy technologies (Windemer, 2019).

Reflections on emergent properties across frontrunner solar landscapes 4.4.3.4

Although most cases pay attention to visibility, multifunctionality and temporality, the spatial arrangement of each case illustrates varying degrees of integration between solar infrastructure and landscape features. In the Kwekerij, these are entwined to a degree that the case is neither just a solar power plant nor just a public park: it is a combination of both. Patches have been configured to allow visitors to walk between the arrays, height of the arrays has been adjusted to address visibility concerns of neighboring residents. In Gänsdorf however, solar infrastructure and landscape features are strictly separated: additional functions are not found within, but next to the PV patches.

Whether landscape features are sustained beyond the decommissioning of the solar infrastructure depends on the type of the features. Features enhancing landscape character (e.g. Southwick) or features able to provide a function independent of solar infrastructure in the future (e.g. Kwekerij) are likely to be sustained. In Midden-Groningen, on the contrary, some of the landscape features are unfamiliar to the host landscape and their existence will be less certain when the SPP is decommissioned.

4.5 Conclusions

This study aimed to contribute to the understanding of solar landscapes by examining 11 frontrunner cases across Europe, guided by the following research question: *what are the visual, functional and temporal properties of frontrunner solar landscapes in Europe?*

The examined frontrunner solar landscapes use a combined spatial arrangement of solar infrastructure and landscape features to address societal concerns. Solar infrastructure operates on system, patch and array level and landscape features are categorized as ecological, recreational and educational, agricultural and water management features. Visibility is reduced in all cases; yet in five cases visibility is simultaneously enhanced in dedicated areas in combination with recreational amenities. Cases contain between 6 and 14 different functions, although the share of land allocated to multifunctionality differs greatly between cases. In addition to electricity generation, habitat creation is identified in all cases, and in 9 out of 11 cases pollinating, screening and small-scale agricultural functions are identified. In eight cases the temporal character is considered in some way, yet only two cases explicitly introduce landscape features to enhance future use of the sites.

Across the cases, our analysis of spatial properties shows how contemporary concerns about SPP, such as visual impact, land use competition and the end-of-life stage are addressed. Next to these empirical findings, we draw three main conclusions from this case-study.

First, although the cases altogether present a portfolio of measures responding to societal concerns, the full potential of the three key properties is yet to be explored. The orientation of PV arrays, for example, is optimized for maximum electricity generation in all cases. Alternative array orientation may support maintaining existing landscape patterns and, simultaneously, reducing peak load on the electricity grid. Another example is the presence of similar landscape features across cases, despite the differences in character of the host landscapes.

Second, despite the additional benefits found in the cases, some (local) trade-offs may still emerge. To illustrate, some of the identified configurations of PV patches provide space for provisioning, regulating or cultural functions but can, at the same time, destroy existing landscape patterns. Furthermore, a high share of land solely dedicated to ecosystem functions increases the total land area needed to generate a set amount of electricity. These examples show the need to assess both individual properties as well as the SPP as a whole. Where existing research on additional benefits for SPPs is mainly theoretical, the empirical evidence in this research resulted in properties and initial indicators to describe, compare and potentially assess additional benefits. Such properties and indicators can become part of environmental impact assessments, multi-criteria decision analysis and other methods to asses not only *negative*, but also *positive* impacts of SPP. For example, assessment of *enhancing visibility* (e.g. through dedicated recreational areas with clear views on solar infrastructure) may enrich impact assessments that consider visibility as a negative property exclusively. Yet, other properties related to visual impact, such as frequency of views and glare still need to be taken into account. Similar, including properties such as temporality in multi-criteria decision analysis may favor alternative proposals of SPP that allow continuation of existing landscape features.

Third, as individual cases diverge in their attention for certain properties, further distinctions within the concept ‘solar landscape’ can be made. To illustrate, some cases focus mainly on visibility and only marginally on multifunctionality. In addition, some cases focus on provisioning and regulating functions, while others focus on cultural functions. A clear distinction between the different types of solar landscapes may help to conceive solar power plants appropriate to the site-specific considerations of local stakeholders and society at large.

Acknowledgements

The authors are grateful to the experts that helped to identify the cases, and to Florian Becker and Coos van Ginkel (both Wageningen University) and Paolo Picchi (Amsterdam Academy of Architecture) for their assistance in the data collection and analysis. Furthermore, we thank Martine Uyterlinde (Netherlands Environmental Assessment Agency) and Adri van den Brink (Wageningen University) for reviewing an earlier version of this paper, and the members of the Dutch National Consortium 'Solar energy and Landscape' and the Solar Research Program (Wageningen University) for providing valuable feedback during presentations of intermediate results. Last, we like to thank the anonymous reviewers for their useful comments and critique.

Semi-transparent PV panels generate electricity, improve the micro-climate and protect the raspberries below from extreme weather conditions. Agrivoltaic Babberich, Gelderland, the Netherlands (source: author).

Chapter 5

Emergent typology of solar power plants: How societal considerations start to shape renewable energy landscapes

Dirk Oudes
Adri van den Brink
Sven Stremke

A modified version of this chapter has been accepted with minor revisions at
Energy Research & Social Science

Abstract

Development of solar power plants (SPP) is no longer limited to remote and low population density areas, but now include urban and rural landscapes where people live, work and recreate. Societal considerations are starting to give rise to a new generation of SPPs that can be broadly defined as multi-purpose SPPs. In addition to electricity production, these multi-purpose SPP include agricultural functions, deliver benefits for flora and fauna, mitigate visual impact or preserve cultural heritage. In this paper, we systematically examine the different spatial forms of multi-purpose SPPs that reflect a range of contemporary societal considerations. The purpose of this research is to create and test an SPP typology that can support more evidence-based and transparent processes, from location finding to implementation and evaluation. Comparative case analysis, expert interviews and questionnaires are used to analyze, organize and distinguish different types of SPP. We propose a typology that consists of four dimensions: energy, economic, nature and landscape. These dimensions lead to three main types, mixed-production, nature inclusive, landscape inclusive, and their combinations. This typology adds to the existing energy landscape vocabulary, provides direction to and ingredients for (local) decision-making on solar energy landscapes. In doing so, the research supports the development of energy landscapes that contribute to global renewable energy targets with increasing attention to societal considerations.

Introduction 5.1

Solar power plants (SPP) contribute to achieving renewable energy targets and mitigating climate change. SPPs are no longer limited to remote and low population density areas, but appear in urban and rural landscapes where people live, work and recreate (Pasqualetti & Stremke, 2018; Roddis et al., 2020). The physical appearance and experience of these landscapes by people is changed by photovoltaic (PV) panels, inverters, transformers and other supporting electrical infrastructure (Bridge et al., 2013; Merida-Rodriguez et al., 2015; Pasqualetti, 2011b; Scognamiglio, 2016). Consequently, new landscapes are created. These are conceptualized as (solar) 'energy landscapes' (Bridge et al., 2013; Nadaï & van der Horst, 2010) and increasingly understood as co-constructions of social and material relations, notably in the ERSS special issue *Spatial Adventures in Energy Studies* (see for example Bridge, 2018; Castán Broto & Baker, 2018; Pasqualetti & Stremke, 2018).

Recent publications highlight the need to include a broad set of societal considerations in the creation of solar energy landscapes, beyond techno-economic considerations such as energy efficiency and cost-effectiveness (Delafield et al., 2021; Sovacool, 2014). Societal considerations such as land use competition (Chiabrando et al., 2009; Denholm & Margolis, 2008), habitat fragmentation (Hernandez et al., 2014; Turney & Fthenakis, 2011) and visual impact (Bevk & Golobič, 2020; Scognamiglio, 2016), become more urgent in the light of (local) resistance against planned SPPs (Fontaine, 2020; Pasqualetti & Brown, 2014; Roddis et al., 2020), which is expected to increase while SPP become a major player to meet renewable energy targets.

Societal considerations regarding SPPs, as with any other energy infrastructure, are commonly discussed during the planning and design process amongst stakeholders (Picchi et al., 2019). Currently, societal considerations are often used to distinguish between suitable and unsuitable sites for SPP development. Bridge (2018) refers to this siting as a strategy of *territorial differentiation*:

stakeholders, often governments, differentiate between spaces based upon local characteristics and geographical conditions according to considerations of suitability. Suitable locations are often those with favorable technical conditions (e.g. high solar irradiance, available grid capacity) and minor negative impacts. Minimizing negative impact is done by identifying low-cost land (e.g. Milbrandt, Heimiller, Perry, & Field, 2014), minimizing ecological effects (e.g. Stoms, Dashiell, & Davis, 2013) or addressing visual aspects (e.g. Apostol, Palmer, et al., 2017; Fernandez-Jimenez et al., 2015). For SPPs, low impact locations often come down to degraded or contaminated land, peripheral areas, infrastructure, surface water and rooftops (Frantál et al., 2018; Hernandez et al., 2019). However, this strategy of finding locations with the least negative impact becomes less effective as the transition progresses and 'easy' locations become scarce (Delafield et al., 2021; Frantál et al., 2018; Pasqualetti & Brown, 2014). This strategy also raises ethical questions about social and environmental displacement (Kramarz, Park, & Johnson, 2021).

In this paper we therefore turn our attention to a strategy where societal considerations change the nature of the SPP itself (Bridge et al., 2013). Stakeholder values and preferences have started to give rise to SPPs with multiple purposes, instead of only electricity production (Oudes & Stremke, 2021). These multi-purpose SPPs produce renewable electricity, but at the same time include agricultural functions (Dupraz et al., 2011), deliver benefits for flora and fauna (Randle-Boggis et al., 2020; Semeraro et al., 2018), mitigate visual impact or preserve cultural heritage (Selman, 2010; Wolsink, 2017).
As a result of including societal considerations, multi-purpose SPPs have a different spatial form when compared to SPPs that are optimized for maximum electricity production. Spatial form in this paper refers to the material and perceivable energy landscape (Calvert et al., 2019), specifically PV infrastructure and accompanying interventions to achieve other purposes. For example, elevated

arrays to enable agricultural functions beneath PV panels. Developing parts of the SPP project area as nature, uncovered by PV panels, is another example of an alternative spatial form. As multiple spatial forms of SPPs exist, they can be differentiated and specified based on their spatial properties. This aligns with what Bridge (2018) refers to as *material differentiation*, where the spatial properties of an SPP function as markers to “specify certain qualities”. An overview of different spatial forms of SPPs is needed to foster the inclusion of societal considerations in evidence-based and transparent planning and design processes (Bidwell, 2016; Stremke, 2015; Stremke & Picchi, 2017).

Several studies have described SPPs with alternative spatial forms that attend to societal considerations. Together, these studies offer a range of possible differentiations. For example, SPPs that provide for suitable habitats (Blaydes, Potts, Whyatt, & Armstrong, 2021; Randle-Boggis et al., 2020), or that address the relationship between SPP, landscape patterns and landscape perception (Scognamiglio, 2016; Stremke & Schöbel, 2019). Recently, several studies have focused on co-locating PV with agriculture, also known as agrivoltaics or agrophotovoltaics (Dupraz et al., 2011; Jain, Raina, Sinha, Malik, & Mathur, 2021; Toledo & Scognamiglio, 2021). This type of SPP is characterized by a synergetic relationship between crop or livestock and PV, as the latter improves microclimatic conditions for the former (Amaducci, Yin, & Colauzzi, 2018; Dupraz et al., 2011; Pascaris, Schelly, Burnham, & Pearce, 2021; Toledo & Scognamiglio, 2021). A few studies have identified variations of SPP. Hernandez et al. (2019) has presented an overview of techno-ecological synergies of solar energy with ‘recipient systems’ (land, food, water and the built environment). Frantal et al. (2018) have identified a group of smart practices of renewable energy, among which SPP, that provides synergy with for example infrastructure, other land uses and cultural heritage. Similarly, Burke (2018) has presented an overview of beneficial practices of solar energy, including floatovoltaics, agrivoltaics and conversion of degraded areas. However, most of the existing literature has either discussed individual *types* of SPP in detail without considering other types or has presented a *typology* of land use combinations, with little attention to spatial form. Existing literature lacks insights in the interaction between societal considerations and the spatial form of SPPs. Such insights, however, can support local participatory planning and design processes as well as evaluation and decision-making for SPPs.

In this paper, we systematically examine the different spatial forms of multi-purpose SPPs that reflect a range of contemporary societal considerations. The purpose of this research is to create and test an SPP typology that can support more evidence-based and transparent processes, from location finding to implementation and evaluation. Comparative case analysis, expert interviews and a questionnaire to case informants are used to analyze, organize and distinguish between different types of ground-mounted SPP. We focus on the latter because they have received most criticism, compared to for example SPPs on water or rooftops. Our research question is: *which societal considerations materialize in Solar Power Plants and what types of multi-purpose SPP can be defined to support evidence-based and transparent planning and design of SPPs?*
Section 5.2 presents the methods and materials of this study that entails a case study, literature analysis as well as development and testing of the typology. The typology of solar power plants is presented in section 5.3, followed by a discussion in section 5.4 and conclusions in section 5.5.

5.2 Methods & materials

5.2.1 Case study and literature analysis

We used a comparative case study and literature analysis to examine how societal considerations start to shape the spatial form of SPPs. To capture a wide range of differences in spatial forms, we identified, selected and analyzed multiple diverse cases (Sovacool, Axsen, & Sorrell, 2018). Initially, over 30 cases in Germany, the Netherlands, United Kingdom and Italy were identified through consultation with both spatial and solar energy experts and internet searches. We asked the experts for cases of exemplary SPP that accommodate multiple purposes (e.g. biodiversity, recreational or aesthetic benefits) in addition to electricity production. The cases provided by experts were supplemented with award winning SPPs identified via internet searches and with cases known to the authors based upon a decade of field observations. A quick-scan revealed the key spatial properties of the cases. Following this quick-scan, we selected cases that varied with regard to key spatial properties, country, scale and local context (e.g. landscape type, urban or rural setting). We excluded cases (1) where other purposes in addition to electricity production were limited or absent, (2) where other purposes were envisioned but not realized, and (3) where insufficient project documentation was available. The resulting 20 cases (table 5.1) were analyzed for their spatial properties. The spatial analysis was performed on the basis of an existing analytical framework that focuses on the interaction between solar infrastructure and the host landscape, visibility, multifunctionality and temporality of SPP (Oudes & Stremke, 2021). Data used were project documentation, including design drawings, satellite imagery and field observations.

The spatial properties found in the cases were related to key societal considerations identified in literature. We used peer-reviewed literature, for example studies examining the development of SPP in specific sites or local communities (e.g. De Laurentis & Pearson, 2018; Fontaine, 2020; Moore & Hackett, 2016; Roddis et al., 2020) or reviews that identified social, environmental or economic implications of SPP (e.g. Hernandez et al., 2014; Scognamiglio, 2016; Turney & Fthenakis, 2011).

Table 5.1. The selected cases. The project area includes all functions associated with the spatial development. For case no. 20, Agri-PV has currently been implemented on only half of the fruit farm.

#	Case	Country	Year constructed	Power of PV system (MWp)	Project size (ha)
1	Solarfeld Gänsdorf	Germany	2009	54,0	180,9
2	Solarpark De Kwekerij	Netherlands	2016	2,0	7,1
3	Valentano	Italy	2011	6,0	17,6
4	Southill Solar	United Kingdom	2016	4,5	18,1
5	Solarpark Hemau	Germany	2002	4,0	18,0
6	Zonnepark Laarberg	Netherlands	2018	2,2	6,4
7	Sinnegreide	Netherlands	2018	11,8	12,0
8	Solarpark Mühlenfeld	Germany	2013	3,5	24,4
9	Zonnepark Midden-Groningen	Netherlands	2019	103,0	121,2
10	Monreale	Italy	2010	5,0	28,0
11	Southwick Estate Solar Farm	United Kingdom	2015	48,0	83,4
12	Energielandschaft Morbach	Germany	2002	4,5	36,3
13	San Gabriele	Italy	2009	4,0	14,5
14	Energie- und Technologiepark Eggebek	Germany	2011	83,5	449,0
15	Merston Community Solar Farm	United Kingdom	2016	10,0	25,0
16	Zonnepark 't Oor	Netherlands	2019	2,1	4,2
17	Eco-zonnepark Ubbena	Netherlands	2017	0,6	2,0
18	Sawmills Solar Farm	United Kingdom	2015	6,5	31,0
19	Verwood Solar Farm	United Kingdom	2015	20,4	44,0
20	Babberich Agri-PV	Netherlands	2020	2,7	3,4

5.2.2 Development and testing of typology

The typology was developed by specifying similar sets of spatial properties related to key societal considerations. We tested different ways to organize the sets of spatial properties by multiple iterations of cross-case comparison and individual case reflection (Eisenhardt, 1989; Yin, 2009). This resulted in four dimensions of SPPs: energy, economic, nature and landscape. The typology has been further supplemented and elaborated in an iterative process of synthesizing the case evidence with feedback from case informants and experts.

Feedback from case informants was gathered using a short e-mail questionnaire to understand how people involved in the development of the SPP interpreted the dimensions. As this paper specifically focuses on multi-purpose SPPs, informants were asked to give their interpretation on the economic, nature and landscape dimension. All case informants have been involved in the development of one of the cases, for example as initiator, designer or developer. We were able to identify and approach informants from 16 of the 20 cases of which 14 (response rate 87%) responded to our questionnaire. In the questionnaire, the case informants were asked to characterize their SPP by distributing 100 points across the economic, nature and landscape dimension and explain their key arguments for this characterization.

In addition to the case informants, experts were interviewed with the purpose to test the typology. We selected 17 experts from an active community of professionals and academics in the Netherlands that is engaged with the spatial development of SPPs. Selected experts were expected to have an overview of the development of multi-purpose SPPs. We were able to interview 14 of these experts (response rate 83%), with backgrounds in solar industry (4), design & consultancy (4), academia (3), government (2) and NGO (1). The interviews were conducted and recorded using Microsoft Teams. The semi-structured interview protocol was tested once in advance and allowed experts to use an SPP case well known to them to engage with the typology. We used cognitive interviewing to understand how the experts interpreted and related the spatial properties of their case to the typology (Willis & Artino, 2013). By discussing the expert case, we received feedback on the dimensions, the types and the spatial properties. Of the 14 experts, 10 discussed a case that was not part of the initial case study, introducing new case evidence to the development of the typology. The interview protocol was designed to question the expert on the delineation of the types and the completeness, comprehensibility and applicability of the spatial properties and types.

The transcribed interviews were analyzed to identify patterns across the expert feedback. The feedback on the properties was used to complement and specify the case analysis framework. Feedback on the dimensions and types was used to inform our understanding of the typology. Major comments by multiple experts were incorporated in the typology, minor comments by one or two experts were addressed by improving the description of the types.

5.3 Typology of solar power plants

This section starts with the societal considerations that we observed shaping the spatial form of the cases, forming the foundation of the typology (5.3.1). Following the foundations, the typology and the accompanying dimensions are explained (5.3.2), further specified by a description of the individual types (5.3.3 - 5.3.6).

5.3.1 Foundations for the typology

We identified economic, nature and landscape considerations that materialized in the spatial form of SPPs (fig. 5.1). An overview of the literature that discusses these considerations can be found in appendix G. *Nature* considerations mainly represented consequences for flora and fauna and their living environment. Cases attended to these considerations by retaining existing ecological qualities or introducing new ecological features. Altering the layout of solar infrastructure by, for example, decreasing the patch density, is also a way to retain or improve the living environment of flora and fauna. *Economic* considerations included the loss of existing land use, effect on tourism and the local economy and grid capacity. Several cases included one or multiple productive land use functions in the spatial form of the SPP, in addition to solar electricity production. *Landscape* considerations mainly represented consequences for landscape patterns and

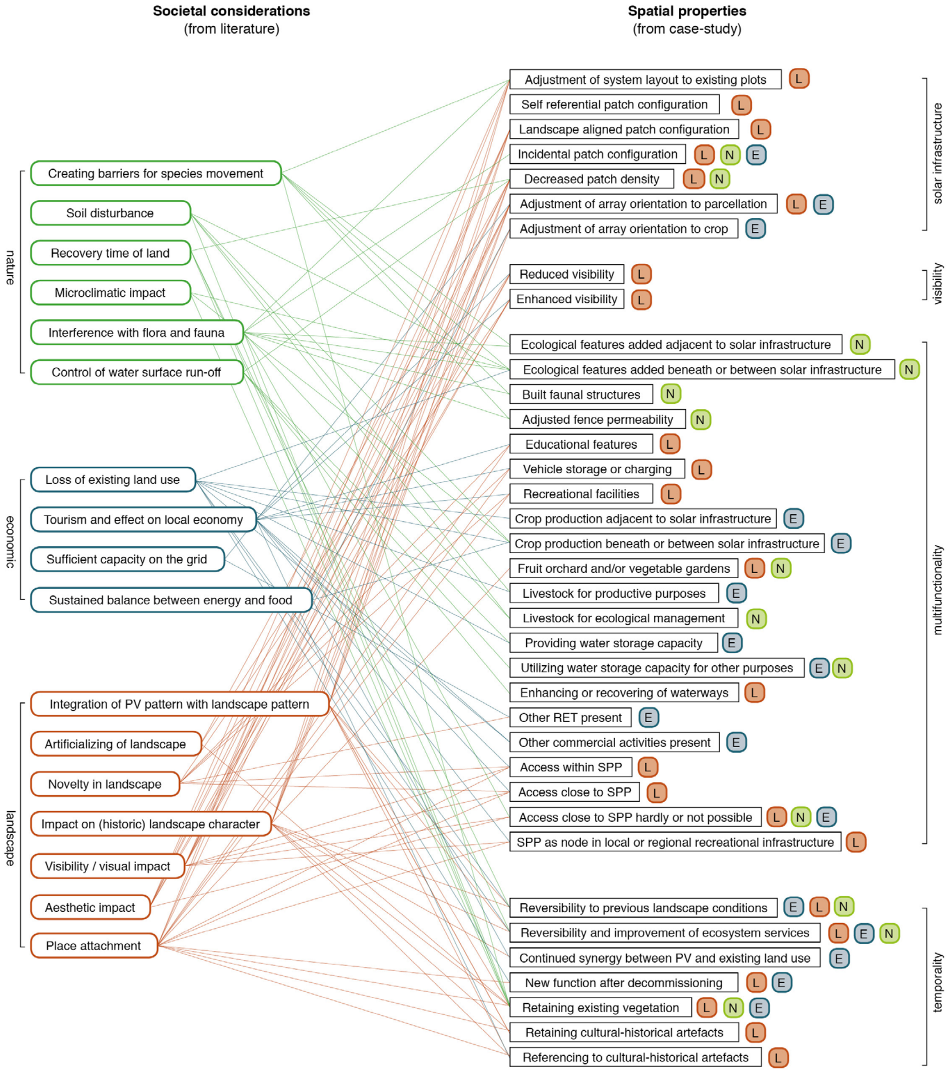


Fig. 5.1. Key societal considerations (left) and spatial properties of cases (right). The societal considerations are categorized into three groups: nature, economic and landscape. The spatial properties have been identified in the cases and are thematically grouped: properties are predominantly related to solar infrastructure, to visibility, to multifunctionality or to temporality in line with the analytical framework of (Oudes & Stremke, 2021).

perception by landscape users. These considerations materialized in the cases through, for example, careful interaction between solar infrastructure and landscape, addressing visibility and providing recreational and education functions for local landscape users.
The spatial properties were based upon earlier research (Oudes & Stremke, 2021) and categorized as properties that are predominantly related to solar infrastructure, visibility, multifunctionality and temporality (fig. 5.1). The expert interviews that included additional case evidence, resulted in the textual adjustment of nine properties, addition of one property and splitting of a property into two separate properties. Some properties mainly reflect either economic, nature or landscape considerations, while other properties can be linked to multiple groups of considerations. For each of the studied cases, the properties of spatial form, or the spatial properties, can be found in appendix H.
Together, inclusion of nature, economic and landscape considerations in the spatial form of SPPs represent three separate dimensions of SPPs that constitute the basis of the typology.

5.3.2 Four dimensions: energy, economic, nature and landscape

The interviewed experts confirmed the economic, nature and landscape dimension as expressions of societal considerations in the spatial form of SPPs. Together with the energy dimension of electricity production, these dimensions shape the spatial form of an SPP (fig. 5.2). Using these four dimensions of the typology, the spatial form of an SPP can be examined and discussed.

The energy dimension forms the basis of a multi-purpose SPP and – in relationship to spatial form – is expressed by energy density. Energy density is indicated by, for example, yearly production per hectare (in MWh/ha/y), power capacity per hectare (in MWp/ha) or spatial footprint of the system (land area occupation ratio, LAOR) (Oudes & Stremke, 2021; Scognamiglio, 2016). The latter indicator is illustratively used in this section because it allows a comparison of SPPs across time as panel efficiency has increased significantly.

This indicator does not, however, account for projects where stakeholders may consider to use more efficient panels to reduce the spatial footprint at a higher financial cost.
Often, energy density of multi-purpose SPPs is lower compared to SPPs that focus only on maximizing electricity production. Attention for the other three dimensions decreases energy density because either available space for PV panels or panel efficiency is reduced.
With the energy dimension as basis, an SPP addresses societal considerations by a predominant focus on either the economic, nature or landscape dimension. Such a focus leads to three main types: *nature inclusive*, *landscape inclusive* and *mixed production* SPPs (fig. 5.2, table 5.2).

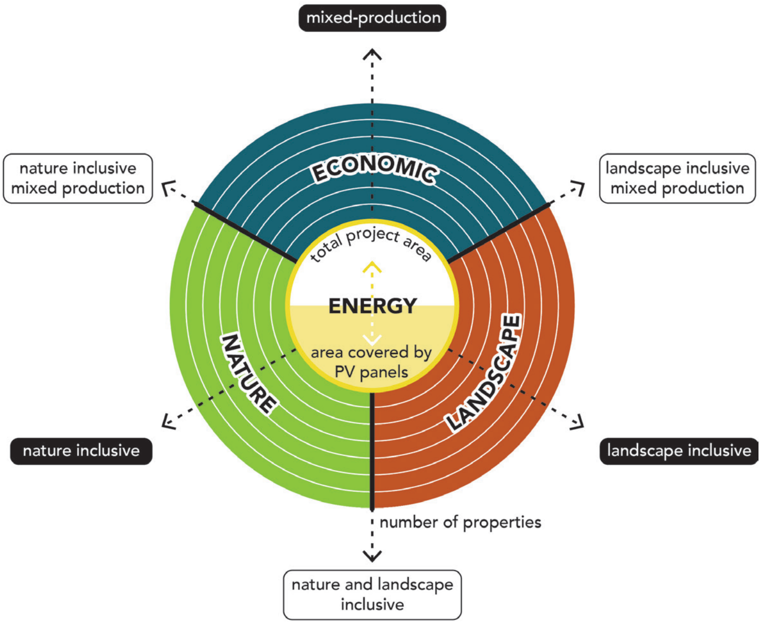


Fig. 5.2. Four dimensions of solar power plants: energy, economic, nature and landscape dimension. The energy dimension forms the basis of the SPP and is expressed by energy density, in this figure by the land area occupation ratio (LAOR) (Oudes & Stremke, 2021; Scognamiglio, 2016). The economic dimension comprises economic activities in addition to electricity production. The nature dimension consists of spatial properties related to nature. For the landscape dimension the same logics apply.

