CZECH UNIVERSITY OF LIFE SCIENCES

Faculty of Environmental Sciences
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VISUAL PREFERENCES FOR WIND TURBINES

DISSERTATION

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STATEMENT

PROHLÁŠENÍ

I declare that this dissertation has been created independently and all external references are mentioned in the work.

Prohlašuji, že jsem disertační práci vypracovala samostatně a že jsem uvedla všechny literární prameny, ze kterých jsem čerpala.

Vendula Běťáková

V Praze dne ……………… …………………………………………..

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DEDICATION
VĚNOVÁNÍ

To my parents

CONTENT

1. INTRODUCTION

Wind energy has become one of the leading type from renewable energy sources (RES), thus the acceptance of wind turbines (WTs) by public is crucial. We can look at the case of Eiffel Tower. Its acceptance is quite well-known story, which is sometimes compared to the acceptance of wind turbines (Gipe, 1993), predominantly because of the industrial appearance of steel structure. Although Eifel Tower was at the beginning greatly opposed by the most Paris citizens and popular artists, it has become later an inherent symbol of the city. Nevertheless, the Eiffel Tower is one unique structure and the story of wind turbines is entirely reverse. Surprisingly, public was in favour with wind parks in 1990s (Krohn & Damborg, 1999), though the situation has changed with greater development. With more and more WTs installations, the public opposition has increased rapidly (Kaldellis & Zafirakis, 2011).

The wind parks are slowly becoming the part of our environment. For someone they present an icon of clean renewable energy, whereas they can be perceived as complete disruption of landscape scale by someone else. European Union has set up targets to be able to produce 50% of energy from renewable sources by the end of 2050 (e.g. Verbruggen & Lauber, 2009). This means even much greater development of renewable sources, in particular wind farms, that countries would be able to achieve these targets. However, the situation nowadays is quite unclear. WTs projects are being delayed or cancelled due to the strong public opposition. There are several reasons for such attitudes, e.g. noise annoyance, danger to flying animals, visual impact, light flickers and other environmental impacts. However, visual impact has the dominant role for the rejection.

Whereas many studies allude the respondent characteristics as appropriate variables having influence on WTs perception (e.g. Ek, 2005; Johansson & Laike, 2007; Meyerhoff et al., 2010), only few studies mention the characteristics of WTs (i.e. height, number) and spatial relations (i.e. distance from the observer or vantage point, landscape type). To focus more on respondents characteristics in research might be explained by the effort to find out the differences in perception according to socio-demographic variables (i.e. age, gender, education, income etc.). While the characteristics of landscape and WTs have not been so evaluated so far. It implies hypothesis that the perception depended more on people than the environment where the WTs should have been placed. As some research shows, the landscape, in particular landscape aesthetics, is also one of the main key factors determining the perception of WTs (Groth & Vogt, 2014b; Lothian, 2008; Molnarova et al., 2012).

Although some studies have analysed the variable characteristics in accordance with visual impact of wind turbines, just very few have made analysis on interaction between these factors. For the moment, the roles of distance from the observer, landscape aesthetics and number of wind turbines, and their interaction are not that clear so far. Besides, there is still a lack of knowledge of some respondent characteristics, e.g. educational orientation, on perception of WTs. Even thought the specific appearance of WTs is well known as the cause of visual impact, there are not studies discussing the alternatives and possibilities of 'different look' of these devices.

This work is focused though on bringing all aspects together, the analysis of these aspects and relations between them.

The abbreviations used in this dissertation:

CULS – Czech University of Life Sciences
EU – European Union
GIS – Geographic information system(s)
HAWT – horizontal axis wind turbine
MW – megawatt
NIABY – Not In Any Backyard
NIMBY – Not In My Backyard
RES – renewable energy sources
UK – United Kingdom
US – United States
VAWT – vertical axis wind turbine
WT – wind turbine
WTs – wind turbines

2. GOALS OF DISSERTATION

The goal of this dissertation is to analyse relevant visual and socio-demographic factors, which have impact on perception of wind turbines in the landscape and associated public acceptance. The main objectives are to examine visual preferences for wind turbines, in particular:

A. To analyse visual preferences for wind turbines from perspective of "physical attributes" of wind turbines (WTs) in terms of:

- Distance from observer:
  - a. to establish whether and how the impact of increasing distance on visual preferences of landscapes changes
  - b. to determine distance thresholds after which the negative visual impact of WTs disappears
- Number of WTs:
  - c. to find out how increasing numbers of WTs influence the visual preferences of landscapes
  - d. to establish if the cumulative effect could be affirmed from the perspective of visual preferences, which could abruptly decrease the visual preferences beyond a certain number of WTs
  - e. to analyse the effect of interaction between number and distance of WTs on visual preferences of aesthetically varying landscapes

B. To analyse visual preferences for WTs from the perspective of socio-demographic characteristics of respondents

- a. to analyse perception of landscapes with and without WTs based on educational orientation
- b. to determine the influence among respondents of their general attitudes towards wind energy, closeness of their homes to WTs, and levels of willingness to live near WTs

C. To propose new architectural vision and methods for visual appearance of wind turbines with funnel based technology

3. REVIEW OF LITERATURE

The goal of this review is to sum up the most relative information specific to the visual impact of wind turbines and its assessment, such that it could serve as a background for the dissertation.

The review covers wide spectrum of problematic issues associated with wind turbines in landscapes, whereas visual impact assessment is indeed a comprehensive practical and theoretical method. In a effort to put all the information in right and logical order, this review goes from historical development (technical parameters and changes during the time) with the focus on a specific location in the Czech Republic, to visual assessment methods which are crucial for this issue. It is closely connected to the decision-making processes, policy system, and NIMBY syndrome. The number of turbines and their relative distance from observer or vantage point are separate topics, which need to be discussed. Besides, other attributes such as noise annoyance, light flickers, danger to birds, are briefly described. In conclusion, the review focuses on visual character of wind turbines structures, showing the current development of some WTs types, and brings up the question about future WTs appearance.

3.1 Wind Energy Historical Development

The power of the wind has been utilised for over 3000 years but it was used just to provide mechanical power until early twentieth. The first windmills, the vertical axis mills, were used in Afghan highlands to grind grain in the 7th century BC and first details about horizontal windmills can be found in historical documents of Persia, Tibet and China at about 1000 AD. They spread to the Europe during 12th century. In Europe, the windmill performance was improved between twelfth and nineteenth century and by the end of nineteenth century, the typical European windmill had a rotor of 25 meters in diameter and could reach the height of 30 meters. They were used for grinding grain and also for pumping the water to drain lakes and marshes (Ackermann, 2005; Burton et al., 2001; Tong, 2010).

Actually, the first wind turbine was constructed in 1891 for the electricity generation by Dane Poul LaCour. During World Wars 1 and 2 the Danish engineers who developed in 1941 the first turbine using modern airfoils, based on advancing knowledge of aerodynamics at this time, improved the technology. At the same time, the American Palmen Putman built the giant turbine with diameter 53 meters, which was unique not just for its size but also the capacity of 1250 kW. However, this device was not that successful because it was dismantled in 1945. After World War 2 the research was concentrated in Denmark and Germany. The main development started in early 1970s (connection to the oil crisis) and the performance has been improved all the time (Manwell et al., 2009). Countries such Germany, the USA and Sweden had enough financial support for research of wind energy and they started to develop large-scale wind turbines with capacity of several megawatts, but many of these prototypes did not perform successfully because of many various technical problems. In the USA there was huge boom during eighties and many wind parks were constructed in California, Texas and some states of the Midwest and now they are being re-equipped with larger modern wind turbines (Ackermann, 2005; Burton et al., 2001).

In summary it took over 20 years for the wind energy to become considered as one of the most important sustainable energy sources. Most of twentieth century people were not really interested in using different alternative energy sources since they had available access to electricity grid system. But during last decade of the 20th century worldwide wind capacity doubled approximately every three years, which indicates very fast recent development (Ackermann, 2005).

Improvements in engineering, materials, and overall construction of the wind turbine rotor have resulted in much larger rotors and with that improved energy generation (Tong, 2010). While in 1985 the rotor diameter was 15 metres, in 1989 it was 30 metres, 70 meters in 1998 and after 2000 it is over 100 metres. With size also the capacity is changing rapidly. Turbine with the 15-meters rotor could provide 50 kW, turbine with 30-meters rotor 300 kW, and only 10 years later the turbine with rotor diameter of around 80 meters were able to produce 2000 kW (Ackermann & Soder, 2000, 2002). Nowadays, the turbine with the capacity 3 MW is a middle size turbine (Ackermann, 2005; Burton et al., 2001). In 1993, Europe passed an important milestone when total installed capacity exceeded 1000 MW (Gipe, 1995). At the end of 20th century wind energy was perceived as a clean, practical, economical and environmentally friendly alternative to fossil fuels (Sahin, 2004).

The development has grown so rapidly, that the management and planning schemes to deal with consequence of larger wind turbines and new associated impacts were completely missing in each country. For example, until the late 1990s the installation of smaller wind turbines in Denmark contributed generally to the positive image of wind power (Moller, 2006). At 1990s the relation between renewable energy and sustainable development was highly supported within the literature (Dincer, 2000). Dincer concluded that exploitation of renewable energy resources and technologies (including wind energy) is a key of sustainable development due to much less environmental impact and being non-depleted in energy production. The largest growth from RES (excl. hydro) in the European Union (EU-27) belongs to on-shore wind power from 1990 to 2007 (Haas et al., 2011). But after the enlarging of the structures and increasing the numbers and location, the public opinion has become a strong aspect for the developers and it turned out it would not be that easy to construct other wind parks (Moller, 2006). Nowadays, wind power does not mean only renewable energy, but other aspects as visual impact on landscapes, noise and etc. are being considered more and more.

Development in the Czech Republic

Wind energy development in the Czech Republic has yet to achieve the same widespread application in comparison to other European countries; the wind potential has not been utilized yet. The first wind turbine was installed in 1993 and 10 more in the period 1993 – 1996. The boom came in the first decade of 21st century (csve.cz). The installation diagram is shown in Figure 1.

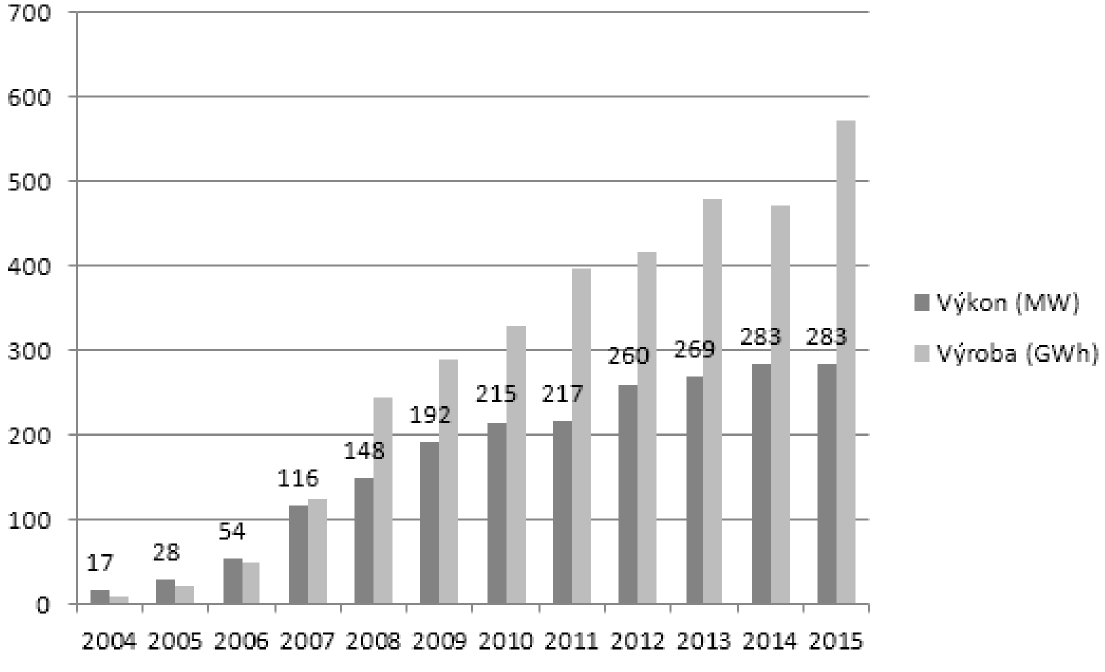

Fig. 1. Diagram of installations in years 2004 – 2014, showing the wattage and production of WTs installed in the Czech Republic (source: http://csve.cz/clanky/grafy/280)

There are several reasons for this later development of wind parks in the Czech Republic. First, geographical: Czech Republic is land-locked country with distinct morphology without seascape (Hanslian & Hosek, 2015), so naturally first development was concentrated at countries by the sea (ocean). Second, legislative: Renewable energy has started to be supported on a national level by the ‘Act on the Promotion of the Use of Renewable Sources’ after 2000 (No 180/2005 Coll.) which assumed a share of 8% of electrical energy gained from renewable sources till 2010 (Frantal & Kunc, 2011). Without national support the interest in RES was rather small in the country. And according to the new direction from European Commission (No.2009/28/ES) the renewable energy sources should raise up to 20% on average in total energy consumption for the whole EU till 2020, the Czech Republic expects 13%.

And last, political – institutional factors that have great influence on permitting system and decision – making process (Sklenicka, 2006; Wolsink, 2007). Renewable energy is, for example, included in the ‘Act on Town and Country Planning and Building Code’ (No.183/2006 Coll.), part 4 Building Code, where the wind turbines are considered as temporary structures. In European context, according to a review on promotion strategies by Haas et al. (2011) the highest support levels for wind turbines projects have been seen in the three countries applying quota systems as the main instrument, i.e. Italy, UK and Belgium.

Fig. 2. Example of wind turbines in the landscape – Krušné hory area (photo by Vendula Běťáková, taken from the hill Mědník)

Nowadays, there are around 160 wind turbines erected in the Czech Republic, the install capacity in total is 283 MW (Fig. 1) and the production is over 572 GWh by the end of 2015 (csve.cz). This represents a growth rate of more than 50 times from the year 2004, when the capacity was 17 MW and production 8.3 GWh. There are several wind parks, e.g. 'Ostružná' (Olomouc region) – 6 turbines (1994), Kryštofovy Hamry (Ustecky region) – 21 turbines (2007) (Fig.2), Horní Loděnice (Olomouc region) – 9 turbines (2009), Andělka (Liberec region) – 6 turbines (2012) and few more.

3.2 Acceptance of Wind Turbines: Examples

Whereas acceptance for wind turbines has changed during the time; it depends on the fast spreading and better technology which can allow higher and greater turbine structures. But the cases are not the same in each country or region, so there are few examples to be compared. It varies from different qualities of surveys. Krohn and Damborg (1999) summed up in 1998 the surveys of countries as Canada, USA, Denmark, Sweden, Britain, the Netherlands and Germany. These countries were in 1990s in favour of wind energy and about 80% of people asked agreed with further development. Yet how is it nowadays? Is the situation the same?

Case 1: Denmark

Denmark was one of the first countries in Europe which started to install wind turbines. In 1994, Denmark produced 17% from total generated energy from wind turbines (Gipe, 1995). Ten years later in 2004 there were about 5400 wind turbines in the country, producing 20% of the electricity consumption. Many of them will reach the end of their lifetimes by the year 2020 (Moller, 2006). Trends are to decrease numbers and increase size, which leads to more apparent visual impact in the landscape. Moller (2006) has done the research using landscape model created by GIS for Northern Jutland County, which was used to assess the visibility of turbines in the period of 1990 to 2010. The results show that a decrease of 400 turbines by 50 larger turbines with better capacity will not add to the comparative impact in general. However, there is the crucial factor when people are being aware of influencing the value of natural landscapes and tourism after (Moller, 2006).

