URBAN AND RURAL REPORTS 2019:4

LANDSCAPE AND WIND ENERGY

A literature study

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Summary

This report presents the findings of a liturature study on landbased wind energy, commissioned by the Norwegian Environment Agency (Miljødirektoratet). The aim of the study was to gain a broad understanding of academic findings and discussions relating to the placement of wind turbines in the landscape.

The findings presented in this report are based on a semi-systematic literature review of academic publications. Publication of academic literature on the relationship between wind power and landscape has greatly increased over the past decade, from less than 20 articles a year prior to 2007 to a mean average of 55,5 in the subsequent 10 years. North America and Europe are the dominant regions of origin for publications. The spectrum of national contexts, academic establishment and disciplinary backgrounds, results in multiple perspectives on landscape, differing relations to wind energy and alternative systems of governance bringing about a diversity of issues considered pertinent for study. Studies reveal a strong and effective opposition to wind developments that is primarily rooted in landscape values. Recent decades have seen development in wind turbine with increased economic efficiency goes hand in hand with increased visibility and widespread visual change in the landscape. As a consequence, wind power development has been referred to in both Europe and the USA as a form of Energy sprawl.

Wind power is relatively free of the environmental impacts linked to conventional forms of energy, e.g. CO_2 production, radioactive waste. However, development of wind energy is widely recognised as having a significant impact on the landscape, affecting sensory experiences, perceptions and sense of place. Studies reveal that aesthetic perceptions have a strong influence on individuals' attitudes towards wind power projects, with the visual impact on valued landscapes tending to be the main focus for anti-wind farm campaigns. Noise impacts, is another commonly mentioned social impacts of wind turbines. A correlation has been identified in numerous studies between auditory and visual annoyance with contextual visual information relating to the sound source influencing individual perceptions.

Place attachment and place identity are arguably the most prominent concerns in relation to the landscape component of an appraisal. Yet research has highlighted that wind turbines can be interpreted by local communities as a means of protecting or enhancing the special characteristics of a locality. At the same time, noise and visual impacts are often assumed to lead to decreases in property values and seen as a significant negative economic impact of wind farms. Similar considerations of impact on tourism are contested, with both negative and positive effects on tourist experience being reported.

Studies rebuke the idea of NIMBYism (not in my backyard), often considered a factor in opposition to wind energy. Opposition or acceptance to the wind farms is the result of multiple factors and cannot be addressed just as a NIMBY-effect. Individuals' relationship to development in a landscape is influenced by their motivations, values, cultural background life situation, as well as their attachment to place. Public support for renewable energy has shown to be less related to environmental beliefs than to economic benefits and concerns about landscape impacts, there is however studies showing that positive opinion on wind turbine appearance reflects a transformation to a clean energy future.

In comparison between wind turbines/developments it is pointed out that wind turbines were seen as less disruptive than other industrial or infrastructure constructions, e.g. factories, telecommunication masts and electric pylons.

As concluding remark, the authors of this review emphasise that each landscape considered for development merits assessment as unique in its own terms, i.e. the terms of all who value the landscape and the development.

Keywords: Wind energy, wind turbines, on-shore, landscape, literature study..

Preface

This literature compilation/review is undertaken as an assignment from the Norwegian Environment Agency (Miljødirektoratet). This review of on-shore wind power and its effects on landscape is performed by the two researcher Andrew Butler and Antoienette Wärnbäck, both employed at the Swedish university of Agricultural Sciences, department of Rural and Urban development, division of Landscape architecture, Sweden. The assignment was undertaken during June–July, 2018 and delivered in August, 2018.

Författare

Andrew Butler, Senior Lecturer at the Division of Landscape Architecture, Department of Urban and Rural Development, Swedish University of Agricultural Sciences. He has been working with issues of developing discourses around landscape planning.

Antoienette Wärnbäck, Researcher at the Division of Landscape Architecture, Department of Urban and Rural Development, Swedish University of Agricultural Sciences. Her research has focused on the practice of impact assessment in planning.

Innehåll

1 Introduction

This report provides a brief overview of literature that investigates the landscape effects of wind power and attempts to elucidate certain aspects of this particular.

The authors are responsible for all content in the report.

In this report, the goal has been to map out the state of relevant international studies.

Reading the report

This document comprises three sections; introduction, findings and conclusions.

The introduction provides the background to the report and the methodological considerations for the study.

The core of the document is taken up by the findings, divided into nine separate chapters:

- *Overview of publications* provides a picture of the geographical distribution, general subject areas and publication frequency of studies dealing with wind energy and landscape.
- *Research persectives on landscape and wind power* provides the academic context for the studies, how landscape is framed and in which context wind energy is addressed.
- *Externalities* lifts the diverse impacts of wind energy taken up in academic studies. These deal with perceptual effects with a main focus on the visual and audible problems associated with wind energy. The effect of wind development on sense of place is also lifted and associated impact on cultural heritage. The final two sections on externalities relate to economic impact of wind turbines, firstly on the cost of housing and then on tourism.
- *Respondents characteristics* reveals the diverse factors influencing individual's relations to wind energy including socio-demographic factors and economic considerations. This section also addresses the relevance of NIMBY (Not In My Back Yard) attitudes.
- *Comparisons with other features* presents reveals how wind energy development compares to other types of development projects, in academic studies.

- *Approaches to siting studies and understanding effects of wind turbines* address the different approaches to pre and post assessment of wind turbines (both qualitative and quantitative approaches).
- *Planning process, policy and legislation* reveals how differing administrative tools impact on wind energy and landscape, including issues of conflicts.
- *Mitigation* addresses how both the landscape and the installation of turbines can limit the perceived impact of wind energy installations.
- *Conclusions* summarise the results in light of the questions framed by Miljødirektoratet.