Table 5.2. Three main types of SPP: mixed production, nature inclusive and landscape inclusive SPP.

Main type	Description	Key spatial properties	Spatial variations
Mixed production (MP SPP)	SPP is optimized for maximum economic profit by mixing electricity production with other profitable land use functions.	- Crop production - Other renewable technology present - Other commercial activities present	- Agrivoltaics (agriphotovoltaics); - Hybrid energy systems - Energy – technology parks
Nature inclusive (Ni SPP)	SPP is developed to improve living conditions of flora and fauna. This may lead to a suboptimal system layout for electricity production.	- Ecological features beneath, between or adjacent to solar infrastructure - Built faunal structures - Adjusted fence permeability	- Ecological features next to a dense PV patch (adjacent multifunctionality) - Ecological features beneath or between PV panels in a porous PV patch (array or patch multifunctionality)
Landscape inclusive (Li SPP)	SPP is developed to improve physical landscape elements or patterns and/ or the use and experience of the SPP by landscape users. This may lead to a suboptimal system layout for electricity production.	- Adjustment of system layout to existing plots - Landscape aligned patch configuration - Reduced visibility - Educational features - Recreational facilities	- Recreational or educational features or a zone that considers visibility next to a dense PV patch (adjacent multifunctionality) - Recreational or educational features next to a porous PV patch or multiple smaller patches (array or patch multifunctionality) - Active engagement of landscape users through recreation and education - Non-active engagement of landscape users; - Preservation of existing landscape elements - Restoration of existing landscape elements - Transformation of the existing landscape and introduction of new landscape elements

In general, the presence of multiple key spatial properties (table 5.2) in a specific dimension and the absence of properties in the other dimensions indicates the main type for an SPP.
Based upon the case study, the expert interviews and the responses from the case informants, attention to the economic, nature and landscape dimension is expressed by a combination of the number and the intensity or scale of the properties. An SPP with many spatial properties related to one of the dimensions, reflects the many considerations, preferences or opportunities that stakeholders have included in the spatial form. At the same time, a consideration can also materialize by including only one or two large-scale features. For example, in Southill Solar (United Kingdom), the local sustainability cooperative decided to dedicate more than half of the project area to biodiversity improvements. Furthermore, case informants used terms such as ‘marginal’ and ‘small-scale’ to indicate certain features were present but were of limited significance for the project as a whole. In addition, seven experts mentioned the aspect of scale, an ecologist for example argued “more space [for nature] is always better from a nature perspective”. This feedback makes clear that attention to a certain dimension is not only the presence of an certain feature, but also its scale in comparison to the other dimensions. To convey the typology in a systematic and transparent way, the examples in the remainder of the results section only show the number of properties related to the dimensions.

In addition to the main types, the cases often expressed a mix of dimensions. These combination types are *nature and landscape inclusive*, *nature inclusive mixed production* and *landscape inclusive mixed production*. Nature and landscape inclusive SPP followed directly from the case study, while the other two combinations were stressed by several experts during the interviews and supported by projects still under construction. In the following, we will describe the three main types, mixed-production (5.3.3), nature inclusive (5.3.4), landscape inclusive (5.3.5) and the types that combine multiple dimensions (5.3.6).

5.3.3 Mixed production SPPs

Mixed production SPPs (MP SPPs) are optimized for economic profit by mixing electricity production with other profitable land use functions. Based upon the case study, we found three major land use functions in addition to solar energy generation: agriculture, other renewable energy technologies and other commercial activities related to the SPP or the site. In SPPs combined with agriculture, often termed ‘agrivoltaics’, PV panels are located between or above some form of agriculture, either crop production or livestock. In a fruit farm in Babberich (the Netherlands), the solar developer placed semi-transparent PV panels above the fruit trees to provide an improved micro-climate and risk reduction, beneficial for the farmer (fig. 5.3). The case informant stressed the continued synergy between the two productive functions as key arguments for this spatial variation (or sub-type) of MP SPP. In other variations of MP SPPs, multiple (renewable) energy technologies are co-located, for instance wind turbines and biomass facilities. Co-location of multiple renewable energy technologies may include a shared use of grid capacity, but it is also used for place branding: Eggebek, a former military airport in Germany, presents itself as an ‘energy and technology park’ and includes other commercial activities related to renewable energy technologies. In this case, the SPP is combined with wind energy testing and research, a biogas facility and other companies related to renewable energy.

5.3.4 Nature inclusive SPPs

Nature inclusive Solar Power Plants (Ni SPP) improve the living conditions for flora and fauna, in addition to renewable electricity production. Key characteristics are space for ecological features (e.g. habitats), creating the proper conditions for these ecological features (e.g. permeability of the fence), and the proper management regime to sustain flora and fauna through time.

Reserving space includes both creation of new habitats (e.g. wildflower meadows, fruit orchards) and retaining existing vegetation. In both situations, stakeholders may decide to adjust the scale and layout of

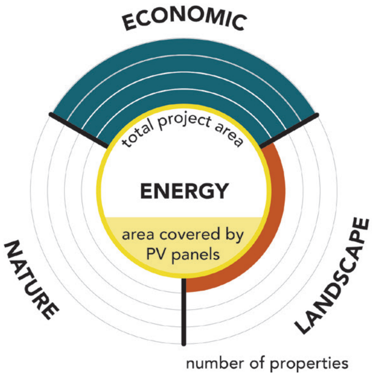


Fig. 5.3. Babberich Agri-PV in the east of the Netherlands. Left: the high number of economic properties in Babberich illustrates the focus on economic considerations. Right: Raspberries grow in an improved micro-climate and the panels protect the fruit from extreme weather conditions. The semi-transparent panels generate electricity and leave enough solar irradiation for the growth of the raspberries.

PV infrastructure to this end. The patch density may be decreased, existing trees are retained or ecologically valuable areas are kept free from PV panels. These two models of creating space for habitats result in two different spatial variations of Ni SPPs: either a relatively dense PV patch with an adjacent area for ecological features, or a relatively porous PV patch with ecological features mainly between or beneath PV panels. The former exhibits *adjacent multifunctionality* while the latter exhibits *array or patch multifunctionality*. Providing the right conditions for the (created or retained) ecological features is related to accessibility: adjusting the permeability of the perimeter (usually a fence) to deny or allow access to certain species, depending on the ecological targets and potentially limiting access for humans when sensitive species are targeted. Experts stressed that proper management of SPPs is needed to achieve the set ecological targets and sustain them through time.

An example of a nature inclusive SPP is solar park Hemau in Germany (fig. 5.4). This SPP is located on a former munition depot that lies within a forest area. Existing areas with high ecological qualities have been kept free from PV panels and new wet and dry ecological areas have been created. The case informant argued the focus on the nature dimension depends not only on these spatial features, but also on securing maintenance directed at improving ecological conditions.

5.3.5 Landscape inclusive SPPs

Landscape inclusive Solar Power Plants (Li SPPs) improve physical landscape elements, landscape patterns, or/and the use and experience of the SPP by landscape users. The experts stressed the significance of the host landscape character when considering the proposed features. To illustrate, a regional government official stated: “in open polder landscapes [...] I would find it strange to use dense vegetation around a large solar park to hide it from sight”.

Indicatively, three sets of variations in spatial form emerge. First, similar to nature inclusive SPPs, landscape inclusive SPPs reserve space for functions other than electricity production *beneath or between* PV panels (array or patch multifunctionality, e.g. walking paths between PV panels) or next to PV panels (adjacent multifunctionality, e.g. a lookout next to PV panels).

Second, variations in *active* and *non-active* engagement with landscape users. Li SPP that *actively* engage landscape users include recreational or educational features. This may vary from providing a visual overview of the SPP from constructed vantage points, to providing public access to the SPP for leisure and community gatherings. Some of these features may affect energy density as community event spaces and similar features require space.

Contrastingly, for Li SPP that *not actively* engage landscape users, stakeholders decided to keep the SPP (partly) away from the perception of landscape users. Such SPPs use for example local landscape elements or low PV arrays to reduce visibility of the PV panels.

The third set of variations involves the kind of interventions done in the existing landscape. Some cases focus on *preserving* existing landscape features, other cases on *restoring* landscape features that were present in the past and again others on *transforming* the site using new landscape features.

An example of a landscape inclusive SPP is Southwick Estate Solar Farm (United Kingdom) (fig. 5.5). Landscape considerations have mainly materialized *next to* the PV patches, focusing on *preserving* the existing hedgerow structure and plot shapes. The existing hedgerow structure has been improved to reduce the visibility on the PV panels. This is therefore an example of an Li SPP with non-active engagement of landscape users.

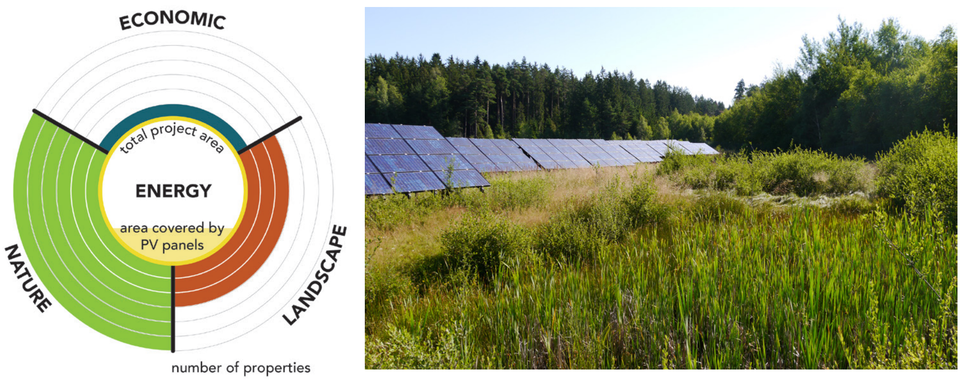


Fig. 5.4. Solar park Hemau in Germany, near Regensburg. Left: Hemau illustrates some attention to landscape and economic considerations, but most measures are taken for nature. The area covered by PV panels is relatively low because of the high row-to-row distance and areas kept free of PV panels to preserve and improve ecological conditions. Right: wet vegetative patches have been created within the SPP.

Fig. 5.5. Southwick Estate Solar Farm, north of Portsmouth, United Kingdom. Left: Southwick pays some attention for nature and economic considerations, but exceeded in the amount of landscape properties. Right: PV patches are aligned in the landscape to maintain existing vegetation intact and reduce visibility.

5.3.6 Combinations of economic, nature and landscape dimension

In addition to SPPs with a single focus on the economic, nature or landscape dimension, attention to diverse societal considerations leads to a combination of multiple dimensions. Departing from the typology (fig. 5.2), combinations of economic-nature, economic-landscape, nature-landscape and economic-nature-landscape can be distinguished. The case study revealed multiple examples of SPPs that focus on both the nature and landscape dimension. In line with the other types, this combination type is referred to as a *nature & landscape* inclusive SPP.

Nature and landscape inclusive SPPs attend to both nature and landscape with spatial features that are synergetic or co-located without synergy. Synergetic nature and landscape features work together to provide benefits for both nature and landscape. For example, using native vegetation to reduce visibility, or using landscape (micro-)relief to improve ecological quality. Similar to Ni SPPs and Li SPPs, spatial variations such as (non) active engagement of landscape users and adjacent or array/patch multifunctionality can be distinguished.

A few cases showed attention to all dimensions. Monreale (Italy) was developed as a demonstration project and includes an olive grove for local olive oil production (economic dimension), an ecological corridor (nature dimension) and aligns with existing landscape patterns (landscape dimension). In addition, one of the experts discussed a case, under construction at the time of the interview, that combined electricity production with nuts and berry production (economic dimension), ecological improvements of the waterways (nature dimension) recovery of historical landscape elements (landscape dimension). Moreover, the agricultural activities are performed by a social farm that employs people whom have difficulties in finding employment (Duurzaam Haren, 2018).

Former munition depot Morbach (Germany) combines the economic and the landscape dimension. This case presents itself as an “interesting mix of renewable energies […] and material flow cycles” offering “a sustainable basis for innovative companies”

(Gemeinde Morbach, 2021). The site is publicly accessible, includes an visitor center and educational activities in the former munition storage bunkers.
Neither the case study nor the expert interviews, revealed evidence for a combination of the economic and nature dimension. Yet, multiple experts emphasized the potential and necessity of this combination for the near future.

Discussion 5.4

This paper presented an emergent typology of SPPs, of solar power plants that consist of an alternative spatial form following inclusion of societal considerations in addition to electricity production. The typology consists of four dimensions: energy, economic, nature and landscape; these dimensions lead to three main types, mixed-production, nature inclusive, landscape inclusive, and their combinations. We will first discuss the application of this typology in the planning and design of SPPs (5.4.1), followed by current and future research (5.4.2) and contribution of this typology to energy landscape vocabulary (5.4.3). We conclude this section by reflecting on methods and data.

Application of typology in planning and design of SPPs 5.4.1

Understanding different spatial forms of SPP gives direction to local stakeholders in shaping their renewable energy landscapes. Existing literature has called for improved decision-making and communication related to siting and design of renewable energy technologies (Steg et al., 2021). Participatory processes need to be transparent, evidence based and inclusive in terms of values, interests and concerns (Oudes & Stremke, 2018; Sovacool et al., 2020; Steg et al., 2021). The presented typology, with the four dimensions and types reflect a wide range of societal considerations to be discussed and negotiated by (local) stakeholders. The overview of spatial properties functions as a preliminary basis of evidence for such discussions as they point to specific spatial interventions. Policymakers, decision-makers and/or (local) stakeholders can subsequently use this base of dimensions, types and properties to set qualitative criteria for an SPP (Oudes & Stremke, 2020; Stremke, 2015). Criteria can be set on different levels of governance, for example from legislation set by national or regional governments to normative criteria agreed upon by local stakeholders (Oudes & Stremke, 2018). Furthermore, the typology expands the range of potential solutions to local stakeholders and allows a discussion not only about renewable energy, but inclusive of other local issues (e.g. nature or landscape related) as well (Roddis et al., 2020). Considering other (local) issues together with renewable energy provision invites local stakeholders to think integrative, potentially supporting high-quality participatory processes (Stober et al., 2021; Von Haaren, Warren-Kretzschmar, Milos, & Werthmann, 2014).

Currently, societal considerations of SPPs are mainly included in the planning and design of SPPs by *territorial differentiation*: identifying suitable and beneficial land use combinations (Bridge, 2018). Solar electricity production is combined with urban areas (rooftops) or degraded land to address land use pressure (Frantál et al., 2018; Hernandez et al., 2019). SPPs located on water bodies have an increased annual electrical output compared to on land-based SPPs and are generally located further away from urban areas (Golroodbari & van Sark, 2020). *Material differentiation* (Bridge, 2018), in this paper specifying a variety of spatial forms of SPPs, is a complementary approach in addressing societal considerations in the planning and design process of renewable energy landscapes. Although the cases studied in this research were mainly located on former agricultural land or brownfields, the typology of spatial form may also be of value in discussing SPPs on other land uses. Alternative spatial forms on other land uses are already recognized in literature, for example green solar rooftops (Schindler et al., 2018) or aquavoltaics, the combination of aquaculture and SPP (Pringle, Handler, & Pearce, 2017). This study places these innovations in a larger thinking framework and opens up the opportunity for other potential combinations, for example nature inclusive solar carparks. The main types and most combinations of dimensions followed from case evidence, either from the case study or the cases discussed during the expert interviews. Only the combination of the economic and nature dimension remains hypothetical for now. Nordberg et al. (2021) too identified this gap and suggest future research on the synergies between electricity production, agriculture and biodiversity improvements.

While both territorial and material differentiation are strategies to include societal considerations in the development of SPPs, potential improvement of local qualities depends on the qualities of the host landscape prior to the intervention. Introduction of new features is not a guarantee for overall improvement of the existing landscape. The existing landscape and SPP are able to interact positively, negatively and neutral. A *positive* interaction between SPPs and the existing landscape occurs when (components of) the existing landscape benefits from the introduction of the SPP. To illustrate, semi-transparent PV panels located above a fruit orchard improve the micro-climate and reduce risk. Similarly, solar carparks in urban landscapes provide a positive interaction as the shade of PV panels reduces excessive heating of the cars beneath in warm circumstances. A *negative* interaction with the existing landscape takes place when essential functions or values are replaced by other functions and values as a result from the introduction of the SPP. An example is the change from highly productive agricultural land to an SPP. Yet, also when a nature inclusive SPP is proposed on a location with high existing ecological qualities, the interaction may be regarded negative, when the net ecological quality reduces as a result of the SPP. When there is no significant positive or negative interaction between SPP and existing landscape, the interaction can be regarded as *neutral*. An example is a rooftop SPP that utilizes the rooftop but hardly interferes with existing functions and values.

In line with Schulz and Skinner (2022), the spatial form of a multi-purpose SPP needs to support a long term improvement in addition to the already existing qualities, avoiding the mere mitigation of negative impacts. On the one hand, this requires clear comparison of the spatial form to the existing landscape to avoid risks of 'greenwashing' (Burke, 2018). On the other hand, this provides the opportunity to move away from the focus on finding sites with the least negative impact, to finding sites with the highest potential increase in (economic, nature or landscape) quality. Identifying locations with the highest potential quality increase requires suitability analysis that not only uses the territory or land use as a variable, but also the proposed spatial form of an SPP. To illustrate, nature inclusive SPPs may be preferred on low-productive agricultural land using native vegetation species to improve local biodiversity. Brownfield sites in urban fringes, on the contrary, may be favorable to landscape inclusive SPPs offering recreational opportunities for inhabitants and other landscape users.

5.4.2 Current and future research

Whether the typology is applied in national or regional suitability studies or in local participatory processes, sufficient knowledge on all dimensions is needed to identify and assess cross-dimensional synergies and trade-offs (Fontaine, 2020). This study partly brings together and articulates knowledge on individual dimensions discussed and examined elsewhere. With regard to the *economic dimension* of SPPs, primarily agrivoltaic systems have been studied for their cost-efficiency (Schindele et al., 2020), land use efficiency (Trommsdorff et al., 2021) and shade effects on pollinators (Graham et al., 2021). Ecological measures of multiple cases of *nature inclusive* SPPs have been monitored and evaluated (e.g. Blaydes et al., 2021; Randle-Boggis et al., 2020). The *landscape dimension,* however, is scarcely studied, while others have already advocated that the energy transition requires "learning to love the landscapes of carbon-neutrality" (Selman, 2010). As this and other research has shown, multi-purpose SPPs also provide positive impacts on the current and future landscape (Lobaccaro et al., 2019; Oudes & Stremke, 2021; Scognamiglio, 2016). Future research could focus, for example, on the long-term landscape changes that take place during the operational stage of the SPP and how these changes are perceived by local landscape users (Sherren et al., 2016). Or, on the capability of landscape users to see, understand and differentiate between main types of SPPs. SPPs with tangible spatial features such as lookouts, community event sites and other recreational or educational facilities may be more easily recognized as 'different', compared to SPPs that enable the preservation of rare grasslands with carefully selected and executed ecological measures and maintenance.

5.4.3 Energy landscape vocabulary

In their first typology of energy landscapes, Pasqualetti and Stremke (2018) stressed the need to advance "the larger conversation" on energy landscapes. That typology distinguished between the substantive qualification (type of energy source), the spatial qualification and the temporal qualification. The paper at hand aims to inform the discourse on solar power plants (*substantive qualification*) by studying their spatial form (*spatial qualification*) and starting to consider temporal aspects. The spatial qualification is influenced by energy density, spatial dominance and the compatibility with other land uses (Pasqualetti & Stremke, 2018). Our research illustrates that adjusting the spatial form (e.g. adjust energy density, elevate PV panels) determines the compatibility with other functions. This means that depending on the spatial form, solar energy landscapes cover the spatial dominance spectrum from entity (sharp borders, monofunctional) to component energy landscape (diffuse borders, multifunctional) (Oudes & Stremke, 2020).

As the energy transition requires a "re-appraisal of the form, function and value" of contemporary landscapes (Bridge et al., 2013; Selman, 2010), the opportunities of SPPs to adapt to societal considerations may prove to be illustrative for other types of energy landscapes. Research on and discourse about energy landscape differentiation can therefore support the transformation of energy systems in a way that meets both the quantitative goals and qualitative considerations by society (Bridge, 2018). This paper has contributed to the vocabulary of solar energy landscapes that may support such a process.

5.4.4 Reflection on methods and data

The typology of SPPs was built upon cases from four European countries (Germany, The Netherlands, United Kingdom and Italy). Although this selection provided national and regional variety in for example landscape type, policy and legal regulations, other contexts may bring forth additional insights on the spatial form of SPPs. Furthermore, the experts that were interviewed were all Dutch and part of a professional and academic community that also includes the authors of this paper. This brings two limitations. The first is that the experts discussed the typology primarily from their daily 'reality' in the Dutch context. However, we believe that the Netherlands, with its high population density and scarcity of space, is representative of other urban delta's in the Global North. The second limitation is that some of the experts were aware of previous work of the authors, which may have led to social desirability bias. To counter this response bias, not uncommon in such studies, experts were continuously asked to articulate themselves as specific as possible and support their arguments with evidence from the expert case.

The case informants scored the attention for landscape lower compared to the outcomes of the case study. This lower attention for landscape of case informants can be explained by the fact that case informants primarily mentioned tangible landscape features added to the case, for example picnic benches, lookouts and charging points for electric bicycles. Less tangible properties, such as alignment of PV patch to landscape patterns, were only mentioned by one case informant.

Conclusion 5.5

This study set out to identify which societal considerations are included in Solar Power Plants, and consequently, what types of multi-purpose SPP can be defined to support more transparent and evidence-based planning and design processes. Our study shows that societal considerations start to shape the spatial forms of SPPs. Informed by case evidence and confirmed by expert interviews, four main dimensions have been identified: energy, economic, nature and landscape. Each of these dimensions, and their interaction, illustrates how co-construction of social and material relations give rise to different types of multi-purpose SPPs. More specifically, the main types *mixed-production*, *nature inclusive*, and *landscape inclusive* SPP have been distinguished through our analysis of 20 different SPPs.

The typology provides an overview of the different spatial forms of multi-purpose SPP but not all types have received equal attention from academia, solar industry or design practice. One type, nature inclusive SPP, is substantiated by multiple cases and already receives substantive attention by scholars. Another type, landscape inclusive SPP, is clearly present in the case evidence, but has yet received little attention in the scientific literature. SPPs that combine economic and nature considerations present an opportunity for future explorations in both academia and practice.

The different types of multi-purpose SPP illustrate the social production of SPPs, drawing them from the realm of technology into the realm of energy landscapes and, ultimately, the social sciences. Energy landscapes are the product of a societal process, involving negotiations between stakeholders. The typology presented in this paper gives direction to and provides ingredients for (local) decision-making on solar energy landscapes. Such evidence based decision making supports a social process that results in energy landscapes that contribute to global renewable energy targets with increasing attention to societal considerations.

Nature- and landscape inclusive solar power plant Abdissenbosch, under construction in Parkstad Limburg, the Netherlands (source: author).

Chapter 6

Discussion and conclusion

Landscape and the energy transition: answering the research questions 6.1

This thesis aimed to identify key tenets for a *landscape inclusive energy transition*, for advancing the energy transition while meeting societal considerations regarding landscape.

To this end, the following four research questions were central to this thesis:

1. How can spatially explicit, evidence-based and stakeholder-informed energy transition targets be defined?
2. How is landscape quality addressed in large-scale transformation projects and what is the role of design, governments and participation?
3. What are the visual, functional and temporal properties of frontrunner solar landscapes in Europe?
4. Which societal considerations materialize in Solar Power Plants and what types of multi-purpose SPP can be defined to support evidence-based and transparent planning and design of SPPs?

The first research question is answered by a methodological framework to analyze energy potentials and define energy transition targets (chapter 2). The framework uses local landscape knowledge, landscape characteristics and stakeholder preferences to advance a landscape inclusive energy transition on the regional scale. By including 'landscape' early in the energy transition process, societal considerations can inform technology and site selection, the timeline for implementation and ultimately the definition of energy targets. These insights can activate policy and decision-makers to adapt existing policies or create new policies to select specific sites and define the criteria for local design of energy landscapes.
The second research question is answered by systematically analyzing the literature on three large-scale landscape transformation projects, to understand how functional, experiential

and future aspects of landscape quality can be addressed in the energy transition (chapter 3). There is ample evidence that landscape transformations can provide benefits for all three aspects of landscape quality. With regard to functional aspects, multi-purpose landscape arise when governments address existing local issues or future demands in the transformation. Furthermore, knowledge of how stakeholders experience their landscape is important to engage them in the landscape transformation process. Future aspects are addressed by anticipating future developments in the early stages of the landscape transformation. The role of environmental design was significant in the landscape analysis and design of the transformation. Governments are essential in setting qualitative criteria for the transformation. Although participation was limited mostly to consulting and informing local stakeholders, including local stakeholder considerations can lead to synergies and support for the transformation.

The third research question is answered by a comparative analysis of solar landscapes (chapter 4). Visual, functional and temporal properties of the examined cases evidence how societal considerations lead to different physical landscapes compared to solar power plants that are only optimized for electricity production. The visual impact can be dealt with by reducing visibility, but also by enhancing visibility in combination with recreational facilities. Ecological, recreational, agricultural and water management features can become part of solar landscapes, addressing considerations of land use competition. These features may increase the needed amount of land for renewable energy provision. Considerations with regard to the end-of-life stage of solar technology are addressed in a few cases only, by creating landscape features that enhance the use of the site after decommissioning.