Danish population has considerable experience with different impacts connected with wind turbines compared to most of other countries using wind energy. It is closely associated with offshore wind turbines development (Ladenburg, 2008). The results show higher preference for offshore turbines to on-land turbines. In addition, people living close to either on-land or offshore turbines were more positive than respondents who were not living close to wind turbines. In other words, prior experience with WTs cause more positive attitude to additional new WTs proposals (Ladenburg, 2009).

Denmark today is still one of the main leading countries in wind industry in Europe.

Case 2: Great Britain and Ireland

Great Britain was on the 6th place from centres of wind generation in 1993 (Gipe, 1995). Survey research conducted in Ireland shows that people in inner zone (living closer to the wind turbines) were more favourable then people in outer zone, and they were more positive after personal experience of already operational windfarms, when they knew what to expect (Warren et al., 2005). The study in Scotland shows that people near the operational site more support and less oppose the local windfarm then respondents from proposed site. The most preferred sites for future windfarm locations were uninhabited areas, offshore and upland areas and less were urban areas, which clearly shows that people do not want to live close to windfarms (Warren et al., 2005). Jones and Eiser (2010) found similar results when offshore development is much preferable than development on identified sites. Onshore development was more acceptable in proposals to be ‘out of sight’, thus the site visibility and landscape concerns have to be discussed. Summarized, residents would apparently much more oppose visible wind turbines in their vicinity.

Case 3: Germany

Germany has been together with Denmark leading country in wind energy production in Europe (Gipe, 1995). The research often shows the positive attitude towards renewable energy in general, but it differs on the local level. There are examples from two regions, when at first the support was strong due to cooperation with local authorities and involvement of local residents, while in second region the developers encountered on strong opposition. The implementation of renewable energy is much more possible when the companies give the accurate information and possibilities to participate during the planning and installation process. Furthermore, landscape evaluation and the choice of the location for the plant are relevant aspects (Zoellner et al., 2008).

As in other countries, the target of German government in energy policy is for 2020 to produce 30% of the electricity from renewable energies. And wind energy has been selected to be a major contributor to this aim. It means replacement of old turbines by modern ones and to build new turbines on land. The expansion has not been universally accepted and there is strong opposition in several regions. The research from 2009 has evaluated results from two regions, where people were familiar with wind power and could see turbines on weekly or daily basis. Results showed that on average people prefer to move turbines further away from residential areas, on the other hand the height of turbines and size of wind park were not the significant attributes. In addition, people were more positive with the programme that could allow electricity generation at comparably lower costs (Meyerhoff et al., 2010).

In Germany, wind power development is supported by the Federal Building Code's definition of wind turbines as privileged projects (Jobert et al., 2007). The factors influencing social acceptance were identified by case studies as visual impact, ownership, information and participation. In particular, involvement of local inhabitants and municipalities are important for successful wind energy projects realization. Recent research has also focused on the impact on tourism, which is associated with mentioned visual impact. The study by Broekel and Alfken (2015), for example, confirmed a negative relation between wind turbines around municipalities and tourism demand for municipalities not located near the coast.

Case 4: Greece

The research from 2008 done in Crete, Greece showed that the 70% of inhabitants accept the existing wind turbines while 20% have negative opinion, mainly because of visual impact and noise (Tsoutsos et al., 2009b). The questionnaires gave the results that overwhelming majority (93%) was positive with existing windparks in the region and general use of the wind power for electricity production. More than half of asked people felt that the landscape was positively influenced. The study proposed three options for evaluation. First scenario was composed by 5 wind turbines of the same type, the second by 22 turbines of the same type and third by 1 turbine of 5 MW (120 m high tower and 126 m rotor diameter). The results showed that the number have little influence on the visual impact. The use of only one turbine of twice bigger size would have more negative visual impact compared with the existing park of 11 windmills, even of designed proposal of 22 windmills (Tsoutsos et al., 2009b).

A study conducted after a significant increase in the utilization in 1999 to 2002 in several islands and mainland Greek territories shows opposite attitudes to new wind projects. Whereas in the Greek islands the public attitude was clearly supportive, in the Greek mainland the public attitude was significantly against wind power applications (Kaldellis, 2005). The lack of proper information was also reflected in the unwillingness of local people to participate in new projects. The divided opinions between islands and mainland population are completed by recent research. Interesting findings were reported by Georgio & Areal (2015). The study was conducted in Greek islands. Results showed willingness of respondents to pay on average 20€ every two months (so 10€ a month) through their electricity bill in return for carbon-free electricity and water saving from the wind farm. Their knowledge and perception towards climate change and renewable energy have a positive effect on their willingness to pay.

Case 5: Netherlands

One of the symbols of Netherlands is the traditional wooden wind mill surrounded with tulips which creates typical romantic atmosphere. But how is the real situation with wind power nowadays? Wolsink (2007) has pointed out the advisory and fair decision-making process which is missing in the policy of renewable schemes. Results from the research from 2007 show the average scores of acceptability of wind turbines in different landscape types; areas as industry and harbour areas, military areas, transport infrastructure and agriculture areas are most acceptable, while dunes on island, nature and recreational areas are highly unacceptable (Wolsink, 2007). It means that landscape with high natural value could be more damaged after wind turbines implementation than developed areas.

Study by (Agterbosch et al., 2009) indicates that local social conditions are necessary for successful implementation. Good example is the province of Zeewolde, which adopted the installation of single turbine by farmers on their land. At the beginning of 21st century, these small private investors represented the majority which contributed to wind turbine capacity installed per year. Conflicts at community level can be explained by a variety of institutional regulatory and social problems at the local level. Research has also reported that the social resistance and a negative popular opinion on wind power are the most critical for project realization (Agterbosch et al., 2007). The local acceptance and clear targets set on local level are crucial factors in energy policy in Netherlands.

Case 6: Czech Republic

Czech Republic is a small scale, landlocked country with various types of rural countryside, surrounded with mountains, where is the highest wind potential (csve.cz). Compared to other mentioned countries, it does not have seascape, so the question of placing WTs may differ, for example offshore WT is not a reason for debate. There can be found yet only few studies focusing on Czech situation with public acceptance within literature. Frantal and Kunc (2011) have done the research focusing on two comparative study areas: Krystofovy Hamry in Krusne Hory Mountains (Fig. 2), located at Czech-German border, where the largest wind park was implemented in the country, and Slezka Harta dam in the Moravian-Silesian region in Jeseniky Mountains, where the construction of wind turbines has been considered. Both areas are less populated, upland with proper wind potential and without any natural protection and very popular touristic areas. The survey results show only small negative impact on the tourism and the destination choice. The wind turbines were perceived to be less disturbing in the landscape than industrial buildings, mines, telecommunication towers and factories etc. However, local residents were more negative with wind power in general as well as the projects in their vicinity than non-residents, when the acceptance in general was higher for all respondents. Personal attitudes of residents to wind turbines in the area of Krystofovy Hamry were more negative due to the current situation of existing wind turbines.

There are several studies evaluating the visual impact of wind turbines and other vertical structures on the landscape character, which is defined by the natural, cultural and historical characteristics and aesthetical values (Sklenicka, 2005). The aim of the study is to limit the area suitable for the location of wind turbines, depending on these characteristics and other spatial limits, natural protection zones, population etc. The results showing the area and its borders are marked in the map, completed with the table of evaluated characteristics.

Frantal (2015) recently presented the results of a survey with local governments and inhabitants of municipalities in the Czech Republic where wind turbines have been implemented and are in operation. The findings prove that perceived positive effects dominate over negative impacts and that a majority of local authorities and inhabitants are willing to support further development in their backyards. A disruption to local landscape was detected as the main factor behind opposition. However, the significance of visual impact proved to be outweighed by subjective appraisal of economic benefits which is spatially and socially structured. The conclusion presents some implications for designing repowering schemes based on the research.

3.3 Technical Parameters of Current Most Used Wind Turbines

Generally speaking wind turbines are the producers of wind energy. The leading type in current wind energy market is horizontal axis wind turbine (HAWT) with three blades (Manwell et al., 2009). Technical design is strongly specific, so there is certain visual impact in the landscape (Kaldellis, 2006). The turbine consists of the tower, which can differ from the height from approximately 50 meters to over 100 meters, and the nacelle (Tong, 2010). The tower is usually white. Some examples of painted towers from green to white can be seen in the landscape to reduce the visual impact, but no studies have supported it yet. The nacelle is the dynamic part which has the nose cone connected to the tower and blades, usually in number of three, sometimes two. The diameter varies as well, depending on the height of the tower. The pitch which drives the blades has variable design; it is one of the most visible parts of the structure (Manwell et al., 2009). The diameter can then easily reach over 100 metres for such structure.

Technically, wind turbines can be placed in '2 types' of location – on-land and offshore (Tong, 2010). These turbines usually differ in size and therefore the productivity as well as associated visual impact. Land based technology has usually 1.5 – 3 MW upwind configuration and 80 – 100 m tapered cylindrical steel tower. The size is variable depending on the area, e.g. on the Great Plains there are 5 MW machines with larger rotors, which requires bigger size of structure. Offshore technology is different due to the surface and other necessary construction methods for the erection of turbines. In that case, they are built in shallow water, where the mono-pile/gravity foundations are constructed (Lyons et al., 2008). The advantage is strong wind (9+ m/s), but the cost is logically much higher. The most of offshore turbines are located at the coast of UK and Denmark in Europe (csve.cz) and in California (Altamont) in Northern America (Tong, 2010).

3.4 Visual Assessment Methods

Visual assessment has been developing since the construction of WTs has started to be spread over the countries. However, the approach was literally different that it is now. It is closely connected with the WTs amount constructed, while at the beginning of WTs 'massive era', there were few projects and visual assessment was not therefore such a 'hot topic'. We can see that also within the literature: 10 years ago there were just few papers focusing on visual assessment, while there are recently many articles, aiming at specific case studies and often with developed own assessing methods.

Basically there are two approaches. First, expertise approach identifies the features of the landscape components, i.e. lines, colours, textures etc., and then classifies the visual quality related to the combination of these parts (Gamboa & Munda, 2007). After the assessment of visual quality of the landscape where the project is planned follows the evaluation of the visual impact of the project. Similar approach is used, for example, in the methodology for assessing the impact on landscape character developed in the Czech Republic (Vorel et al., 2006). Another expert evaluation was analysed by Hofer et al. (2016). A survey with local experts was carried out to evaluate different preferences of stakeholders from different wind energy-related fields, such as economy, science, administration, environmental protections, and local public initiatives.

As other, there are perception/experience approaches such as public preference models, which rate the visual quality of the landscape based on the observers´ individual preferences of the whole landscape. These assessment methods on visual impact of wind turbines on landscape quality use usually one of these types of questionnaire to obtain the public opinion (Molnarova et al., 2012):

- verbal questionnaires
- photo-based questionnaires
- questionnaires based on computer simulations
- questionnaires filled in while viewing actual landscape

However, many other specific techniques and methods have been developed for the visual assessment of WTs. This chapter will thus shortly describe the most relevant and used methods in this context, with examples found within the literature.

Zoellner et al. (2008) has used, for example, the combination of qualitative and quantitative approach. Qualitative methodology was used in the 1st phase interviews with members of local authorities, operating companies, nature protection organizations and members of citizens´ initiatives. The 2nd phase worked on intra-individual level. After that the quantitative methods were used with standardised questionnaires including the influencing factors (Zoellner et al., 2008). Beside, quantitative and qualitative methods were also used by other research to collect primary data by semi-structured interviews and a questionnaire survey in South Africa case study (Lombard & Ferreira, 2014).

Quecheetest, as next, is a very simple method and the aim is to determine if a construction will damage the 'natural beauty' of a landscape. It is based on 2 questions: *Will the project have any 'adverse' aesthetic impacts on the scenic quality of the area? And if so, will those impacts be considered 'undue' when taking into consideration the type of development proposed and its surroundings?* The essential elements of this method are the 'harmony' and the 'compatibility' (Tsoutsos et al., 2009a).

Next to it, simulated computer programmes are very often used for the planning schemes of new development. There are several examples of using such methods. Windpro programme is well known Windows modular based software, suite for the design and planning of wind turbines and wind parks. Firstly, the maps are scanned into the PC and then the user can use several toolbars to add other attributes as surface roughness, local obstacles and topography. Then it is possible to get the visibility from any point depending on the height of turbine structure and the terrain. Clearly, the results are more accurate as more "real" the computer model is (Tsoutsos et al., 2009a). Similar method to it is 'Viewshed analysis' in GIS which is using ArcGIS software and it works on similar principals. It can determine the zones of visual impact using mapping of the affected area (Gamboa & Munda, 2007). Visual thresholds were developed by Shang and Bishop (2000). It works with the terms as detection, recognition and visual impact, considering the visual size (angle), visual contrast (grey scale percentage), visual contrast direction and shape type (tank or tower) (Tsoutsos et al., 2009a).

After year 2000, GIS was often preferred method to develop wind farm location criteria and produce maps of the most suitable sites for locating wind farms. For example, study conducted in UK used simple GIS analysis to evaluate all the layers and then classified them according their perceived importance in the landscape (Baban & Parry, 2001). GIS as a visual assessment tool was found very useful for spatial wind source analysis, as it can quantify and visualize technical WTs potential considering the system performance, topographic limitations, environmental and land use constraints (Siyal et al., 2015).

Bishop (2002) used GIF animation, when the simplified model of wind turbine was constructed in POV-Ray and the blades in an angle of 120 degrees were rotating in 15 frames animation and rendered. This rendered turbine was 15 times copied and pasted to the same landscape. These 15 landscape views with the blades in changing position were converted to the animated GIF with the resolution around 500 pixels. This method also works with the contrast which is calculated between the turbine and background of an image, depending on the intensity of an evaluated object, sky intensity and distance from the viewer (Bishop, 2002).

Spatial aspects determine the visibility of wind turbines from chosen points and the algorithm calculates it considering surface elevation, dimensions of facilities, landscape relief and Earth curvature. The result of the process is the visibility map, in which each location has indicative value if the facility is visible from that point (Rodrigues et al., 2010).

At the beginning of 21st centrury, Spanish method was developed from Hurtado et al. (2004) for the evaluation of visual impact. It is based on the equation: $PA = \alpha * b * c * d * e$, PA: the Partial Assessment coefficient, α: the visibility coefficient of wind park (WP) from town or village, b: the visibility coefficient of town from WP, c: the visibility coefficient of the WP taken as a 'cuboid', depending on the side of view and on the number of WTs, d: the distance coefficient between town and WP, e: the population coefficient of the town. The coefficients have their special calculation or can be obtained from tables given from the authors. It covers all important attributes which might be determining for the visibility.

Palmer (2015) used method of effect size thresholds proposed by Stamps (2000) to evaluate the change in scenic quality and enjoyment. Respondents evaluated 20 viewpoints, frequently used in the area. Although the scenic impacts were found very large, the effect on enjoyment was very small and determined as a trivial by respondents. This study recommends evaluating all important viewpoints in the area, which may be affected by proposed wind turbines development. Such method could prevent the cumulative effects.

Most recent popular method is the combination of GIS and 3D techniques, which permits a simple interpretation of results. The Blender software for 3D animation in cooperation with GIS tools can be useful for the choice of optimum localizations of a wind turbine (Wrozinski et al., 2016). As some studies mentioned (e.g. Sklenicka, 2006), wind turbines with rotating blades are more suspicious in the scenery then stationary turbines, so the 3D animation might be more accurate for the WTs interpretation in the landscape.

Visual assessment is frequently used in combination with acoustic analysis. Visual-acoustic landscape simulations of wind parks offer a potential instrument for public participation, allowing experiencing the visual and the acoustic landscape impact. The results show that there was nearly no difference in the rating of the annoyance of wind turbine noise between the recordings and the simulation. With regard to the visual landscape assessment the ratings based on the simulations were lower than the ones based on the recordings (Manyoky et al., 2016).

Very actual method mentioned within the literature is using psycho-physiological approach to quantify objectively the intensity of emotions associated with the visual impact of wind turbines. The method is based on showing different landscape pictures to respondents in a laboratory (Maehr at al., 2015). Maehr at al. (2015) used images of turbines and other constructions (churches, pylons and power-plants) against rural scenes, and provided psycho-physiological and self-report measures of their emotional reactions.