Process

This assignment was performed as a modified systematic literature review following Thomé et al. (2016).

The steps were: (i) database selection, (ii) keywords search, (iii) review of selected abstracts, (iv) application of criteria for inclusion/exclusion of studies, (v) full-text review of selected papers, (vi) backward search and (vii) forward search in retrieved papers. Our approach differed from Thomé et al. in that we limited the intitial search to a specific time frame and used a single database in response to time and financial restricions of this commission.

The study was planned and excecuted to address questions formulated by Miljødirektoratet for this project. These were:

- What is the knowledge status of the effects on the landscape of wind power?
- What distinguishes wind power from other types of action with regards to landscape impact?
- Are there any studies of how the impact of landscaping varies between different people/groups and between different types of areas?
- Are there any landscapes or landscape elements that are affected more than others?
- What experience has been gained with regard to the impact and disturbances of wind power?
- Are Results consistent across countries /regions?

Documents were retrieved from the Scopus academic journal database. The eligibility of documents for initial consideration were based on the following criteria:

- Topic—articles containing the terms; “wind energy”, “wind farms”, “wind power” or “wind turbines” and “landscape” in the article titles, abstract or keywords.
- Study design—qualitative and quantitative empirical studies were both considered eligible.

- Language—articles in both English and Nordic languages were considered for the study.
- Publication status—Peer reviewed articles and academic books and chapters were included in the study.
- Year of publication—articles published between 2010 and 2018 were considered (the top 40 cited articles even if they were outside these dates were also included).

2 Overview of publications

An initial search in Scopus for "wind energy" or "wind farms" or "wind power" or "wind turbines" and landscape returned a total of 737 publications. Academic literature on the relationship between wind power and landscape has greatly increased over the past decade, from less than 20 articles a year prior to 2007 to a mean average of 55,5 in the subsequent 10 years (see figure 1).

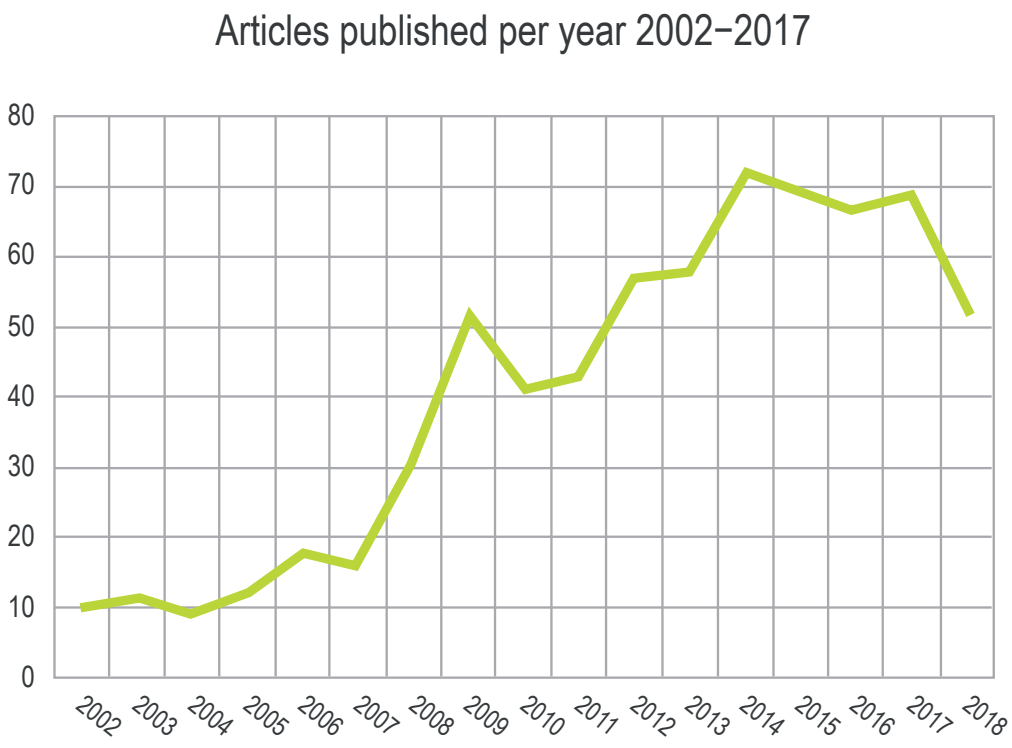

Figure 1 articles published 2002-2018 (Scopus).

The results of the search revealed output from 118 different publication sources, primarily multidisciplinary journals. Only 18 of the sources provide more than 5 publications with the vast majority of journals (75) publishing only one or two papers.

The retrieved texts have been published by researchers from 57 different countries (table 1). North America and Europe are the dominant areas for this literature. There are also a number of studies from Asia and a smattering from South America and Africa

Table 1. Top 20 nationality of authors publishing work in the initial search.

USA	135
UK	98
Germany	85
Spain	40
Italy	36
France	30
Sweden	24
China	20
Canada	19
Poland	19
Australia	18
Netherlands	18
Denmark	17
Switzerland	17
Czech Republic	16
Greece	11
Portugal	11
Japan	10
Norway	9
Austria	7

The publications found come from a broad range of subjects, yet are dominated by Environmental science (304), Energy studies (198), Social sciences (175), Engineering (146), Biological sciences (126) and Earth and planetary sciences (90). Other studies under this search include; Physics and astronomy (36), Computer sciences (34), Arts and humanities (19) Medicines (16) and Mathematics (14).

3 Research perspectives on landscape and wind power

The spectrum of national contexts, academic establishments and disciplinary backgrounds, results in multiple perspectives on landscape, differing individual and societal relations to wind energy and alternative systems of governance bringing about diverse issues considered pertinent for study.