The fourth research question is answered by means of a typology of multi-purpose solar power plants. The typology consists of economic, nature and landscape dimensions that illustrate how different societal considerations lead to different types of solar power plants (chapter 5). The mixed-production type combines electricity production with other economic functions such as food production. The nature-inclusive type combines electricity production with the improvement of living conditions for flora and fauna. The landscape inclusive type combines electricity production with the improvement of the physical landscape or/and the use and experience of the landscape. The typology provides a basis for more systematic stakeholder-informed decision-making on solar power plants.

The findings of this PhD research indicate that including the concept of landscape in the energy transition discourse supports the continuity of the energy transition and at the same time helps to meet societal considerations regarding landscape. In this final chapter, this mutual approach is articulated as *landscape inclusive energy transition*. First, I will present and discuss five key tenets for a landscape inclusive energy transition – the first tentative building blocks that provides directions for continued innovation in research, policy and practice in the domain of renewable energy (6.2). The tenets suggest a more comprehensive understanding of the concept 'landscape' is needed in the energy transition (6.3). Furthermore, I will discuss the limitations of the research design of this thesis (6.4) and present recommendations for environmental planning and design (6.5). In the last section of this chapter, I argue that a *landscape inclusive energy transition* provides the conditions and means to merge considerations about landscape, justice and nature in the energy transition (6.6).

Five tenets for a landscape inclusive energy transition 6.2

Tenet 1: Knowledge and understanding of a landscape as foundation 6.2.1

In a landscape inclusive energy transition, knowledge on and understanding of specific landscapes from regional to local scale is used as a foundation for site selection and design.

Knowledge on landscape is used for defining regional energy transition targets; it consists of landscape characteristics, local landscape knowledge and stakeholder preferences (chapter 2). Physical *landscape characteristics* such as relief, land use and building types are used to identify the potential for solar energy, wind energy, heat-cold storage, water power and biomass. These physical landscape characteristics are generally available in maps and databases and prone to expert evaluation. Furthermore, *landscape knowledge of local stakeholders* provides a detailed view on energy potentials and consequently a strong basis for regional and local renewable energy targets. Including local knowledge reveals sites unwanted for renewable energy provision, or unexpected potential sites, in an early stage. In the case example of Parkstad Limburg (Chapter 2), making use of a proposed highway sound barrier for PV was an energy potential identified by local stakeholders. *Stakeholder preferences* influenced the composition of the future energy mix, partly determined by technology selection and explicitly including or excluding certain parts of the landscape for energy provision. Recent research confirms the benefits of inclusion of stakeholder preferences in regional energy potential mapping. When local stakeholders are involved *after* sites have been designated, it may “solidify existing divergent attitudes” towards a renewable energy project and frustrate participatory processes (Müller, Backhaus, & Buchecker, 2020, p. 9). Furthermore, local stakeholder knowledge and preferences can result in landscape specific potentials that would have been missed when limiting to physical landscape characteristics exclusively (Wolsink, 2017).
Knowledge on landscape is also key to the local design of energy landscapes (chapter 4). For solar landscapes, critical elements of the local design are existing landscape patterns and elements, solar infrastructure and their interactions. Knowledge consists of both the physical landscape (e.g. matching size and shape of PV patches to existing plots) as well as the way landscape users interpret and experience that landscape (e.g. adjusting the height of PV panels to decrease the visibility for nearby inhabitants).

6.2.2 Tenet 2: Active use of time

In a landscape inclusive energy transition, policy makers, designers, developers and landscape users actively use time in the development of energy landscapes.

Existing research on landscape change regards time as a rather *passive* factor: over time, preferences of local stakeholders may change in favor of the landscape change, pointing to the adaptability of communities (Park & Selman, 2011; Sherren et al., 2016). Such a view means waiting for landscape users to adapt to landscape change, at best appreciating the new status quo, but potentially spurring a carelessness of their landscape. The findings in this thesis show the potential to engage with time as an *active* factor in the development of energy landscapes.

First, as stressed in the previous tenet, local designs of energy landscape may *incorporate historic patterns and elements*, responding to past versions of landscapes (chapter 4). Although this may come at the cost of a lower energy density, preserving patterns and elements connects to previous generations and sustains place identity (Le Dû-Blayo, 2011).

Second, engagement of local stakeholders with energy landscapes is often diminished once renewable energy technology is operational in the *present* (Moore & Hackett, 2016). Multi-purpose energy landscapes encompass other-than-energy functions that stakeholders can engage with during the *operation stage*, such as a fruit orchard that needs maintenance or a recreational walking path (chapter 4). In addition to their active contribution to site selection and design stages, landscape users can be given the opportunity to propose changes to the energy landscape during *operation stage* as expectations change or new ideas emerge (Schulz & Skinner, 2022). The additional functions and services provided by multi-purpose energy landscapes require clear agreements embedded in policy and legislation to be resilient to changing circumstances. Changing ownership or economic circumstances for example, may threaten the continuity of these functions through time (chapter 5).

Third, considering the *future*, the limited timespans of some renewable energy technologies (e.g. 20-30 years) are often matched with temporary permits. Specific design measures, such as the creation of a robust hedgerow structure, provide benefits for the landscape at the end-of-life stage of the technology (chapter 4). Finally, the end-of-life of energy technology in a certain project marks a window of opportunity for landscape users to adapt that energy landscape to the new situation.

6.2.3 Tenet 3: Energy landscapes respond to the diversity of society

In a landscape inclusive energy transition, the diversity of societal interests, values and concerns together shape a large variety of multi-purpose renewable energy landscapes.

The first tenet stressed the significance of knowledge on both the physical landscape and its interpretation and experience by stakeholders. New energy landscapes, at least to some degree, need to reflect the character of the physical landscape and the expectations voiced by communities.

The typology of multi-purpose solar power plants (chapter 5) provides the directions to take into account both the physical landscape and how it is interpreted and experienced. Insight in a large variety of multi-purpose energy landscapes supports communities to shape their energy landscape their way (Wolsink, 2017). Although the typology may help stakeholders to converge to a shared solution, it may also help to identify where stakeholder diverge, as some functions are hard to align and competing interests emerge (Arts et al., 2017; Kühne, 2020). Instead of aiming for consensus between stakeholders, the typology may help to understand the different responses of stakeholders to renewable energy development in a specific landscape (Batel, 2020).

Multi-purpose energy landscapes represent a new level of options to be considered in decision-making. Recent studies argue that community acceptance is supported if stakeholders understand how alternative technologies and locations have been weighed in relation to the project they are confronted with (Firestone & Kirk, 2019; Roddis et al., 2020). This weighing can be supported on the regional scale by the methodological framework proposed in chapter 2. On the local scale, the typology of solar power plants adds the option of different spatial forms of an energy landscape (chapter 5). Awareness of the variation in spatial form allows communities to co-design energy landscapes, rooted in existing landscape characteristics and local considerations, constructing landscape identity (Basnou, Pino, Davies, Winkel, & De Vreese, 2020; Storie & Külvik, 2019). While spatial variation may be new for highly standardized renewable energy projects, variation in spatial form is common in other landscape changes. Farmsteads in the Netherlands for example, have a different layout and appearance, not only according to soil or landscape type, but also according to local customs and belief systems. In some regions for example, the increased wealth of the farmer was expressed by gardens in English landscape garden style (De Wit & Meeus, 2011).

At the same time, societal considerations incite technological innovations that, in turn, affect energy landscapes. For example, the use of fixed PV array widths in Solarfeld Gänsdorf (2009) resulted in left-over spaces on the plots with PV arrays. Newer cases showed a higher variability in array width that resulted in improved alignment of the PV patch with the plot shape (chapter 4).

The typology presented in chapter 5 provides directions for communities, but is not yet specific enough to evaluate design proposals of future solar power plants. Future research is needed to inform developers, decision-makers, designers and landscape users about evaluation of alternative designs. Relevant topics are for example determining a set of minimum criteria and synergies and trade-offs between spatial properties.

Tenet 4: Coupling energy with other societal challenges 6.2.4

In a landscape inclusive energy transition, other grand challenges of the 21st century such as food security and biodiversity are coupled with energy development in specific landscapes.

Energy provision can be combined with other objectives that lead to multifunctionality in the local design of an energy landscape (chapter 4 and 5). Multifunctionality refers to the inclusion of functions additional to energy provision within the boundaries of a renewable energy project. The cases illustrated the wide range of possibilities to include other-than-energy functions in solar landscapes. The findings showed that societal considerations drive towards a spatial form of solar power plants that incorporates for example food security (e.g. agrivoltaics), the biodiversity crisis (e.g. nature inclusive solar power plants) and flood retention as a means of adaptation to changing climate.

Coupling of societal challenges in landscape transformation requires cross-sectoral collaboration to achieve multiple policy goals (Fürst, Luque, & Geneletti, 2017). As other policy goals are included in energy landscapes, this may lead to a more widely shared necessity of landscape change and improve robustness during the operational stage. Roddis et al. (2020) pointed to the significance of other societal challenges for community acceptance. Space required for societal challenges such as climate adaptation and food security are considered by landscape users when they are confronted with proposed solar power plants. Being aware that societal challenges can be combined in the same landscape is therefore relevant for policy makers.

This thesis illustrated that multifunctionality per se within the boundary of a project area can be achieved rather easily. Case evidence of solar landscape showed large differences in the degree of multifunctionality (chapter 4). It is therefore important that policy frameworks are equipped to assess whether there is genuine cross-sectoral collaboration and understanding of landscape (tenet 1). If these notions are absent, multifunctionality can also become standardized, with little attention for landscape character and could therefore be perceived by the community as ‘greenwashing’ (Burke, 2018).

Tenet 5: Multi-level coordination of landscape 6.2.5

In a landscape inclusive energy transition, landscape is considered and landscape values coordinated from local to international scale and vice versa by governments as well as other public and private stakeholders involved in landscape governance.

In landscape transformation projects, regional and national governments were important in setting overarching qualitative ambitions (chapter 3). Objectives set on higher governance levels influence landscape quality on the local scale. Precedence for multi-level coordination is found in European biodiversity policy (Natura 2000), where nature conservation targets shared on the European level influence the conditions and expectations of local developments. Although such multi-level coordination is not without conflicts (Strzelecka, Rechciński, Tusznio, Akhshik, & Grodzińska-Jurczak, 2021), some values need to be considered on a larger scale to assess interventions on a local scale. For example, habitats and migration routes of birds inform site selection of wind turbines (Dai, Bergot, Liang, Xiang, & Huang, 2015).

Policy and legislation of different governance levels puts constraints on energy potential (chapter 2). Some of these spatially explicit constraints are controlled by the local government, while others are bound in national or even international legislation. Other constraints were the direct result of stakeholder considerations and not (yet) part of policy or legislation.

In turn, these stakeholder considerations may lead to trade-offs for regional or national energy targets and landscape quality (chapter 4). Energy landscapes conceived with low energy densities – to allow for ecological or recreational features – may negatively affect regional energy transition targets. Similarly, landscape quality may be negatively affected if local stakeholders prefer to camouflage energy infrastructure, using landscape elements atypical compared to the landscape character.

Whether landscape values are part of governmental ambitions, policies and legislation or preferences of local stakeholders, they can all have consequences for energy transition or landscape quality on another level. Awareness of these levels is therefore essential to meet societal expectations with regard to energy landscapes on a local level (Devine-Wright et al., 2017). Coordination between different levels on *how* energy transition should take place in a landscape is needed to avoid conflicts between different governance levels (Calvert, Smit, Wassmansdorf, & Smithers, 2021). Additional research is needed to understand how responses of landscape users on the local level are affected by what governments and other stakeholders do on other levels (Batel, 2020). The findings of this thesis point to, for example, multi-level coordination of how different types of solar power plants are distributed in a given area.

6.3 A comprehensive understanding of landscape

The findings of this thesis represent first building blocks for a landscape inclusive energy transition. Together, they point to a more *comprehensive understanding of landscape* for energy transition and other transformative challenges. As described in the introduction, the conventional understanding of landscape is that of a *scenery* in a *stable-state*. This flawed understanding has led to landscape being considered an 'obstacle' in the energy transition. Landscape scholars, however, have started to explore a more comprehensive understanding of landscape (1.4). Building on that knowledge, the following four sections provide directions for 'landscape' to become a systemic catalyzer for the 21st century energy transition.

6.3.1 Embracing landscape as object and subject

Proponents of a comprehensive understanding of landscape embrace 'landscape' both as physical landscape (object) and how people interpret and experience that landscape (subject). Landscape is undeniably shaped by both natural processes and human activity, yet while different people look at the same physical landscape they will interpret and experience it differently

(Antrop & Van Eetvelde, 2017). To avoid conflicts at the eve of landscape transformation, these 'different' landscapes need to be acknowledged and become part of participatory processes(Moore & Hackett, 2016).

All too often, the different interpretations and experiences of landscapes are not accounted for in research. Wehrle et al. (2021) for example, set out to calculate the costs of 'disturbed landscapes'. In this study, wind turbines by definition 'disturb' landscapes, yet their cost-efficiency is high compared to alternative energy technologies. Favoring alternative technologies with a lower cost-efficiency over wind turbines will therefore lead to higher costs. In this way, this study calculates the financial costs of preserving 'undisturbed landscapes'. This is energy transition and landscape as 'zero-sum game' in action. While their methods and conclusions may be sound, the premise that energy infrastructure is always perceived negatively has been dismissed by others (Firestone & Kirk, 2019; Wolsink, 2017) and disregards positive associations with renewable energy landscapes.

Landscape quality presents a relevant analytical concept to understand and treat landscape both as object and subject (chapter 3). Such a concept can be used to explore and discuss which expectations a landscape needs to meet (considering functional, experiential and future aspects) and according to which interests (economic, environmental, social, cultural). The use of 'spatial quality' in successful river adaptation projects in the Netherlands (Busscher et al., 2018; F. Klijn et al., 2013) suggests exploration of this concept in the energy transition.

6.3.2 Balanced attention for the past, present and future of landscape

Proponents of a comprehensive understanding of landscape balance attention for the past, present and future of landscapes. Besides attention to the present, attention to the past and the future in landscape projects may be one of the remedies towards climax thinking: the belief that our current landscape is the intended endpoint for our given context (Sherren, 2021). The physical landscape and its interpretation and experience by people, are subject to change (Tress & Tress, 2001). To illustrate, climate change results in increased peak flows into the rivers, leading to human adaptation of the river system. The way people adapted also changed: from raising the height of dikes to a cross-sectoral approach that allowed other functions and values to benefit as well. In the past decades, a 2 billion euro program of two dozen river adaptation projects in the Netherlands are testimonies of these changes (Rijke et al., 2012).

Proponents of a comprehensive understanding of landscape therefore critically question the overemphasis on the present landscape, or the 'tyranny of the now' (Krznaric, 2021). If the future is allowed to be different from the present, local stakeholders may be more open to an active role in the discourse about and decisions regarding their landscape. This thesis showed some first evidence of this active role. Stakeholders, for example, added a vegetable garden to *solar park de Kwekerij*, while it was already operational (Chapter 4). This active role may vary from local stakeholders themselves doing construction and maintenance, to stakeholders deciding on the change that is subsequently realized by companies (De Waal & Stremke, 2014). While change is inevitable, there is no such thing as a free pass to change whatever is necessary. Energy transition requires conscious decisions on the landscapes that need to be preserved for future generations (Pinto-Correia & Kristensen, 2013).

6.3.3 Facilitate engagement of stakeholders and society at large

Proponents of a comprehensive understanding of landscape facilitate active engagement with local stakeholders and society at large in the planning and design of energy landscapes.

On the local level, this thesis argued to include options of spatial form in decision-making and co-design, as a means for landscape users to engage in the proposed landscape change. Such engagement requires additional time and efforts of policy makers, designers, developers as well as the landscape users. However, active involvement in the design process, acquiring knowledge, shaping the narrative and tuning to familiar landscape elements is essential for securing community acceptance (Wolsink, 2017) and may even help to build an 'acquired aesthetics' in case of energy landscapes (Selman, 2010). For future progress in this direction, social acceptance and justice scholars need to acknowledge the existence of different spatial forms of energy landscapes. Cousse (2021) for example, studied the effect of 'installation size' of PV systems on social acceptance. For this she distinguished between a ground-mounted PV installation and a rooftop installation. Evidently, this distinction accounts for different installation *sizes*. Yet, it also obscures the actual location of the installations (ground-mounted versus rooftop), oversimplifies the spatial form of energy landscapes and, most importantly, how stakeholders relate to those different spatial forms.

Engagement of stakeholders in the energy transition through actively shaping energy landscapes contributes to recent theories of 'material participation'. Material participation refers to practices where "everyday things, devices and environments [...] acquire the capacity to engage and to mediate involvement with public affairs" (Marres, 2015, p. 2). When stakeholders embrace a comprehensive understanding of landscape, landscapes become a medium to facilitate engagement with stakeholders, from design to implementation (Nassauer, 2012). Engagement of stakeholders with energy landscapes may in turn lead to energy citizenship (Ryghaug, Skjølsvold, & Heidenreich, 2018). The participatory approach used in Southill Solar (see section 1.1) provides a promising perspective on material participation involving a large number of landscape users.

On the societal level, this thesis showed that a single driver for landscape transformation is able to simultaneously address multiple other societal challenges. A comprehensive understanding of landscape combines diverse interests, values and concerns and therefore invites cross-sectoral collaboration as is already identified, for example for the food-energy-water nexus (Yuan & Lo, 2022). Cross-sectoral collaboration that leads to synergies between multiple societal challenges in energy, increases the resilience of such solutions. An example is agrivoltaics that combines crop production with renewable energy provision and has positive effects on local climate regulation and water conservation (Barron-Gafford et al., 2019). The synthetic and integrative character of landscape (Antrop, 2006) is well suited for collaboration between different sectors and disciplines (Vicenzotti et al., 2016).

Local and societal interests will not always lead to easy consensus amongst stakeholders. Decision-making therefore needs to attend to issues of distributional and procedural justice (Baxter et al., 2020; Wolsink, 2007a). To engage with the diversity of stakeholders and their different relations to a landscape, a broader understanding of participation might be useful. Instead of participation as a rigid procedure that needs to be followed in formal procedures, a systemic approach that accounts for the diversity and interrelatedness of collective participatory practices is needed (Chilvers, Pallett, & Hargreaves, 2018).

6.3.4 Shaping landscape on multiple scales

Proponents of a comprehensive understanding of landscape shape landscape on multiple scales. The findings in this thesis made clear that interests, values and concerns of stakeholders differ according to scale. Decision-making isolated on a single scale is therefore insufficient for a landscape inclusive energy transition. Shaping landscape on multiple scales has yielded benefits for several other 21st century societal challenges, for example climate change adaptation. There, the combination of hydrological and landscape quality objectives from the national government empowered the local government to integrate flood protection measures with urban development, recreation and road infrastructure (chapter 3). Such a clear and shared frame has the ability to anchor a planning process that considers both the physical as experiential aspects of landscape (Calvert et al., 2021).

Shaping landscape on multiple scale levels has at least two directions. For policy makers, designers, researchers and other stakeholders primarily occupied with landscape on the local scale, being involved on higher scales brings awareness and possibly influence on the effects on the local level. The regional energy strategies in the Netherlands for example, have been important for local municipalities to negotiate and understand the effects on their territory. Similarly, stakeholders shaping landscape on the national scale need to be aware of the conditions and circumstances of the local scale, where landscape transformation is implemented (see also the first tenet).

Shaping landscape on multiple scales requires expectation management of local stakeholders. The local scale is sometimes insufficient to assess the importance of landscape values, similar to how Natura 2000 areas or protection of red species are determined. Such values will need to be determined on a higher scale level, therefore affecting possible solutions on the local scale. However, higher level constraints can and should be critically examined, as landscape values may change or the designated status of some areas may insufficiently reflect the conditions and qualities in the real world.

Although awareness of other scales might limit local solutions, shaping landscape on multiple scales possibly informs a more evenly distribution of benefits and burdens of the energy transition, giving an impetus to a more just energy transition (Jenkins, McCauley, Heffron, Stephan, & Rehner, 2016).

Limitations 6.4

The context of the Netherlands 6.4.1

The tenets for a landscape inclusive energy transition have been identified on the basis of research that is inherently limited by resources such as time and funding, and took place in a specific context.

Although this thesis draws from international cases, the scope of the research was predominantly influenced by the context of

the Dutch energy transition. Decisions on the focus of the four individual research modules have been informed by my own observations and reflections on the recent energy transition in the Netherlands, supplemented by exchanges with colleagues, students, commissioners, energy professionals, designers and scholars involved in the Dutch energy transition.
Moreover, because landscapes are different through space and time, research involving landscape can only provide generalizable knowledge under similar conditions (A. Van den Brink, Bruns, Tobi, & Bell, 2017). The findings therefore apply to the energy transition in the Netherlands and other countries with similar landscapes. The findings, put differently, may apply in countries and situations that have comparable physical, social, cultural and economic conditions. Additional research in different contexts or focusing on other energy technologies may lead to additional knowledge and, possibly, additional tenets.

6.4.2 Identification of innovative cases

The focus of this thesis on built cases of solar power plants has limitations for the findings, as recent innovations of PV technology and application have not been included. The solar power plant cases in chapters 4 and 5 mostly consist of crystalline silicon or thin film PV panels that have already reached the highest level of technological readiness (TRL). TRL is a measure to assess the maturity of a technology, with levels ranging from 1 (basic principles observed) until 9 (proven in operational environment) (Héder, 2017). Recently, it seems that innovations in solar technology are quickly maturing from demonstration projects (TRL 6-8) to fully operational (TRL 9). These technological innovations provide additional opportunities and challenges for a landscape inclusive energy transition, as has been recently acknowledged (Toledo & Scognamiglio, 2021). To illustrate, bifacial panels absorb solar energy from both sides, leading to floating applications on water (Ziar et al., 2021). Semi-transparent panels for example, allow some of the light to pass through, enabling combination of agriculture and electricity production (Riaz, Imran, Younas, & Butt, 2021). Together with colleagues of the Landscape Architecture chair group in Wageningen I am, for example, involved in a research project to explore the implications of agrivoltaic practices on landscape quality. The use of colors and prints on PV panels is another innovation that is part of building integrated photovoltaics (Pelle, Lucchi, Maturi, Astigarraga, & Causone, 2020; TNO, n.d.). These innovations lead to highly customized PV panels for the built environment, but have implications for landscape as well. Recently, my colleagues of the chair group studied stakeholder preferences of different colors, prints and array shapes in a participatory design project (Wageningen University, 2021).

Focus on solar power plants 6.4.3

This thesis has argued for a landscape inclusive energy transition, for a substantial part based upon solar power plant case evidence. Research on the interaction between solar power plants and landscape has been limited, while their number has increased over the past decade (Comello et al., 2018). The cases examined in this thesis showed that considerations from local stakeholders and society at large shape multi-purpose energy landscapes (tenet 3 and 4). Whereas these findings may apply to other kinds of renewable energy infrastructure as well, the spatial properties of solar infrastructure are significantly different from, for example, wind turbines and hydropower plants. These different spatial properties will also lead to other ways of shaping multi-purpose energy landscapes, for example fishery reservoirs for hydropower dams (Schulz & Skinner, 2022) or wind turbines in forest areas (Bunzel, Bovet, Thrän, & Eichhorn, 2019).

Collaboration with landscape users 6.4.4

Collaboration with landscape users has been limited in this research. The research presented in chapter 2 was built upon interviews with civil servants and aldermen of the involved municipalities. Involving local communities in energy potential mapping and energy target definition may require adjustments of the proposed methodological framework. While the current framework uses interviews and questionnaires to gather stakeholder preferences, involving local communities may require regional design ateliers (Kempenaar et al., 2021) or methods of participatory mapping (Stremke & Picchi, 2017). In chapter 5, one informant per case (e.g. the designer, initiator or developer) was involved to test their interpretation of the dimensions of the solar power plant typology. Future research involving a larger sample of landscape users can provide more detailed insights on the applicability of the typology in planning and design practice and understanding how societal considerations shape physical energy landscapes.

The comparative case analysis was limited to the physical landscape and did not study the interaction between considerations and physical landscape during the planning and design process. Other researchers of my chair group currently employ action research to examine these interactions in participatory processes on solar landscapes.

6.5 Recommendations for environmental planning and design

A *comprehensive understanding of landscape* affects the way in which environmental planning and design operates in landscape transformation projects. Based upon the findings of this thesis and in sync with the four key aspects of *comprehensive understanding of landscape* articulated heretofore, this section outlines four sets of recommendations.

6.5.1 Examine the interpretation and experience of landscape

Embracing landscape both as object and subject, inherently changes the role and position of environmental planners and designers. Planners and designers need to be immersed in a landscape by studying the physical landscape and devising ways to understand how people interpret and experience this landscape. Participatory mapping and related methods are needed to identify how local stakeholders interpret and experience their landscape (e.g. Fagerholm et al., 2021; Stremke & Picchi, 2017). Recent research suggests that mapping of 'meaningful places' may support an open discussion between stakeholders, because it reveals divergent meanings on landscape before siting decisions are made (Müller et al., 2020).

Furthermore, decisions based upon interpretation, experience and subsequently evaluation of the landscape are represented by energy potential maps. What and why parts of the landscape are considered a 'potential' for a certain intervention (in energy transition: a specific type of technology) is often clouded by implicit techno-economic considerations or planning regulations. Although planning regulations embed collective landscape values (Bridge et al., 2013), these values may come from a time prior to the awareness of climate change. To avoid overemphasis on the present landscape (tenet 2), a transparent discussion is needed on the values rather than how they are formalized in planning regulations. For example, many planning regulations exclude forest areas for wind energy development, reflecting the decision that the adverse impacts of turbines do not outweigh their positive impacts. However, decision-makers and landscape users may re-evaluate the values of the forest area if they learn about trade-offs of alternative solutions, for example higher costs of solar energy or locating turbines closer to settlements (Siegrist, Sütterlin, & Keller, 2014).

6.5.2 Explore the potential of the past, present and future of energy landscapes

A balanced attention for the past, present and future of landscape leads to several recommendations for environmental planning and design. First, with a comprehensive understanding of landscape, end-of-life decisions need to be discussed and accounted for in policies, local implementation and evaluation of energy landscapes. A landscape can benefit from the maturing of functions and services during the time a power plant is operational (e.g. 20-30 years). Policy makers therefore need to consider potential future states of energy landscapes and use backcasting to identify the interventions and policies needed in the present (Windemer & Cowell, 2021). Members of cultural heritage committees should not only focus on preserving existing characteristics but also how a renewable energy project can improve landscape characteristics.