In addition, the quantitative visual impact assessment is greatly complex discipline as it analyses a quantity of objective and subjective factors, i.e. landscape type (morphology, natural elements, cultural and historical elements, other technical structures), scale of the landscape, distance from observation points, technical parameters of turbines – their size, rotor diameter, pitch type, number, paint colour, structure and the conditions, how often, how long and where people are faced with, daylight conditions (i.e. contrast with sky and landscape, sky conditions – clear sky, stormy sky, haze etc.), impact of rotating blades etc. All these attributes have more or less influence on perception of WTs in the landscape. In some cases, WTs are very suspicious devices with strong visual impact, otherwise, they can be perceived very weakly under different conditions.

3.5 Decision-making Process and Policy

The phenomenon ‘renewable energy’ has become crucial target in national policy in many countries, when it is planned to reach the capacity during period from ‘x’ to ‘y’, or till year ‘Z’, but just part of it is realized, due to many significant institutional factors. Few studies have focused on this problematic issue to figure out the main reasons of this fail. It appears that the central control system for renewable schemes is not the most effective way, and wind energy is clear example. It happened many times that the concept was in favour with majority but when it came to the realization, developers had to stand against strong opposition which stopped the project (Wolsink, 2007). Such scenario is supported by most of the studies stating usually at the beginning of introduction or abstract ‘general acceptance but local rejection’.

Many reasons for that can be pointed out: weak or no communication with local authorities and residents, bad investigation of the landscape and natural conditions or doubt fairness of implementation decisions. The process is not often very clear and people are not announced with the background of the decision (Wolsink, 2007). Facilitating local participation in project planning can help to arrive at a better recognition and involvement of the multiple interests (environmental, economic and landscape) that are relevant at the local level of implementation (Breukers & Wolsink, 2007). Study by McLaren (2007) also reported that high levels of participatory planning led more likely to publicly accepted and successful wind projects. With the different approach of institutions and developers, the literature has mentioned also different public attitudes, either very positive or strongly negative.

"The wind turbines are killing the area! (..) Our wind is not for sale!" (Wolsink, 2007)

"I approve wind turbines in general. All things considered, I am an opponent of wind turbines." (Zoellner et al., 2008)

"Oh, those old things! I love them. They are very relaxing." (Warren et al., 2005)

People expect fairness and equal acting of developers and institutions. It is clear that each specific project do impact local communities (Horbaty et al., 2012). IAE Wind Task 28 on Social acceptance of wind energy projects aims to facilitate the wind energy projects by reviewing current practises, emerging ideas and exchanging successful practises between participating countries (Hall et al., 2013). It should connect project developers, local planning offices and general public. The approach enables to understand the opposition behaviour and critical assessment of emerging strategies for social acceptance. It has analyzed many aspects related to social acceptance of wind energy, including impacts on landscape and ecosystems, standard of living, implementation of energy policy and spatial planning, distribution of cost and benefits and procedural justice. For instance, a belief, that wind farm will provide economic benefits to the community, lends support for more wind turbines development (Bidwell, 2013). Similar findings were presented by survey conducted in Switzerland, when regional benefits seem to promisingly increase local acceptance of wind energy projects (Walter, 2014).

After a conference held in 2006 in Switzerland, the collection of best papers summarized the social acceptance of renewable energies. Despite government having very ambitious targets, the social acceptance is a constraining factor in achieving these targets. It was classified into three parts: socio-political, community and market acceptance. First two are important for understanding the contradictions between general support and negative attitudes to specific projects (Wustenhagen et al., 2007). Community acceptance is based on procedural and distributional justice and trust, socio-political on technologies and policies, and market, of course, on consumers and investors. Since then, many studies have focused on this issue, attempting to find reasons for public opposition and propose practical solutions.

It is obvious that almost all countries that utilize wind energy for power generation have policies specific to wind energy. Successful countries in wind energy utilization are the USA, Canada, Denmark, Germany, Turkey, Australia, China, Japan, and South Korea (Saidur et al., 2010). For these countries, the existence of wind energy policies managed to increase wind power generation significantly. In general, most countries' policies include tax exemption, the quota system, subsidies, Feed-in Tariff, involvement of research institutions, target implementation, legislation on wind energy or renewable energy law and others.

However, extensive research by Minelli et al. (2014) pointed out that to date; no international guidelines exist to guide quantitative visual impact assessment of these facilities, making the planning process somewhat subjective. Beside, Masurowski et al. (2016) mentioned, that the same minimal thresholds (e.g. distance) cannot be applied for all areas because the conditions are varying in each region (state, or country). Aitken (2010a) pointed out the same opinion: what applies in one country (or region) does not need to be applied in another, due to, for example, different cultural and political conditions. Toke et al. (2008) found, for example, that financial support was strongest in Germany, Denmark and Spain. Also landscape protection organizations vary in strength, e.g. England and Wales has very strong and influential established system for landscape protection compared to Spain with almost non-existing one (Toke et al., 2009).

Also the government strategy is not always very clear. For example, study conducted in Ireland (Gonzalez et al., 2016) showed preferences for the governmental policy coordinated and integrated at the local level. Gonzalez et al. (2016) pointed out that a consistent use of standardised GIS-based spatial analysis at a local scale could usefully present an opportunity to visualise the highly constrained and contested nature of the Irish countryside. The strategy developed by Welsh government demonstrated revealed approach by examining the acceptable location on a national level. The qualities of landscape might be represented at the national level, alongside other energy policy considerations like resource availability, economic efficiency and technical feasibility (Cowell, 2010).

Waren & McFadyen (2010) tested perception of windfarm owned by community and windfarm owned by developers. These results support the contention that a change of development model towards community ownership could have a positive effect on public attitudes towards windfarm developments in Scotland. The data also indicate that local attitudes could become even more positive if future windfarms were owned by local communities. Similar preferences for community ownership were also reported by Ek & Persson (2014). In Denmark, for example, ninety percent of commercial wind farms are owned by local cooperatives and individuals (Sovacool & Ratan, 2012).

Recent studies have used choice experiment as a method for the wind turbines assessment. Ek & Persson (2014) found, for example, that consumer preferences may improve the public acceptance. Respondents preferred whole or partial ownership by community, avoiding recreational and mountainous areas, and involvements of locals in the planning and implementation process. Community engagement from early stage in the process was also confirmed as a important factor, reported by study from Atlantic City, US (Bates & Firestone, 2015). Research conducted in Ireland based on discrete choice experiment showed preferences for community inclusion, compensation and provision to community and increasing setback distances (Brennan & Van Rensburg, 2016). Respondents preferred turbines that were further away from residential settlements, and this is consistent with other studies (Meyerhoff et al., 2010; Vecchiato, 2014). Externalities associated with wind farms are also reduced by the positive benefits provided by wind energy as reported by Groothuis et al. (2008).

3.6 NIMBY Syndrome

NIMBY syndrome has been often discussed within the literature, as it has been used as an explanation for public opposition by developers, hence it 'deserves' separate chapter in this review. The term NIMBY means exactly 'Not-In-My-Backyard' and has been analysed in many different cases of infrastructure facilities (e.g. the sitting of hazardous, nuclear and conventional waste facilities, nuclear and conventional power plants, highways, railroads etc. and of social facilities as well). Since the application of wind power began, developers have faced resistance with turbines sitting, and ever since, these problems have been explained by appealing to the NIMBY argument (Wolsink, 2000). NIMBY effect has been background motive for most of the research on WTs acceptance represented by case studies, which analyse preferences for already erected WTs or planned in selected regions and compare evaluation of habitants living in different distances from wind parks (Meyerhoff, 2013; Swofford & Slattery, 2010; Zoellner et al., 2008).

Local residents oppose the project according to NIMBY logic in their aim to maximise their own individual utility. Such people are in favour with wind energy in general and welcome every project not implemented in their vicinity. They support every project of renewable energy as long as it is not in their backyard (Wustenhagen et al., 2007). This phenomenon is closely corresponding with selfishness of individual people. There are many studies (Bell et al., 2005; Bishop, 2002; Devine-Wright, 2005; Ek, 2005; Krohn & Damborg, 1999; Tsoutsos et al., 2009; Warren et al., 2005; Wolsink, 2000, 2007) which focus on this topic, but as research shows there is very weak relation between NIMBY syndrome and wind power attitude; projects have found small or no evidence of the NIMBY syndrome (Rygg, 2012; Wolsink, 2012). Wolsink (2007) has found in his studies that NIABY syndrome, Not-In-Any-Backyard, is much stronger then NIMBY itself, which supports the conclusion, that NIMBY is not relative factor for the assessment of wind turbines.

Petrova (2013) has made detailed review on Nymbyism associated with wind turbines perception. She concluded that the opposition is connected more with the association of these structures with surroundings, i.e. symbolic and affective association. Wind turbines are perceived more as the aesthetic degradation of the landscape. Later, Petrova (2016) proposed a novel framework for organizing community concerns into four categories: visual/landscape, environmental, socioeconomic, and procedural. The aforementioned NIMBY effect has become an implicit phenomenon when planning most large investment proposals, including wind parks. It sometimes appears in research today that respondents are concerned about being labelled as exhibiting NIMBY behaviour (Horst, 2007). The literature has thus established more acceptable explanations of opposition to WT construction, namely place attachment (Devine-Wright & Howes, 2010; Haggett, 2011; Hall et al., 2013; Jones et al., 2011; Lombard & Ferreira, 2014), sense of identity (Horst, 2007), and confidence in the construction itself and in its benefits (Aitken, 2010a).

3.7 Respondents´ characteristics

Research relating to wind energy assessment has often taken into consideration the respondents´ characteristics to evaluate visual impact of WTs.

The main characteristics of respondents have been identified as socio-demographic (gender, age, education, general attitude towards wind energy), occurrence of WTs near the respondents' homes, daily contact with WTs (Ladenburg et al., 2013), and prior experience with WTs (Ladenburg, 2009). Ladenburg (2009) found that people are more positive when they could see offshore wind farms located far from the coast, and therefore the acceptance of future wind farms depends on the location of existing and planned farms. The similar findings were found when respondents visited sites where WTs were constructed (Ladenburg, 2010). Stronger opponents to WTs appear to be older and more highly educated (Ek, 2005;

Ladenburg, 2010), and differences between sexes are often minimal (Ek, 2005). However, Linden at al. (2015) found opposite findings: males have more negative attitudes towards wind power, while older people have more positive attitudes. Study by Liu et al. (2013) reported that residents with higher level of income were more likely to be willing to pay more for green electricity, so were the younger people. However, it is important to mention that each study has been conducted in different country, i.e. Sweden, China etc., so the findings may likely differ for such reason.

The results of certain studies demonstrate that people living in the vicinity of WTs paradoxically perceive them more positively than do inhabitants living further from WTs (Meyerhoff, 2013; Warren et al., 2005). Nevertheless it is not entirely clear to what extent people can become accustomed to wind parks and what causes the positive perception of inhabitants frequently spending time in the vicinity of WTs. There are conflicting results concerning the extent to which the perception of WTs is influenced by living in their vicinity. Whereas a study by Eltham et al. (2008) demonstrated a more positive attitudes among respondents regarding the wind farm’s visual attractiveness after construction (compared to a recall of their opinions before construction), another study by Groth and Vogt (2014a) reports the opposite findings. A negative opinion of WTs lasts for as long as several years after construction is completed, with the main causes being increased electricity prices and noise from turbine operation. Similar results can be found in a study from Texas, where people living the closest to WTs are the least supportive of wind parks (Swofford & Slattery, 2010).

General attitude was determined as a strong predictor for the acceptance of wind energy projects by several studies (e.g. Jones et al., 2011; Walter, 2014). General attitude is likewise closely connected with term ‘past behaviour’, thoroughly examined by Read et al. (2013). Past behaviour was found as the best predictor for the future attitude to wind energy projects (Read et al., 2013). In this study, it was concluded that respondents with negative past behaviour were likely to be negative to future/planned wind turbines.

At least, there is a group of emotional respondents´ characteristics having influence on wind turbines perception. As mentioned earlier, place attachment is one of the reasons for public opposition to wind parks (Haggett, 2011; Hall et al, 2013). Health risk perception and community economic benefits also consistently predict wind turbines support (Baxter et al., 2013). Research conducted in Finland shows interesting findings regarding the small municipalities (Linden at al. 2015). Such municipalities were likely to have a more negative attitude, although people living in municipality with weak economy had likely a more positive attitude. Such findings may correlate with hypothesis that having wind turbines in the proximity of municipality may bring some economic benefits.

Nevertheless, research conducted in UK shows the community benefits are not always perceived positively by local members of the community. The results stressed out the decisions to specify the relevant local community and form of community benefits (Aitken, 2010b). Aitken (2010b) found that benefits package was perceived as representing a bribe from the earliest stages the community. This sense of unfairness continued to influence perceptions of the community benefits package even after it had become a reality. Similar findings were reported by (Walker et al., 2014). Potential increase in wind projects support can be diminished by bribery perception of community benefits. Hence, it seems very important to distinguish the differences between real benefits and bribery for successful implementation.

In conclusion, prominent predictors include general attitude, community (place) attachment, environmental values, visual attractiveness of wind turbines, and issues relating to perceived fairness and equity. The findings support calls for greater community involvement in decisions regarding proposed schemes (Jones et al., 2011). However, it has often been observed that countries which have higher rates of wind power development are also those where there is greater community involvement (e.g. Germany and Denmark) (e.g. Toke, 2005). While broader community involvement and ownership may lead to greater acceptance in other European countries such as Germany or Denmark, social or cultural differences may make it difficult to apply these same approaches in the UK (Aitken, 2010a). Approaches to public participation need to be developed in relation to particular social and cultural contexts.

3.8 Number of Wind Turbines

Does the attribute of number correspond with the landscape type? What is the crucial factor which creates the cumulative effects – when ‘enough is enough’, when landscape is ‘full up’ (Campbell, 2004)? Is one turbine more or less ‘irritating’ then three, five, ten turbines? Are two turbines better than one? How many turbines in the landscape are already too many? These are questions which are not easily answered because it is changing with other attributes, mainly the landscape type and technical parameters of turbines. This is significant according to many studies (Kaldellis, 2006; Meyerhoff et al., 2010; Tsousos et al., 2009b, Wolsink, 2007). In Netherlands, for example, the research unambiguously showed the minimal favour for turbines in natural protected area Wetland, that landscapes with mountainous morphology and natural elements are considered as more beautiful; thence the sitting of the structures would be less welcome.

Other important factor for perception is the scale of the landscape (Coeterier, 1996; Fry et al., 2010), when large and open landscapes of many kilometres of the same character can get less interesting for the observer. Therefore the turbines of high number might cause minimal visual damage, while small scaled and closed landscapes with natural variety can be less suitable for turbines. Research in Denmark showed that replacement of 400 old turbines with 50 new ones will not increase the overall visibility of wind turbines in the region, but enlarge the relative impact of large turbines. This means that long-range visibility caused by smaller turbines is reduced, while short- to middle-range visibility of large turbines is amplified (Moller, 2005).

Spatial issues are also of practical significance concerning the size of wind farms (Warren et al., 2005). It is clear from this and previous research (Devine-Wright, 2005) that public has a clear preference for smaller wind farms, even if this means having more than one wind farm in the locality. Wind farms of small number of large turbines are generally preferred to those with large numbers of smaller turbines. This is supported by the other research: People prefer reducing the number of turbines by replacing smaller turbines with larger ones, even though the larger ones might be visible from a higher number of residences (Ladenburg et al., 2012).

Ladenburg et al. (2012) has done the research on two development schemes: increase in the number of turbines and replacement of smaller turbines with larger ones to increase the current capacity. Respondents see the turbines on daily basis. Results showed the positive general attitude to increasing the number of turbines on land and replacing smaller turbines with larger ones. With seeing than 20 turbines it was significantly more negative; more turbines respondents see every day, the more negative are towards additional wind turbines. Cumulative effects are conditional on whether the respondent can see the turbines from the residence or not.