Studies reveal a strong and effective opposition to wind developments that is primarily rooted in landscape values (Toke et al. 2008). The concept 'Landscape' acts as a boundary object, helping to bridge scientific disciplines and society, developing discussions around a single term. Yet, rather than offering a solid, objective, building block between disciplines, landscape is contested between several polarities (Jerpåsen & Larsen 2011; Leibenath & Otto 2014; Woods 2003). Landscape has been conceptualised as a physical setting, visual representation, a site of culture and polity, a lived experience or a combination of them all (Butler 2014), it is both the phenomenon and its perception (Wylie 2007). Differing understandings of the landscape are utilised even within the same national and disciplinary contexts (Antonson 2011; Sandström & Hedfors 2018; Niță et al. 2015).

Landscape as a visual entity is the dominant conceptualisation presented in the retrieved literature. Such a view focuses discussions on the visual influence of wind turbines as a distraction or improvement to the visual quality of a viewed area (Broekel & Alfken 2015; Pedersen & Larsman 2008; Pedersen & Persson Waye 2004; Wolsink 2007a, 2007b). A secondary perspective on landscape, lifted in several studies, relates to perceptions, identity and attachment to place (Leibenath & Otto 2014; Maruyama, et al. 2007; Van Veelen & Haggett 2016). In these studies, the perceived connections are recognised as being both subjective and dynamic, thus complex and difficult to truly ascertain (Leibenath & Otto 2014; Maruyama, et al. 2007; Pasqualetti 2000, 2011). Subjectivity relating to landscape is in part seen as being reliant on national and cultural context (Tokea, Breukers and Wolsink 2008).

Leibenath and Otto (2014) observed three different landscape concepts alive in German wind farm debates; 'landscape as a beautiful, valuable area'; 'landscape as an area shaped by humans'; and 'landscape as something subjectively perceived'. These different concepts create opposing political claims all with the same apparent common focus. Hence, any argument built on landscape can be countered by an alternative landscape argument. Issues related to wind turbines pits environment against

environment, the global against the local, creating 'green on green' conflicts (Warren, et al. 2005).

How landscape is recognised is constructed through discourses and procedures, defining what is valued in a landscape. Development of wind power affects both the discussion and the practices which create understanding of landscape (Nadaï & Labussière 2015). As a result, wind farms have a materiality unique to each potentially affected landscape and community, based on historical and societal factors (Batel and Devine-Wright 2014). Landscape once perceived as natural transform into landscapes of energy, bringing about conflict over the meaning (Pasqualetti 2000). Realising this helps better understand the way in which the energy transition might raise issues for landscape protection.

Renewable energy facilities by their nature tend to be decentralised, located in rural areas which have an absence of existing industries, areas often characterised by declining agricultural sector and seasonal tourism. Consequently, wind energy can be seen as providing a degree of economic security (Nadaï and van der Horst 2010).

Recent decades have seen development in wind turbine technology with a relationship between turbine height and output. Increased economic efficiency goes hand in hand with increased visibility, resulting in more widespread visual change in the landscape (Nadaï and van der Horst 2010). Climate policies aimed at cutting carbon dioxide emissions increase the areal impact of energy (McDonald, Fargione et al. 2009). As a consequence, wind farms are more wide spread compared to conventional energy (Cuevas, Tabales et al. 2016) and has been referred to in both Europe and the USA as a form of Energy sprawl (McDonald, Fargione et al. 2009; Prados 2010)

4 Externalities

This section highlights the diverse external impacts of wind energy addressed in academic studies. Externalities include ecological, visual, perceptual, heritage and economic effects of wind turbines on the landscape.

Wind power is relatively free of the environmental impacts linked to conventional forms of energy, e.g. CO_2 production, radioactive waste. However, they are not free of negative externalities. Construction of wind farms has been linked to reduced precipitation (Zhang, Meng et al. 2017) and local climate change through decreased wind speed (Dai, Bergot et al. 2015). The infrastructure associated with wind energy, including access routes, is recognised as bringing about ecosystem fragmentation and habitat loss (Jones, Pejchar et al. 2015; Zhang, Meng et al. 2017). Wind farm constructions have been identified as affecting reindeer migration corridors (Skarin, Nellemann et al. 2015); as being detrimental to raptor populations (Péron et al. 2017; Sur, Belthoff et al. 2018), migratory birds (Kirby et al. 2008) and bat colonies (Minderman et al. 2017). Other externalities include deforestation and erosion (during construction) and interference with radio waves and weather radars (Dai, Bergot et al. 2015). Development of wind energy is also widely recognised as having a significant impact on the landscape, affecting sensory experiences, perceptions and sense of place. This chapter deals with the visual and audible effects, the perceptual impact on sense of place, the impact on cultural heritage and the economic side effects of wind energy.

Visual

It is recognised in numerous studies that aesthetic perceptions, have the strongest influence on individuals' attitudes towards wind power projects (Broekel and Alfken 2015; Möller's 2010; Warren et al. 2005). These attitudes are however not solely negative, as shown in Warren and McFadyen's (2010) study in Scotland. In their study the visual impact of turbines was viewed by the community as a positive addition to the landscape. However, the visual impact on valued landscapes has tended to be the main focus for anti-wind farm campaigns (Wüstenhagen, Wolsink et al. 2007, Wolsink and Breukers 2010).

Palmer (2015) points out that while the magnitude of scenic impacts may be extensive and sometimes unreasonable, users of these scenic resources have indicated

that while there may be a noticeable negative effect on their enjoyment, it is modest and has almost no anticipated effect on their continued use of affected areas.
As a landscape issue, concerns increase as turbines become taller. In a study in Northern Jutland, Möller (2010) reported that installation of very large wind turbines led to a higher visibility on a regional level, while the removal of many small turbines, which they replaced, did not impacted the visual quality to a measurable extent (Möller 2010).