Second, policy makers need to consider *re-design* of energy landscapes as a more encompassing alternative to technology focused end-of-life decisions such as *permit extension* or *repowering* (Windemer, 2019). Increased technological efficiency provides opportunities to address societal considerations in physical energy landscapes, as illustrated by this thesis. Planners and designers should become involved in the re-design of 1st generation of renewable energy landscapes. These energy landscapes have been mostly realized from an economic and energetic perspective. However, current repowering practice often lacks conscious reflection on the landscape. In contrast, the recent regional plan of the province of Flevoland (the Netherlands), proposes a re-design of an organically grown wind energy landscape to a situation that involves fewer wind turbines that are more in line with the landscape characteristics (Province of Flevoland, 2016).

Third, civil servants, consultants and other professionals involved in the organization of participatory processes need to find ways to include future generations in the conversation on landscape change. Roman Krznaric (2021), in his latest book, refers to the so-called Future Design movement in Japan, where in such processes a share of the participants are asked to represent future generations.

6.5.3 Expand the variety of energy landscapes by engaging with different landscape users

Different physical landscapes and engagement with local stakeholders and society at large lead to a variety of energy landscapes. The evidence from solar landscapes and multi-purpose solar power plants in this thesis provides first directions to adjust the spatial form of energy landscapes in direct response to societal considerations. Planning and design can use these directions, along with comprehensive landscape analysis methods, to continue expanding the variety of energy landscapes. This calls for a role as 'boundary spanner' for environmental designers and planners. Planners and designers as boundary spanners "combine multiple spatial objectives, cross disciplinary boundaries, and bring together varying interests and values" (M. Van den Brink et al., 2019, p. 22). To conceive a variety of energy landscapes, requires, amongst others, a clearly defined role and an involvement at the start of a planning process (M. Van den Brink et al., 2019).

With an increasing variety of energy landscapes that include multiple functions and reflect societal considerations, environmental impact assessments (EIA) and other evaluative methods need to be adjusted. Contemporary assessment methods implicitly or explicitly consider renewable energy technology as an intervention with inherent negative externalities. With a comprehensive understanding of landscape, methods need to assess the energy landscape as *complete landscape* rather than the impacts of a *technology on a landscape*. Assessment methods of energy landscapes therefore need to include societal considerations, notions of past, present and future, and capture positive impacts in addition to negative impacts. A comprehensive understanding of landscape requires involvement of both experts and communities in assessment studies (Bevk & Golobič, 2020; Kühne, 2020). These adjustments may increase the complexity of assessment methods yet may yield benefits along the way because of cross-sectoral collaboration and early involvement of landscape users.

Establish feedback between multiple scales 6.5.4

Feedback between scales is essential because decisions on the national or regional level can enable or render local qualitative decisions impossible. Support of national governments is needed to ensure that spatial policies, subsidy schemes and other instruments enable the realization of qualitative local ambitions. If national financial instruments and legislation only include criteria such as economic or technical efficiency, or even GHG emission reduction, quality will be limited to exceptional cases. In the Netherlands, for example, the current development of agrivoltaic projects is troublesome because they don't fit well in subsidy schemes. While multifunctionality is one of the spatial principles in the Dutch National Climate Agreement (Klimaatakkoord, 2019), subsidy schemes are not yet favoring multifunctional over monofunctional solutions.

Feedback mechanisms between the scales is therefore essential, especially feedback that originates from local landscape change. Experience of landscape change by stakeholders on the local scale can lead to feedback mechanisms that influences decision-making on other scales (Claessens, Schoorl, Verburg, Geraedts, & Veldkamp, 2009). National and provincial policy and decision-makers need to understand how their policy and legislation complicates local projects (De Boer, Zuidema, & Gugerell, 2018). Feedback mechanisms may lead to adapted policy and consequently improved future implementation.

6.6 Next generation energy landscapes: just, nature and landscape inclusive?

Embracing a *comprehensive understanding of landscape* is not only beneficial for a *landscape inclusive energy transition*, but also provides avenues to contribute to both a just and *nature inclusive transition*. In this last section of the dissertation I position 'landscape' with respect to these other two prominent strands of academic research in the energy transition. The relationship between landscape, justice and nature was already recognized almost 30 years ago by Kenneth Olwig. He described landscape as "nexus of community, nature, justice and environmental equity" (Olwig, 1996, pp. 630–631).

Among the multitude of etymological origins of the word *landscape*, one strand points to how law and customs shaped a specific landscape, in tandem with natural processes. Landscapes are expressions of power and therefore also become an arena for contesting power (Jones, 2006). Increasingly, the spatial dimensions of energy justice are acknowledged (Bouzarovski & Simcock, 2017). Moreover, realizing energy transition targets is considered to be dependent on energy landscapes being understood as “the production of a discourse about sustainability, equity and justice” (Bosch & Schmidt, 2020, p. 10). In the energy transition, justice features prominently on the agenda of social sciences, often distinguishing distributional, procedural and recognitional justice (Jenkins et al., 2016; Sovacool et al., 2020).

The call for multi-scale coordination of decisions on landscape increases chance for *distributive justice*, as justice on one scale does not necessarily imply justice on another scale (Bouzarovski & Simcock, 2017). For example, if all regions are energy neutral, burdens and benefits may be evenly distributed on the regional level. On a local level however, benefits and burdens may be unequally distributed as sites with, for example, heritage designation are excluded from renewable energy development and lead to increased pressure elsewhere in the region. The awareness of multiple scales will lead to questions on the transformation of landscapes and social displacement elsewhere. Questions, for example, to opponents of wind parks in the Netherlands whom argue for the preservation of ‘their’ existing landscape, while coal from South-American mines – shipped and used in the Netherlands – transforms landscapes ‘of others’ (Cardoso, 2018). Similar to the geographical scale, aspects of intergenerational justice emerge when considering the temporal scale and the rights of future generations (Sherren, 2021). For future generations, it is not only essential *that* energy landscapes are created (to mitigate climate change) but also *how* and *what kind* of energy landscapes are created. This gives a responsibility to the current generation to decide not only which landscapes to preserve but also to create a legacy of energy landscapes that is meaningful for future generations as well. This thesis has illustrated some means to actively use ‘time’ to account for intergenerational justice.

A landscape inclusive energy transition is beneficial for *procedural justice* as it introduces stakeholder preferences already in early stages of the energy transition (tenet 1) and allows stakeholders to shape energy landscapes (tenet 3). The latter is a powerful tool to engage stakeholders in decision-making on energy landscapes. In a recent study of 25 innovative energy projects, Stober et al. (2021) studied the quality of the participatory processes. One of their findings is that the ability of participants to be engaged in the design of the project is an essential condition for empowerment, in their study the highest level of participation. Being engaged in the design contrasts with current practices of ‘hiding’ energy infrastructure that is used to “manipulate [...] meanings and values to avoid conflicts and gain social acceptance” (Ferrario & Castiglioni, 2017, p. 834).

Furthermore, using knowledge of the landscape and its users in the energy transition brings the question on whom is *recognized* as landscape user to the start of a planning and design process. This question has dimensions far beyond this thesis, but its findings at least stress the need to bring more stakeholders together than the landowner and inhabitants living nearby. Moreover, an energy transition that departs from landscape instead of technology, may lead to landscape users taking the initiative for renewable energy provision, establishing themselves as ‘serious partners’ in the energy transition (Rasch & Köhne, 2017).

Working on a landscape inclusive energy transition therefore calls for an increased sensitivity of planners and designers on issues of justice. Future research where both fields collaborate could study whether the spatial form of an energy landscape is a just representation of local interests, values and concerns. Paired with the temporal dimension, longitudinal research could be used to investigate how changing power relations influence the spatial form of an energy landscape.

Natural processes are at the heart of landscape and the energy transition is increasingly seen as an opportunity to improve the ecological conditions in landscapes (Hernandez et al., 2019; Moore-O'Leary et al., 2017). Recent research has especially focused on planning and management of solar power plants to improve ecosystem services (Randle-Boggis et al., 2020; Semeraro et al. 2018). A landscape inclusive energy transition embraces not only the interpretation and experience of people – human processes affecting landscape – but also acknowledges, supports and maintains natural processes. Knowledge of existing landscape characteristics, such as linear vegetation patterns or microrelief provide the conditions for ecological improvements. This thesis pointed to restoring lost landscape features or introducing new landscape features that improve ecological conditions. While interventions on the site may improve local biodiversity (Randle-Boggis et al., 2020) considering the larger landscape context of the project area provides additional opportunities. Considering these higher scales, especially with linear landscape features and ecological stepping stones, can improve species movement and increase ecological robustness (Blaydes et al., 2021). Moreover, a regional approach to the siting of solar power plants could result in new ecological networks with solar power plants as hotspots (Semeraro et al., 2018). Frontrunner regions planning multiple of such solar power plants could serve to research both the opportunities and challenges of a so-called 'eco-energy network'.

From a cross-sectoral perspective, a landscape inclusive energy transition supports synergies with other societal challenges on various spatial scales. Recent research, for example, suggests to deliberately site solar power plants with honeybee facilities near fruit orchards to improve pollination, creating synergy between ecological and economic objectives (Armstrong, Brown, Davies, Whyatt, & Potts, 2021). Planning for a landscape inclusive energy transition connects food security, local economy and renewable energy (Armstrong et al., 2021). Finally, the identification of the hybridized sub-type *nature and landscape inclusive solar power* *plant* (chapter 5) highlights the potential synergy between ecological improvements and experience by landscape users, for example using landscape-specific vegetation to reduce the visibility of solar infrastructure (chapter 5). Future research should identify which ecological objectives can be realized in solar power plants that are open to the public and which ecological objectives necessitate solar power plants to be inaccessible to visitors.

This thesis articulated five tenets for a landscape inclusive energy transition that supports the continuity of the energy transition and at the same time helps to meet societal considerations regarding landscape. The energy transition and, with that, stakeholders and landscape, benefit from a more comprehensive understanding of landscape. The absence of 'landscape' or, in different places, the conventional and thus limited understanding of landscape in energy transition arenas has led to a situation where landscape has become a perceived obstacle to the transition. This thesis has revealed that a more comprehensive understanding can move 'landscape' from problem to solution space and, eventually, become a catalyst for the 21st century energy transition. Understanding landscape as co-construction of natural processes, human activities and diverse experiences provides promising avenues for environmental planners and designers to establish solid grounds with both natural and social sciences in pursuit of an *inclusive* energy transition.

Wind energy landscape in the Sierra Nevada region, Andalucia, Spain (source: author).

References

References

Albrechts, L. (2004). Strategic (spatial) planning reexamined. *Environment and Planning B: Planning and Design, 31*(5), 743–758. https://doi.org/10.1068/b3065

Albrechts, L., Healey, P., & Kunzmann, K. R. (2003). Strategic spatial planning and regional governance in europe. *Journal of the American Planning Association, 69*(2), 113–129. https://doi.org/10.1080/01944360308976301

Amaducci, S., Yin, X., & Colauzzi, M. (2018). Agrivoltaic systems to optimise land use for electric energy production. *Applied Energy, 220*(March), 545–561. https://doi.org/10.1016/j.apenergy.2018.03.081

Antrop, M. (2000). Changing patterns in the urbanized countryside of Western Europe. *Landscape Ecology, 15*(3), 257–270. https://doi.org/10.1023/A:1008151109252

Antrop, M. (2005). Why landscapes of the past are important for the future. *Landscape and Urban Planning, 70*(1–2), 21–34. https://doi.org/10.1016/J.LANDURBPLAN.2003.10.002

Antrop, M. (2006). Sustainable landscapes: Contradiction, fiction or utopia? *Landscape and Urban Planning, 75*(3–4), 187–197. https://doi.org/10.1016/j.landurbplan.2005.02.014

Antrop, M., & Van Eetvelde, V. (2017). *Landscape perspectives: the holistic nature of landscape* (Vol. 23). Dordrecht: Springer. https://doi.org/10.1007/978-94-024-1183-6

Apostol, D., McCarty, J., & Sullivan, R. (2017). Improving the visual fit of renewable energy projects. In D. Apostol, J. Palmer, M. Pasqualetti, R. Smardon, & R. Sullivan (Eds.), *The Renewable Energy Landscape: Preserving Scenic Values in our Sustainable Future* (pp. 167–197). Abingdon, Oxon; Routledge. https://doi.org/10.1111/j.1477-8947.1989.tb00353.x

Apostol, D., Palmer, J., Pasqualetti, M. J., Smardon, R., & Sullivan, R. (2017). *The renewable energy landscape: preserving scenic values in our sustainable future*. Abingdon, Oxon; Routledge.

Armstrong, A., Brown, L., Davies, G., Whyatt, J. D., & Potts, S. G. (2021). Honeybee pollination benefits could inform solar park business cases, planning decisions and environmental sustainability targets. *Biological Conservation, 263*, 109332. https://doi.org/10.1016/j.biocon.2021.109332

Armstrong, A., Ostle, N. J., & Whitaker, J. (2016). Solar park microclimate and vegetation management effects on grassland carbon cycling. *Environmental Research Letters, 11*(7). https://doi.org/10.1088/1748-9326/11/7/074016

Arnstein, S. R. (1969). A Ladder Of Citizen Participation. *Journal of the American Planning Association, 35*(4), 216–224. https://doi.org/10.1080/01944366908977225

Arts, B., Buizer, M., Horlings, L., Ingram, V., Van Oosten, C., & Opdam, P. (2017). Landscape Approaches: A State-of-the-Art Review. *Annual Review of Environment and Resources, 42*, 439–463. https://doi.org/10.1146/annurev-environ-102016-060932

Balta-Ozkan, N., Watson, T., & Mocca, E. (2015). Spatially uneven development and low carbon transitions: Insights from urban and regional planning. *Energy Policy, 85*, 500–510. https://doi.org/10.1016/J.ENPOL.2015.05.013

Barrett, T. L., Farina, A., & Barrett, G. W. (2009). Aesthetic landscapes: An emergent component in sustaining societies. *Landscape Ecology, 24*(8), 1029–1035. https://doi.org/10.1007/s10980-009-9354-8

Barron-Gafford, G. A., Pavao-Zuckerman, M. A., Minor, R. L., Sutter, L. F., Barnett-Moreno, I., Blackett, D. T., … Macknick, J. E. (2019). Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands. *Nature Sustainability, 2*(9), 848–855. https://doi.org/10.1038/s41893-019-0364-5

Basnou, C., Pino, J., Davies, C., Winkel, G., & De Vreese, R. (2020). Co-design Processes to Address Nature-Based Solutions and Ecosystem Services Demands: The Long and Winding Road Towards Inclusive Urban Planning. *Frontiers in Sustainable Cities, 2*, 1–4. https://doi.org/10.3389/frsc.2020.572556

Batel, S. (2020). Research on the social acceptance of renewable energy technologies: Past, present and future. *Energy Research and Social Science, 68*. https://doi.org/10.1016/j.erss.2020.101544

Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low carbon energy and associated infrastructures: A critical discussion. *Energy Policy, 58*, 1–5. https://doi.org/10.1016/j.enpol.2013.03.018

Baxter, J., Walker, C., Ellis, G., Devine-Wright, P., Adams, M., & Fullerton, R. S. (2020). Scale, history and justice in community wind energy: An empirical review. *Energy Research and Social Science, 68*, 101532. https://doi.org/10.1016/j.erss.2020.101532

Bélanger, P. (2009). Landscape as Infrastructure. *Landscape Journal, 28*(1), 79–95. https://doi.org/10.1145/2505515.2507827

Bevk, T., & Golobič, M. (2020). Contentious eye-catchers: Perceptions of landscapes changed by solar power plants in Slovenia. *Renewable Energy, 152*, 999–1010. https://doi.org/10.1016/j.renene.2020.01.108

Bidwell, D. (2016). Thinking through participation in renewable energy decisions. *Nature Energy, 1*. https://doi.org/10.1038/nenergy.2016.51

Blaschke, T., Biberacher, M., Gadocha, S., & Schardinger, I. (2013). "Energy landscapes": Meeting energy demands andhuman aspirations. *Biomass and Bioenergy, 55*, 3–16. https://doi.org/10.1016/j.biombioe.2012.11.022

Blaydes, H., Potts, S. G., Whyatt, J. D., & Armstrong, A. (2021). Opportunities to enhance pollinator biodiversity in solar parks. *Renewable and Sustainable Energy Reviews, 145*, 111065. https://doi.org/10.1016/j.rser.2021.111065

Bongers, J., Broers, W., Janssen, F., Kimman, J., & Weusten, P. (2014). *Parkstad Limburg Energietransitie (PALET): Achtergrondrapport 1*. Heerlen.

Boréus, K., & Bergström, G. (2017). *Analyzing text and discourse: eight approaches for the social sciences*. London: Sage Publications.

Borgogno Mondino, E., Fabrizio, E., & Chiabrando, R. (2015). Site selection of large ground-mounted photovoltaic plants: A GIS decision support system and an application to Italy. *International Journal of Green Energy, 12*(5), 515–525. https://doi.org/10.1080/15435075.2013.858047

Bosch, S., & Schmidt, M. (2020). Wonderland of technology? How energy landscapes reveal inequalities and injustices of the German Energiewende. *Energy Research and Social Science, 70*, 101733. https://doi.org/10.1016/j.erss.2020.101733

Bosch, S., & Schwarz, L. (2019). The energy transition from plant operators' perspective-a behaviorist approach. *Sustainability (Switzerland), 11*(6). https://doi.org/10.3390/su11061621

Bouzarovski, S., & Simcock, N. (2017). Spatializing energy justice. *Energy Policy, 107*, 640–648. https://doi.org/10.1016/j.enpol.2017.03.064

Brandt, J., & Vejre, H. (2004). Multifunctional landscapes - motives, concepts and perceptions. In J. Brandt & H. Vejre (Eds.), *Multifunctional Landscapes: Volume 1 Theory, Values and History* (pp. 3–32). Southampton: WIT Press.

Bridge, G. (2018). The map is not the territory: A sympathetic critique of energy research's spatial turn. *Energy Research and Social Science, 36*, 11–20. https://doi.org/10.1016/j.erss.2017.09.033

Bridge, G., Bouzarovski, S., Bradshaw, M., & Eyre, N. (2013). Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy, 53*, 331–340. https://doi.org/10.1016/J.ENPOL.2012.10.066

Bunzel, K., Bovet, J., Thrän, D., & Eichhorn, M. (2019). Hidden outlaws in the forest? A legal and spatial analysis of onshore wind energy in Germany. *Energy Research and Social Science, 55*, 14–25. https://doi.org/10.1016/j.erss.2019.04.009

Burgess, P. J., Rivas Casado, M., Gavu, J., Mead, A., Cockerill, T., Lord, R., … Howard, D. C. (2012). A framework for reviewing the trade-offs between, renewable energy, food, feed and wood production at a local level. *Renewable and Sustainable Energy Reviews, 16*(1), 129–142. https://doi.org/10.1016/J.RSER.2011.07.142

Burke, M. J. (2018). Mutually-Beneficial Renewable Energy Systems. *Relations, 6*(1), 87–116. https://doi.org/10.7358/rela-2018-001-burk

Busscher, T., van den Brink, M., & Verweij, S. (2018). Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch "Room for the River" program. *Journal of Flood Risk Management*. https://doi.org/10.1111/jfr3.12448

Butler, A., & Sarlöv-Herlin, I. (2019). Changing landscape identity—practice, plurality, and power. *Landscape Research, 44*(3), 271–277. https://doi.org/10.1080/01426397.2019.1589774

Calvert, K., Greer, K., & Maddison-MacFadyen, M. (2019). Theorizing energy landscapes for energy transition management: Insights from a socioecological history of energy transitions in Bermuda. *Geoforum, 102*, 191–201. https://doi.org/10.1016/j.geoforum.2019.04.005

Calvert, K., Pearce, J. M., & Mabee, W. E. (2013). Toward renewable energy geo-information infrastructures: Applications of GIScience and remote sensing that build institutional capacity. *Renewable and Sustainable Energy Reviews, 18*, 416–429. https://doi.org/10.1016/j.rser.2012.10.024

Calvert, K., Smit, E., Wassmansdorf, D., & Smithers, J. (2021). Energy transition, rural transformation and local land-use planning: Insights from Ontario, Canada. *Environment and Planning E: Nature and Space*. https://doi.org/10.1177/25148486211024909

Cardoso, A. (2018). Valuation Languages Along the Coal Chain From Colombia to the Netherlands and to Turkey. *Ecological Economics, 146*, 44–59. https://doi.org/10.1016/j.ecolecon.2017.09.012

Carlisle, J. E., Kane, S. L., Solan, D., & Joe, J. C. (2014). Support for solar energy: Examining sense of place and utility-scale development in California. *Energy Research and Social Science, 3*(C), 124–130. https://doi.org/10.1016/j.erss.2014.07.006

Carullo, L., Russo, P., Riguccio, L., & Tomaselli, G. (2013). Evaluating the Landscape Capacity of Protected Rural Areas to Host Photovoltaic Parks in Sicily. *Natural Resources, 04*(07), 460–472. https://doi.org/10.4236/nr.2013.47057

Casprini, P. (2013). *Siena carbon free - goal reached*. Siena. Retrieved from http://www.provincia.siena.it/var/prov/storage/original/application/395f72cc44c6d83188ca1d561cf453be.pdf

Castán Broto, V., & Baker, L. (2018). Spatial adventures in energy studies: An introduction to the special issue. *Energy Research and Social Science, 36*, 1–10. https://doi.org/10.1016/j.erss.2017.11.002

CBS. (2009). *De verborgen aantrekkingskracht van Parkstad Limburg. De nieuwe groei heet krimp: een perspectief voor Parkstad Limburg*. Heerlen.

CBS. (2010). *Regionale prognose 2009-2040: Vergrijzing en omslag van groei naar krimp*. Heerlen.

Cevallos-Sierra, J., & Ramos-Martin, J. (2018). Spatial assessment of the potential of renewable energy: The case of Ecuador. *Renewable and Sustainable Energy Reviews, 81*, 1154–1165. https://doi.org/10.1016/j.rser.2017.08.015

Chiabrando, R., Fabrizio, E., & Garnero, G. (2009). The territorial and landscape impacts of photovoltaic systems: Definition of impacts and assessment of the glare risk. *Renewable and Sustainable Energy Reviews, 13*(9), 2441–2451. https://doi.org/10.1016/j.rser.2009.06.008

Chiabrando, R., Fabrizio, E., & Garnero, G. (2011). On the applicability of the visual impact assessment OAISPP tool to photovoltaic plants. *Renewable and Sustainable Energy Reviews, 15*(1), 845–850. https://doi.org/10.1016/j.rser.2010.09.030

Chilvers, J., Pallett, H., & Hargreaves, T. (2018). Ecologies of participation in socio-technical change: The case of energy system transitions. *Energy Research and Social Science, 42*, 199–210. https://doi.org/10.1016/j.erss.2018.03.020

Claessens, L., Schoorl, J. M., Verburg, P. H., Geraedts, L., & Veldkamp, A. (2009). Modelling interactions and feedback mechanisms between land use change and landscape processes. *Agriculture, Ecosystems and Environment, 129*(1–3), 157–170. https://doi.org/10.1016/j.agee.2008.08.008

Comello, S., Reichelstein, S., & Sahoo, A. (2018). The road ahead for solar PV power. *Renewable and Sustainable Energy Reviews, 92*, 744–756. https://doi.org/10.1016/j.rser.2018.04.098

Council of Europe. (2000). European Landscape Convention. European Treaty Series – No. 176. Florence. Retrieved from https://rm.coe.int/1680080621

Cousse, J. (2021). Still in love with solar energy? Installation size, affect, and the social acceptance of renewable energy technologies. *Renewable and Sustainable Energy Reviews, 145*, 111107. https://doi.org/10.1016/j.rser.2021.111107

Cowell, R. (2010). Wind power, landscape and strategic, spatial planning-The construction of "acceptable locations" in Wales. *Land Use Policy, 27*(2), 222–232. https://doi.org/10.1016/j.landusepol.2009.01.006

Creswell, J. W. (2009). *Research design : qualitative, quantitative, and mixed methods approaches*. Sage.

Crotty, M. (1998). *The foundations of social research: meaning and perspective in the research process*. Crows Nest, NSW: Allen & Unwin.

Crowe, S. (1958). *The landscape of power*. London: Architectural Press.

Cuppen, M. E., & Winnubst, M. (2008). How public participation influenced the legitimation of a policy process: the case of a dike relocation. In J. Koppenjan & N. Ryan (Eds.), *IRSPM Annual conference 2008* (pp. 1–25). Brisbane, Australia: Queensland University of Technology.

Dai, K., Bergot, A., Liang, C., Xiang, W. N., & Huang, Z. (2015). *Environmental issues associated with wind energy - A review. Renewable Energy, 75*, 911–921. https://doi.org/10.1016/j.renene.2014.10.074

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

Davis, J. (2011). *Urbanising the Event : how past processes, present politics and future plans shape London's Olympic Legacy. Department of Architecture*. The London School of Economics and Political Science, London. Retrieved from http://etheses.lse.ac.uk/382/

Davis, J., & Thornley, A. (2010). Urban regeneration for the London 2012 Olympics: Issues of land acquisition and legacy. *City, Culture and Society, 1*(2), 89–98. https://doi.org/https://doi.org/10.1016/j.ccs.2010.08.002

De Boer, J., Zuidema, C., & Gugerell, K. (2018). New interaction paths in the energy landscape: the role of local energy initiatives. *Landscape Research, 43*(4), 489–502. https://doi.org/10.1080/01426397.2018.1444154

De Jong, J., & Stremke, S. (2020). *Evolution of Energy Landscapes : A Regional Case Study in the Western Netherlands*.

De Jonge, J. (2009). *Landscape architecture between politics and science : an integrative perspective on landscape planning and design in the network society*. Wageningen: Uitgeverij Blauwdruk.

De Laurentis, C., & Pearson, P. J. G. (2018). Understanding the material dimensions of the uneven deployment of renewable energy in two Italian regions. *Energy Research and Social Science, 36*, 106–119. https://doi.org/10.1016/j.erss.2017.11.009

De Marco, A., Petrosillo, I., Semeraro, T., Pasimeni, M. R., Aretano, R., & Zurlini, G. (2014). The contribution of Utility-Scale Solar Energy to the global climate regulation and its effects on local ecosystem services. *Global Ecology and Conservation, 2*, 324–337. https://doi.org/10.1016/j.gecco.2014.10.010

De Sousa, C., & D'Souza, L.-A. (2011). *From Brownfields to Parkland–Elmhurst Park and Fresh Kills Park, New York, NY: Sustainable Brownfields Revitalization Best Practices*. University of Illinois.