3.9 Distance from the Observer

Compared to research done on number of wind turbines the distance factor as the visual threshold was evaluated in just small amount of studies till nowadays. Furthermore, the results are diverse and clear conclusion for role of this attribute has not been set up yet. E.g.

the research in South Australia did not appreciably prove the reduction of negative visual effects of a wind farm with distance (Lothian, 2008), whereas research in the Czech Republic show significantly increased preferences for landscapes with WTs with increasing distance (Molnarova et al., 2011). Recent study by Vries et al. (2012) found that distance decay of impacts is stronger for barns and business parks than turbines. Moreover the mitigating measures in case of wind turbines make little or no difference in public acceptance.

Till nowadays just small amount of studies have worked out to determine the minimal distance, where the turbines loose the visual impact. The maximum distances at which the wind turbines are still perceived to have a significant impact were examined by Bishop (2002, 2005). For a wind turbine with a 50 m high tower and a 3-blade rotor of 26 m long blades, Bishop found the distance to be 10 km in 'ideal' conditions (clear visibility and stormy sky) and 6 km in prevailing conditions (slightly hazy, sky other than stormy). This distance was therefore much less than the detectable visibility of the turbines (more than 30 km in ideal conditions and 20 km in prevailing conditions (Bishop, 2002, 2005). However, these results are based on 50 m high tower, whereas wind turbines with the tower over 100 m are usually constructed today, so the research in this field would need to be updated regarding the increasing height.

A similar approach to landscape thresholds was used in a methodology developed for assessing the suitability of wind turbines siting from the standpoint of landscape character (Vorel et al., 2006). This method combined empirically determined visual thresholds and visual barriers to determine the so-called Affected Landscape Area. The distance factor is important to determine the minimal distance of turbines from the residential area and vantage points, which is not clearly set up yet, and the distance, when the visual impact of wind turbines can disappear. For example, study by Spiropoulou et al. (2015) set up the minimum distances of 1000 m from areas of port facilities for offshore wind turbines.

From economical perspective, research conducted in Germany presents a novel approach to assess the impact of varying minimum distances on the wind energy potential of a region, predicted form the spatial structure of the settlements (Masurowski et al., 2016). The findings show that even 100 m more distance can cause a reduction of more than 50%. Applying this approach to Germany, the study shows those regions where the energy potential very sensitively reacts to a change in the minimum distance. Minimal distances to housing are varying, also because of the spatial character of the area.

The recent visual impact assessment found that 150 m tall wind turbines should by conducted at 12 km at maximum (Wrozynski et al., 2016). After the GIS data applied, the model identified places, for example, at about 22 km away from the wind turbine which was located in the zone of visibility of the whole wind turbine. The observer perspective view did not indicate that WT was visible, only after render made at 20x zoom showing no visible barriers between view point and WT. such finding indicates that even 150 m tall WT would unrecognizable after several km, e.g. 12 km as reported by this study (Wrozinski et al., 2016). However, this study did not compare visibility in different weather conditions, as was determined by Bishop (2002).

3.10 Additional Attributes

3.10.1 Noise (and Light Flickers)

The visual impact is confirmed by many studies to be the main factor; however, the noise is often the formal argument and crucial factor in the juridical dispute about the project. The noise coming from the turbine can have aerodynamic and mechanic source (Gamboa & Munda, 2006). The mechanical noise is caused by the gearbox, the generator and bearings. The level depends on the rated power and construction, so the larger conversion system is the more sound is producing. Aerodynamic noise is caused by blades sweeping the air, when the level of sound depends on the speed, shape and features of the blades. Moreover, turbulences and their amount have big influence on off coming sound, so it depends on local conditions of each place and how the wind is blowing (Magoha, 2002). Interaction of wind turbines blades with atmospheric turbulences may result in characteristic ‘whooshing’ sound (Oerlemans et al., 2007).

Pedersen and Larsman (2008) found that noise is perceived even much stronger when wind turbines are visible for residents. Such founding was also published by other study: visual perception of wind turbine generators was associated with greater frequency of reported negative health effects (Onakpoya et al., 2015). The research found high visual annoyance to wind turbines associated with reduced quality of life (Feder et al., 2014).

In general, there are no official recommendations about the minimal distance between windpark and residential area, e.g. in Catalonia (Spain) some authors suggest 300 m and others at least 1 km (Gamboa & Munda, 2006). In the case of the village in Netherlands, the conditions in the permit for noise were raised from 40 dB to 50 dB; otherwise the turbines could not have been built. The selected location for the wind turbines was 250 meters from the village, where the noise became a significant annoying factor (Wolsink, 2000). People can also complain about the noise during the construction and operation time (Warren et al., 2005).

Flashing lights can be particularly annoying at night. They should be used for wind turbines higher than 60 meters, so many designers prefer to keep the height of tower lower than that (Kaldellis, 2005).

3.10.2 Danger to Birds and Bats

Avian animals (birds) are one of the largest victim groups in mortality collision of wind turbines around the world (Drewitt & Langston, 2006). There are several potential effects on birds caused by increasing wind energy development, the evidence has been found with the collisions, displacement due to disturbance, barrier effect and habitat loss. Their consequences might be the mortality of birds or more subtle changes to conditions or breeding success. The majority of studies have the results in only low level of mortality of birds, however, these studies were mostly done on wind farms located far away from birds concentration. From available records there are rates very variable per turbines which go from 0.01 to 23 collisions annually, but e.g. at Navarre the numbers are much higher, where the minimum of killed birds, especially eagles, is over 70 (Drewitt & Langston, 2006).

Recent technology has reduced the risk of collision of migrating birds by increasing the size and visibility of blades, slowing the speed of rotating and using tubular towers with internal ladders with underground wiring to eliminate roosting and nesting on the turbine itself (Magoha, 2002). The bird disturbance has been and will continue to be important issue for wind energy developers. On the other hand, these approaches will increase the visual impact, so the design has to be upgraded more efficiently for all impacts.

Regarding the proposed future wind farms in Northern sea and coastal side of Germany, Huppop et al. (2006) investigated year-round bird migration over the North Sea with regard to offshore wind farms, using radar, thermal imaging and visual and acoustic observations. The findings confirmed that large numbers migrating birds are crossing the German Bight, from which almost half of the birds fly at 'dangerous' altitudes with regard to future wind farms. A large number of avian interactions at offshore plants can be expected, especially in view of the number and planned area of projected wind farms. The study suggested abandonment of wind farms in zones with dense migration, turning off turbines on nights predicted to have adverse weather and high migration intensity, and actions to make wind turbines more recognizable to birds. On the other hand, such recommendation will increase wind turbine visibility and therefore may lower public acceptance.

Same research methods using vertical radars were applied to evaluate bird migration in Dutch offshore area to measure offshore wind farms´ impacts both on seabirds and land birds (Fijn et al., 2015). Research conducted by Belgium team on realistic scenario of 10000 wind turbines in North Sea showed also negative significant impact on bird population, collision risk of both local and migrating birds (Brabant et al., 2015). Furthermore, wind turbines proximity to natural habitats may reduce the breeding success of nesting birds (Balotari-Chiebao et al., 2016).

3.10.3 Environmental impacts

Wind energy is believed to have the least adverse environmental impacts. But with increasing use of turbines for harnessing wind energy, the adverse environmental impacts are increasingly coming to light. The additional constructions necessary for the turbine erection have to be taken into consideration while assessing environmental impacts caused by wind turbines construction – the access roads, the power generator, power lines, open space, ground movement, fencing etc. Fencing, for example, can give the turbines even more hostile and interrupting character in the landscape (Kaldellis, 2005). The wildlife impacts can be categorized as direct and indirect impacts. The direct impact presents the mortality from collisions with wind turbines while the indirect impacts are avoidance, habitat disruption and displacement (Saidur et al., 2011).

Negative public perception is increasing emphasis on installing windfarms several kilometres offshore. But such moves have serious implications for marine life which is already under great stress due to impacts of overfishing, marine pollution, global warming, ozone hole and ocean acidification (Tabassum-Abbasi et al., 2014). Offhore wind farms pose significant risk to marine invertebrates, fish, and mammals due to habitat fragmentation, noise, vibrations, electromagnetic interference, etc., just as inland wind farms set a risk to land-based wildlife Lovich & Ennen, 2013). Although wind energy is a “clean energy”, its construction causes deforestation, which leads to CO2 absorption capacity loose and probable release of the already stored carbon. The same is territorial fragmentation and biodiversity lost in the area (Gamboa & Munda, 2006).

For ground ecology it is now generally accepted, that the impact of wind turbines is quite low (Magoha, 2002). However, wind parks should avoid sensitive areas with rare habitats, habitats of endangered species and other protected areas (Wolsink, 2007). But the greatest of emerging concerns is the likely impact on the weather, and possibly the climate. Large wind farms can influence local weather but are also likely to influence the climate and can bring in significant changes in it (Walsh-Thomas et al., 2012)

3.10.4 Cost and Efficiency

Efficiency and cost payback is one of keys for placing wind turbines (exact place, height, distance apart of each turbines, direction of rotating blades etc.), particularly for developers and also the efficiency of the whole renewable energy sources concept. It is generally known that the turbine should pay for itself approximately in 10 years and in the knowledge it is temporary structure for approximately 20 years, it means it starts to 'earn' after its half-life. The research confirmed that the improved technology, greater efficiency, and with the increasing cost of traditional, competing sources such as oil and natural gas, wind energy is close to becoming self-sustaining financially without the extensive federal government support that exists today Welch & Venkateswaran, 2009).

Total costs for installing a commercial-scale wind turbine varies significantly depending on the number of turbines ordered, cost of financing, when the turbine purchase agreement was executed, construction contracts, the location of the project, and other factors. Cost components for wind projects include things other than the turbines, such as wind resource assessment and site analysis expenses; construction expenses; permitting and interconnection studies; utility system upgrades, transformers, protection and metering equipment; insurance; operations, warranty, maintenance, and repair; legal and consultation fees (windustry.org). The costs for a utility scale wind turbine in 2012 ranged from about $1.3 million to $2.2 million per MW of nameplate capacity installed. This cost has come down dramatically from what it was just a few years ago. Most of the commercial-scale turbines installed today are 2 MW in size and cost roughly $3-$4 million installed. At last, it is important to mention the operation and maintenance (O&M) costs which will be the key to the economic viability of large offshore wind farms planned worldwide (Krokoszinski, 2003).

Efficiency is very variable aspect due to many conditions; mostly it depends on the structure of the turbine (the height and technical design) and the wind blowing, if it is frequent and permanent. According to Wind Energy Foundation, between 2008 and 2012, wind power has provided 36.5 % of all new generating capacity in the United States (windenergyfoundation.org). Most of the studies focusing on cost and efficiency were conducted in Germany. Recent study by McKenna et al. (2014) analysed, for instance, the cost-potential curves for onshore wind energy in Germany. The paper concluded currently economic potential of 400-800 TWh/a, and associated generation costs in the range from 5 to 15 €ct/kWh. Jager et al. (2016) found similar results for German federal state of Baden-Wurrtemberg by using feasible analysis considering social-economic constrains. Feasible potential was determined between 11.8 and 29.1 TWh (for that region), with costs between 6.7 and 12.6 €ct/kWh. In European context, an analysis made for Europe (EU28) showed very large variations between countries: between 6 and 50 €ct/kWh. The largest potentials and lowest generation costs were to be found in the UK, Poland and Sweden (McKenna et al., 2015). Five-year earlier research found similar economic values, but in less wide range: the generation costs of an onshore wind farm between 4.5 and 8.7 €cent/kWh; 6–11.1 €cent/kWh when located offshore (Blanco, 2009).

Hodiernal study area has focused also on the cost of property values affected by the construction of wind farms. Sunak & Madlener (2016) found that properties whose view was strongly affected may decreased by about 12%, but in contrast properties with a minor view on wind turbines experienced no devaluation. However such beliefs may entail, that the change in landscape caused by the construction of a wind farm, can have an adverse impact on the view from some properties, and thus may negatively affect their price. Lately, research has concentrated more on the wind turbine layout optimization to increase the wind power utilization. For example, study conducted in China shows the importance of hub heights of wind turbines (Chen et al., 2016). Compared to the layout with identical hub height wind turbines, the one with multiple hub height wind turbines can increase the total power output and decrease the cost per unit power output remarkably, especially for the wind farm over complex terrain.

3.11 Other Wind Turbine Concepts

Wind turbines design has been developed into two ‘families’: From the perspective of rotor placement, the driving force of turbines, we talk about horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). Actual used one is three-bladed turbine from HAWT family, which appears to be the most sufficient type. It is also worth to mention that large number of other types have been proposed, and in some cases built (Manwell et al., 2009).

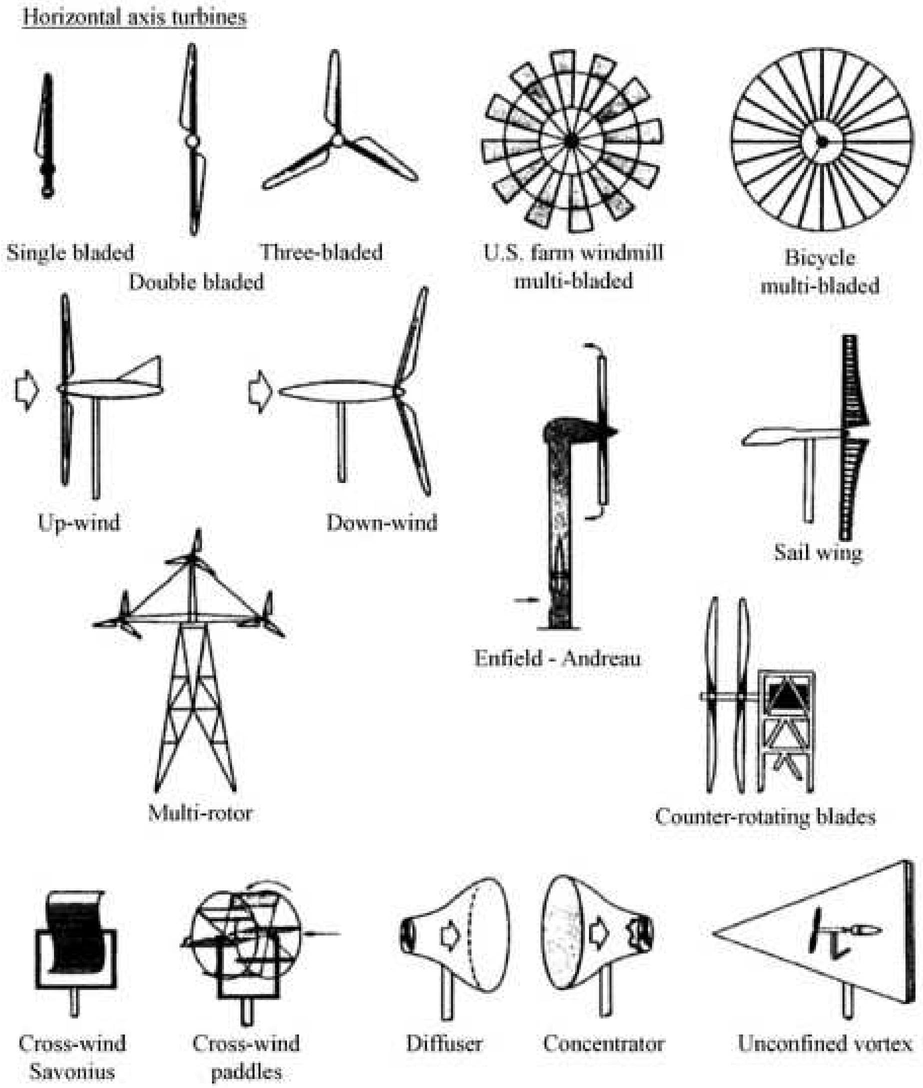

Fig.3. Various concepts for horizontal axis wind turbines (Eldridge, 1980)

In case of HAWT there are more types based on number of blades, i.e. single and double bladed, and multi-bladed. The turbines are also specified by the orientation of pitch – up-wind and down-wind, which has then influence on angle of blades (Tong, 2010). Similar approach is caused by diffuser or concentrator. More HAWT types are shown in Figure 3. From the visual perspective, some of VAWT seem to be very interesting. However, none of these have met the similar degree of success as those with a horizontal-axis, lift-driven rotor (Manwell et al, 2009). The closest to the efficiency of HAWT was the Darrieus VAWT. The concept was studied in Canada and the United States in 1970s. Despite the appealing design, this turbine has some reliability issues so it has never become the leading type in wind industry. Other type, the Savonious, is based on rotor using drag instead of lift, however, these rotors show to be inherently inefficient. In some types of design, the idea is to channel wind to increase the productivity of rotor. The literature explains that to build such effective rotor which could even withstand very strong occasional winds is very expensive and therefore the turbine is cost inefficient (van Bussel, 2007). Other VAWT types are shown in Figure 4.