Distance from turbines also plays a significant role. Numerous studies have revealed that turbine heights are more likely to be accepted if they are sited far from residential areas and sites of aesthetic interest (Bishop 2002; Meyerhoff et al. 2010; Molnarova et al. 2012).

The movement of turbines adds to visual impact, the shadow flickering from moving blades affecting the immediate vicinity (Rudolph et al. 2017). Additionally, the perceived size of turbines, when rotating, is 10–20% greater than a static object (Bishop and Miller 2007). However, when turbines are in operation the public perception them in a more positive manner than when stationary, as working turbines produce energy, while when stationary turbines are seen as intrusions with no evident purpose (Bishop and Miller 2007).

An additional visual detractor is aviation obstruction lights installed on wind turbines (Rudolph et al. 2017; Gustafsson and Möller 2013). This is most evident for xenon lights which compared to LED or colour markings on blades, caused increased stress to local residents and negatively affected the acceptance of wind turbines.

Noise

Noise impact, is another commonly mentioned social factor in wind turbine placement (Saidur et al. 2011, Tabassum et al. 2014). Sound from wind turbines is twofold; mechanical and aerodynamic (Leung and Yang 2012). It is the aerodynamic aspect, producing noise of low frequency sound levels rather than absolute volume, which is the most dominant issue (Leung and Yang 2012).

Noise involves both social and technical components; the level of sound and how individuals perceive the sound and its source. The measurement of sound does not necessarily clarify perceptions of noise, as such measurements primarily address sound characteristics and quality (Thorne 2011). Although measurements can record, exposure to certain sound levels, this does not directly correlate with the level of nuisance. Consequently, objective impacts are difficult to measure, being experienced differently by different individuals (Haggett 2012). Studying an extensive rural area in Germany, Yu et al. (2017) concluded that the perceived annoyance is associated with people's attitudes toward wind farms, rather than actual sound produced.

A correlation has been identified in numerous studies between aural and visual annoyance (Klæboe and Sundfør 2016; Maffei et al. 2013; Pedersen and Larsman 2008; Pedersen et al. 2009; Yu et al. 2017). Specific contextual visual information relating to the sound source influences individual perceptions (Maffei et al. 2013). Song et al. (2016),

revealed that higher annoyance was registered even if larger turbines produced the same noise level, this related to the visibility of wind turbines, background noise levels in wind farm area, etc. A study by Maffei et al. (2013) revealed that when the colour was close to red or white, the noise was perceived as significantly louder and noisier; while when the colour was close to green or blue, noise was perceived significantly softer and quieter. These results further confirm the interconnectedness between the auditory and visual components and that the presence of specific contextual visual information associated with sound source influences individual perceptions in a broad way (Maffei et al. 2013).

Numerous studies have attempted to evaluate sound nuisance and associated health effects (Janssen, Vos et al. 2011; Van Renterghem, Bockstael et al. 2013). Results have correlated sound levels with self-reported health effects; sleep disturbance and psychological distress, (Bakker et al. 2012; Song, Di et al. 2016), however other studies have disputed these effects (Knopper and Ollson 2011). Instead of ultimately debating whether health effects are directly linked to the exposure to turbine sound or not, it has been argued to be more fruitful to take a precautionary approach and thoroughly address the issues that create stress and frustration related to sound annoyance in the first place (Walker et al. 2014).

Perceptual qualities and sense of place

Place attachment and place identity are arguably the most prominent concerns in relation to the landscape component of an appraisal. Place attachment occurs when an individual develops positive emotional connection to a location, while place identity relates to how the physical and symbolic attributes of a place co-construct an individual's sense of self (Devine-Wright 2005). Local communities may interpret the impacts of wind turbines in a significantly different way to 'outsiders' and will attempt to protect the attributes that make a locality important to them. Place attachment is frequently correlated with the amount of time an individual has spent in a particular place, as emotional and affective links are said to be cultivated over time (Van Veelen and Haggett 2016). Newcomers to an area may not have developed these links and, in consequence, may be less place-protective. Nevertheless, newcomers might also seek to protect the characteristic that attracted them to a particular area in the first place (Roopali 2011). The relationship between an individual and place is clearly multifunctional (Cashmore, Rudolph et al. 2018).

Wind turbines can be interpreted by local communities as a means of protecting or enhancing the special characteristics of a locality. Drawing on research conducted in Scotland, Van Veelen and Haggett (2016) reveal that wind farms were seen to positively contribute to place identity. The installation of wind turbines can support existing community structures (Kirchhoff, Kebir et al. 2016); protecting a locality from 'outside' interventions by commercial interests. Research conducted in the USA showed that wind turbines were sometimes viewed favourably as they were interpreted

as restricting suburban sprawl (Mulvaney, Woodson et al. 2013). In Japan, considerable value is placed by private individuals on self-identifying as an investor in wind energy, and new social networks and economic activities have developed around some wind farms (Maruyama, Nishikido et al. 2007). The focus on the importance of place attachments and place identity emerged in wind farm scholarship partly in response to critiques that portray local opposition as scientifically irrational and based on self-interests, notably through the application of the label NIMBY (Not in My Back Yard) (Cashmore, Rudolph et al. 2018).

Cultural heritage

Jerpåsen and Larsen (2011) recognise that distance and visibility do not necessarily capture the main conflicts connected with wind turbines. An important delineation is highlighted between impact on landscape aesthetics and impact on cultural heritage (Masser 2006). If turbines do not disrupt the intelligibility of heritage sites and setting, then the issue will be largely aesthetic (Masser 2006). Work within cultural heritage has increasingly moved from focusing on the site to considering the setting, drawing on the surroundings in which a place is experienced (English Heritage 2008; UNESCO 2005). Preserving the setting of cultural heritage sites is not just important for the experience but also for knowledge understanding and meaning (Jerpåsen and Larsen 2011).