De Waal, R., & Stremke, S. (2014). Energy Transition: Missed Opportunities and Emerging Challenges for Landscape Planning and Designing. *Sustainability, 6*(7), 4386–4415. https://doi.org/10.3390/su6074386

De Wit, S., & Meeus, J. (2011). Een tweede jeugd voor traditionele boerenerven. *Tuin & Landschap*, (24), 6–11.

Delafield, G., Donnison, C., Roddis, P., Arvanitopoulos, T., Sfyridis, A., Dunnett, S., … Logan, K. G. (2021). Conceptual framework for balancing society and nature in net-zero energy transitions. *Environmental Science & Policy, 125*, 189–201. https://doi.org/10.1016/j.envsci.2021.08.021

Delicado, A., Figueiredo, E., & Silva, L. (2016). Community perceptions of renewable energies in Portugal: Impacts on environment, landscape and local development. *Energy Research and Social Science, 13*, 84–93. https://doi.org/10.1016/j.erss.2015.12.007

Denholm, P., & Margolis, R. M. (2008). Land-use requirements and the per-capita solar footprint for photovoltaic generation in the United States. *Energy Policy, 36*(9), 3531–3543. https://doi.org/10.1016/j.enpol.2008.05.035

Devine-Wright, P. (2011a). From backyards to places: Public engagement and the emplacement of renewable energy technologies. In P. Devine-Wright (Ed.), *Renewable Energy and the Public: From NIMBY to Participation*. Earthscan. https://doi.org/10.1108/ijshe.2011.24912bae.004

Devine-Wright, P. (2011b). Public engagement with large-scale renewable energy technologies: Breaking the cycle of NIMBYism. *Wiley Interdisciplinary Reviews: Climate Change, 2*(1), 19–26. https://doi.org/10.1002/wcc.89

Devine-Wright, P. (2013). Explaining "NIMBY" Objections to a Power Line: The Role of Personal, Place Attachment and Project-Related Factors. *Environment and Behavior, 45*(6), 761–781. https://doi.org/10.1177/0013916512440435

Devine-Wright, P., & Batel, S. (2013). Explaining public preferences for high voltage pylon designs: An empirical study of perceived fit in a rural landscape. *Land Use Policy, 31*(2013), 640–649. https://doi.org/10.1016/j.landusepol.2012.09.011

Devine-Wright, P., Batel, S., Aas, O., Sovacool, B., LaBelle, M. C., & Ruud, A. (2017). A conceptual framework for understanding the social acceptance of energy infrastructure: Insights from energy storage. *Energy Policy, 107*, 27–31. https://doi.org/10.1016/j.enpol.2017.04.020

Devine-Wright, P., & Howes, Y. (2010). Disruption to place attachment and the protection of restorative environments: A wind energy case study. *Journal of Environmental Psychology, 30*(3), 271–280. https://doi.org/10.1016/j.jenvp.2010.01.008

Doubleday, K., Choi, B., Maksimovic, D., Deline, C., & Olalla, C. (2016). Recovery of inter-row shading losses using differential power-processing submodule DC-DC converters. *Solar Energy, 135*, 512–517. https://doi.org/10.1016/j.solener.2016.06.013

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

Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A., & Ferard, Y. (2011). Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. *Renewable Energy, 36*(10), 2725–2732. https://doi.org/10.1016/j.renene.2011.03.005

Duurzaam Haren. (2018). *Zorgboerderij de Mikkelhorst - Investeren in zonnepanelen voor onze groene parel*. Retrieved December 3, 2021, from https://www.duurzaamharen.nl/project/polycultuur-zonnepark-de-mikkelhorst/

Eisenhardt, K. M. (1989). Building Theories from Case Study Research Published by : Academy of Management Stable. *The Academy of Management Review, 14*(4), 532–550.

Energietransitienota Duurzame Energie Achterhoek (2015). Retrieved July 8, 2017, from https://www.oostgelre.nl/bestand/energietransitienota-duurzame-energieachterhoek

Energy Technology Support Unit (ETSU). (1993). Attitudes towards wind power. A survey of opinion in Cornwall and Devon. *ETSU report W/13/00* 354/038/REP Harwell: Energy Technology Support Unit (ETSU).

European Commission. (2021). *A European Green Deal: striving to be the first climate-neutral continent*. Retrieved March 7, 2022, from https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

European Parliament, & European Council. (2018). Directive (EU) 2018/2001 of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources. *Official Journal of the European Union, L 328*, 1–140. Retrieved from http://data.europa.eu/eli/dir/2018/2001/2018-12-21

Evans, G. (2014). Designing legacy and the legacy of design: London 2012 and the Regeneration Games. *Architectural Research Quarterly, 18*(4), 353–366. https://doi.org/Doi: 10.1017/s1359135515000081

Fagerholm, N., Raymond, C. M., Olafsson, A. S., Brown, G., Rinne, T., Hasanzadeh, K., … Kyttä, M. (2021). A methodological framework for analysis of participatory mapping data in research, planning, and management. *International Journal of Geographical Information Science, 35*(9), 1848–1875. https://doi.org/10.1080/13658816.2020.1869747

Farina, A. (2006). *Principles and Methods in Landscape Ecology. Austral Ecology*. https://doi.org/10.1111/j.1442-9993.2007.01854.x

Fast, S., Mabee, W., Baxter, J., Christidis, T., Driver, L., Hill, S., … Tomkow, M. (2016). Lessons learned from Ontario wind energy disputes. *Nature Energy, 1*(2), 1–7. https://doi.org/10.1038/nenergy.2015.28

Fernandez-Jimenez, L. A., Mendoza-Villena, M., Zorzano-Santamaria, P., Garcia-Garrido, E., Lara-Santillan, P., Zorzano-Alba, E., & Falces, A. (2015). Site selection for new PV power plants based on their observability. *Renewable Energy, 78*, 7–15. https://doi.org/10.1016/j.renene.2014.12.063

Ferrario, V., & Castiglioni, B. (2017). Visibility/invisibility in the “making” of energy landscape. Strategies and policies in the hydropower development of the Piave river (Italian Eastern Alps). *Energy Policy, 108*, 829–835. https://doi.org/10.1016/j.enpol.2017.05.012

Firestone, J., & Kirk, H. (2019). A strong relative preference for wind turbines in the United States among those who live near them. *Nature Energy, 4*(4), 311–320. https://doi.org/10.1038/s41560-019-0347-9

Fontaine, A. (2020). Debating the sustainability of solar energy: Examining resource construction processes for local photovoltaic projects in France. *Energy Research and Social Science, 69*, 101725. https://doi.org/10.1016/j.erss.2020.101725

Frankl, P. (1968). *Principles of architectural history: the four phases of architectural style, 1420-1900*. MIT Press.

Frantál, B., Van der Horst, D., Martinát, S., Schmitz, S., Teschner, N., Silva, L., … Roth, M. (2018). Spatial targeting, synergies and scale: Exploring the criteria of smart practices for siting renewable energy projects. *Energy Policy, 120*, 85–93. https://doi.org/10.1016/j.enpol.2018.05.031

Freitas, S., & Brito, M. C. (2019). Non-cumulative only solar photovoltaics for electricity load-matching. *Renewable and Sustainable Energy Reviews, 109*, 271–283. https://doi.org/10.1016/j.rser.2019.04.038

Frolova, M. (2010). Landscapes, water policy and the evolution of discourses on hydropower in Spain. *Landscape Research, 35*(2), 235–257. https://doi.org/10.1080/01426390903557956

Fthenakis, V., & Kim, H. C. (2009). Land use and electricity generation: A life-cycle analysis. *Renewable and Sustainable Energy Reviews, 13*(6–7), 1465–1474. https://doi.org/10.1016/j.rser.2008.09.017

Fürst, C., Luque, S., & Geneletti, D. (2017). Nexus thinking–how ecosystem services can contribute to enhancing the cross-scale and cross-sectoral coherence between land use, spatial planning and policy-making. *International Journal of Biodiversity Science, Ecosystem Services and Management, 13*(1), 412–421. https://doi.org/10.1080/21513732.2017.1396257

Gemeente Groningen. (2008). *Routekaart Groningen Energieneutraal 2025* (Roadmap Groningen Energy neutral 2025).

Gemeente Groningen. (2011). *Masterplan Groningen Energieneutraal* (Masterplan Groningen Energy neutral). Retrieved July 8, 2017, from https://gemeente.groningen.nl/%0Dgroningen-geeft-energie

Gemeente Utrecht. (2011). *Programma Utrechtse energie 2011–2014* (Energy Program of Utrecht 2011–2014). Retrieved July 26, 2017, from https://www.utrecht.nl/%0Dfileadmin/uploads/documenten/9.digitaalloket/Milieu/Programma-Utrechtse-%0DEnergie-definitief.pdf

Gemeinde Morbach. (2021). *Gewerbegebiet Energielandschaft*. Retrieved September 17, 2021, from https://www.morbach.de/leben-arbeiten/wirtschaft/gewerbegebiete/gewerbegebiet-energielandschaft/

Golroodbari, S. Z., & van Sark, W. (2020). Simulation of performance differences between offshore and land-based photovoltaic systems. *Progress in Photovoltaics: Research and Applications, 28*(9), 873–886. https://doi.org/10.1002/pip.3276

Graham, M., Ates, S., Melathopoulos, A. P., Moldenke, A. R., DeBano, S. J., Best, L. R., & Higgins, C. W. (2021). Partial shading by solar panels delays bloom, increases floral abundance during the late-season for pollinators in a dryland, agrivoltaic ecosystem. *Scientific Reports, 11*(1), 1–13. https://doi.org/10.1038/s41598-021-86756-4

Grêt-Regamey, A., & Wissen-Hayek, U. (2013). *Multicriteria decision analysis for the planning and design of sustainable energy landscapes*. In S. Stremke & A. van den Dobbelsteen (Eds.), Sustainable energy landscapes: Designing, planning and development (pp. 111–132). Boca Raton: CRC Press.

Grêt-Regamey, Adrienne, Altwegg, J., Sirén, E. A., van Strien, M. J., & Weibel, B. (2017). Integrating ecosystem services into spatial planning—A spatial decision support tool. *Landscape and Urban Planning, 165*, 206–219. https://doi.org/10.1016/j.landurbplan.2016.05.003

Guerin, T. (2017a). A case study identifying and mitigating the environmental and community impacts from construction of a utility-scale solar photovoltaic power plant in eastern Australia. *Solar Energy, 146*, 94–104. https://doi.org/10.1016/j.solener.2017.02.020

Guerin, T. (2017b). Evaluating expected and comparing with observed risks on a large-scale solar photovoltaic construction project: A case for reducing the regulatory burden. *Renewable and Sustainable Energy Reviews, 74*, 333–348. https://doi.org/10.1016/j.rser.2017.02.040

Haines-Young, R., & Potschin, M. (2012). The links between biodiversity, ecosystem services and human well-being. In D. Raffaelli & C. Frid (Eds.), *Ecosystem Ecology* (pp. 110–139). Cambridge. https://doi.org/10.1017/cbo9780511750458.007

Haines-Young, R., & Potschin, M. (2018). *Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure*. Fabis Consulting. Retrieved from www.cices.eu

Hastik, R., Basso, S., Geitner, C., Haida, C., Poljanec, A., Portaccio, A., … Walzer, C. (2015). Renewable energies and ecosystem service impacts. *Renewable and Sustainable Energy Reviews, 48*, 608–623. https://doi.org/10.1016/j.rser.2015.04.004

Haurant, P., Oberti, P., & Muselli, M. (2011). Multicriteria selection aiding related to photovoltaic plants on farming fields on Corsica island: A real case study using the ELECTRE outranking framework. *Energy Policy, 39*(2), 676–688. https://doi.org/10.1016/j.enpol.2010.10.040

Havinga, R., & der Nederlanden, H. (2018). *Ruimte voor de Rivier - oogst ruimtelijke kwaliteit*. Utrecht.

Healey, P. (2007). *Urban Complexity and Spatial Strategies: Towards a relational planning for our times*. London: Routledge.

Healey, P., Khakee, A., Motte, A., & Needham, B. (1999). European developments in strategic spatial planning. *European Planning Studies, 7*(3), 339–355. https://doi.org/10.1080/09654319908720522

Héder, M. (2017). From NASA to EU: The evolution of the TRL scale in Public Sector Innovation. *Innovation Journal, 22*(2), 1–23.

Heeres, N., van Dijk, T., Arts, J., & Tillema, T. (2017). Coping with interrelatedness and fragmentation at the infrastructure/land-use interface: The potential merits of a design approach. *Journal of Transport and Land Use, 10*(1), 409–435. https://doi.org/10.5198/jtlu.2016.883

Hekkenberg, M., & Lensink, S. M. (2013). 16% hernieuwbare energie in 2020–wanneer aanbesteden? (16% renewable energy in 2020–when to put out to tender?) (ECN 6.00661). *ECN*. Retrieved from https://zoek.officielebekendmakingen.nl/blg-%0D212445.pdf.

Hernandez, R. R., Armstrong, A., Burney, J., Ryan, G., Moore-O'Leary, K., Diédhiou, I., … Kammen, D. M. (2019). Techno–ecological synergies of solar energy for global sustainability. *Nature Sustainability, 2*(7), 560–568. https://doi.org/10.1038/s41893-019-0309-z

Hernandez, R. R., Easter, S. B., Murphy-Mariscal, M. L., Maestre, F. T., Tavassoli, M., Allen, E. B., … Allen, M. F. (2014). Environmental impacts of utility-scale solar energy. *Renewable and Sustainable Energy Reviews, 29*, 766–779. https://doi.org/10.1016/j.rser.2013.08.041

Holland Solar. (2019). *Gedragscode zon op land, 1–9*. Retrieved from https://hollandsolar.nl/u/files/gedragscode-zon-op-land.pdf

Hooimeijer, P., Kroon, H., & Luttik, J. (2001). *Kwaliteit in meervoud*. Gouda: Habiforum, Expertisenetwerk Meervoudig Ruimtegebruik.

Hoolachan, A. (2017). *Scalar Politics: Sustainability planning under Localism and the delivery of London's Olympic legacy*. University of Cambridge. Retrieved from https://www.repository.cam.ac.uk/handle/1810/269398

Horner, R. M., & Clark, C. E. (2013). Characterizing variability and reducing uncertainty in estimates of solar land use energy intensity. *Renewable and Sustainable Energy Reviews, 23*, 129–137. https://doi.org/10.1016/j.rser.2013.01.014

Hoversten, M. E., & Swaffield, S. R. (2019). Discursive moments: Reframing deliberation and decision-making in alternative futures landscape ecological planning. *Landscape and Urban Planning, 182*, 22–33. https://doi.org/10.1016/j.landurbplan.2018.10.005

Howard, D. C., Burgess, P. J., Butler, S. J., Carver, S. J., Cockerill, T., Coleby, A. M., … Scholefield, P. (2013). Energyscapes: Linking the energy system and ecosystem services in real landscapes. *Biomass and Bioenergy, 55*(0), 17–26. https://doi.org/10.1016/j.biombioe.2012.05.025

Hulsker, W., Wienhoven, M., van Diest, M., & Buijs, S. (2011). *Evaluatie ontwerpprocessen Ruimte voor de Rivier (Evaluation design processes Room for the River)*. Rotterdam.

Hutchinson, P. (2015). *Landscape , Power and Biopolitics A Foucauldian Analysis of Freshkills Park , New York City*. University of Canberra, Canberra. Retrieved from http://www.canberra.edu.au/researchrepository/

Ingold, T. (1993). The Temporality of the Landscape. *World Archaeology, 25*(2), 152–174. https://doi.org/10.1080/00293652.2016.1151458

Ioannidis, R., & Koutsoyiannis, D. (2020). A review of land use, visibility and public perception of renewable energy in the context of landscape impact. *Applied Energy, 276*(March), 115367. https://doi.org/10.1016/j.apenergy.2020.115367

IPCC. (2021). *Technical Summary. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Climate Change 2021: The Physical Science Basis.

IRENA. (2022). *Energy Transition*. Retrieved March 3, 2022, from https://www.irena.org/energytransition

Jablonska, B., Epema, T., Willems, E., Visser, H., Opstelten, I., & Hub, E. (2011). Innovative Concepts for Energy Neutral Districts in 2050. Petten: *ECN*.

Jain, P., Raina, G., Sinha, S., Malik, P., & Mathur, S. (2021). Agrovoltaics: Step towards sustainable energy-food combination. *Bioresource Technology Reports, 15*, 100766. https://doi.org/10.1016/j.biteb.2021.100766

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research and Social Science, 11*, 174–182. https://doi.org/10.1016/j.erss.2015.10.004

Jones, M. (1991). The elusive reality of landscape. Concepts and approaches in landscape research. *Norsk Geografisk Tidsskrift, 45*(4), 229–244. https://doi.org/10.1080/00291959108552277

Jones, M. (2006). Landscape, law and justice - Concepts and issues. *Norsk Geografisk Tidsskrift, 60*(1), 1–14. https://doi.org/10.1080/00291950600618726

Kahneman, D. (2013). *Thinking, fast and slow*. New York: Farrar, Strous and Giroux.

Kapetanakis, I. A., Kolokotsa, D., & Maria, E. A. (2014). Parametric analysis and assessment of the photovoltaics' landscape integration: Technical and legal aspects. *Renewable Energy, 67*, 207–214. https://doi.org/10.1016/j.renene.2013.11.043

Kempenaar, A., Puerari, E., Pleijte, M., & van Buuren, M. (2021). Regional design ateliers on 'energy and space': systemic transition arenas in energy transition processes. *European Planning Studies, 29*(4), 762–778. https://doi.org/10.1080/09654313.2020.1781792

Kempenaar, A., & van den Brink, A. (2018). Regional designing: A strategic design approach in landscape architecture. *Design Studies, 54*, 80–95. https://doi.org/10.1016/j.destud.2017.10.006

Klijn, F., de Bruin, D., de Hoog, M. C., Jansen, S., & Sijmons, D. (2013). Design quality of room-for-the-river measures in the Netherlands: role and assessment of the quality team (Q-team). *International Journal of River Basin*

Management, 11(3), 287–299. https://doi.org/10.1080/15715124.2013.811418

Klijn, J. A. (1995). *Hierarchical concepts in landscape ecology: pitfalls and promises. Report 100*. Wageningen, DLO Winand Staring Centre. https://doi.org/10.1111/j.1460-9568.2009.06623.x

Klimaatakkoord. (2019). *National Climate Agreement the Netherlands. The Hague*. Retrieved from https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/national-climate-agreement-the-netherlands

Kramarz, T., Park, S., & Johnson, C. (2021). Governing the dark side of renewable energy: A typology of global displacements. *Energy Research and Social Science, 74*, 101902. https://doi.org/10.1016/j.erss.2020.101902

Krznaric, R. (2021). *The good ancestor: how to think long term in a short-term world*. London SE - xii, 323 p.: WH Allen, an imprint of Ebury Publishing.

Kühne, O. (2020). Landscape Conflicts — A Theoretical Approach Based on the Three Worlds Theory of Karl Popper and the Conflict Theory of Ralf Dahrendorf , Illustrated by the Example of the Energy System Transformation in Germany. *Sustainability, 12*(17), 6772.

Kühne, O., Weber, F., & Berr, K. (2019). The productive potential and limits of landscape conflicts in light of Ralf Dahrendorf's conflict theory. *SocietàMutamentoPolitica, 10*(19), 77–90. https://doi.org/10.13128/SMP-25391

Landscape Institute. (2015). LI Awards 2015. *Retrieved March 3*, 2022, from https://www.landscapeinstitute.org/awards/2015-li-awards/

Le Dû-Blayo, L. (2011). How Do We Accommodate New Land Uses in Traditional Landscapes? Remanence of Landscapes, Resilience of Areas, Resistance of People. *Landscape Research, 36*(4), 417–434. https://doi.org/10.1080/01426397.2011.583010

Leibenath, M., & Lintz, G. (2018). Understanding 'landscape governance': the case of wind energy landscapes in Germany. *Landscape Research, 43*(4), 476–488. https://doi.org/10.1080/01426397.2017.1306624

Lenzholzer, S., Duchhart, I., & Koh, J. (2013). "Research through designing" in landscape architecture. *Landscape and Urban Planning, 113*, 120–127. https://doi.org/10.1016/j.landurbplan.2013.02.003

Lenzholzer, S., Duchhart, I., & van den Brink, A. (2017). The relationship between research and design. In A. van den Brink, D. Bruns, H. Tobi, & S. Bell (Eds.), *Research in Landscape Architecture: methods and methodology* (pp. 54–64). New York: Routledge.

Lindberg, O., Birging, A., Widén, J., & Lingfors, D. (2021). PV park site selection for utility-scale solar guides combining GIS and power flow analysis: A case study on a Swedish municipality. *Applied Energy, 282*(PA), 116086. https://doi.org/10.1016/j.apenergy.2020.116086

Linnerud, K., Toney, P., Simonsen, M., & Holden, E. (2019). Does change in ownership affect community attitudes toward renewable energy projects? Evidence of a status quo bias. *Energy Policy, 131*, 1–8. https://doi.org/10.1016/j.enpol.2019.04.039

Lobaccaro, G., Croce, S., Lindkvist, C., Munari Probst, M. C., Scognamiglio, A., Dahlberg, J., … Wall, M. (2019). A cross-country perspective on solar energy in urban planning: Lessons learned from international case studies. *Renewable and Sustainable Energy Reviews, 108*(March), 209–237. https://doi.org/10.1016/j.rser.2019.03.041

Loorbach, D., & Rotmans, J. (2010). The practice of transition management: Examples and lessons from four distinct cases. *Futures, 42*(3), 237–246. https://doi.org/10.1016/j.futures.2009.11.009

LoS Stadomland. (2020). *Visie buitengebied: Het land van Wageningen, Wageningen in het land*. Wageningen.

Lovell, S. T., & Johnston, D. M. (2009). Designing landscapes for performance based on emerging principles in landscape ecology. *Ecology and Society, 14*(1). https://doi.org/10.5751/ES-02912-140144

Lovich, J. E., & Ennen, J. R. (2011). Wildlife Conservation and Solar Energy Development in the Desert Southwest, United States. *BioScience, 61*(12), 982–992. https://doi.org/10.1525/bio.2011.61.12.8

Marres, N. (2015). *Material Participation: Technology, the Environment and Everyday Publics*. Basingstoke: Palgrave Macmillan.

Martín-Chivelet, N. (2016). Photovoltaic potential and land-use estimation methodology. *Energy, 94*, 233–242. https://doi.org/10.1016/j.energy.2015.10.108

Massi Pavan, A., Mellit, A., & De Pieri, D. (2011). The effect of soiling on energy production for large-scale photovoltaic plants. *Solar Energy, 85*(5), 1128–1136. https://doi.org/10.1016/j.solener.2011.03.006

May, J. (2008). On Technology, Ecology, and Urbanism. In M. Ballesteros (Ed.), *Verb Crisis* (pp. 103–115). Barcelona: Actar Publishers.

Mehalic, B. (2009). *Flat-plate & evacuated-tube solar thermal collectors*. Retrieved October 8, 2013 from http://www.homepower.com/articles/solar-water-heating/equipment-products/flat-plate-evacuated-tube-solar-thermal-collectors.

Merida-Rodriguez, M., Lobon-Martin, R., & Perles-Rosello, M.-J. (2015). The Production of Solar Photovoltaic Power and Its Landscape Dimension. In M. Frolova, M.-J. Prados, & A. Nadaï (Eds.), *Renewable Energies and European Landscapes: Lessons from Southern European Cases* (pp. 255–277). Springer. https://doi.org/10.1007/978-94-017-9843-3

Milbrandt, A. R., Heimiller, D. M., Perry, A. D., & Field, C. B. (2014). Renewable energy potential on marginal lands in the United States. Renewable and Sustainable *Energy Reviews, 29*, 473–481. https://doi.org/10.1016/j.rser.2013.08.079

Miller, C. A., Iles, A., & Jones, C. F. (2013). *The Social Dimensions of Energy Transitions. Science as Culture, 22*(2), 135–148. https://doi.org/10.1080/09505431.2013.786989

Moore-O'Leary, K. A., Hernandez, R. R., Johnston, D. S., Abella, S. R., Tanner, K. E., Swanson, A. C., ... Lovich, J. E. (2017). Sustainability of utility-scale solar energy - critical ecological concepts. *Frontiers in Ecology and the Environment, 15*(7), 385–394. https://doi.org/10.1002/fee.1517

Moore, S., & Hackett, E. J. (2016). The construction of technology and place: Concentrating solar power conflicts in the United States. *Energy Research and Social Science, 11*, 67–78. https://doi.org/10.1016/j.erss.2015.08.003

Mori, A. S. (2011). Ecosystem management based on natural disturbances: Hierarchical context and non-equilibrium paradigm. *Journal of Applied Ecology, 48*(2), 280–292. https://doi.org/10.1111/j.1365-2664.2010.01956.x

Müller, S., Backhaus, N., & Buchecker, M. (2020). Mapping meaningful places: A tool for participatory siting of wind turbines in Switzerland? *Energy Research and Social Science, 69*(April), 101573. https://doi.org/10.1016/j.erss.2020.101573

Nadaï, A., & van der Horst, D. (2010). Introduction: Landscapes of Energies. *Landscape Research, 35*(2), 143–155. https://doi.org/10.1080/01426390903557543

Nassauer, J. I. (2012). Landscape as medium and method for synthesis in urban ecological design. *Landscape and Urban Planning, 106*(3), 221–229. https://doi.org/10.1016/j.landurbplan.2012.03.014

Neal, P. (2011). *Learning Legacy: Lessons learned from the London 2012 Games construction project. Learning Legacy: Programme Management Framework*. London: Olympic Delivery Authority. Retrieved from http://learninglegacy.independent.gov.uk/themes/health-and-safety/research-summaries.php

Neefjes, J., & Bleumink, H. (2021). *De Veluwe: landschapsbiografie van Nederlands grootste natuurgebied*. Wageningen: Uitgeverij Blauwdruk.

Nikologianni, A., Moore, K., & Larkham, P. (2017). Effective ways to deliver sustainability in urban and regional landscape strategies. *Acta Horticulturae*, (1189), 131–136.