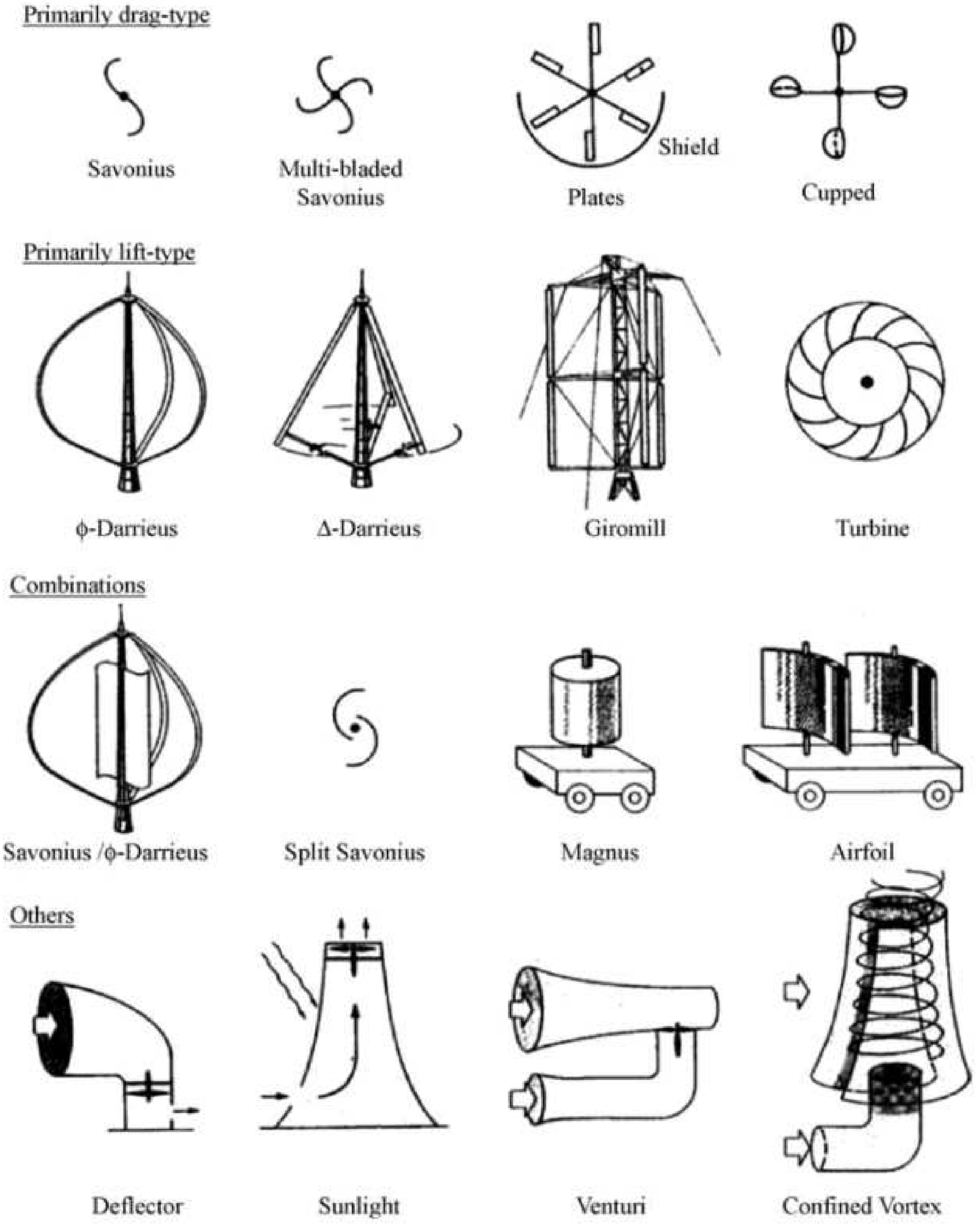

Fig.4. Various concepts for vertical axis wind turbines (Eldridge, 1980)

3.12 Review Conclusion

Around approximately 15 years after the boom of wind turbines projects implementation has started and spread this technology over the world (mainly United States, European Union, but also other countries as China, Middle East etc.) there is still evident public opposition against such projects. Research is now (year 2016) much further in social acceptance analysis than it was 10 years ago. Conducted studies try to find optimal solutions, analyse the reasons for public opposition / acceptance and based on the results propose the suitable solution. However, based on such studies the public acceptance varies a lot pursuant to the location (and also country) where the wind farm project is planned.

The development of wind energy has recently grown exponentially; there is new deployment of wind turbines every year. The governments have set up clear target in renewable energy; however, the public opposition for specific projects is strong that the achieving of these targets has become more difficult.

Conclusive comments found within the review:

- Visual impact has significant role in wind farms assessments
- Positively perceived wind energy in general, opposition to concrete projects on local level
- National aims versus local constrains
- Visual impact assessment has been done much later than construction of wind farms has started
- Recent studies bring new methods for analyzing
- Significant effects on landscape quality and attractiveness
- Perceived fairness and community involvement may be the key in decision-making process
- Economic benefits improve the wind turbines acceptance
- Other environmental impacts have started to play more mayor role, in particular impact on wildlife, climate changes
- Birds are the most affected animals by collisions with wind turbines
- Noise may have influence on human health
- Noise annoyance is increased while the turbines are visible

- What helps to improve local acceptance in one country (region) does not mean to be helpful in another; due to different cultural and political context
- General attitude is the best predictor from respondents´ characteristics
- Differences between males and females does not play important role

Missing knowledge regarding the visual preference for wind turbines

- Distance thresholds
- Numbers thresholds
- Relation between landscape type and distance
- Relation between landscape type and number
- Relation between number and distance
- Educational orientation of respondents – does it influence the perception?
- Relation between education orientation and other characteristics (e.g. general attitude)
- Detailed analysis of alternative WTs
- Visual proposals of other wind turbine concepts

4. RESULTS OF DISSERTATION

Dissertation is presented as a selection of articles (see attachments 1 – 3), which findings are presented by published papers in respective scientific journals. All papers are completed with the comments in following chapter.

ATTACHMENT 1

ARTICLE 1: **Betakova V**, Vojar J, Sklenicka P. (2015). Wind turbines location: How many and how far? Applied Energy 151: 23-31

Status: published in 'Applied Energy'
Indexed in Web of Science, Scopus
IF_{2015} = 5,746

ATTACHMENT 2

ARTICLE 2: **Betakova V**, Vojar J, Sklenicka P. (2016). How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process

Status: accepted to 'Energy, Sustainability and Society'
Indexed in Scopus, Web of Science

ATTACHMENT 3

ARTICLE 3: **Betakova V**, Kumble P. (2016). Futuristic wind power systems suitable as artistic sculptures.

Status: submitted to 'Design Issues' (DESI)
Indexed in Scopus, Web of Science

5. COMMENTS TO RESULTS

5.1 Common ground

This dissertation is a selection of three papers focused on visual preference of wind turbines. Visual impact presents the connectivity of the articles, whereas each one deals with the topic from different perspective. First paper **‘Wind turbines location: How many and how far?’** analyses in detail the characteristics of wind turbines themselves, i.e. their number and distance from observer or vantage point in relation to landscape quality. Second paper **‘How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process’** concentrates on respondents´ characteristics, in particular educational orientation, general attitude, occurrence of WTs in respondents´ vicinity and willingness to live close to WTs. Whereas first two papers use same assessment method to analyse differences of WTs perception from different point of view, the third paper **‘Futuristic Wind Power Systems Suitable as Artistic Sculptures’** presents review of WTs appearance in general and proposals of possible future look as an alternative to traditional wind turbines.

5.2 Brief report on scientific papers

In detail, first paper **‘Wind turbines location: How many and how far?’** analyses numbers of WTs and their distance from observer to determine preferences for increasing number of WTs and increasing distance. In particular, the aim is to find out the crucial thresholds, either for cumulative effects or for distances when visual impact may disappear. The crucial thresholds for distances were set up at 10 km for aesthetically valuable landscapes and 5 km for visually unattractive landscapes. To avoid misunderstanding, survey was designed for specific type of WT (Vesta, with the height of 105 m), so applying these findings to parametrically different WT may be confusing. Importantly, research confirmed significant effect on landscape aesthetics. Moreover, most ‘beautiful’ landscape for after adding WTs evaluated as the worst, and vice versa. This was as a phenomenon mentioned first time in the literature, that WTs placement to landscapes of high aesthetic quality may have such strong effect on their perceived ‘beauty’. WTs as technical structures completely outweighed the natural and aesthetic values.

The survey was conducted without emphasis on respondents' characteristics. The group was selected of university students, so the evaluation was not assured by the complex population sample. The reason for that was clearly statistical. This approach is usual in sociological studies of this type, whereby students are chosen as survey respondents and the students are from relevant fields (a relatively homogeneous sample). In such case, they are future experts in the given area and users of the results as an alternative to a balanced demographic sample (e.g. Brush, 1979; Kaplan et al., 2006; Pettit et al., 2011). The method we have chosen corresponds to a standardized, structured survey *sensu* Kane (1983). Typical cases in which such homogeneous samples of respondents are used are in determining the effects of variables expressing partial aspects of the overall analysis (in our case, the effects of various numbers of WTs and their various distances) or in comparing various approaches in visually analysing landscapes and the like.

Second paper **'How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process'** analyses respondents' characteristics regardless the visual quality of landscape, number of WTs or their distance from observer. General attitude, as confirmed by other studies (e.g. Jones et al., 2011; Molnarova et al; Walter, 2014), was determined as significant factor having influence on WT perception. Mainly, when general attitude was negative, the perception of WT was estimated significantly lower than by respondent with neutral or positive attitude. Very interesting findings were found for educational orientation, and actually first time mentioned within the literature. Technically orientated respondents evaluated WTs as the same without influence of their general attitude. On the other hand, environmentally orientated respondents assessed WTs differently according to general attitude: those with negative attitude at lowest ratings and those with positive attitude at highest ratings. However, the highest ratings from environmental orientation were still lower than those from technical.

The research was deliberately targeted to university students with certain orientations – in an environmental direction, which produces graduates for making observations regarding WTs from the viewpoint of environmental protection or landscape protection, as well as from a technical or engineering direction, which produces graduates who may one day be designing WTs. Concerning the difference in evaluating WTs between the two types of schools, the manuscript explains that the students with the more technical orientation evaluate WTs significantly more positively than do the environmentally oriented students.

Third paper **'Futuristic Wind Power Systems Suitable as Artistic Sculptures'** does not include any statistical analyses of respondents´ ratings. It is purely aimed at the visual and aesthetic character of wind turbine structure, with emphasis on alternative WT types than most common used one – the horizontal axis WT with three blades. It reviews also the actual trends in wind energy industry and market. Several types of these alternative WT were found, described and discussed. The paper brings new approach and thinking about aesthetics and visual impact on environment, either natural landscapes or urban areas. And it proposes several architectural looks how such devices could be completed and put in operation. Psychological, philosophical and artistic approach is presented with highlights on visual effects and other environmental impacts.

In this paper, no calculation or technical analyzes are made. First, the developed alternative models of WTs are based on know-how of the companies, as they are tested by these companies. Second, the aim of this article is not to design and calculate 'better' functional WT model (to traditional WTs), as this is very much engineering task. On the other hand, the paper proposes possible visual appearance. It cannot assure the efficiency, pay-back or cost investment, but it can help to mitigate visual impact or even improve the acceptance by public. Artistic sculpture producing some energy is better than sculpture without any energy production.

Visual impact was reported to be the most significant factor for public opposition by many studies (Betakova et al., 2015; Groth & Vogt, 2014b; Kaldellis, 2006; Lothian, 2008; Molnarova et al., 2012; Vries et al., 2012; Wolsink, 2007 etc.). Although recent research has brought new types of survey, there is still a lack of comprehensive research explaining and proposing the visual assessment methodology for wind energy development. All three papers in this dissertation bring new approaches and views to the issue and contribute to the knowledge from different perspectives.

5.3 Contribution and application of findings/proposals

The findings extended the knowledge regarding the visual impact of wind turbines in all three presented papers. Each article brings at least one novel approach / finding which have not been mentioned in the literature before. Therefore this dissertation is a singular piece of work and enhances existing cognizance in this field.

Visual impact of wind turbines is the most significant factor perceived by public next to other environmental concerns, e.g. impact on wildlife, noise annoyance (Pedersen, 2008) etc. In particular, influence on landscape aesthetics has been determined as a relevant reason for public negative attitudes to proposed wind farms (Kontogianni et al., 2014; Lothian, 2008; Molnarova et al., 2012; Wolsink, 2002, 2007). Wind turbines' main characteristics are their number and associated construction height, and distance from the observer or vantage point. Some studies have focused on effect of WTs number placed within the landscape in terms of replacing smaller wind turbines by less large wind turbines (Ladenburg et al., 2012; Moller, 2005; Warren et al., 2005). Beside, only few studies have analysed the distance threshold (Bishop, 2002; Molnarova et al, 2012).

First study **'Wind turbines location: How many and how far?'** has analysed all three aspects: number of WTs, distance from the observer or vantage point, and landscape quality. Such detailed analysis has not been made before. Although each of the physical attributes has been tested separately and affirmed to be a significant factor, there was still a lack of dimensional research on consistent evaluation of these attributes. The study´s methodology uses comprehensive statistical analysis to explain various situations. Accordingly, the goal was to verify and furthermore specify the effect of distance from the observer or vantage point and number of WTs located in various landscapes (types) on the perception of those landscapes (with and without WTs).

The study was continuously designed on the model of three tested photographs used in previous research by CULS (Molnarova et al., 2012). These images presented three types of Czech landscapes, with various natural features and human impact. The perceived attractiveness of each landscape (type) was affirmed at the same level as evaluated in previous research. This study furthermore extended visualised photographs with added more WTs. Whilst study by Molnarova et al. (2012) used visualised one and four WTs in two distances for each image, our study made much more comprehensive WTs application. For the analysis of distance thresholds one WT was visualised in 7 distances (0.75 km, 1.5 km, 3 km, 5 km, 7.5 km, 10 km, 15 km). The number of WTs was selected in six types of group (1, 5, 10, 15, 20, 25) in two distances of 1.5 km and 5 km. Such amount of visualisation allowed gaining detailed evaluation of each situation.

The results and methodology of this study can make a essential contribution to reducing negative visual impact in the WT planning process. To achieve higher public support, the placement of WTs must respect the aesthetic qualities of the landscape with consideration for its general character, natural and cultural attributes, observation points, and other factors. Observation points are important for people for enjoyments of scenic views, as confirmed by other study (Palmer, 2015). Landscape aesthetics was confirmed to be a substantial factor for public opposition (e.g. Lothian, 2008; Wolsink, 2007). This study furthermore revealed the possibility of destroying landscape aesthetics entirely by placing WTs. Visual preferences were after adding WTs evaluated higher for less attractive landscapes then the most beautiful one. Naturally, landscapes without added WTs were evaluated vice versa, according to their perceived ‘beauty’.