As Jerpåsen and Larsen (2011), reveal from a Norwegian perspective there are multiple settings relating to diverse local storylines, experiences and relationships to the landscape. Cultural heritage sites as places of remembrance and for aesthetic perceptions are based on the general public's perceptions of those sites. To understand the relevance of cultural sites and landscape values requires a variety of actors (experts, the general public and interest groups) with differing political views (Jerpåsen and Larsen 2011).

As revealed in a study in England, wind farms can ultimately form part of the cultural heritage of an area as through familiarity they may become a valued part of the landscape (Wheeler 2017).

Impact of property values

Noise and visual impacts are often assumed to lead to a decrease in property values, which is considered a significant negative economic impact of wind farms. However, in a study in Denmark, both on-shore and off-shore wind farms showed minimal impacted on the value of residential housing in a 3 km radius; at 1 km prices reduced by 3–6% when at least two turbines are present. The impact increases marginally with the number of turbines. These findings are enforced by Sunak & Madlener's (2016) German study, where properties with a minor view of the wind turbines experienced

no devaluation (Sunak and Madlener 2016). Scholars examining the linkages between distance, visibility and noise e.g. in Ontario (Vyn and McCullough 2014) and in the UK (Gibbons 2015) have provided no evidence for the assumption of loss of property value (Firestone, Bates et al. 2015).

Impact on tourism

The potential socio-economic effects of wind turbines are also reflected in concerns about their impacts on tourism. Yet the actual impact of wind farms on tourism remains contested, with both negative and positive effects on tourist experience being reported (de Sousa and Kastenholz 2015), yet there is limited evidence of a negative link between wind farms and tourism.

In a study of tourists' perceptions of wind turbines in the Czech Republic, most tourists perceive wind turbines neutrally or positively; they did not affect decisions to visit a place (Frantál and Kunc 2011). Similar findings have been recorded in Iceland, where tourists were more positive to wind turbines than locals (Frantál, Bevk et al. 2017). Yet in an earlier study from Sweden by Devlin (2005) visitors favoured landscapes unaffected by modern change. Visitors dislike many wind turbines close to the viewpoint (Arnberger, Eder et al. 2018). In Cornwall in the UK for some people wind turbines were off-putting while for other they acted as an attraction (Eltham, Harrison et al. 2008). It has even been suggested that wind farms were a potential object of energy tourism (Frantál and Kunc 2011; Liu, Upchurch et al. 2016).

5 Respondents characters

This section draws on the diverse factors influencing individual's relations to wind energy as expressed in academic literature.

As landscape is a relation between humans and their surroundings, the individual and community who perceives the surrounding is central for understanding the impact of intervention in the landscape (Council of Europe 2000).

Opposition to wind power development has often been referred to as NIMBYism (NIMBY: not in my back yard), however local issues and the aspects which create controversy differ between communities (Rygg 2012). Opposition or acceptance to wind farms is the result of multiple factors (Klæboe and Sundfør 2016; Wilson and Dyke 2016). Even individuals who support wind power recognise its detrimental impact on the landscape scene (Molnarova et al. 2012).

How individuals relate to a landscape is influenced by their motivations, values, cultural background, life situation, and their attachment to place (Frantál et al. 2017). It has been observed in studies in the Icelandic highlands (Frantál et al. 2017), rural Central Europe (Frantál and Kunc 2011) and the North Sea coast (Gee 2010) that certain individuals perceive wind turbines negatively, while others, in the same context, view them in a positive light. Acceptance of proposed development is dependent on how a community views itself and the surrounding landscape. Not every community identifies with local wind power and public opinions reflect socially and culturally constructed aspects of the wind turbine (Firestone, Bates et al. 2015)

The frequency with which individuals see wind turbines relates to their level of support for renewable energy; greater exposure to wind turbines brings greater acceptance (Mariel, Meyerhoff et al. 2015; Molnarova, Sklenicka et al. 2012; Olson-Hazboun et al. 2016). Young people and men with low income also possess a stronger pro-wind power attitude (Mariel, Meyerhoff et al. 2015). Yet, males tend to be more sensitive to landscape changes (Molnarova, Sklenicka et al. 2012). This last point relates to the frequently documented masculine aesthetic appreciation as dominating viewer of the landscape (Strumse 1996).

In a study in Midwest USA, the factors which influenced resident's acceptance or rejection related to the concrete benefits to the community, such as reduced energy bills (Mulvaney, Woodson et al. 2013). Strong local concerns regarding the economy, modernisation, and employment opportunities rather than support for sustainable energy are seen as influencing acceptance of wind energy (Rygg 2012). Perceived positive cost-benefit acts as a strong predictor for a reported acceptance of wind

turbines (Zoellner et al. 2008). Consequently, public support for renewable energy is less related to environmental beliefs than to economic benefits and concerns about landscape impacts (Olson-Hazboun, Krannich et al. 2016). Similar findings were linked to positive psychological effect and acceptance of wind turbines in Scotland in relation to community ownership (Warren and McFadyen 2010). Local ownership may counteract some of the objections to wind power schemes raised on landscape grounds (Breukers and Wolsink 2008; Tokea, Breukers and Wolsink 2008; Warren and McFadyen 2010) or the development in general (Toke 2005). Allowing people to benefit economically has also shown to significantly decrease risk of noise annoyance (Pedersen, van den Berg, Bakke and Bouma 2009).

It has been shown in a study in Northern Jutland, Denmark, where acceptance of turbines has to a large degree been built on community financial opportunities that this becomes less likely as new technologies require larger investments and hence opposition to new wind energy has increased (Möller 2006; Möller 2010).