Nimmo, A., Frost, J., Shaw, S., & McNevin, N. (2011). Delivering London 2012: master planning. *Proceedings of the Institution of Civil Engineers - Civil Engineering, 164*(5), 13–19. https://doi.org/10.1680/cien.2011.164.5.13

Nordberg, E. J., Julian Caley, M., & Schwarzkopf, L. (2021). Designing solar farms for synergistic commercial and conservation outcomes. Solar Energy, 228(October), 586–593. https://doi.org/10.1016/j.solener.2021.09.090

NREL. (2013). National Center of Photovoltaics. Retrieved October 8, 2013, from https://www.nrel.gov/pv/cell-efficiency.html

Olwig, K. R. (1996). Recovering the Substantive Nature of Landscape. *Annals of the Association of American Geographers, 86*(4), 630–653.

Oudes, D., & Stremke, S. (2018). Spatial transition analysis: Spatially explicit and evidence-based targets for sustainable energy transition at the local and regional scale. *Landscape and Urban Planning, 169*, 1–11. https://doi.org/10.1016/j.landurbplan.2017.07.018

Oudes, D., & Stremke, S. (2020). Climate adaptation, urban regeneration and brownfield reclamation: a literature review on landscape quality in large-scale transformation projects. *Landscape Research, 45*(7), 905–919. https://doi.org/10.1080/01426397.2020.1736995

Oudes, D., & Stremke, S. (2021). Next generation solar power plants ? A comparative analysis of frontrunner solar landscapes in Europe. *Renewable and Sustainable Energy Reviews, 145*, 111101. https://doi.org/10.1016/j.rser.2021.111101

Owens, M. (2012). The impact of the London Olympics on the Lower Lea: regeneration lost and found? *Australian Planner, 49*(3), 215–225. https://doi.org/10.1080/07293682.2012.706963

Park, J. J., & Selman, P. (2011). Attitudes toward rural landscape change in England. *Environment and Behavior, 43*(2), 182–206. https://doi.org/10.1177/0013916509355123

Pascaris, A. S., Schelly, C., Burnham, L., & Pearce, J. M. (2021). Integrating solar energy with agriculture: Industry perspectives on the market, community, and socio-political dimensions of agrivoltaics. *Energy Research and Social Science, 75*, 102023. https://doi.org/10.1016/j.erss.2021.102023

Pasqualetti, M. J. (2000). Morality , Space , and the Power of Wind-Energy Landscapes. *Geographical Review, 90*(3), 381–394.

Pasqualetti, M. J. (2011a). Social barriers of renewable energy landscapes. *The Geographical Review, 101*(2), 201–223.

Pasqualetti, M. J. (2011b). The Next Generation of Energy Landscapes. In S. D. Brunn (Ed.), *Engineering Earth* (pp. 461–482). Springer. https://doi.org/10.1007/978-90-481-9920-4

Pasqualetti, M. J. (2013). Reading the Changing Energy Landscape. In *Sustainable Energy Landscapes: Designing, Planning, and Development* (pp. 11–44). CRC Press. https://doi.org/10.1201/b13037-4 LK - https://wur.on.worldcat.org/oclc/7349989676

Pasqualetti, M. J., & Brown, M. A. (2014). Ancient discipline, modern concern: Geographers in the field of energy and society. *Energy Research and Social Science, 1*, 122–133. https://doi.org/10.1016/j.erss.2014.03.016

Pasqualetti, M. J., Gipe, P., & Righter, R. W. (2002). *Wind power in view: energy landscapes in a crowded world*. San Diego: Academic Press.

Pasqualetti, M. J., & Stremke, S. (2018). Energy landscapes in a crowded world: A first typology of origins and expressions. *Energy Research and Social Science, 36*, 94–105. https://doi.org/10.1016/j.erss.2017.09.030

Pelle, M., Lucchi, E., Maturi, L., Astigarraga, A., & Causone, F. (2020). Coloured BIPV technologies: Methodological and experimental assessment for architecturally sensitive areas. *Energies, 13*(17). https://doi.org/10.3390/en13174506

Petticrew, M., & Roberts, H. (2008). Why Do We Need Systematic Reviews? In *Systematic Reviews in the Social Sciences: A Practical Guide* (pp. 1–26). Wiley. https://doi.org/10.1002/9780470754887.ch1

Picchi, P., van Lierop, M., Geneletti, D., & Stremke, S. (2019). Advancing the relationship between renewable energy and ecosystem services for landscape planning and design: A literature review. *Ecosystem Services, 35*(August 2018), 241–259. https://doi.org/10.1016/j.ecoser.2018.12.010

Pijlman, J., & Bosman, R. (2014). *Nieuwe energie voor de Stedendriehoek. Routekaart naar een energieneutrale regio Stedendriehoek in 2030*. Retrieved July 8, 2017, from http://www.regiostedendriehoek.nl/leefomgeving/publicaties/%0Dnieuwe-energie-voor-de-stedendriehoek.pdf

Pinto-Correia, T., & Kristensen, L. (2013). Linking research to practice: The landscape as the basis for integrating social and ecological perspectives of the rural. *Landscape and Urban Planning, 120*, 248–256. https://doi.org/10.1016/j.landurbplan.2013.07.005

Pistoni, R. (2020). *Landscape planning and design for energy transition in France and the Netherlands: principles, practices, recommendations*. Ecole Nationale Supérieure de Paysage.

Poggi, F., Firmino, A., & Amado, M. (2018). Planning renewable energy in rural areas: Impacts on occupation and land use. *Energy, 155*, 630–640. https://doi.org/10.1016/j.energy.2018.05.009

Pollak, L. (2007). Matrix Landscape: Construction of Identity in the Large Park. In J. Czerniak, G. Hargreaves, & J. Beardsley (Eds.), *Large Parks* (pp. 87–119). New York: Princeton Architectural Press New York.

Prados, M. J. (2010). Renewable energy policy and landscape management in Andalusia, Spain: The facts. *Energy Policy, 38*(11), 6900–6909. https://doi.org/10.1016/j.enpol.2010.07.005

Pringle, A. M., Handler, R. M., & Pearce, J. M. (2017). Aquavoltaics: Synergies for dual use of water area for solar photovoltaic electricity generation and aquaculture. *Renewable and Sustainable Energy Reviews, 80*, 572–584. https://doi.org/10.1016/j.rser.2017.05.191

Province of Flevoland. (2016). *Regioplan Windenergie Zuidelijk en Oostelijk Flevoland. Lelystad*. Retrieved from https://www.flevoland.nl/getmedia/720306d8-6fa8-45eb-86a4-490be4c65ddb/Regioplan-Windenergie-dv.pdf

Randle-Boggis, R. J., White, P. C. L., Cruz, J., Parker, G., Montag, H., Scurlock, J. M. O., & Armstrong, A. (2020). Realising co-benefits for natural capital and ecosystem services from solar parks: A co-developed, evidence-based approach. *Renewable and Sustainable Energy Reviews, 125*, 109775. https://doi.org/10.1016/j.rser.2020.109775

Rasch, E. D. D., & Köhne, M. (2017). Practices and imaginations of energy justice in transition. A case study of the Noordoostpolder, the Netherlands. *Energy Policy, 107*, 607–614. https://doi.org/10.1016/j.enpol.2017.03.037

Redeker, C. (2018). *Rhine Cities - Urban Flood Integration (UFI): German and Dutch Adaptation and Mitigation Strategies*. A+BE | Architecture and the Built Environment; No 4 (2018): Rhine Cities - Urban Flood Integration (UFI).

Riaz, M. H., Imran, H., Younas, R., & Butt, N. Z. (2021). The optimization of vertical bifacial photovoltaic farms for efficient agrivoltaic systems. *Solar Energy, 230*, 1004–1012. https://doi.org/10.1016/j.solener.2021.10.051

Rijke, J., van Herk, S., Zevenbergen, C., & Ashley, R. (2012). Room for the river: Delivering integrated river basin management in the netherlands. *International Journal of River Basin Management, 10*(4), 369–382. https://doi.org/10.1080/15715124.2012.739173

Roddis, P., Carver, S., Dallimer, M., Norman, P., & Ziv, G. (2018). The role of community acceptance in planning outcomes for onshore wind and solar farms: An energy justice analysis. *Applied Energy, 226*, 353–364. https://doi.org/10.1016/j.apenergy.2018.05.087

Roddis, P., Roelich, K., Tran, K., Carver, S., Dallimer, M., & Ziv, G. (2020). What shapes community acceptance of large-scale solar farms? A case study of the UK's first 'nationally significant' solar farm. *Solar Energy, 209*, 235–244. https://doi.org/10.1016/j.solener.2020.08.065

Rodrigues, M., Montañés, C., & Fueyo, N. (2010). A method for the assessment of the visual impact caused by the large-scale deployment of renewable-energy facilities. *Environmental Impact Assessment Review, 30*(4), 240–246. https://doi.org/10.1016/j.eiar.2009.10.004

Rodriguez, J.-F. (2012). Hydropower landscapes and tourism development in the Pyrenees. *Revue de Géographie Alpine*, (100–2), 0–16. https://doi.org/10.4000/rga.1819

Roth, M., Eiter, S., Röhner, S., Kruse, A., Schmitz, S., Frantál, B., … Van der Horst, D. (2018). *Renewable Energy and Landscape Quality*. Jovis Verlag GmbH.

Russell, A., & Firestone, J. (2021). What's love got to do with it? Understanding local cognitive and affective responses to wind power projects. *Energy Research and Social Science, 71*, 101833. https://doi.org/10.1016/j.erss.2020.101833

RVO. (2022). *Kenmerken SDE++*. Retrieved March 4, 2022, from https://www.rvo.nl/subsidie-en-financieringswijzer/sde/aanvragen/kenmerken

Ryghaug, M., Skjølsvold, T. M., & Heidenreich, S. (2018). Creating energy citizenship through material participation. *Social Studies of Science, 48*(2), 283–303. https://doi.org/10.1177/0306312718770286

Salak, B., Lindberg, K., Kienast, F., & Hunziker, M. (2021). How landscape-technology fit affects public evaluations of renewable energy infrastructure scenarios. A hybrid choice model. *Renewable and Sustainable Energy Reviews, 143*, 110896. https://doi.org/10.1016/j.rser.2021.110896

Sánchez-Pantoja, N., Vidal, R., & Pastor, M. C. (2018). Aesthetic impact of solar energy systems. *Renewable and Sustainable Energy Reviews, 98*, 227–238. https://doi.org/10.1016/j.rser.2018.09.021

Scannell, L., & Gifford, R. (2010). Defining place attachment: A tripartite organizing framework. *Journal of Environmental Psychology, 30*(1), 1–10. https://doi.org/10.1016/j.jenvp.2009.09.006

Schindele, S., Trommsdorff, M., Schlaak, A., Obergfell, T., Bopp, G., Reise, C., … Weber, E. (2020). Implementation of agrophotovoltaics: Techno-economic analysis of the price-performance ratio and its policy implications. *Applied Energy, 265*, 114737. https://doi.org/10.1016/j.apenergy.2020.114737

Schindler, B. Y., Blaustein, L., Lotan, R., Shalom, H., Kadas, G. J., & Seifan, M. (2018). Green roof and photovoltaic panel integration: Effects on plant and arthropod diversity and electricity production. *Journal of Environmental Management, 225*, 288–299. https://doi.org/10.1016/j.jenvman.2018.08.017

Schulz, C., & Skinner, J. (2022). Hydropower benefit-sharing and resettlement : A conceptual review. *Energy Research & Social Science, 83*, 102342. https://doi.org/10.1016/j.erss.2021.102342

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. https://doi.org/10.1016/j.rser.2015.10.072

Selman, P. (2006). *Planning at the landscape scale*. London: Routledge. Retrieved from http://catdir.loc.gov/catdir/toc/ecip0510/2005008165.html

Selman, P. (2009). Planning for landscape multifunctionality. *Sustainability: Science, Practice and Policy, 5*(2), 45–52. https://doi.org/10.1080/15487733.2009.11908035

Selman, P. (2010). Learning to love the landscapes of carbon-neutrality. *Landscape Research, 35*(2), 157–171. https://doi.org/10.1080/01426390903560414

Semeraro, T., Pomes, A., Del Giudice, C., Negro, D., & Aretano, R. (2018). Planning ground based utility scale solar energy as green infrastructure to enhance ecosystem services. *Energy Policy, 117*(August 2017), 218–227. https://doi.org/10.1016/j.enpol.2018.01.050

Sherren, K. (2021). From Climax Thinking toward a Non-equilibrium Approach to Public Good Landscape Change. In J. B. Jacquet, J. H. Haggerty, & G. L.

Theodori (Eds.), *Energy Impacts: A Multidisciplinary Exploration of North American Energy Development* (pp. 17–44). University Press of Colorado.

Sherren, K., Beckley, T. M., Parkins, J. R., Stedman, R. C., Keilty, K., & Morin, I. (2016). Learning (or living) to love the landscapes of hydroelectricity in Canada: Eliciting local perspectives on the Mactaquac Dam via headpond boat tours. *Energy Research and Social Science, 14*, 102–110. https://doi.org/10.1016/j.erss.2016.02.003

Sherren, K., Parkins, J. R., Owen, T., & Terashima, M. (2019). Does noticing energy infrastructure influence public support for energy development? Evidence from a national survey in Canada. *Energy Research and Social Science, 51*, 176–186. https://doi.org/10.1016/j.erss.2019.01.014

Shirai, H. (2014). *The evolving vision of the Olympic legacy : the development of the mixed-use Olympic Parks of Sydney and London. The London School of Economics and Political Science*. Retrieved from http://etheses.lse.ac.uk/956/

Siegrist, M., Sütterlin, B., & Keller, C. (2014). Why have some people changed their attitudes toward nuclear power after the accident in Fukushima? *Energy Policy, 69*, 356–363. https://doi.org/10.1016/j.enpol.2014.02.026

Sijmons, D. (1990). Regional planning as a strategy. *Landscape and Urban Planning, 18*(3–4), 265–273. https://doi.org/10.1016/0169-2046(90)90014-S

Sijmons, D., Hocks, B., Kuijers, T., Norkunaite, G., Witte, J., Vermeulen, M., … Rijpers, Y. (2017). *Energie en Ruimte - Een nationaal perspectief*. Rotterdam: Vereniging Deltametropool.

Sijmons, D., Hugtenburg, J., van Hoorn, A., & Feddes, F. (2014). *Landscape and Energy: Designing Transition*. Rotterdam: nai010 publishers.

Sinha, P., Hoffman, B., Sakers, J., & Althouse, L. (2018). Best Practices in Responsible Land Use for Improving Biodiversity at a Utility-Scale Solar Facility. *Case Studies in the Environment*, 1–12. https://doi.org/10.1525/cse.2018.001123

Smil, V. (2010). *Power Density Primer : Understanding the Spatial Dimension of the Unfolding Transition to Renewable Electricity Generation (Part I – Definitions)*.

Smith, A. (2014a). "De-Risking" East London: Olympic Regeneration Planning 2000–2012. *European Planning Studies, 22*(9), 1919–1939. https://doi.org/10.1080/09654313.2013.812065

Smith, A. (2014b). From green park to theme park? Evolving legacy visions for London's Olympic Park. *Architectural Research Quarterly, 18*(4), 315–323. https://doi.org/10.1017/S1359135515000056

Sociaal-Economische Raad. (2013). *Energieakkoord voor duurzame groei*. Den Haag.

Sovacool, B. K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research and Social Science, 1*, 1–29. https://doi.org/10.1016/j.erss.2014.02.003

Sovacool, B. K., Axsen, J., & Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. *Energy Research and Social Science, 45*, 12–42. https://doi.org/10.1016/j.erss.2018.07.007

Sovacool, B. K., Hess, D. J., Amir, S., Geels, F. W., Hirsh, R., Rodriguez, L., … Yearley, S. (2020). Sociotechnical agendas : Reviewing future directions for energy and climate research. *Energy Research & Social Science, 70*, 101617. https://doi.org/10.1016/j.erss.2020.101617

Steenbergen, C. M. (2008). *Composing landscapes : analysis, typology and experiments for design*. Basel: Birkhäuser Verlag.

Steg, L., Perlaviciute, G., Sovacool, B. K., Bonaiuto, M., Matthies, E., Matti, S., … Pahl, S. (2021). *A Research Agenda to Better Understand the Human Dimensions of Energy Transitions, 12*, 1–11. https://doi.org/10.3389/fpsyg.2021.672776

Steinitz, C. (1990). A Framework for Theory Applicable to the Education of Landscape Architects (and Other Environmental Design Professionals). *Landscape Journal, 9*(2), 136–143. https://doi.org/10.3368/lj.9.2.136

Stiles, R. (1994). Landscape theory: a missing link between landscape planning and landscape design? *Landscape and Urban Planning, 30*(3), 139–149. https://doi.org/10.1016/0169-2046(94)90053-1

Stober, D., Suškevičs, M., Eiter, S., Müller, S., Martinát, S., & Buchecker, M. (2021). What is the quality of participatory renewable energy planning in Europe? A comparative analysis of innovative practices in 25 projects. *Energy Research and Social Science, 71*. https://doi.org/10.1016/j.erss.2020.101804

Stoms, D. M., Dashiell, S. L., & Davis, F. W. (2013). Siting solar energy development to minimize biological impacts. *Renewable Energy, 57*, 289–298. https://doi.org/10.1016/j.renene.2013.01.055

Storie, J. T., & Külvik, M. (2019). Transformative actions on communities and landscapes: the case of Kaldabruna village. *Landscape Research, 44*(3), 337–350. https://doi.org/10.1080/01426397.2019.1585769

Stremke, S. (2015). Sustainable Energy Landscape: Implementing Energy Transition in the Physical Realm. *Encyclopedia of Environmental Management*, 1–9. https://doi.org/10.1081/E-EEM-120053717

Stremke, S., & Koh, J. (2011). Integration of Ecological and Thermodynamic Concepts in the Design of Sustainable Energy Landscapes. *Landscape Journal, 30*(2), 194–213. https://doi.org/10.3368/lj.30.2.194

Stremke, S., Koh, J., Neven, K., & Boekel, A. (2012). Integrated Visions (Part II): Envisioning Sustainable Energy Landscapes. *European Planning Studies, 20*(4), 609–626. https://doi.org/10.1080/09654313.2012.665617

Stremke, S., & Picchi, P. (2017). Co-designing energy landscapes: application of participatory mapping and Geographic Information Systems in the exploration of low carbon futures. *Handbook on the Geographies of Energy*, 368–379.

Stremke, S., & Schöbel, S. (2019). Research through design for energy transition: two case studies in Germany and The Netherlands. *Smart and Sustainable Built Environment, 8*(1), 16–33. https://doi.org/10.1108/SASBE-02-2018-0010

Stremke, S., & van den Dobbelsteen, A. (Eds.). (2013). *Sustainable energy landscapes : designing, planning, and development*. Boca Raton, FL [etc.]: CRC.

Stremke, S., van Kann, F., & Koh, J. (2012). Integrated Visions (Part I): Methodological Framework for Long-term Regional Design. *European Planning Studies, 20*(2), 305–319. https://doi.org/10.1080/09654313.2012.650909

Strzelecka, M., Rechciński, M., Tusznio, J., Akhshik, A., & Grodzińska-Jurczak, M. (2021). Environmental justice in Natura 2000 conservation conflicts: The case for resident empowerment. *Land Use Policy, 107*. https://doi.org/10.1016/j.landusepol.2021.105494

Sugarman, J. (2009). *Environmental and community health: A reciprocal relationship*. In: Campbell, Lindsay; Wiesen, Anne, Eds. Restorative Commons: Creating Health and Well-Being through Urban Landscapes. Gen. Tech Rep. NRS-P-39. US Department of Agriculture, Forest Service, Northern Research Station: 138-153.

Thayer, R. L. (1994). *Gray world, green heart: technology, nature, and sustainable landscape*. New York: Wiley.

Thayer, R. L., & Freeman, C. M. (1987). Altamont: Public perceptions of a wind energy landscape. *Landscape and Urban Planning, 14*(C), 379–398. https://doi.org/10.1016/0169-2046(87)90051-X

TNO. (n.d.). *Solar Visuals - Aesthetic Solar Panels*. Retrieved March 9, 2022, from https://www.tno.nl/en/focus-areas/techtransfer/spin-offs/solar-visuals-aesthetic-solar-panels/

Toledo, C., & Scognamiglio, A. (2021). Agrivoltaic Systems Design and Assessment : A Critical Review , and a Descriptive Model towards a Sustainable Landsape Vision (Three-Dimensional Agrivoltaic Patterns). *Sustainability, 13*(12), 6871.

Tolli, M., Recanatesi, F., Piccinno, M., & Leone, A. (2016). The assessment of aesthetic and perceptual aspects within environmental impact assessment of renewable energy projects in Italy. *Environmental Impact Assessment Review, 57*, 10–17. https://doi.org/10.1016/j.eiar.2015.10.005

Torres-Sibille, A. del C., Cloquell-Ballester, V. A., Cloquell-Ballester, V. A., & Artacho Ramírez, M. Á. (2009). Aesthetic impact assessment of solar power plants: An objective and a subjective approach. *Renewable and Sustainable Energy Reviews, 13*(5), 986–999. https://doi.org/10.1016/j.rser.2008.03.012

Tress, B., & Tress, G. (2001). Capitalising on multiplicity: A transdisciplinary systems approach to landscape research. *Landscape and Urban Planning, 57*(3–4), 143–157. https://doi.org/10.1016/S0169-2046(01)00200-6

Trommsdorff, M., Kang, J., Reise, C., Schindele, S., Bopp, G., Ehmann, A., ... Obergfell, T. (2021). Combining food and energy production: Design of an agrivoltaic system applied in arable and vegetable farming in Germany. *Renewable and Sustainable Energy Reviews, 140*. https://doi.org/10.1016/j.rser.2020.110694

Trutnevyte, E., Stauffacher, M., & Scholz, R. W. (2011). Supporting energy initiatives in small communities by linking visions with energy scenarios and multi-criteria assessment. *Energy Policy, 39*(12), 7884–7895. https://doi.org/10.1016/j.enpol.2011.09.038

Tsai, C. Y., & Tsai, C. Y. (2020). See-through, light-through, and color modules for large-area tandem amorphous/microcrystalline silicon thin-film solar modules: Technology development and practical considerations for building-integrated photovoltaic applications. *Renewable Energy, 145*, 2637–2646. https://doi.org/10.1016/j.renene.2019.08.029

Tscharntke, T., Klein, A. M., Kruess, A., Steffan-Dewenter, I., & Thies, C. (2005). Landscape perspectives on agricultural intensification and biodiversity - Ecosystem service management. *Ecology Letters, 8*(8), 857–874. https://doi.org/10.1111/j.1461-0248.2005.00782.x

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

Tuan, Y.-F. (1977). *Space and Place: the perspective of experience*. Minneapolis: University of Minnesota Press.

Turney, D., & Fthenakis, V. (2011). Environmental impacts from the installation and operation of large-scale solar power plants. *Renewable and Sustainable Energy Reviews, 15*(6), 3261–3270. https://doi.org/10.1016/j.rser.2011.04.023

United Nations. (2015). *Paris Agreement*. Paris. Retrieved from http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

Urgenda. (2015). *The Urgenda climate case against the Dutch government*. Retrieved October 15, 2015, from http://www.urgenda.nl/en/climate-case/

Van den Brink, A., & Bruns, D. (2012). Strategies for Enhancing Landscape Architecture Research. *Landscape Research, 6397*(July 2014), 1–14. https://doi.org/10.1080/01426397.2012.711129

Van den Brink, A., Bruns, D., Tobi, H., & Bell, S. (2017). *Research in Landscape Architecture: methods and methodology*. (A. van den Brink,

D. Bruns, H. Tobi, & S. Bell, Eds.). New York: Routledge. https://doi.org/doi:10.4324/9781315396903

Van den Brink, M., Edelenbos, J., van den Brink, A., Verweij, S., van Etteger, R., & Busscher, T. (2019). To draw or to cross the line? The landscape architect as boundary spanner in Dutch river management. *Landscape and Urban Planning, 186*, 13–23. https://doi.org/10.1016/j.landurbplan.2019.02.018

Van den Dobbelsteen, A., Broersma, S., & Stremke, S. (2011). Energy Potential Mapping for Energy-Producing Neighborhoods. *International Journal of Sustainable Building Technology and Urban Development, 2*(2), 170–176. https://doi.org/10.5390/SUSB.2011.2.2.170

Van der Horst, D., & Vermeylen, S. (2011). Local rights to landscape in the global moral economy of carbon. *Landscape Research, 36*(4), 455–470. https://doi.org/10.1080/01426397.2011.582941

Van Etteger, R. (2016). *Beyond the visible : prolegomenon to an aesthetics of designed landscapes*. Wageningen University. https://doi.org/10.18174/385562

Van Vuurde, M., Gorissen, F., de Heer, J., de Jong, J., de Bonth, L., Slooff, L., & Sibbing, S. (2019). *ZonneWijzer: Gelderse Gebiedsgids voor zonnevelden*. Arnhem: Gelders Energieakkoord (GEA).

Van Zalk, J., & Behrens, P. (2018). The spatial extent of renewable and non-renewable power generation: A review and meta-analysis of power densities and their application in the U.S. *Energy Policy, 123*(August), 83–91. https://doi.org/10.1016/j.enpol.2018.08.023

Vicenzotti, V., Jorgensen, A., Qviström, M., & Swaffield, S. (2016). Forty years of Landscape Research. *Landscape Research, 41*(4), 388–407. https://doi.org/10.1080/01426397.2016.1156070

Vitruvius, P. (n.d.). *De Architectura (translated by Morris Hicky Morgan, 1960. The Ten Books on Architecture*. Courier Dover Publications. ISBN 0-486-20645-9).