The study determined the interaction between landscape visual quality and distance. The visual impact of WTs in landscapes with high aesthetic values disappeared at a distance of around 10 km. In less-attractive landscapes with stronger human influences, this breakpoint was at around half that distance (about 5 km). The close proximity of WTs to any type of landscape was considered to be a very negative intrusion, regardless of the visual attractiveness of the landscape itself. The perceived landscape was overlooked by the dominance of WT structure in very close distance. Consequently, visibility zones were proposed to objectify the intensity of WTs’ visual impact on the landscape and thus to mitigate the visual impact of WTs as much as possible. The distance thresholds were proposed by only few studies till now. Bishop (2002) determined distances for a wind turbine with a 50 m high tower and a 3-blade rotor of 26 m long blades to be 10 km in ‘ideal’ conditions (clear visibility and stormy sky) and 6 km in prevailing conditions (slightly hazy, sky other than stormy). However, present WTs are now much higher, so these findings need to be updated to fit current development. The distance was predominantly set up in connection with measuring the level of noise. The crucial distance was determined in this manner 250 – 300 meters, but the visual impact according to our study would be very high at this distance.

The results of this study did not confirm the cumulative effects, which were expected for the high number of WTs placed in the scenes. We expected sudden changes in ratings, but the decrease was rather linear. Nevertheless, some authors found cumulative effects, mainly when respondents see WTs on a daily basis (Ladenburg et al., 2012; Ladenburg & Dahlgaard, 2012). Naturally, the number of WTs in a group was perceived more negatively in a close distance of 1.5 km compared to middle-range distance of 5 km. It also negatively influenced the high aesthetic value of the landscape in this close distance. This finding confirms again the locating of WTs to be unsuitable in attractive landscapes, especially in close distance to observation points.

Study findings extended the knowledge about wind turbines physical attributes, i.e. their number and distance from observer, and also landscape quality. As a first, it reported significant interactions between all three tested factors. Such detailed analysis enables to apply our methodology for visual impact assessment for other cases, using visibility zones. To get direct interactions between factors, we excluded respondents´ characteristics from statistical model as variables. Identification of respondent was included as a random factor.

Respondents´ characteristics were assessed as variables by the second study **‘How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process’**. In this study, physical parameters of wind turbines and landscapes were not identified as variables, though as a random factor. Four characteristics were analysed: general attitude toward wind energy, educational orientation, presence of WTs near respondents´ homes (up to 10 km) and willingness to live close to WTs. All tested factors were found significant. University students as groups of respondents reflected future possible WTs constructor and members of environmental authorities; see detailed explanation above in paragraph 5.2.

General attitude was confirmed to have essential influence on wind turbines perception, as reported by other studies (e.g. Jones et al., 2011; Molnarova et al., 2012; Walter, 2014). Our study as a first demonstrated strong interaction between general attitude and educational education. Whilst technically oriented respondents evaluated images with WTs at the same ratings regardless their general attitude, environmentally oriented respondents´ ratings were dependent on the general attitudes. Naturally, lowest ratings corresponded with negative general attitude, and vice versa. Such finding correlates with the study by Wolsink (2010) presenting different attitudes between environmentalists and government architect on proposed large wind park in protected area Wadden Sea in Netherlands. The influence of knowledge from a certain professional orientation on the perception of WTs is therefore evident.

Hence, the paper discussion proposes interdisciplinary courses in this area. These courses may provide technical knowledge to environmentalists and expand the knowledge of environmental issues among engineers and planners. To obtain basic environmental knowledge and recognize the landscape values which are often at risk of being disturbed by the construction of WTs, is important for planners to understand the situation. They should be able to judge at the very initial stage of planning whether a proposal will or will not be successful. At the same time, environmentalists can learn more about technological (and economic) considerations. Such thinking should teach both groups to understand the ‘other’ perspective and be able to do compromises. Study by Westerberg et al. (2015) demonstrates similar findings regarding the knowledge and education which increased visual preferences. Tourist community preferences for wind farms were likely to be influenced by the information they had on climate change and other environmental and economical impacts of wind turbines.

Interesting results were found for the interaction of general attitude toward wind energy and willingness to live near WTs. In our case, positive general attitude was entirely outweighed by unwillingness to live close to WTs. Even respondents with negative attitudes but willing to live close to WTs scored much better ratings. Such findings may imply to NIMBY syndrome which has not been proved by literature (Devine-Wright, 2005; Ek, 2005; Rygg, 2012; Wolsink, 2007, 2012). Literature found better explanation for such behaviour – the place attachment (Devine-Wright & Howes, 2010; Haggett, 2011; Hall et al., 2013; Jones et al., 2011; Lombard & Ferreira, 2014) or sense of identity (Horst, 2007). Nevertheless, the willingness to live close to WTs plays important role in decision-making process and WTs implementation. Our findings may be extended by later study focusing on reasons why respondents are not willing to live near WTs, e.g. noise annoyance, visual distraction and pollution, disruption os sense of place, other environmental impacts etc.

Who should be included in the planning and decision-making process? Our study, based on findings and experience, suggests including three groups of respondents to the planning process. The first group would consist of inhabitants living in the close proximity of the proposed wind farm location (i.e. within 1.5 km). Those are thus directly affected acoustically and visually by the WTs. Similar distance thresholds are reported by other studies, focused on visual and acoustic impacts (Gamboa & Munda, 2006; Pedersen and Larsman, 2008; Wolsink, 2000). The second group should include inhabitants of indirectly affected areas between ca 1.5 km and 10 km distant. This group then faced only to visual impacts of WTs (Betakova et al., 2015; Read et al., 2013). The third group should encompass respondents selected from vacationers and other occasional visitors to the assessed area. The study by Palmer (2015) confirmed large scenic impacts in evaluation of observation points often used by tourists. Research conducted in Latvia, for example, showed that visibility of WTs influences the willingness of tourists to visit recreation sites and impacts directly on their duration of stay Veidemane & Nikodemus, 2015).

What professional knowledge should the responsible employee of the planning and sanctioning public administration authority have in order to ensure that the proposal is assessed adequately and impartially? We tried to get more insight in this field and proposed recommendations based on our findings. First, we believe that such person(s) should have neutral general attitude. As stated before, general attitude has significant influence on the perception. So to assure objective assessment would be much easier with such attitude toward wind energy. Second, communication between developers and local communities should be mediated by such person, as representative of the sanctioning bodies. It would help to ensure transparency and more efficient planning of wind park construction. Communication and fairness has been designated as important factor by other studies (Aitken, 2010b; Horbaty et al., 2012; Jones et al., 2011; Wolsink, 2007).

Finally, higher ratings were found by respondents with positive general attitude who were living close to WTs. Beside, those respondents with negative attitude to wind energy and not living near WTs awarded the lowest ratings. It supports the hypothesis that people can get accustomed to WTs to a certain degree. This finding has also been demonstrated by other studies (Eltham et al., 2008; Warren et al., 2005). Our results may be helpful for assessing planned wind farm project in the vicinity of already existing one. For example, recent study by Frantal (2015) conducted in the Czech Republic also demonstrated that majority of local authorities and inhabitants were willing to support further wind energy development in their proximity.

In both papers **'Wind turbines location: How many and how far?'** and **'How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process'** we have evaluated the visual preferences for traditional wind turbines visualised within the landscape – specifically the Vestas 90 (height 105 m, rotor diameter 90 m) – which is typical horizontal axis WT with three blades, the most frequently used type. In first research we have analysed preferences according to physical attributes of WTs and in a second one the preferences influenced by respondents characteristics. Our findings and conclusions evoked to make a survey of alternative wind turbines to HAWT and search in the market if another solution existed. Some currently used prototypes were found and applied.

The third paper entitled **'Futuristic Wind Power Systems Suitable as Artistic Sculptures'** analysed WT type so-called wind concentrator exploiting the Venturi effect, which is accelerating wind in the channel. These devices can be also identified as channel (or funnel) based wind turbines. Research through current market found five operating or testing wind turbines by private companies, alphabetically named: the BAT, Flo Design, Invelox, Next-Gen Wind, and Wind Tamer. Although there are just few of them in operation nowadays, the principle of its structure can be used in further architectural designing. This is a first report dealing with such topic and what is more exciting, giving some visual proposals for future look of these devices. I put together the technical information of wind turbines types, also promoted by examples from historical development, and my personal architectural approach and ideas.

The literature has established HAWT type with three blades as the most efficient wind device (Manwell et al., 2009). Although other types are being tested, the boom of new alternative WTs has not come up yet. The experienced efficiency and reliability make important pros to continue with traditional WT technology. On the other hand increasing public opposition and visual impact may play a role in rethinking the current adjusted methods of applying wind energy development. These alternative WT may start with minor developments for small municipalities or entities on much smaller scale. The architectural design is based on simple idea, as the rotor is placed inside the structure (in the channel), the exterior can be adjusted according to the place, needs, symbolic and other aesthetic requirements.

Renewable energy production, in particular wind energy, does not just present the system of “build and produce” without site-specific solutions to mitigate their visual character in the landscape and surroundings. Mastering the impacts upon landscape character should be considered distinctive for such structures, as suggested by developed methodology for Czech Republic (Vorel et al., 2006). Channel-based turbines have many advantages, relative to the design variability and site accommodation. Thus they can be used to create effective economical and aesthetically attractive systems with a variety of benefits specific to their aesthetics character upon landscape (Nohl, 2001). However, the total energy output may not be on par in comparison with traditional wind turbines at this stage of their engineering evolution. Nevertheless, the critical factor to remember is that a device designed in accordance with the surrounding landscape can find its appropriate utilization.

To connect engineering and art pieces is always very exciting task. ‘Go Green’ movement drives the exploring a confluence of art and engineering. For example, Sarangan et al. (2015) presented design for any aesthetic lightening for outdoor installation, with solar powered LED lightening system. These small technological innovations, connecting of something aesthetically pleasant, powered by RES may step by step become important part of electricity-grid network system. My paper presents new dimension for artistic performance. Artistic sculptures are popular to be installed on squares, promenades or in parks in the cities. Designs presented show that such art pieces can provide multiple services: the production of energy while also allowing people enjoy and admire the artistic installation. People may not even realize the wind power generation hidden in the structure. Thus, artistic performance will have new dimension: the visual beauty that brings ‘clean’ energy; and thereby contributes to the reduction of pollution. First, air pollution often associated with coal-fired power plants. And second, visual pollution associated with traditional wind turbines. The main functions of such artistic sculptures will be not just aesthetic, but also industrial.

The paper also emphasises the design in accordance with nature and symbolic proposals. The coherence with landscape, for example, has been reported as a predictor of scene attractiveness by Van der Jagt et al. (2014). The system could be incorporated into existing historical towers, or even build as a new one in alliance with cultural attributes. The retrofitting to existing structures might help reducing the cost expanses for construction, as once the load-bearing structure is standing. The same principle was presented at Fabos conference (Betakova, 2016). Especially within Czech Republic territory there many abandoned industrial parks, usually with some high towers, e.g. park near Frenstat pod Radhostem, used for mining (Betakova, 2016). The installation of wind power into such structures and adjusting the exterior look may bring a life to the area again. First, by attracting people as a new touristic attraction in the place. Second, by producing ‘clean’ energy and supplying local electricity network. And third, by proposing a solution what to do with such unused large parks and areas which none uses.

Symbolic meaning is important for all cultures and countries. What would be Paris without Eiffel tower, Tehran without Azadi Tower or Liberec without Jested Tower? We accept such symbolic elements as an inherent part of the city, state, region, culture. I propose that even wind turbine can have such a meaning. Of course, traditional turbines play opposite role because of their visual impact caused by enormous size, characteristic appearance, large numbers and usually impropriate scale to surroundings. Such symbolic memorials, towers, statues and sculptures, with the addition of wind power generation could become a visually sustainable model for electrical energy generation. It can raise the public acceptance of wind turbines in general and improve knowledge and awareness of RES, their advantages and energy consumption globally.

It will be long journey of testing, improving, negotiation with people and authorities. I believe that connection of art and energy production, aesthetic and wind industry has a potential and we will see some exciting installations in the future.

6. CONLUSION

Wind energy has been generally accepted as one of the most environmentally friendly solutions for electricity production. However, as any other renewable energy technology it has pros on one hand and cons on the other. There are environmental issues which has been discussed within the literature, i.e. influence on climate and its changes, impact on wildlife (especially avian and marine fauna), noise annoyance to human or animals, other environmental impacts (loss of habitat, deforestation etc.). Nevertheless, the greatest reason for constructing less wind parks than planned by governments and developers is the public opposition, predominantly caused by visual impact. Positive general attitude toward wind energy vs. local rejection may now sounds as a cliché; most of the literature starts with such statement.

But still, according to older (Bell et al., 2005; Bishop, 2002; Devine-Wright, 2005; Ek, 2005; Warren et al., 2005; Wolsink 2000, 2007) as well recent studies (Brennan & Van Rensburg, 2016; Ek & Persson, 2014; Jones et al., 2011; Meyerhoff, 2013), local acceptance seems to be a breakpoint in development. This work suggests at once three improvements or opportunities to help higher public acceptance. First, how to assess wind turbines suitability within the landscape, based on visibility zones, landscape quality assessment and considering the physical attributes of WTs, i.e. number and distance. Second, how to improve respondents´, sanctioning authorities´ and planers´ knowledge regarding environmental and technical issues via, for example, interdisciplinary courses. Third, how to propose alternative visually attractive solutions which may attract much more observers and raise public enjoyment of wind energy.

The landscape quality including aesthetic, natural and cultural values should be assessed before any wind energy development is planned. Landscape type was confirmed by our study to be significant factor in relation with numbers of WTs and also distance from observer. Even attractive landscapes could be perceived after placing certain number of WTs as less attractive than those which are not valued that much. Such careless planning can lead to complete degradation of protected areas. Similar approach was reported by Wolsink (2010). On the other hand, placing WT in very close distance, i.e. ca 500 m, may be disturbing in any type of landscape. So the distance, also in relation with WT numbers, is an important factor to be considered. Proposed visibility zones by our first study will differ in distance thresholds just according to evaluated landscape quality (and WT technical parameters, i.e. height).

Planning of wind energy development and decision-making process may be improved by higher knowledge regarding the environmental and also technical issues. Complex education and knowledge is important either for planners and engineers, and also members of sanctioning bodies. Straight technically or environmentally oriented thinking will be likely causing conflicts between involved parties. Beside, general attitude toward wind energy has been determined as one of the most significant respondent characteristics, also reported by other studies (e.g. Jones et al., 2011; Molnarova et al., 2012; Read et al., 2013; Walter, 2014). It has influence on possible accommodation to wind energy implementation. But even respondents with positive attitude toward wind energy can be greater opponents just because of their unwillingness to live near a wind park. So the involvement o local inhabitants and municipalities, together with educational common ground of all involved parties and mutual communication will be necessary.

As visual impact is often mentioned in the literature as one of the most significant factors having influence on further development, other alternative and visually different WT types are not discussed at all. It is likely the tested efficiency and largely spread development of traditional wind turbines from HAWT family, which take all the attention. Hence, I put together materials for ‘wind concentrators’ found within the literature and also by search through current market options. Such turbines, also labelled as channel based turbines, have one great advantage over other WTs. Whereas the rotor is placed inside that channel (funnel), the exterior can be designed and adjusted according to the requirements and conditions of the place and other context. To design exterior of such technical device gives us an opportunity to combine the aesthetic and industrial function.

Concluded, based on our findings and literature review, the visual impact causing public rejection and landscape aesthetic degradation has to be mitigated in some way. All conclusions summed up in this work are useful in this manner and can be applied in practical wind energy assessment.

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ATTACHMENTS

ATTACHMENT 1: Article 1 – Wind turbines location: How many and how far?

ATTACHMENT 2: Article 2 - How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process

ATTACHMENT 3: Article 3 - Futuristic Wind Power Systems Suitable as Artistic Sculptures

ATTACHMENT 4: Curriculum Vitae

ATTACHMENT 5: Publications

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Wind turbines location: How many and how far?