Respondents' general attitudes towards sustainable energy have been identified as a significant factor influencing evaluation of wind farm development (Molnarova et al. 2012). However, community opinion of wind energy has been shown to change considerably over time (Wilson and Dyke 2016).

In a study in Sweden Johansson and Laike (2007) found opposition to wind power related to only a few perceptual and attitudinal factors; perceived unity of the environment; individual's attitude towards the impact on landscape aesthetics and recreation, and general attitude towards wind power; of minor importance was the effects of wind turbines on individual's everyday life (Johansson and Laike 2007).

The anticipated visibility of wind energy development and the concern that such development will despoil the landscape, affect the degree of endorsement received for particular sites (Jones and Eiser 2010). Yet, positive opinion on wind turbine appearance reflects a transformation to a clean energy future, while negative opinion reflects that the turbine does not fit the landscape (Firestone, Bates et al. 2015). Wind turbines can have higher symbolic associations, related to global climate change or as Pasqualetti (2000) points out: a symbolic reconnection to energy use. However we observed an absence of longitudinal studies on this topic.

6 Comparison with other landscape features

In this section we present academic findings of how wind energy development compares to other types of development projects.

Frantál and Kunc's (2011) study from the Czech Republic revealed that wind turbines were perceived as less disruptive than other industrial or infrastructure constructions, e.g. factories, telecommunication masts and electric pylons. This study was supported in a study in the UK, were images of wind turbines were considered to be as pleasant yet less calming than traditional structures such as churches, and more pleasant than other energy-production facilities for example electricity pylons (Maehr et al. 2015). In a study using Electroencephalographic techniques on individuals, Grima Murcia et al. (2017) recorded no significant differences for landscapes with wind turbines or without them.

7 Approaches for siting studies and understanding effect of wind turbines

The studies dealing with impact of wind turbines on the landscape cover both subjective and objective studies, ranging from laboratory studies to on site engagement with the landscape.

Numerous studies utilise multi-criteria methods for siting wind turbines (Torres et al. 2007; Chen, et al. 2017). While primarily aim at optimising efficiency and maximising productivity, they also use objective indicators to assess the size of the visual impact of wind turbines in the landscape, for example visibility, colour, fractality and continuity which can be traced from photographs (Tsoutsos et al. 2009). Optimal turbine location is characterised by maximum distance to protected areas, maximum distance to settlements and highest possible energy production (Eichhorn et al. 2017; Höfer, Sunak et al. 2016; Mardani, Zavadskas et al. 2017).

Multi-criteria approaches are dependent on Geographical Information Systems (GIS) for assessing landscape issues in wind farm development. These studies often deal with the visual impact of wind farms, focusing on inter-visibility (Minelli, et al. 2014) in order to predict and evaluate the view from different observation points (Molina-Ruiz et al. 2011; Shang and Bishop 2000). Using computer simulated images with modified optical properties, such as size, contrast, objects' type and landscape form (Shang and Bishop 2000). These quantified visual impact indicators can then be utilised to determine whether the installation is visible from suggested observation points (Rodrigues et al. 2010).

The use of digital photographs provides an upper limit for visibility of an object (Gustafsson and Möller 2013; Bishop 2002). This brings in the issues of what conditions should be used as the benchmarks. It is recommended that images should not represent best or worst atmospheric and light conditions (Bishop 2002) in order to attain a true reflection of the impact.

GIS data on wind turbines has also been combined with information from sales transactions to assess the impact post installation (Sims et al. 2008; McCarthy and Balli 2014), and supported choice experiments and willingness-to pay approaches, for assessing individual responses to planned wind farm projects (Ek and Persson 2014;

Knapp and Ladenburg 2015; Ladenburg and Dubgaard 2007, Ladenburg and Lutzeyer 2012; Meyerhoff et al. 2010).

A further technological advancement has been 3D analysis of proposed wind turbines. An example of this is the Spanish evaluation method (Hurtado et al. 2004), predicting the visual impact of wind turbines prior to construction through a 3D analysis of the turbines and the surrounding area, in order to record simulated images from strategic points. 3D studies can provide static or dynamic simulations. Static simulations include images or models that show a proposed project, viewed by a static observer; while dynamic simulations, e.g. animation or video, reveal how a proposed project appears to a moving observer (Baban and Parry 2000; Molina-Ruiz et al. 2011). Virtual reality provides a means for presenting the visual impact and provide an imagine of future landscape for the stakeholders (Lizcano, Manchado et al. 2017) and can addressing both visual and acoustical aspects (Maffei, Lachini et al. 2013). Early engagement with 3D visualisation and participatory approaches are seen as effective means to identify potential conflicts at an early stage of the planning process (Lange and Hehl-Lange 2005).

However, visualisation cannot provide indication of how actors' value a landscapes, nor how values may be altered by the siting of wind turbines (Phadke 2010). How people relate themselves to material objects, i.e. landscape cannot be measured through traditional objective approaches e.g. GIS or landscape metrics. Landscape values are determined by cultural, natural and socio-economic factors, making it difficult to generalise quantitative findings to other locations (Álvarez-Farizo and Hanley 2002). In order to develop a general indicator of aesthetic impact of wind farms, there is need to incorporate aspects of the subjective aesthetic impact (Sibille et al. 2009).

Most studies have explored attitudes towards wind farms and the various debates surrounding them, yet have focused on responses to proposed sites, as opposed to actual impacts of windfarms on local residents (Wheeler 2017). The objectification of visual impacts does not necessarily reflect human perceptions and values, as the latter encompass more affective attachments and less neutral features than the spatial relationship between an object and its reified surroundings suggest (Kokologos et al. 2014; Wróżyński et al. 2016). Through the VESPA approach community concerns to wind turbine development are dealt with through four categories—visual/landscape and noise factors, environmental, socioeconomic, and procedural aspects (Petrova 2016).