Vizzari, M. (2011). Spatial modelling of potential landscape quality. *Applied Geography, 31*(1), 108–118. https://doi.org/10.1016/j.apgeog.2010.03.001

Von Haaren, C., Warren-Kretzschmar, B., Milos, C., & Werthmann, C. (2014). Opportunities for design approaches in landscape planning. *Landscape and Urban Planning, 130*, 159–170. https://doi.org/10.1016/J.LANDURBPLAN.2014.06.012

Wageningen University. (2021). *In My Backyard Please! Naar maatschappelijke acceptatie van in het landschap geïntegreerde zonneparken*. Retrieved March 9, 2022, from https://www.wur.nl/nl/project/In-My-Backyard-Please-Naar-maatschappelijke-acceptatie-van-in-het-landschap-geintegreerde-zonneparken.htm

Wang, Q., M'Ikiugu, M. M., & Kinoshita, I. (2014). A GIS-based approach in support of spatial planning for renewable energy: A case study of

Fukushima, Japan. *Sustainability (Switzerland), 6*(4), 2087–2117. https://doi.org/10.3390/su6042087

Waters, J. (2016). *Producing space and reproducing capital in London's Olympic Park: an ethnography of actually-existing abstract space. Department of Anthropology*. University of Sussex. Retrieved from http://sro.sussex.ac.uk/id/eprint/65087/

Wehrle, S., Gruber, K., & Schmidt, J. (2021). The cost of undisturbed landscapes. *Energy Policy, 159*, 112617. https://doi.org/10.1016/j.enpol.2021.112617

Weller, R. (2008). Planning by Design Landscape Architectural Scenarios for a Rapidly Growing City. *Journal of Landscape Architecture*, (6), 37–41. https://doi.org/10.1080/18626033.2008.9723401

Willis, G. B., & Artino, A. R. (2013). What Do Our Respondents Think We're Asking? Using Cognitive Interviewing to Improve Medical Education Surveys. *Journal of Graduate Medical Education, 5*(3), 353–356. https://doi.org/10.4300/jgme-d-13-00154.1

Windemer, R. (2019). Considering time in land use planning: An assessment of end-of-life decision making for commercially managed onshore wind schemes. *Land Use Policy, 87*, 104024. https://doi.org/10.1016/j.landusepol.2019.104024

Windemer, R., & Cowell, R. (2021). Are the impacts of wind energy reversible? Critically reviewing the research literature, the governance challenges and presenting an agenda for social science. *Energy Research & Social Science, 79*, 102162. https://doi.org/10.1016/j.erss.2021.102162

Winnubst, M. H. (2011). *Turbulent waters: cross-scale conflict and collaboration in river landscape planning*. Nijmegen: PhD thesis.

Wissen Hayek, U., Spielhofer, R., Salak, B., Hunziker, M., Kienast, F., Thrash, T., … Gret-Regamey, A. (2019). *ENERGYSCAPE – Recommendations for a Landscape Strategy for Renewable Energy Systems Recommendations for a Landscape Strategy*. Zurich. Retrieved from https://doi.org/10.3929/ethz-b-000383049

Wolsink, M. (2007a). Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation. *Energy Policy, 35*(5), 2692–2704. https://doi.org/10.1016/j.enpol.2006.12.002

Wolsink, M. (2007b). Wind power implementation: The nature of public attitudes: Equity and fairness instead of "backyard motives". *Renewable and Sustainable Energy Reviews, 11*(6), 1188–1207. https://doi.org/10.1016/j.rser.2005.10.005

Wolsink, M. (2017). Co-production in distributed generation: renewable energy and creating space for fitting infrastructure within landscapes. *Landscape Research, 6397*, 1–20. https://doi.org/10.1080/01426397.2017.1358360

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. Energy Policy, 35(5), 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001

Yin, R. K. (2009). *Case study research: design and methods. Applied social research methods series (4th ed., Vol. 5)*. Thousand Oaks CA: Sage. https://doi.org/10.1097/FCH.0b013e31822dda9e

Yuan, M. H., & Lo, S. L. (2022). Principles of food-energy-water nexus governance. *Renewable and Sustainable Energy Reviews, 155*, 111937. https://doi.org/10.1016/j.rser.2021.111937

Ziar, H., Prudon, B., Lin, F. Y., Roeffen, B., Heijkoop, D., Stark, T., … Isabella, O. (2021). Innovative floating bifacial photovoltaic solutions for inland water areas. *Progress in Photovoltaics: Research and Applications, 29*(7), 725–743. https://doi.org/10.1002/pip.3367

Zon in Landschap. (2022). *Een nationaal consortium voor innovatie en onderzoek*. Retrieved March 7, 2022, from https://zoninlandschap.nl

Wind park Egmond aan Zee, the first Dutch off-shore wind park in the North sea, the Netherlands (source: author).

Appendices

Appendix A

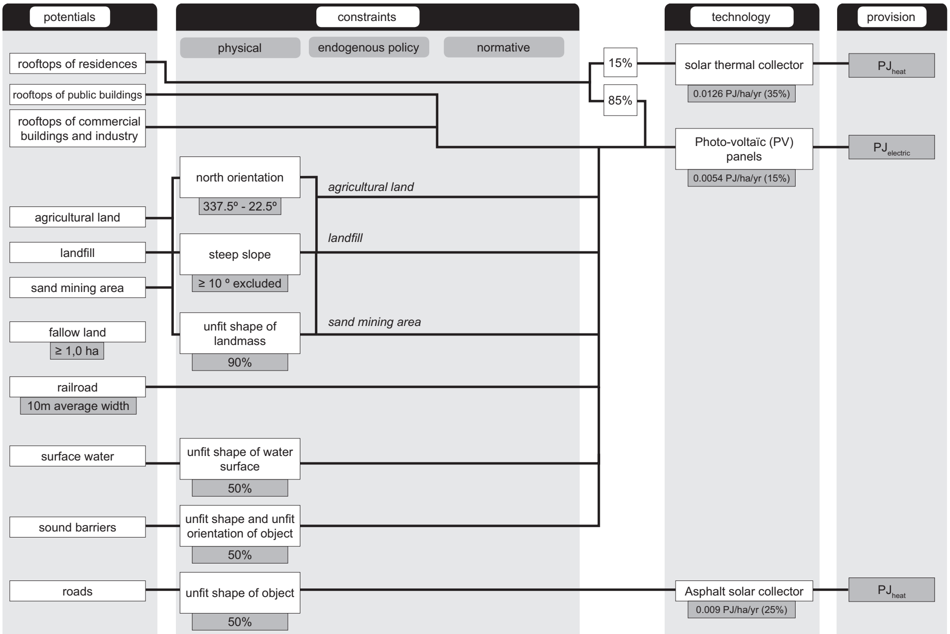
Relative influence of constraints per solar technology (influence of specific constraints over total influence of constraints)

Technology	Location/ land use	Type of constraint	Constraint	Gross potential (PJ)	Reduced potential (PJ)	Influence of constraint (%)
Asphalt collector	roads	physical	unfit shape of object		2,37	100%
			Subtotal	**4,97**	**2,37**	**100%**
Solar thermal collector	Rooftops of residential buildings	physical	unfit shape and unfit orientation of building		0,89	96%
		endogenous policy	settlements with heritage status		0,03	3%
		normative	landmarked buildings (castles)		< 0,01	1%
			Subtotal	**1,62**	**0,92**	**100%**
PV panels	Rooftops of residential buildings	physical	unfit shape and unfit orientation of building		5,04	96%
		endogenous policy	settlements with heritage status		0,16	3%
		normative	landmarked buildings (castles)		0,03	1%
			Subtotal	**7,20**	**5,23**	**100%**
	Rooftops of commercial buildings and industry	physical	unfit shape and unfit orientation of building		1,11	99,0%
		endogenous policy	settlements with heritage status		< 0,01	1,0%
			Subtotal	**2,76**	**1,11**	**100%**
	Rooftops of public buildings	physical	unfit shape and unfit orientation of building		0,23	98%
		endogenous policy	settlements with heritage status		< 0,01	2%
			Subtotal	**0,58**	**0,24**	**100%**

Technology	Location/ land use	Type of constraint	Constraint	Gross potential (PJ)	Reduced potential (PJ)	Influence of constraint (%)
	Agricultural land	normative	Protected landscape: national landscape South-Limburg		53,96	66%
		physical	north orientation		14,33	17%
		normative	food production		9,86	12%
		physical	steep slope		2,96	4%
		physical	unfit shape of landmass		1,22	1%
			Subtotal	**83,42**	**82,33**	**100%**
	Fallow land	physical	unfit shape of landmass		0,01	100%
			Subtotal	**0,12**	**0,01**	**100%**
	Sand mining area	physical	slope		0,76	63%
		physical	north orientation		0,28	23%
		physical	unfit shape of landmass		0,16	13%
			Subtotal	**2,61**	**1,20**	**100%**
	Landfill	physical	slope		0,05	49%
		physical	north orientation		0,04	35%
		physical	irregular shape of landmass		0,02	16%
			Subtotal	**0,27**	**0,11**	**100%**
	Railway tracks	normative	Protected landscape: national landscape South-Limburg		0,18	100%
			Subtotal	**0,52**	**0,18**	**100%**
	Surface water	physical	unfit shape of water surface		0,46	64%
		normative	ponds and lakes for leisure use		0,26	36%
			Subtotal	**1,05**	**0,72**	**100%**
	Sound barriers	physical	unfit shape and unfit orientation of object		0,01	100%
			Subtotal	**0,02**	**0,01**	**100%**
TOTAL				**105,17**	**94,43**	

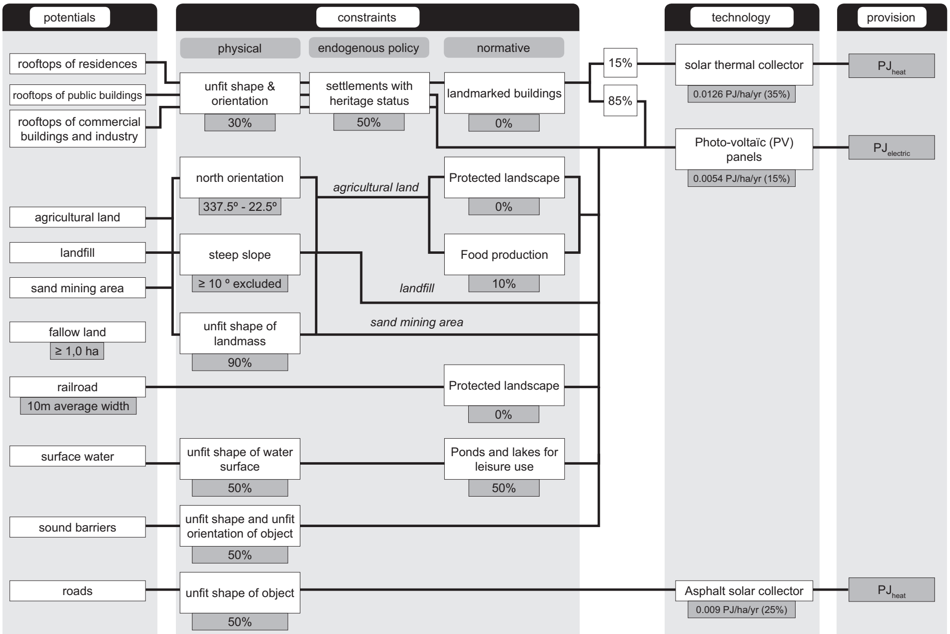
Appendix B

Flowchart for solar energy in the reference scenario



Appendix C

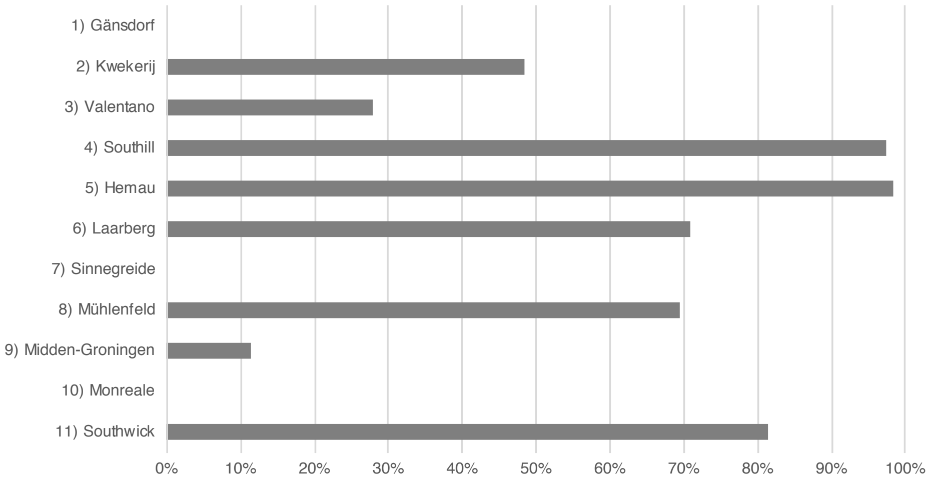
Flowchart for solar energy in the desired scenario



A

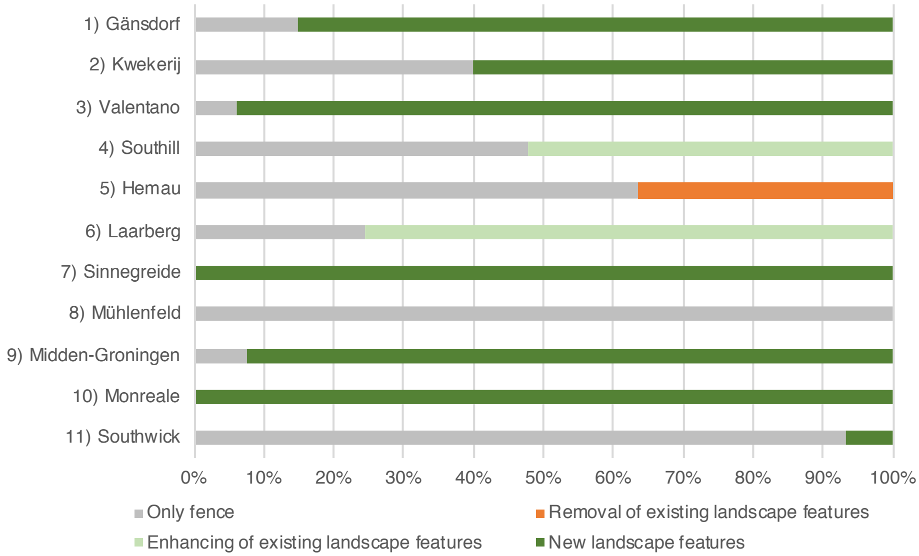
Appendix D

Share of existing eye-level vegetation (e.g. forest patches or hedgerows) along the edge of the solar landscapes



Appendix E

In addition to fencing, three types of measures were applied along the edge of the solar landscapes: removal of existing landscape features, enhancing existing landscape features and new landscape features.



Appendix F

Presence of functions in the cases.

Section	Division	Code	
Provisioning (Biotic)	Biomass	1.1.1.1	
	Biomass	1.1.1.2	
	Biomass	1.1.3.1	
Provisioning (Abiotic)	Non-aqueous natural abiotic ecosystem outputs	4.3.2.4	
Regulation & Maintenance (Abiotic)	Transformation of biochemical or physical inputs to ecosystems	5.1.2.1	
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	2.1.2.3	
	Regulation of physical, chemical, biological conditions	2.2.1.3	
	Regulation of physical, chemical, biological conditions	2.2.2.1	
	Regulation of physical, chemical, biological conditions	2.2.2.2	
	Regulation of physical, chemical, biological conditions	2.2.2.3	
	Regulation of physical, chemical, biological conditions	2.2.4.2	
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	3.1.1.1	
	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	3.1.1.2	
	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	3.1.2.1	
	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	3.1.2.2	
	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	3.1.2.4	
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	3.2.2.1	
Cultural (Abiotic)	Indirect, remote, often indoor interactions with physical systems that do not require presence in the environmental setting	6.2.2.1	

	Simple descriptor	Absolute presence	Relative presence
	Any crops and fruits grown by humans for food; food crops	5	45%
	Material from plants, fungi, algae or bacterial that we can use	2	18%
	Livestock raised in housing and/or grazed outdoors	4	36%
	Solar power	11	100%
	Natural protection	3	27%
	Screening unsightly things	9	82%
	Regulating the flows of water in our environment	6	55%
	Pollinating our fruit trees and other plants	9	82%
	Spreading the seeds of wild plants	1	9%
	Providing habitats for wild plants and animals that can be useful to us	11	100%
	Ensuring the organic matter in our soils is maintained	1	9%
	Using the environment for sport and recreation; using nature to help stay fit	4	36%
	Watching plants and animals where they live; using nature to destress	5	45%
	Researching nature	3	27%
	Studying nature	5	45%
	The beauty of nature	6	55%
	The things in nature that we think should be conserved	7	64%
	Things in the physical environment that we think are important to others and future generations	4	36%

Appendix G

Societal considerations of solar power plants identified in literature.

Societal consideration	Category
Loss of existing land use / land availability	Economic
Tourism and effect on local economy	Economic
Sustained balance between energy and food	Economic
Sufficient capacity on the grid	Economic
Landscape fragmentation (creating barriers for movement of species and their genes)	Nature
Soil disturbance (clearing of soil)	Nature
Recovery time	Nature
Microclimatic impact (heat effect PV modules)	Nature
Interference with flora and fauna / wildlife impact	Nature
Control of water surface runoff	Nature
Integration of PV pattern with landscape pattern	Landscape
Artificializing of landscape (through panels, supporting structures and electrical infrastructure)	Landscape
Loss of greenspace for exercise and relaxation (recreation)	Landscape
Novelty (peculiarity, landmark) in landscape	Landscape
Impact on (historic) landscape character	Landscape
Visibility / visual impact of SPP (including glare)	Landscape
Place attachment (expression of love, emotional bond, strong affection to site or wider area)	Landscape
Aesthetic impact (color, fractality, geometry)	Landscape

	Literature
	(Calvert, Pearce, & Mabee, 2013; Chiabrando et al., 2011; De Laurentis & Pearson, 2018; Denholm & Margolis, 2008; Hastik et al., 2015; Ioannidis & Koutsoyiannis, 2020; Lobaccaro et al., 2019; Roddis et al., 2020; Scognamiglio, 2016)
	(Roddis et al., 2020)
	(Toledo & Scognamiglio, 2021)
	(De Laurentis & Pearson, 2018; Fontaine, 2020; Lindberg, Birging, Widén, & Lingfors, 2021)
	(Hernandez et al., 2014; Lobaccaro et al., 2019; Scognamiglio, 2016)
	(Hernandez et al., 2014; Moore-O'Leary et al., 2017)
	(Roddis et al., 2020; Scognamiglio, 2016; Turney & Fthenakis, 2011)
	(Chiabrando et al., 2009)
	(Chiabrando et al., 2009; Fontaine, 2020; Hastik et al., 2015; Hernandez et al., 2014; Lovich & Ennen, 2011; Randle-Boggis et al., 2020; Roddis et al., 2020; Turney & Fthenakis, 2011)
	(Scognamiglio, 2016)
	(Lobaccaro et al., 2019; Merida-Rodriguez et al., 2015; Scognamiglio, 2016)
	(Apostol, Palmer, et al., 2017; Chiabrando et al., 2011; Haurant et al., 2011; Hernandez et al., 2014; Lobaccaro et al., 2019; Merida-Rodriguez et al., 2015)
	(Fontaine, 2020; Roddis et al., 2020)
	(Bevk & Golobič, 2020)
	(Apostol, Palmer, et al., 2017; Lobaccaro et al., 2019; Roddis et al., 2020; Scognamiglio, 2016)
	(Apostol, Palmer, et al., 2017; Bevk & Golobič, 2020; Carullo et al., 2013; Chiabrando et al., 2011; Fernandez-Jimenez et al., 2015; Fontaine, 2020; Lobaccaro et al., 2019; Roddis et al., 2020; Scognamiglio, 2016; Stremke & Schöbel, 2019; Tolli, Recanatesi, Piccinno, & Leone, 2016; Tsoutsos et al., 2005)
	(Carlisle, Kane, Solan, & Joe, 2014; Moore & Hackett, 2016; Roddis et al., 2020)
	(Kapetanakis et al., 2014; Sánchez-Pantoja et al., 2018; Scognamiglio, 2016; Torres-Sibille et al., 2009)

A

Appendix H

Overview of the spatial properties across the cases. The spatial properties were based upon earlier research (Oudes & Stremke, 2021) and can be categorized as properties that are predominantly related to solar infrastructure, visibility, multifunctionality and temporality. Some properties mainly reflect either economic, nature or landscape considerations, while other properties can be linked to multiple groups of considerations.

Category	Spatial property	Economic (E)	Nature (N)	Landscape (L)	Exemplary case
Solar infrastructure	Adjustment of system layout to existing plots			x	11
	Self-referential patch configuration			x	6
	Landscape aligned patch configuration			x	19
	Incidental patch configuration	x	x	x	5
	Decreased patch density		x	x	17
	Adjustment of array orientation to parcellation	x		x	12
	Adjustment of array orientation to crop	x			20
Visibility	Reduced visibility			x	1
	Enhanced visibility			x	2
Multifunctionality	Ecological features added adjacent to solar infrastructure		x		10
	Ecological features added beneath or between solar infrastructure		x		8
	Built faunal structures		x		19
	Adjusted fence permeability		x		4
	Educational features			x	12
	Vehicle storage or charging			x	6

	1. Solarfeld Gänsdorf	2. Solarpark De Kwekerij	3. Valentano	4. Southill Solar	5. Solar park Hemau	6. Zonnepark Laarberg	7. Sinnegreide	8. Solarpark Mühlenfeld	9. Zonnepark Midden-Groningen	10. Monreale	11. Southwick Estate Solar Farm	12. Energielandschaft Morbach	13. San Gabriele	14. Energie- und Technologiepark Eggebek	15. Merston Community Solar Farm	16. Zonnepark 't Oor	17. Eco-zonnepark Ubbena	18. Sawmills Solar Farm	19. Verwood Solar Farm	20. Babberich Agri-PV
	L			L			L		L	L	L				L	L		L	L	L
		L				L														
				L			L		L	L	L				L	L	L		L	
					N			N				E		E		N		N	L	
		L					L				L						N	N		
												E		E			L			
																				E
	L	L	L	L	L	L	L	L	L	L	L		L	L				L	L	
	L	L				L		L							L					
	N	N	N	N	N	N	N	N	N	N	N					N	N	N	N	
		N		N	N			N		N			N		N		N	N	N	
	N	N		N		N					N				N	N	N	N	N	
		N	N	N	N	N	N	N	N	N	N		N		N	N		N	N	
		L		L	L	L		L				L	L			L				
		L				L	L	L					L							

A

Category	Spatial property	Economic (E)	Nature (N)	Landscape (L)	Exemplary case
	Recreational facilities			x	2
	Crop production adjacent to solar infrastructure	x			10
	Crop production beneath or between solar infrastructure	x			20
	Fruit orchard and/or vegetable gardens		x	x	7
	Livestock for productive purposes	x			3
	Livestock for ecological management		x		5
	Providing water storage capacity	x			6
	Utilizing water storage capacity for other purposes	x	x		2
	Enhancing or recovering of waterways			x	7
	Other RET present	x			14
	Other commercial activities present	x			12
	Access within SPP			x	2
	Access close to SPP			x	16
	Access close to SPP hardly or not possible	x	x	x	
	SPP as node in local or regional recreational infrastructure			x	8
Temporality	Reversibility to previous landscape conditions	x			9
	Reversibility and improvement of ecosystem services	x	x	x	15
	Continued synergy between PV and existing land use	x			20
	New function after decommissioning	x		x	2
	Retaining existing vegetation	x	x	x	18
	Retaining cultural-historical artefacts			x	5
	Referencing to cultural-historical artefacts			x	13

	1. Solarfeld Gänsdorf	2. Solarpark De Kwekerij	3. Valentano	4. Southill Solar	5. Solar park Hemau	6. Zonnepark Laarberg	7. Sinnegreide	8. Solarpark Mühlenfeld	9. Zonnepark Midden-Groningen	10. Monreale	11. Southwick Estate Solar Farm	12. Energielandschaft Morbach	13. San Gabriele	14. Energie- und Technologiepark Eggebek	15. Merston Community Solar Farm	16. Zonnepark 't Oor	17. Eco-zonnepark Ubbena	18. Sawmills Solar Farm	19. Verwood Solar Farm	20. Babberich Agri-PV
		L	L			L	L	L												
										P			P	P						
																				P
	L	L		L		L	L									L				
			P		N	N								P	N	N			N	
	P			P	P							P				P		P		
						P														
		N								P										
			L				L													
												P		P						
												P		P						
		L										L				?				
	L		L			L	L	L	L		L		L		L	L			L	
				N	N					L				P			N	L		P
		L						L			L								L	
				P					P		P			P						
										P	L				P					
																				P
	P	L																		
			L							L			L							
		N		N		L		N			L	P						L		
					L							L		L						

Dual-axis tracker solar park ‘Las Gabias’ in olive and almond grove landscape, Andalucia, Spain (source: author).

Summary
Samenvatting

Summary

Energy transition and landscape are often considered as zero-sum game: progress for the former equals (perceived) losses for the latter. These perceived losses stem from the transformation of familiar and cherished landscapes, driven by the need to achieve renewable energy targets and mitigate climate change. Landscapes have specific physical characteristics and are interpreted and experienced differently by people. Especially in areas with high population density, the implications of landscape transformation caused by the energy transition may therefore be severe. Accordingly, landscape is a key arena for the energy transition where the interests, values and concerns of local stakeholders and society at large meet. This arena encompasses diverse stakeholders: local inhabitants, energy cooperatives, NGOs, industry, grid operators, policy makers, decision makers and researchers.

Many of these agents disregard or have a limited view on the concept of ‘landscape’.
‘Landscape’ is often *disregarded* in setting energy targets, selecting sites and designing renewable energy projects. Instead, the focus lies on technological performance and cost-efficiency, and societal considerations with regard to landscape are ignored.
When ‘landscape’ is present in the siting and design of renewable energy projects, it is often considered as *scenery*. Consequently, evaluation of landscape quality of proposals is limited to the effects of energy infrastructure on viewsheds. This overemphasis on the visual aspect of landscape leads to rejecting the proposal or taking interventions that focus on reducing visibility without considering the characteristics of the host landscape. Furthermore, landscape is frequently considered to be in a *stable-state*. As a result, the current state of the landscape remains unquestioned and is used as the reference point for any potential change. This overemphasis on the present landscape leads to pushing the challenge of the energy transition to communities living somewhere else or in the future.

The disregard of landscape and the limited, conventional understanding of landscape disrupts the continuity of the energy transition *and* has negative consequences for the quality of our landscapes.
As a result, both scholars and society at large start to call for an energy transition that includes ‘landscape’ more prominently in the processes of defining energy targets, designing renewable energy projects and developing energy policies. Physical landscapes start to emerge that are not merely optimized according to technological or economic parameters, but reflect physical landscape characteristics and societal considerations. Examples are multi-purpose solar power plants and ‘solar landscapes’. Multi-purpose solar power plants aim to achieve objectives in addition to electricity production such as food production, improving ecological qualities or enabling recreational activities. Key to the concept of ‘solar landscapes’ is the re-configuring of PV patterns and including agricultural or recreation functions in relationship to characteristics of the existing landscape, or creating new, distinct patterns.