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HIGHLIGHTS

- Negative impact of wind turbines (WTs) diminished with distance from observer.
- Impact disappeared at 5–10 km with respect to landscape's aesthetic quality.
- Negative effects increased with number of WTs in an approximately linear manner.
- A cumulative effect of higher numbers of WTs was not confirmed.
- Distance and numbers interacted significantly with landscape aesthetic quality.

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ABSTRACT

Existing research relating to visual impact of wind turbines (WTs) affirms this to be an essential parameter for public acceptance in most cases as well as for the planning process and permitting of planned wind farms. This study brings new findings about the impact of two crucial factors: numbers of WTs (1–25) visible and distances of WTs (0.75–15 km) from the observer (e.g. from residential buildings, landmarks, observation points). Photographs of three aesthetically varying landscapes with various numbers of WTs (Vestas V90, height 105 m, rotor diameter 90 m) at various distances were evaluated in terms of visual preferences. The results show significant effect from the aesthetic value of a given landscape on the impact of both tested factors. An important finding is that the landscape with the highest aesthetic quality initially was evaluated to be the absolute worst after the addition of WTs and vice versa. Increasing numbers of WTs in the least attractive landscape had less visual impact than did doing so in the two more attractive landscapes. This helps explain strong public opposition to locating WTs in aesthetically valuable landscapes and their greater acceptance in less-attractive landscapes. Increasing stepwise from 1 to 25 WTs within a given landscape progressively decreased visual preferences, although the cumulative effect of a higher number of WTs was not confirmed. We also established threshold distances after which the negative visual impact of a WT disappeared (10 km for the most attractive landscape, 5 km for the least attractive one). Based on these findings, visibility zones were proposed for practical assessment of WTs' visual impact. The study's results can make a substantial contribution towards reducing negative visual impact in WT planning and thus achieving greater public acceptance of these devices.

1. Introduction

Visual impact has become the most distinctive among public perceptions of wind turbines (WTs), ranking higher than such other environmental concerns as the impact on bird populations [1] and noise annoyance [2]. According to the Ministry of the Environment of the Czech Republic, for example, 85% of proposed wind farm projects in the country have been cancelled due to their visual impacts. Despite the obvious importance of visual impact, public authorities still lack understanding regarding the inter-relationships between WT placement, landscape, and public perceptions.

Considering that rapid development of wind energy is one of the main means of reaching renewable energy targets and that negative public attitudes are emerging, there is a need for comprehensive research on visual preferences regarding wind turbines and associated influencing factors. Existing research findings on the visual impact of WTs indicate two general types of variable factors influencing the visual assessment of WTs. These can be termed "physical attributes" and "respondents' characteristics". Molnarova et al. [3] reviewed the main papers focused on visual assessment, and almost

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all of those studies allude to respondents' characteristics. Meanwhile, other factors have not yet all been rigorously evaluated. The main characteristics of respondents have been identified as socio-demographic (gender, age, education, general attitude towards wind energy), occurrence of WTs near the respondents' homes, daily contact with WTs [4], and prior experience with WTs [5].

In order to understand public behaviour, papers often refer to the phenomenon of NIMBYism (Not In My Backyard), which has been analysed due to the many cases of wind projects being rejected in certain areas [6–9]. This issue was reviewed by Petrova [10], who explained the reasons for opposition to establishing WTs. Petrova concluded that the NIMBY syndrome does not adequately explain visual and landscape concerns. Most often the reasons for opposition are aesthetic degradation and visual impact, in which cases it is more important to consider the affective and symbolic association of these structures with the landscape. The NIMBY effect has been the background motive for most research on WT acceptance, and it has consisted of case studies analysing the preferences for WTs already erected or for those planned in selected regions and comparing the evaluation of inhabitants living at various distances from wind parks [11–13]. In addition, recent studies have been based also on choice experiments whereby respondents select from several presented possibilities that option most tolerable for them with regard to their acceptance of new wind farms locations [14,15].

The major physical attributes of importance, meanwhile, include the characteristics of the WTs themselves (height, number, colour, rotor diameter and moving blades), landscape qualities, and distance from the observer. Specifically, distance from the observer means distance from such visually sensitive areas and structures as residential and recreation buildings, cultural features, and landmarks.

The research has quite often taken into consideration awareness of the imposing size and height of these structures. The height factor has been analysed in most studies, predominantly with an emphasis on cumulative effect and interaction with numbers of WTs. Warren et al. [16] and Devine-Wright [8] found that the public has a clear preference for smaller wind farms, even if this means having more than one wind farm in a given locality. Moreover, people prefer reducing the number of turbines by replacing smaller turbines with larger ones even though larger ones might be visible from a larger number of residences [4]. Other results show a less positive attitude for more than five on-land turbines and a cumulative effect for five turbines encountered per day in long thresholds [17]. Research in Denmark demonstrated similar findings. Replacement of 400 old turbines with 50 new, larger ones did not increase the overall visibility of wind turbines in the region. Long-range visibility caused by the smaller turbines was reduced while the short- to middle-range visibility of the large turbines was amplified [18].

Compared to the amount of research done on numbers of wind turbines, only a few studies have so far evaluated the distance factor as a visual threshold. Moreover, the results for those studies are diverse and no clear conclusion for the role of this attribute has yet been established. Research in South Australia, for example, did not substantially prove a reduction of negative visual effects of a wind farm with greater distance [19], whereas research in the Czech Republic showed a positive relationship between visual preferences and increasing distance [3]. A recent study by Vries et al. [20] found that distance decay of impacts is stronger for barns and business parks than for turbines. The maximum distances at which wind turbines can still be distinctly perceived (in this case a wind turbine on a tower 50 m high with a 3-blade rotor having blades 26 m long) were determined by Bishop [21] to be 10 km in "ideal" conditions (clear visibility and stormy sky) and 6 km in prevailing conditions (slightly hazy, sky other than stormy). In view of their rapid development and increasing size, turbine towers 100 m tall are today considered to be usual, and so the relevance of these findings may not fit the current state of the art. A usual methodology for assessing the impact of vertical structures on landscape character takes an approach similar to that of visual thresholds and barriers to determine the so-called Affected Landscape Area. Application of the methodology involving visibility zones as a general approach could be used in any situation [22]. Other studies detecting the visibility are using, for instance, GIS methods [23,24] or other visibility software [25]. Although the distance factor remains an open issue in relation to visual assessment of wind parks, it is a factor needing to be incorporated into research with a detailed focus on determining thresholds and its relationships to other factors.

The public perception of WTs might be influenced by such other attributes as the aesthetic and visual quality of the landscape where they are to be located. Type of landscape has been determined to be an important factor in visual assessment of a landscape in which a turbine is situated [26], although just a few papers have verified this affirmation. Research in the Netherlands has unambiguously shown minimal acceptability for turbines in wetlands of a natural protected area, that landscapes with mountainous morphology and natural elements are considered to be more beautiful, and thence that siting the structures in such areas would be less welcome [27]. Similarly, research in South Australia has tested 68 coastal and inland locations where wind farms could be located, both without wind farms and with wind farms digitally added to the scene. Wind farms were generally viewed as having a negative effect on landscapes of higher scenic quality but a positive effect on landscapes of lower scenic quality. The study concluded that wind farms should avoid areas of higher perceived scenic quality, particularly on the coast, and be located in areas of lower scenic quality [19,28]. Research in the Czech Republic has shown significantly stronger preferences for wind turbines in landscapes of low visual quality than in visually attractive landscapes [3,29]. Vries et al. [20] confirmed that wind turbines have always had a considerable negative impact on scenic beauty, especially when the landscape is considered to be very attractive.

Although each of the physical attributes distance from the observer, number of WTs, and type of landscape has been tested separately and affirmed to be a significant factor, there is still a lack of dimensional research on consistent evaluation of these attributes. In order to understand the interaction between these factors, research needs to be undertaken which uses comprehensive statistical analysis to explain various situations which can be very changeable. A proposal that might be accepted in one type of landscape, for example, might be rejected in another one. Consequently, the goal of the present study was to verify and furthermore specify the effect of distance from the observer and number of WTs located in various landscapes on the perception of those landscapes. Regarding distance from the observer, the aims were to (1) establish whether and how the impact of increasing distance on visual preferences of landscapes changes, and (2) determine distance thresholds after which the negative visual impact of WTs disappears. In terms of WT numbers, the aims are to (3) find out how increasing numbers of WTs influence the visual preferences of landscapes, and (4) establish if the cumulative effect could be affirmed from the perspective of visual preferences, which could abruptly decrease the visual preferences beyond a certain number of WTs. An additional objective of this study was to (5) analyse the effect of interaction between number and distance of WTs on visual preferences of aesthetically varying landscapes.

2. Materials and methods

2.1. Study design

The study examined visual preferences for three different landscapes (A, B, and C) of varying aesthetic quality. It was designed to collect new data determining the effects of WT distance from the observer and of the number of WTs. Photographs used in the survey were taken with a digital camera having a basic focal length of 50 mm during a summer day with clear weather conditions. For the photomontages, Adobe Photoshop was used to digitally add to each image one of the most common types of WT recently being setup in Central Europe – the Vestas V90 (with hub height 105 m, rotor diameter 90 m). Examples of several situations with and without WTs are shown in Fig. 1. The positions of the blades were rotated differently in order to obtain a realistic photomontage. Evaluation was setup using a 15-point assessment scale from +7 to −7, with 0 representing a neutral attitude, "+7" the most positive one, and "−7" the most negative attitude. Simple questionnaires were developed for respondents to fill in a rating value for each correspondingly numbered picture. The choice of rating value was intended merely to answer the question, How do you like this picture?

To examine all three factors (distance of WTs from the observer, number of WTs, and landscape visual quality), the research was divided into two experimental parts. The goal of the first experiment was to analyse visual preferences for distance of a WT from the observer (Fig. 1b–e shows examples of WT added at several distances). For this purpose, one single turbine was digitally added to each image at several distances: 750 m, 1.5 km, 3 km, 5 km, 7.5 km, 10 km and 15 km. This made a set of 21 modified photographs (3 × 7) plus 3 unedited photographs in order to have an evaluation of the turbineless landscape for comparison. The selected distances reflected an established methodology for impact assessment on landscape character [22] and previous research undertaken at Czech University of Life Sciences [3]. The second experiment focused on the number of turbines (1, 5, 10, 15, 20, and 25), which were visualised at distances of 1.5 km and 5 km and always with turbines 300 m apart from each other (Fig. 1f–i). This consisted, then, of a set of 36 photographs (2 × 3 × 6) plus 3 photographs without turbines. The chosen numbers of WTs correspond to the arrangements of existing wind farms in the Czech Republic [30,31] and other countries [4,18]. The distances of 1.5 km and 5 km represent short-range and middle-range distances [3,21], for which strong and middle-strong visibility for the turbines was presumed.

The photographs were randomly ordered in both sets to avoid their presentation from the least number of WTs to the most, as well as from the closest to the furthest, as that could lead to a poorer evaluation caused by the "growing effect". Simultaneously, the pictures of landscapes with no turbines were randomly placed within each set. Images were evaluated by two relatively homogenous groups of respondents, both composed of university students. Whereas the first group was made up of students from biological and

Fig. 1. Example photographs used in the survey. Image a. is an unedited photograph of landscape A. Images (b–i) – present examples of adding wind turbines (WTs) to the starting image. Image (b). – landscape B with one WT digitally added at a distance of 0.75 km. Image (c) – landscape C with one WT digitally added at a distance of 1.5 km. Image (d) – landscape A with one WT digitally added at a distance of 5 km. Image (e) – landscape B with one WT digitally added at a distance of 10 km. Image (f) – landscape C with five WTs digitally added at a distance of 1.5 km. Image (g) – landscape A with 25 WTs digitally added at a distance of 1.5 km. Image (h) – landscape B with five WTs digitally added at a distance of 5 km. Image (i) – landscape C with 25 WTs digitally added at a distance of 5 km.

ecological programmes at Czech University of Life Sciences, the second group comprised students in civil engineering and technical programmes at Czech Technical University. The survey was undertaken in 2013. Images were projected onto a screen in a lecture hall to groups of students totalling 169 respondents. In order to ensure an equal response time for the pictures, each image appeared on the screen for precisely 10 s.

The photographs of the landscapes were selected to reflect varying aesthetic and visual quality. Landscape A is a part of the České Středohoří Protected Landscape Area, characterised by typical mountainous terrain, treeless hills, a high proportion of natural elements, rich land cover in its comparatively small scale, and minimal human impact. The land cover consists of several types of small-scale vegetation which compose a visually contrasting mosaic in colour pattern and attractive scenic view. Landscape B is located around Želiv, Central Bohemia. It has an intermediate scale and combines agricultural and forest landscapes with less distinctive morphology. There are greater human influences, but these are still in balance with the natural elements. Land cover is defined by larger fields, meadows and forests. The mosaic is less rich in vegetation types. Landscape C, around Neratovice, Central Bohemia, is intensively exploited lowland dominated by human impact and man-made structures and with a relatively low presence of natural elements. Land cover consists predominantly of large fields and urbanised area. There is rather little variation in contrast and colour, and so the impression is rather monotonous and featureless.

2.2. Data processing

The effect of one WT placement at various distances from the observer on landscape perception (the goal of the first experiment) was analysed using generalised linear mixed models (GLMM). These models work with two types of categorical explanatory variables – those with fixed and random effects. In our study, the variable with random effects is the identification of the respondent (see below). To avoid pseudoreplication, GLMM should be used in experiments with temporal or spatial correlation in the data or in cases (as in our case) of repeated measurements [32].

Within GLMM, we used the *glmer* function, which is a part of the *lme4* package of R statistical freeware, version 2.15.0 [33]. Each respondent provided ratings of 24 photos (seven distances plus a control landscape without any WT for each of the three landscape types). Landscape perception (i.e. respondents' ratings of the photos; $n_{\text{resp.}} = 169 \times 24$ ratings = 4056 rows) represented in our model a semi-quantitative response variable on a 15-point assessment scale (from -7 to +7, including zero). This variable was converted into a variable with a binomial distribution comprising two vectors – the real landscape assessment value of each respondent and the supplement to the maximum evaluation value. For example, if a certain landscape assessment by any person was +5, the supplement to the maximum evaluation (+7) was 2. The value +5 represents here success, i.e. how the particular respondent liked the landscape, and the supplement 2 represents failure (the higher this value, the lower is the assessment). Likewise, if the respondent gives an evaluation of -2, the supplement is 9. Following the rules for modelling with binomial errors (according to Crawley [32]), we used the cbind function and bound together the two aforementioned vectors of the response variable into a single object *y*. This object *y* was then used in GLMM analyses as the response variable with a binomial distribution. The distance of WTs from an observer, as the quantitative variable (seven distances and a control landscape), landscape type (nominal variable with three levels – landscapes A, B and C), and the interaction between these two variables comprised the explanatory variables in our model. As mentioned above, each respondent evaluated 24 different photographs. To avoid pseudoreplications, the identification of the respondent was included as a random factor in the model and GLMM were therefore used. Using GLMM and the identity of respondent as a random factor, we also solved the potential problem of differing evaluation among respondents according to their school and other characteristics.

Table 1
Effect of wind turbine (WT) distance, WT number, type of landscape, and interactions of these variables on landscape perception. All assessed variables were found to be significant.

Variable	χ	df	p
Number of WTs	2047.20	1	$<10^{-6}$
Distance of WTs	1081.30	1	$<10^{-6}$
Landscape	69.51	2	$<10^{-6}$
Landscape: numbers	155.29	2	$<10^{-6}$
Landscape: distance	73.19	2	$<10^{-6}$
Distance: numbers	9.64	1	0.002

To analyse the interaction between the distance and number of WTs (second experiment), we used the same statistical procedure as in the first experiment (i.e. GLMM with the respondents' ratings as response variable). The distance of WTs from the observer (1.5 or 5 km, nominal variable) and the number of WTs (1, 5, 10, 15, 20 or 25, quantitative variable) constituted the model's explanatory variables. Because the experiment was run with three landscapes (A, B and C), the effect of landscape type and all possible double interactions, including the target interaction between the distance and the number of WTs, were also analysed (Table 1).To avoid pseudoreplication, the identification of the respondent was again included as a random factor in the model.