Visits to the actual landscape have been used to assess the actual impact after installation. Engaging directly with the landscape involves all sensory organs and is seen as revealing more information than 'laboratory' methods and static photographs (Frantál, Bevk et al. 2017). Approaches such as Intercept surveys capture people's perceptions when they are engaged directly with the landscape, providing contextual validity (Palmer 2015). With the immersive path method respondents walk through the area in question and respond directly on questions relating to their experience and perceptions (Jallouli and Moreau 2009).

Conversely, numerous studies of perceptions to wind turbines have been made in laboratories, under the assumption that all variables can be controlled. These

have included laboratory based simulation (visual and aural) experiences to enable consistency of variables between different cases (Ribe, Manyoky et al. 2018); measuring skin conductance response from landscape image elicitation (Maehr, Watts et al. 2015); and electroencephalographic techniques for studying perceived visual impact of wind turbine (Grima Murcia et al. 2017).

However, assumptions are made on the rationale that assessments reflect accepted truths and that there is common acceptance for wind turbines (Batel and Devine-Wright 2014). However, there is a need to question the inherent bias of the process; who commissioned assessment, how knowledgeable and engaging were involved, how do media and campaigns shape views and how reflective are views of public opinion (McGowan and Sauter 2005; Aitken 2010), assumptions that will frame all discussion on wind energy (Aitken 2010). Additionally, researchers warn against generalising from small samples in specific contexts (Maehr, Watts et al. 2015).

8 Planning processes, policy and legislation

Planning process, policy and legislation reveals how differing administrative tools impact on wind energy and landscape, including issues of conflicts.

Both U.S. and European examples of local opposition to wind energy development show that community acceptability of wind farms depends on procedural legitimacy in siting decisions as well as the perceived aesthetic fit between wind farms and the local landscape (Bohn and Lant 2009). Siting of wind farms need to mediate between both energy policy and landscape policy (Nadaï and Labussière 2013) as wind farm development brings landscape management and energy policy in to conflict (Nadaï and Labussière 2010). This requires consideration of scale and specifics of site (Nadaï and Labussière 2014). Both social and institutional innovation are needed if conflicts between energy production and landscape are to be resolved (Labussière and Nadaï 2015).

Pasqualetti (2011) found five common threads in the opposition to wind farms; immobility (the site specificity of the landscape as a resource), immutability (an expectation of landscape permanence), solidarity (the close relationship between people and the land), imposition (a sense of marginalisation), and place identity (a loss of security). There is substantial evidence of the benefits to be gained from early, sustained engagement of local communities in wind farm siting. It is seen as providing better chances of success, gains trust, helps identify and address concerns, and can communicate the developments potential risks and benefits (Jones and Eiser 2010). Consequently, deliberative planning strategies can help combat local opposition grounded in concerns over landscape damage (Jones and Eiser 2010). This requires developers to engage in local politics and include local residents who will be exposed to proposed schemes (Toke 2005) as well as a shift towards community-focused development strategies (Jones and Eiser 2010). It has been observed that transparency, early and accurate information as well as possibilities to participate during the planning and installation process, leads to increased public acceptance of turbines (Zoellner et al. 2008). Van der Horst and Vermeylen (2012) point out the need to analyse formal powers values of different stakeholders and the mechanisms of power which (re)enforce them; recognising the politics which reside in issues of landscape and wind power (Nadaï and Labussière 2017).

Local wind turbine ownership tends to coincide with a higher rates of wind power acceptance than corporate ownership (Warren and Birnie 2009). The benefits of

local ownership supports calls for systems of financial support for community wind development (Toke et al. 2008), Providing financial incentives e.g. selling shares in the schemes to local people (Toke 2005). Yet even with community support, at times the local governments negatively impact wind farm development within their jurisdictions (Mulvaney, Woodson et al. 2013).

Overall, results suggest that ceasing to frame renewable energy as an environmental issue and instead framing it in a way that invokes locally relevant, social values may promote broader public support (Olson-Hazboun et al. 2016). In a discussion which builds on both the 'Global' and 'local', it is difficult to argue that one term is inherently more legitimate than the other; a conflict between local conservation and global climate (Leibenath and Otto 2014) or 'Green on green' issues (Warren et al. 2005). Local places are never unanimous in their values, instead they are almost always cauldrons of conflict, competing aspirations, and vastly different degrees of political and economic power (Oles and Hammarlund 2011). Firestone, et al. (2018) working in the USA recognise that a community being able to influence the outcome, and having a say in the planning process are all statistically significant predictors of a process perceived as being 'fair'—a more positive attitude.

Drawing boundaries around acceptable locations for large-scale wind energy development, making them formally demarcated and measurable, may restrict the scope for future reflexivity in energy policy (Cowell 2010). Wolsink (2007) suggests that institutional changes that create involvement and trust of actors, before localisation of wind turbines is defined, are needed.

9 Mitigation

In this section we address how both the landscape and the installation of turbines can limit the perceived impact of wind energy installations.

The literature assessed recognises the relevance of landscape with high aesthetic quality and that special landscapes should be avoided during development of wind power projects (Bishop 2002; Wolsink 2007; Meyerhoff, Ohl et al. 2010; Frantál and Kunc 2011). However, the question of what an aesthetic landscape is, and to whom, it is aesthetic, is seldom broached, beyond reliance on official designations e.g. national parks, regional parks etc. Leibenath and Otto (2014) see that landscape types, which are used as justification for placement of turbines, tend to be considered as uncontested categories. As the concept of 'landscape' is employed by both supporters and opponents of development, so several landscapes can exist at the same place.