Previous research primarily focused on energy *technologies* instead of energy *landscapes*: technology and landscape are commonly considered to be separate entities. As early as 1958, British landscape architect Sylvia Crowe advocated in *The Power of Landscape* an alternative approach: to start designing ‘complete landscapes’, instead of mitigating inertia between technology and landscape.

Studies focusing on the ‘complete landscapes’ for energy transition are still rare. While other scholars too advocate this, they have so far remained theoretical and without sufficient detail to inform the processes of defining energy targets, designing renewable energy projects and developing energy policies. This overall knowledge gap points to the need for what is in this PhD thesis referred to as *landscape inclusive energy transition*: an energy transition that embraces a comprehensive understanding of landscape, beyond 'scenery' and 'stable state'. Despite the benefits of a landscape inclusive energy transition, it is unclear whether and how landscape can turn from a perceived obstacle into a systemic catalyzer for the 21st century energy transition.

Therefore, the aim of this thesis was to identify key tenets for a *landscape inclusive energy transition*, for advancing the energy transition while meeting societal considerations regarding landscape. The following questions were used to guide the research, each one studied in an individual research module:

1. How can spatially explicit, evidence-based and stakeholder-informed energy transition targets be defined?
2. How is landscape quality addressed in large-scale transformation projects and what is the role of design, governments and participation?
3. What are the visual, functional and temporal properties of frontrunner solar landscapes in Europe?
4. Which societal considerations materialize in Solar Power Plants and what types of multi-purpose SPP can be defined to support evidence-based and transparent planning and design of SPPs?

First, a *methodological framework was developed* to help researchers analyzing energy potentials and define energy transition targets (chapter 2). The framework enables the use of local landscape knowledge, landscape characteristics and stakeholder preferences to advance a landscape inclusive energy transition on the regional scale. By including 'landscape' early in the energy transition process, societal considerations can inform technology and site selection, the timeline for implementation and ultimately the definition of energy transition targets. These insights can assist policy and decision-makers to adapt existing policies or to create new policies to identify sites within their region and define criteria for the local design of renewable energy landscapes.

For answering the second research question, the literature on *three large-scale landscape transformation projects was systematically analyzed*, to understand how the functional, experiential and future aspects of landscape quality can be addressed in the energy transition (chapter 3). There is ample evidence that landscape transformations can provide benefits for all three aspects of landscape quality. With regard to functional aspects, multi-purpose landscapes arise when governments address existing local issues or future demands in the transformation. Furthermore, how stakeholders experience their landscape needs to be understood by designers and governments for them to be genuinely involved in the landscape transformation process. Future aspects are addressed in landscape transformation projects by anticipating future demands of stakeholders or society at large in the design.

A *comparative analysis of solar landscapes* was used to answer the third research question (chapter 4). Visual, functional and temporal properties of the examined cases evidence how societal considerations lead to different physical landscapes, compared to solar power plants that are only optimized for electricity production. The visual impact can be dealt with by reducing visibility but also by enhancing visibility in combination with recreational facilities. Ecological, recreational, agricultural and water management features can become part of solar landscapes, directly mitigating land use competition. Considerations with regard to the end-of-life stage of solar technology are addressed in few cases only, by creating landscape features that enhance the use of the site after decommissioning.

Finally, the fourth research question was answered by means of a *typology of multi-purpose solar power plants*. The typology consists of economic, nature and landscape dimensions that illustrate how different societal considerations lead to different types of solar power plants (chapter 5). The mixed-production type combines electricity production with other economic functions such as food production. The nature-inclusive type combines electricity production with the improvement of the conditions for flora and fauna. The landscape-inclusive type combines electricity production with the improvement of the physical landscape or/and the use and experience of the landscape. The typology provides a basis for more systematic stakeholder-informed decision-making on solar power plants.

These findings indicate that including the concept of landscape in the energy transition discourse supports the continuity of the energy transition and at the same time helps to meet societal considerations regarding landscape. This mutual approach is here articulated as a *landscape inclusive energy transition*, for which I identified five tenets. In a landscape inclusive energy transition: (1) knowledge on and understanding of specific landscapes is used as a foundation for site selection and design, (2) policy makers, designers, developers and landscape users actively use time in the development of energy landscapes, (3) the diversity of societal interests, values and concerns together shape a large variety of multi-purpose renewable energy landscapes, (4) other grand challenges of the 21st century such as food security and biodiversity are coupled with energy development in specific landscapes, and (5) landscape is considered and landscape values coordinated from local to international scale and vice versa by governments as well as other public and private stakeholders involved in landscape governance.

These five tenets suggest that a more *comprehensive understanding* of the concept 'landscape' is needed in the energy transition and other transformative challenges. Proponents of this comprehensive understanding of landscape (1) embrace 'landscape' both as physical landscape (object) and how people interpret and experience that landscape (subject), (2) balance attention for the past, present and future of landscapes, (3) facilitate engagement with local

S

stakeholders and society at large during planning and design, and (4) shape landscape on multiple scales.

A more comprehensive understanding can move ‘landscape’ from problem to solution space and, eventually, become a catalyst for the 21st century energy transition. Understanding landscape as co-construction of natural processes, human activities and diverse experiences provides promising avenues for environmental planners and designers to establish solid grounds with both natural and social sciences in pursuit of an inclusive energy transition.

Samenvatting

Energietransitie en landschap worden vaak gezien als een 'zero-sum game': voortgang voor het eerste staat gelijk aan (beleefde) verliezen voor het laatste. Deze beleefde verliezen ontstaan door de transformatie van vertrouwde en gekoesterde landschappen, gedreven door de noodzaak om hernieuwbare energie doelen te behalen en klimaatverandering tegen te gaan. Landschappen hebben specifieke fysieke kenmerken en worden verschillend geïnterpreteerd en beleefd door mensen. Vooral in gebieden met een hoge bevolkingsdichtheid kunnen de gevolgen van landschapstransformatie veroorzaakt door de energietransitie groot zijn. Om die reden is het landschap de 'arena' voor de energietransitie, waar de belangen, waarden en zorgen van lokale stakeholders en de maatschappij als geheel bij elkaar komen. Deze arena omvat verschillende stakeholders: lokale inwoners, energie coöperaties, ngo's (niet-gouvernementele organisaties), bedrijfsleven en industrie, netbeheerders, beleidsmakers, bestuurders en onderzoekers.

S

Veel van deze stakeholders hebben nauwelijks aandacht voor landschap of hebben een beperkte blik op het concept 'landschap'. 'Landschap' wordt vaak genegeerd bij het bepalen van energietransitie doelen, locatiekeuzes en ontwerpen aan hernieuwbare energie-projecten. In plaats daarvan ligt de focus op de technologische prestaties en kostenefficiëntie, en worden maatschappelijke overwegingen met betrekking tot landschap genegeerd.
Als 'landschap' wel meegenomen wordt in locatiekeuze en ontwerp van hernieuwbare energieprojecten, wordt het voornamelijk gezien als achtergrond of *decor*. Het gevolg hiervan is dat beoordeling van de landschappelijke kwaliteit van projectvoorstellen wordt beperkt tot de (on)zichtbaarheid van energie infrastructuur. De visuele aspecten van landschap worden hierdoor teveel benadrukt, waardoor projectvoorstellen worden afgewezen of maatregelen worden genomen om zichtbaarheid te verminderen, zonder daarbij

rekening te houden met karakteristieken van het landschap. Verder wordt ‘landschap’ ook vaak gezien als een *stabiel* fenomeen. Het gevolg hiervan is dat de huidige staat van het landschap niet kritisch bevraagd wordt en als referentiepunt geldt voor elke mogelijke verandering. Als het huidige landschap teveel benadrukt wordt in de energietransitie leidt dat tot het verschuiven van de opgave naar de gemeenschappen die elders leven of toekomstige gemeenschappen.

Dit negeren van het landschap en het beperkte, conventionele begrip van ‘landschap’ verstoort de continuïteit van de energietransitie *en* heeft negatieve gevolgen voor de kwaliteit van onze landschappen.
Om deze reden vragen onderzoekers en de maatschappij als geheel om aandacht voor een energietransitie waarin ‘landschap’ een prominentere plek krijgt in de processen om energiedoelen te bepalen, hernieuwbare energieprojecten te ontwerpen en energiebeleid te ontwikkelen. Steeds meer fysieke landschappen ontstaan die niet alleen maar zijn geoptimaliseerd volgens technische en economische parameters, maar die fysieke kenmerken van landschappen en maatschappelijke overwegingen weerspiegelen. Voorbeelden zijn multifunctionele ‘solar power plants’ en ‘solar landscapes’. Multifunctionele ‘solar power plants’ hebben andere doelen naast elektriciteitsproductie door middel van zonnepanelen, zoals voedselproductie, het verbeteren van ecologische kwaliteit of het faciliteren van recreatieve activiteiten. Kenmerkend voor het concept ‘solar landscapes’ zijn het aanpassen van patronen van zonnepanelen en het meenemen van agrarische of recreatieve functies in samenhang met de karakteristieken van het bestaande landschap, of het maken van nieuwe, onderscheidende patronen.
Eerder onderzoek heeft zich voornamelijk gericht op *energie technologieën* in plaats van *energielandschappen*: technologie en landschap worden gewoonlijk gezien alsof ze los van elkaar staan. Al in 1958 pleitte de Britse landschapsarchitect Sylvia Crowe voor een andere benadering: begin te ontwerpen aan ‘complete landschappen’, in plaats van het ontbreken van de samenhang tussen techniek en landschap te verdoezelen.

Studies die zich richten op deze 'complete landschappen' in de energietransitie zijn nog zeldzaam. Hoewel andere onderzoekers wel op het belang hiervan wijzen, blijven ze vooralsnog theoretisch en te weinig specifiek om bij te dragen aan het bepalen van energiedoelen, ontwerpen aan hernieuwbare energieprojecten en ontwikkelen van energiebeleid. Het ontbreken van deze kennis geeft aan dat er noodzaak is voor wat in deze PhD thesis wordt omschreven als een *landschaps-inclusieve energietransitie*: een energietransitie die een veelomvattender begrip van landschap omarmt, meer dan een 'decor' of een 'stabiel' fenomeen. Ondanks de voordelen van een landschaps-inclusieve energietransitie is het nog onduidelijk of en hoe landschap in plaats van dat het als obstakel wordt ervaren, juist een katalysator kan zijn voor de 21^{e}-eeuwse energietransitie.

Daarom is het doel van deze thesis om de basisprincipes van een *landschaps-inclusieve energietransitie* te onderscheiden, om de energietransitie vooruit te helpen alsook maatschappelijke overwegingen rondom landschap mee te nemen. De volgende vragen zijn gebruikt als leidraad in het onderzoek, elke bestudeerd in een individuele onderzoeksmodule:

1. Hoe kunnen energietransitie doelen worden bepaald die ruimtelijk expliciet, evidence-based en door stakeholders geïnformeerd zijn?
2. Hoe wordt omgegaan met landschappelijke kwaliteit in grootschalige landschapstransformaties en wat is de rol van ontwerp, overheden en participatie?
3. Wat zijn de visuele, functionele en temporele eigenschappen van voorloper 'solar landscapes' in Europa?
4. Welke maatschappelijke overwegingen zijn terug te vinden in 'solar power plants' (SPP) en welke typen multifunctionele SPPs kunnen worden gedefinieerd voor een een evidence-based en transparant planning en ontwerpproces van SPPs?

Als eerste is een *methodologisch raamwerk ontwikkeld* om onderzoekers te helpen energiepotenties te analyseren en energietransitie doelen te bepalen (hoofdstuk 2). In het raamwerk wordt gebruik gemaakt van lokale kennis van landschap, landschapskarakteristieken en voorkeuren van stakeholders om een landschaps-inclusieve energietransitie op de regionale schaal te bevorderen. Door 'landschap' vroeg in het energietransitie proces mee te nemen, kunnen maatschappelijke overwegingen de keuze voor technologie en locatie ondersteunen, een tijdspad voor de uitvoering informeren en uiteindelijk energietransitie doelen bepalen. Deze inzichten kunnen beleidsmakers en bestuurders helpen om bestaand beleid aan te passen of nieuw beleid te maken, om locaties binnen de regio te vinden en om criteria voor het lokale ontwerp van hernieuwbare energie landschappen te bepalen.

Om de tweede onderzoeksvraag te beantwoorden is de literatuur van *drie grootschalige landschapstransformaties systematisch geanalyseerd*, om te begrijpen hoe met functionele-, belevings- en toekomst aspecten van landschappelijke kwaliteit kan worden omgegaan in de energietransitie (hoofdstuk 3). Er is ruim bewijs dat landschapstransformaties voordelen voor alle drie de aspecten van landschappelijke kwaliteit kunnen hebben. Met betrekking tot functionele aspecten gaat het om multifunctionele landschappen die ontstaan als overheden bestaande, lokale opgaves of toekomstige vragen meenemen in de transformatie. Hoe stakeholders hun landschap beleven moet worden begrepen door ontwerpers en overheden voordat ze oprecht betrokken kunnen worden bij het proces van landschapstransformatie. Toekomstaspecten worden meegenomen in landschapstransformatieprojecten door in het ontwerp te anticiperen op toekomstige vragen van stakeholders of de maatschappij als geheel.

Een *vergelijkende analyse van 'solar landscapes'* is gebruikt om de derde onderzoeksvraag te beantwoorden (hoofdstuk 4). Visuele, functionele en temporele eigenschappen van de onderzochte cases tonen aan hoe maatschappelijke overwegingen leiden tot verschillende fysieke landschappen, vergeleken met monofunctionele 'solar power plants' die alleen maar geoptimaliseerd zijn voor elektriciteitsproductie. Visuele impact kan worden aangepakt door zichtbaarheid te verminderen, maar ook door zichtbaarheid juist te verbeteren in combinatie met recreatieve faciliteiten. Ecologische, recreatieve, agrarische en waterbeherende elementen kunnen onderdeel worden van 'solar landscapes', en zo direct landgebruikscompetitie te verlichten. Overwegingen die gaan over de fase wanneer zonnepanelen het einde van hun levenscyclus hebben bereikt, worden maar in enkele cases geadresseerd. Dit gebeurt door landschapselementen toe te voegen die het gebruik van de plek verbeteren wanneer het energiesysteem is ontmanteld.

Tot slot, de vierde onderzoeksvraag is beantwoord door middel van een *typologie van multifunctionele solar power plants*. De typologie bestaat uit de dimensies economie, natuur en landschap die illustreren hoe verschillende maatschappelijke overwegingen leiden tot verschillende typen solar power plants (hoofdstuk 5). Het 'gemengde-productie' type combineert elektriciteitsproductie met andere economische functies zoals voedselproductie. Het 'natuur-inclusieve' type combineert elektriciteitsproductie met het verbeteren van de omstandigheden voor flora en fauna. Het 'landschaps-inclusieve' type combineert elektriciteitsproductie met het verbeteren van het fysieke landschap en/of het gebruik en de beleving van het landschap. De typologie vormt een basis voor een meer systematische, stakeholder geïnformeerde besluitvorming van solar power plants.

Deze resultaten geven aan dat het betrekken van het concept 'landschap' in het discours van de energietransitie de continuïteit van de energietransitie ondersteunt en tegelijkertijd helpt om maatschappelijke overwegingen rondom landschap hierin mee te nemen. Deze tweezijdige benadering is hier geformuleerd als een *landschaps-inclusieve energietransitie*, waarvoor ik vijf basisprincipes heb onderscheiden. In een landschaps-inclusieve energietransitie: (1) wordt kennis en begrip van specifieke landschappen gebruikt als basis voor locatiekeuzes en ontwerp, (2) gebruiken beleidsmakers, ontwerpers, ontwikkelaars en landschapsgebruikers tijd op een actieve manier in de ontwikkeling van energielandschappen, (3) vormt de diversiteit van maatschappelijke belangen, waarden en zorgen gezamenlijk een variatie aan multifunctionele hernieuwbare energielandschappen, (4) worden andere grote uitdagingen van de 21^{e} eeuw, zoals voedselveiligheid en biodiversiteit, gekoppeld aan energie voorziening in specifieke landschappen, en (5) wordt landschap meegenomen en landschapswaarden gecoördineerd van de lokale tot de internationale schaal en vice versa, door overheden alsook andere publieke en private stakeholders die betrokken zijn bij de governance van landschappen.

Deze vijf basisprincipes suggereren dat een meer *veelomvattend begrip* van het concept ‘landschap’ nodig is in de energietransitie en andere transformerende opgaves. Voorstanders van zo’n veelomvattend begrip van landschap (1) omarmen ‘landschap’ zowel als fysiek landschap (object) en hoe mensen dat landschap interpreteren en beleven (subject), (2) houden aandacht voor verleden, heden en toekomst van energielandschappen in evenwicht, (3) maken betrokkenheid van lokale stakeholders en de maatschappij als geheel mogelijk tijdens planning en ontwerp en (4) geven vorm aan landschappen op meerdere schaalniveaus.

Een veelomvattender begrip kan ‘landschap’ van probleem naar oplossing doen verschuiven om eens een katalysator te worden voor de 21^{e}-eeuwse energietransitie. ‘Landschap’ zien als co-constructie van natuurlijke processen, menselijke activiteiten en diverse ervaringen vormt een veelbelovende gezamenlijke basis voor ruimtelijke planners en ontwerpers om samen met natuur- en sociale wetenschappen te streven naar een inclusieve energietransitie.

Acknowledgments

Before I get to the point where I thank those directly involved in my PhD research, I would like to take one step back. Since I was introduced to the field of landscape architecture starting my studies in Wageningen in 2005, I have been fortunate to have been inspired by a range of former professors. Professor Jusuck Koh was the first to point me to ‘energy landscapes’ during my studies, although at that time I hardly understood the concept and few scholars had published about this topic. During my master’s thesis, I had multiple conversations with the late professors Meto Vroom and Klaas Kerkstra about ‘technology’ in landscapes, a topic they both dealt with in their research. These conversations broadened my thinking that was later deepened in my collaborations with Jhon van Veelen, whom dedicated a large part of his career to both theory and practice of designing the electricity grid in the Dutch landscape.

These encounters paved the way for working with energy landscapes in collaboration with my promotor Sven Stremke, to whom I am deeply grateful for his supervision of this PhD thesis. Sven, I have benefitted a lot from your personal approach, sharp questions and the confidence you showed in me over the past years. The way that you have always encouraged me to follow my own path and passions has helped me to develop both as person and researcher. Our shared fascination for real-world energy landscapes has brought us to many places around the world, something I hope we can continue doing in the future.
Adri van den Brink was the other consistent factor over the course of my PhD research, until he unexpectedly passed away in September 2021. Although I have missed him as a person and co-promotor in the final stages of this thesis, I am grateful for his supervision, support and enthusiasm throughout my research. Adri committed to my PhD research from the start, despite that he knew large parts of his supervision would be as emeritus professor. I have truly

enjoyed his fresh perspective on my research, his wise one-liners and his eagerness to keep learning about new topics.

I want to thank the Amsterdam Academy of Architecture for the opportunity to follow my curiosity in energy landscape research. Despite the long periods of restrictions caused by the pandemic, I have enjoyed being part of the teaching, the ongoing conversation on design research and the many celebrations and festivities that have been organized. I have always felt welcome at the Academy and attribute that to the cheerful and open-minded collaboration with my colleagues. I especially want to thank Madeleine, David, Joseefke, Hanneke, Mildred, Sanne, Matty and Janna for their interest and support in my research and their help with the big and small things related to my work. Furthermore, I would like to thank the members of the advisory committee of our research group in Amsterdam, being Jannemarie de Jonge, Andy van den Dobbelsteen, Dirk Sijmons and Lennert Goemans for their constructive feedback on my work during our yearly meetings. Especially Jannemarie, you have been an example for me in many ways during my four years at Wing. I will always remember your sincere interest in me as a person and your support to pursue my academic curiosity.

I want to thank my paranymphs, Ilse Voskamp and Paolo Picchi for their support throughout the PhD research and the preparations towards and during the defense. Ilse, it was a pleasure to work with you despite that we both had our own PhD projects. Thanks for all the fruitful conversations about work and personal life, and being my ‘helpdesk’ for questions related to a PhD that you had already dealt with. Paolo, although most of our collaboration will materialize in another book, working with you has also shaped this research, not in the least your contributions to the fieldwork in chapter 4 of this thesis. I have enjoyed our travels together in the Netherlands and abroad. I hope to be able to visit you in Italy in the coming years and finally respond to your generous hospitality.

I am grateful to my colleagues in Wageningen, although my presence and contributions have been limited due to the time I spend in Amsterdam and in the home office. I want to thank Kevin, Laszlo, Merel and Sjoerd for sharing experiences, tips and jokes about doing a PhD research. Coos and Florian, I enjoyed supervising your MSc thesis and am grateful that you agreed to dedicate part of your work to the research that materialized in chapter 4. Many thanks to Annelies and Audrey for being there and helping when needed. Monique, this book would not be here like this without you, thanks for all your work and attention to detail. I am thankful for the NRGlab community, among which Igor, Rudi, Roberta and Daniela, to be able to share insights and curiosity even across national borders.

During my research I have crossed paths with many researchers, designers, policy-makers, developers, local inhabitants and others working on and concerned with the energy transition. This research has benefitted greatly from their willingness to engage with me and my research. Picking up the phone, replying to an email, being interviewed, reviewing draft versions of papers, giving me a tour in a solar landscape, it has increased the quality of this research and my personal joy in my work. I especially would like to thank Volmar and Ralph, with whom I have already shared a decade long journey of advancing the energy transition in Parkstad Limburg. Furthermore, I am grateful to all the anonymous reviewers of the individual chapters. In addition, I would like to thank professor Eveline van Leeuwen, professor Kate Sherren, professor Sören Schöbel-Rutschmann and professor Wim Sinke for their time and energy invested as members of the committee for the examination of my PhD thesis.

I would like to thank my family and friends for their support over the past years. Specifically my parents, not only for helping out with the kids in the final stages, but mainly for always being there to

listen and support my choices at the pivoting points of my life, from childhood to the present day.
Finally, I am blessed with a wonderful family of my own. Leanne, thanks for knowing me better than myself sometimes, taking care of everything when I was abroad and your encouragement to do what I like to do most. Veerle and Stan, I'm not sure if and what you will remember from this period when you grow older, but I am glad you were part of it, you have helped me to keep perspective on what's really important in life.

photo by Maarten Noorddijk

About the author

Dirk Oudes is landscape architect, researcher and associate of the NRGlab, a research laboratory on energy transition. He studied landscape architecture at Wageningen University in the Netherlands both on a bachelor and master level. Following his studies, he worked as freelance landscape architect for H+N+S landscape architects and Jhon van Veelen and participated in the post-academic professional experience programme (PEP). He started working on the topic of energy transition during a 1-year appointment as junior researcher at Wageningen University. He continued working on the energy transition and other spatial challenges with design- and consultancy firm Wing. After a four-year period at Wing, he joined the research group High-Density Energy Landscapes of Sven Stremke. This temporary research group of the Amsterdam Academy of Architecture performed academic research on the role of design in the energy transition and at the same time disseminated knowledge relevant for designing the energy transition amongst the students of landscape architecture, urban design and architecture. Dirk worked at the Academy as research fellow, taught classes and wrote his PhD thesis in affiliation with Wageningen University. As part of his PhD thesis, he supervised master students and undertook extensive fieldwork in 20+ solar parks across Europe. The results of three of his research projects have been published in peer-reviewed journals. In addition to his work as PhD researcher he collaborated, among others, with leading design offices in The Netherlands and contributed as spatial expert to the negotiations of the National Climate Agreement in 2018. He is frequently invited as speaker, jury member and expert critic, and has been advisor for the Dutch Creative Industries Fund. Furthermore, he is co-author of the book *The Power of Landscape - Novel Narratives to Engage with the Energy Transition* (nai010 publishers, 2022) - that examines energy landscapes in Europe and the US in the present, past and future. Following his doctoral research, Dirk will start working with the landscape architecture chair group at Wageningen University. He will continue his research on a landscape-inclusive energy transition while contributing to the Bachelor and Master programs of Landscape Architecture at Wageningen University.

Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment

D I P L O M A

for specialised PhD training

The Netherlands research school for the
Socio-Economic and Natural Sciences of the Environment
(SENSE) declares that

Hendrik Herman Oudes

born on 24th February 1987 in Alkmaar, The Netherlands

has successfully fulfilled all requirements of the
educational PhD programme of SENSE.

Wageningen, 30 June 2022

Chair of the SENSE board

Prof. dr. Martin Wassen

The SENSE Director

Prof. Philipp Pattberg

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

K O N I N K L I J K E N E D E R L A N D S E
A K A D E M I E V A N W E T E N S C H A P P E N

SENSE

The SENSE Research School declares that **Hendrik Herman Oudes** has successfully fulfilled all requirements of the educational PhD programme of SENSE with a work load of 31.7 EC, including the following activities:

SENSE PhD Courses

- Environmental research in context (2018)
- Grasping Sustainability (2018)
- Research in context activity: 'Organising the online Webinar "Designers in the world of Science" (2020)'

Other PhD and Advanced MSc Courses

- Qualitative Data Analysis: Procedures and Strategies, Wageningen University (2018)
- Scientific writing, Wageningen Graduate Schools (2019)

External training at a foreign research institute

- Doctoral Colloquium on Research Methods and Methodology, EuroLeague for Life Sciences Czech Republic (2018)

Management and Didactic Skills Training

- Teaching in several MSc course at the Academy of Architecture Amsterdam (2018)
- Supervising two MSc students with thesis entitled 'The bright side of solar energy' (2019) and 'Not just another solar field: A multifunctional EnergyGarden for Mastwijk (NL)' (2020)

Oral Presentations

- *Case study of frontrunner photovoltaic parks in Europe: an environmental design perspective.* Energy Research and Social Science conference, 28-31 May 2019, Tempe, United States of America

SENSE coordinator PhD education

Dr. ir. Peter Vermeulen

The research described in this thesis is financially supported by the Amsterdam Academy of Architecture, The Netherlands.

Financial support from Wageningen University for printing this thesis is gratefully acknowledged.

Cover design by Dirk Oudes
Layout by Monique Jansen and Dirk Oudes

Printed by proefschriftenprinten.nl on FSC-certified paper