However, the type of landscape in which the turbine is sited continues to be a significant factor in visual landscape evaluations (Van de Wardt and Staats 1988). It is considered that the type of landscape is more important than other visual and scenic factors such as the design of wind turbines and the number and the size of turbines (Wolsink 2007). As landscape types is key for acceptance of localisation, a strategy is often to place wind turbines in landscape types that communities do not consider of high value (Tokea, Breukers and Wolsink 2008). A study by Molnarova et al. (2012) concluded that respondents were sensitive to the placement of wind turbines in landscapes of 'high aesthetic quality' and had higher levels of acceptance of these same structures in landscapes deemed 'unattractive'. Consequently, development should not intrude on favoured landscapes (Pasqualetti 2000). If development is anticipated to be 'out of sight' it will likely be considered in largely general terms, and hence be deemed relatively acceptable (Jones and Eiser 2010).

Shorter vegetation is considered preferable for placement of turbines; thus agricultural, barren, grass and scrub land. While forest is considered less suitable (Höfer, Sunak et al. 2016). A study by Diffendorfer and Compton (2014) supported this, their study took into account the impact of fragmentation by access roads and new ancillary structures etc.

There is an assumption that social acceptance will increase with increased distance from urban areas and places of interest (Höfer, Sunak et al. 2016). The number of installations and distance from viewers has been taken up by numerous researchers (Betakova et al. 2015; Molnarova et al. 2012; Möller 2010) and already in the late 1980's Thayer and Freeman (1987) lifted the preference for fewer, larger turbines in a given

land area rather than more, smaller ones. Molnarova et al. (2012) reported that wind turbines are easier for the public to accept when there are a limited number of turbines in the landscape, and acceptance is greater if the development is removed from observer's view (settlements, transportation infrastructure and viewpoints etc.) (Molnarova et al. 2012). Betakova et al. (2015) concluded that the number of wind turbines should be no more than 1–25 and the distance from the observer at key sites should be at least 0,75–15 km, impact disappeared at 5–10 km with respect to landscape's aesthetic quality. However smaller groups of wind turbines present economic disadvantages (Möller 2010). It is also recognised that both from a visual and auditory perspective people's acceptance increase with increased distance for wind turbines (Bishop 2002; Molnarova, Sklenicka et al. 2012). Results from Wolsink (2007a) show that in general, clustering in farms is better appreciated than many scattered solitary turbines and that very large farms are less popular than smaller ones.

Thayer and Freeman's (1987) study identified that neutral colour scheme and orderly, uniform arrays of wind turbines developed higher level of acceptance. In Maffei et al. (2013) study, wind turbines with colours closer green or blue, were perceived as softer and quieter than white or red toned turbines.

In a study of impact from aircraft navigation lights on wind turbines it was noted that LED or colour markings on blades created less stress and higher acceptance of wind energy in the observer than Xenon lighting. Their study also suggested that navigation lights should be synchronised, and light intensity adjustments applied for each situation (Pohl et al. 2012).

While the recommended minimum safe distance to turbines varies with different studies 300 (Petit 1994) and 500 (Simao 2009), acceptance of wind turbines increases with distance (Molnarova, Sklenicka et al. 2012). Social acceptance increases with increased distance from urban areas and places of interest (Höfer et al. 2016). The negative impact on residential well-being after the construction of wind turbines is also characterised by temporal "decay" (Wen et al. 2018) after a period of five years the perceived impact of construction decreases (Krekel and Zerrahn 2017).

However, guidelines and regulations for reducing visual impact and sound levels are not sufficient to predict and to mitigate annoyance problems, they also need to address social interpretation of the annoyance (Haggett 2012; Cashmore, Rudolph et al. 2018).

10 Conclusions

In conclusion we return to the questions which framed this study.

What is the knowledge status of the effects on the landscape of wind power?

Literature and thus knowledge of wind power and landscape has increased dramatically over the past decade. Earlier studies took a more generic stance on the visual contribution of wind turbines on the landscape. Recently the perceptions and values of individuals and communities has come to the forefront. Numerous studies deal with specifics of siting wind turbines, for example the relevance of the colour of turbines or the visual impact of aircraft warning lights. Hence, studies show increasing engagement with the multisensory dimension of wind power.

What distinguishes wind power from other types of action with regards to landscape impact?

Wind turbines are perceived more favourably than other infrastructure elements in the landscape, including those associated with industry. This is especially true when the turbines are operational and in motion.

Are there any studies of how the impact of landscaping varies between different people/groups and between different types of areas?

The studies reported in this report show that there are differences between how individuals perceive wind turbines in the landscape. However, the main factors which seem to dominate the acceptance of wind turbines are whether a communities see green energy in a positive light and if the community will benefit financially or socially (e.g. maintaining rural cohesion).

Are there any landscapes or landscape elements that are affected more than others?

It is recognised in many of the studies that special/valued landscapes should be avoided, however the idea of special landscape is dependent on the national and social context. As a specific measure, studies recognise that open landscapes are more conducive to facilitate wind energy than forested or small scale agricultural landscapes.

What experience has been gained with regard to the impact and disturbances of wind power?

As wind energy has developed turbines have increased in height and wind farm increased in size, creating greater visual impact on the landscape. Yet the literature points to disturbance to the landscape being based on how individuals perceive and value both the landscape and wind energy. As summed up by Mason and Milbourne (2014), each landscape, considered for development merits assessment as unique in its own terms, i.e. the terms of all who value the landscape and the development.

Are results consistent across countries /regions?

The acceptance of wind turbines based on whether they are seen as beneficial, either environmentally or financially appear a commonality, irrespective of national context. The diversity of opinions and values expressed in the different literature is more reliant on individuals than social context. However, a significant difference across the reviewed literature is the policy context; how both landscape and wind energy are recognised in policy.

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