The significance of each explanatory variable in both models was analysed by deletion tests, using backward selection procedure. The final models, consisting of only significant variables, were checked in the end using standard statistical diagnostics [32].

3. Results

3.1. Effect of WT distance

In the first experiment with one WT situated at different distances, we found that the distance of WTs from the observer significantly affected the perception of the assessed landscapes ($\chi = 870.25$, df = 2, $p < 10^{-6}$). The farther away the WT was situated, the more positive was the image's evaluation. Those landscapes without any WT were assessed with the highest ratings. Since the experiment was deliberately performed using three different landscapes (A, B, and C), we also analysed the interaction between the distance variable and the type of landscape. We found that the perception of a WT varied at different distances according to a landscape's aesthetic quality. Whereas the perception of WTs at different distances was similar for landscapes with high aesthetic quality (A and B), and with a positive effect of increasing distance, the perception of WTs in a less-attractive landscape with stronger human impact (C) was less influenced by distance. The difference in evaluation between photographs with WTs at the closest (750 m) and furthest (15 km) distances was more than twice as great for landscapes of higher aesthetic quality ($A_{\text{dif}} = 7.17$, $B_{\text{dif}} = 7.00$) compared to the unattractive landscape with distinctive human influence ($C_{\text{dif}} = 3.28$).

Images of landscapes with one WT at a distance of 750 m were perceived very similarly, regardless of the aesthetic quality of the landscape (mean evaluation: $A_{0.75\text{km}} = -2.67$, $B_{0.75\text{km}} = -2.92$, $C_{0.75\text{km}} = -2.79$). The perception of landscapes with the WT at a distance of 1.5 km was substantially more positive (around 2 points higher for all landscapes) compared to the closest distance

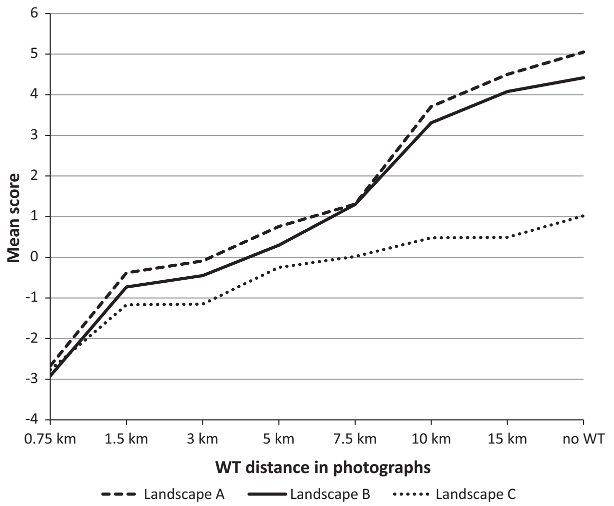

Fig. 2. Effect of distance from observer of a single wind turbine (WT) on perception of a landscape. At right of horizontal axis, "no WT" refers to the reference value for a landscape without WT.

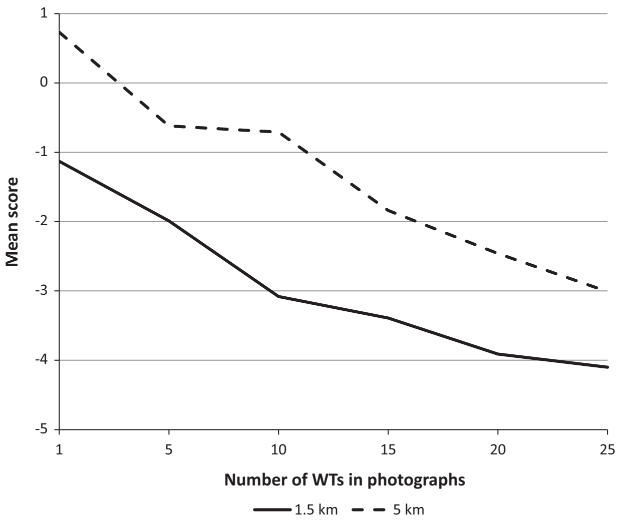

Fig. 3. Interaction plot of distance and numbers of wind turbines (WTs) showing different perception scores (mean score, vertical axis) for various numbers of WTs (number of WTs in photographs, horizontal axis) at two assessed distances from the observer (1.5 and 5 km).

of 750 m. The more attractive landscape had concurrently greater improvement in its perception (Fig. 2). The evaluation of landscapes A and B increased rather slightly between 1.5 and 7.5 km with the distance of the WT, but a major shift in the perception of landscapes with the WT (A and B) occurred in between the distances of 7.5 and 10 km. At that distance point, the scores for both landscapes A and B amplified sharply. Regarding landscape C, this shift is less evident and can be distinguished at a closer distance, between 3 and 5 km. The evaluations of all landscapes with one WT at distances of 10 km and greater very closely resemble the assessments of the landscape without WT (Fig. 2). We concluded that from the visual point of view one WT ceases to reduce visual preferences beyond a distance of 10 km for higher-quality landscapes (A and B), whereas for the less-attractive landscape C this point is even closer, around 5 km.

3.2. Interaction between distance and numbers of WT

Whereas the first experiment analysed the impact of distance for one WT, the goal of the second experiment was to test the interaction between WT distances from the observer and number of WTs. Therefore, we assessed the perception of various numbers of WTs (1, 5, 10, 15, 20 and 25) at two distances (1.5 and 5 km).

The impact of WT distance on the evaluation was highly significant (Table 1). Regardless of their number, WTs were perceived at a closer distance (1.5 km) more negatively ($\text{mean}_{1.5\text{km}} = -2.93$) than at a distance of 5 km ($\text{mean}_{5\text{km}} = -1.33$). The impact of WT number was the most significant of the tested variables, irrespective of distance from the observer. The higher the number of WTs, the more negative the score (Table 1, Fig. 3).

We also found the interaction between numbers of WTs and distance to be significant (Table 1). Visual preferences diminished with increasing numbers of WTs at both tested distances. This diminution did not have a uniform character (Fig. 3), however. At distance 1.5 km, the score's decrease was steady and relatively steep from 1 to 10 WTs. When the number of WTs was greater than 10, the decrease was less striking. In particular the evaluation of 20 versus 25 WTs did not essentially differ ($\text{mean}_{20\text{WT}1.5\text{km}} = -3.91$ vs. $\text{mean}_{25\text{WT}1.5\text{km}} = -4.10$). In any case, WTs from 10 and up were perceived as a significant source of deterioration at such a close distance. A different situation existed, however, for the distance of 5 km. In this case, the most significant decrease in the evaluation was determined already between 1 and 5 WTs, while the ratings between 5 and 10 WTs did not really vary statistically ($\text{mean}_{5\text{WT}5\text{km}} = -0.62$ vs. $\text{mean}_{10\text{WT}5\text{km}} = -0.71$). Somewhat in contrast to the nearer distance, the following increase in WT number up to the maximum tested amount of 25 WTs led to a relatively steady and steep diminution in score. Although lower numbers of WTs (between 5 and 10) could be perceived rather equivalently at the further distance, the increasing number of WTs up to 25 was nevertheless discernible (Fig. 3).

3.3. Effect of landscape aesthetics

All three landscapes (A, B, and C) were assessed differently (Table 1), and furthermore this evaluation varied if WTs were or were not situated in the landscape. The assessment of photographs with WTs –regardless of their number and distance from the observer – was the most negative for the most attractive landscape A having the most natural character ($\text{mean}_{\text{A\_WT}} = -2.42$). The other landscapes B and C with WTs added were evaluated very similarly (respectively, $\text{mean}_{\text{B\_WT}} = -1.98$ and $\text{mean}_{\text{C\_WT}} = -2.00$). An entirely different situation occurred in assessing landscapes without WTs, wherein landscape A had the most positive score ($\text{mean}_{\text{A}} = 5.52$). Landscape B also had a highly positive score ($\text{mean}_{\text{B}} = 4.83$), whereas landscape C (the least attractive one) without WTs had a substantially lower score ($\text{mean}_{\text{A}} = 1.93$). The location of WTs was crucial in our findings since the greatest visual impact of WTs on landscape aesthetics was demonstrated in attractive landscapes with natural character, where the decrease of aesthetic evaluation was the most significant (Fig. 4). In contrast, the aesthetic deterioration was much less for landscapes which were not considered to be particularly attractive to begin with.

The landscape aesthetic quality was also determined to be an important factor in interactions with the number of WTs and distance from the observer (Figs. 5 and 6). Our findings show significant interaction between landscapes and distance (Table 1). WTs (regardless of their number) at a closer distance of 1.5 km are perceived as especially disruptive in the most attractive landscape A, while the evaluation of WTs for the other two landscapes (B and C) was similar and less severe (Fig. 5). At a distance of 5 km, the difference in perception according to the landscapes' aesthetic quality was not very pronounced. The results also implied a

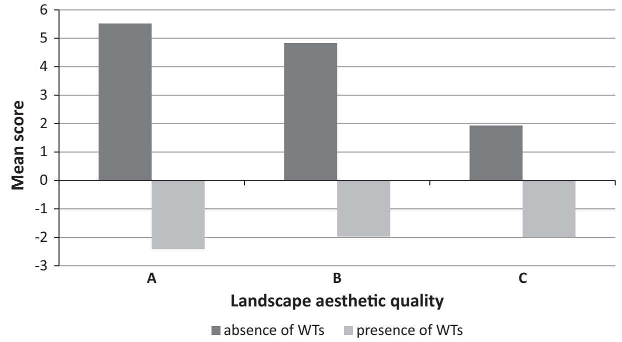

Fig. 4. Perception (mean score, vertical axis) of three assessed landscapes (landscape aesthetic quality, horizontal axis) according to the absence (dark grey columns) and presence (light grey columns) of wind turbines in the photographs.

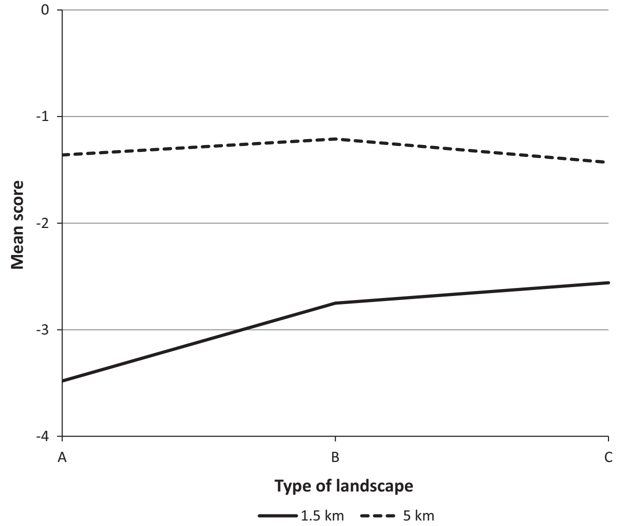

Fig. 5. Interaction between landscapes (landscape aesthetic quality, horizontal axis) and distance of wind turbines (1.5 and 5 km) from the observer.

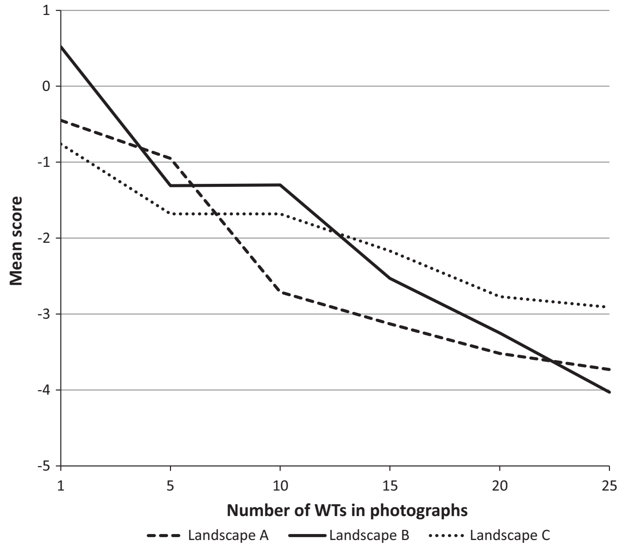

Fig. 6. Interaction between landscapes according to their aesthetic quality and number of wind turbines (number of WTs in photographs, horizontal axis).

difference in perception between distances of 1.5 and 5 km (regardless of the number of WTs). This difference was greatest for the most attractive landscape A ($A_{dif1.5\_5km}$ = 2.12), lower for B ($B_{dif1.5\_5km}$ = 1.54), and lowest for the least attractive landscape C ($C_{dif1.5\_5km}$ = 1.13).

The interaction of WT number and landscape aesthetic quality (regardless of the distance) was likewise significant (Table 1). The decrease in evaluation with increasing number was evident for all tested landscapes, although this trend was seen to differ substantially depending upon the landscape type (Fig. 6). The greatest difference in landscape perception with the lowest (1) versus highest (25) number was found for landscape B (B_{dif1_25WT} = ca 4.55). This different was smaller for landscape A (A_{dif1_25WT} = ca 3.28) and least of all for landscape C (C_{dif1_25WT} = ca 2.15). Increasing numbers of WTs thus had the lowest visual effect on the perception of the least attractive landscape having higher human impact and fewer natural elements.

4. Discussion

This study's results indicate a significant impact of all tested factors (i.e. number of WTs, their distance from the observer, and the aesthetic quality of a landscape) on visual preferences. From our earlier study [3] and other studies [21,34,35], it is apparent that these attributes are crucial factors in most situations regarding public acceptance of WTs. The aim of this study was not just to replicate earlier research, however, and thus to reconfirm this determinative impact. Rather, it was to quantify ranges of these factors and, if possible, to establish their threshold values.

4.1. Effect of WT distance and visibility zones

In the case of a single WT placement at distances of 750 m to 15 km from the observer, landscape attractiveness was continuously reduced for each evaluated photograph. The closer the WT was situated to the observer the lower preferences which were found for this landscape. However, this gradient was not wholly linear.

An interesting finding concerns the perception of a WT at a distance of 750 m in all evaluated landscapes. Although the evaluation of landscapes with WTs at greater distances was significantly different for the more attractive landscapes (maximum scores +4.4 and +4.3 for A and B, respectively) and the less attractive one (maximum score +0.2), it essentially did not differ at the shortest distance (ranging between −2.7 and −2.9). These results confirmed the dominance of such a closely situated WT in any landscape. The WT's proximity and its location in the foreground of the evaluated photographs fundamentally disturbed the scale of the presented landscape in terms of the relationship between the WT with other landscape features [10]. The visual value of a landscape in the background of a picture and its attractiveness were thus eliminated. With slight exaggeration, regarding short distances we can speak about the evaluation of "a wind turbine with surrounding landscape", whereas at long distances it is an evaluation of "a landscape with wind turbines".

We detected more significant changes for all three landscapes, especially between the distances of 1.5 km and 750 m, wherein WTs situated closer to the observer caused a significant decline in visual preferences. In the case of the two visually more valuable landscapes A and B, a similar steep gradient was also detected between the distances 7.5 and 10 km. Otherwise, steep gradients in visual preferences evaluation were indicated at the nearest (for all landscapes) and at the furthest (for the two more attractive landscapes) distance at which the visual impact of WT was perceived. At middle-range distances, the gradient was more gradual.

This finding can correspond with a general ability sensitively to assess outer distances (either close or near) but a lesser ability to detect differences at middle-range distances [18].

Whereas all landscapes with WTs are perceived at close proximity very similarly, the visual impacts at distances further from the observer differ more distinctly. The negative impact of WTs fades out around 10 km distant for landscapes A and B, and in the case of the less-attractive landscape C this occurs already around 5 km. This indicates that WTs situated in landscapes considered to be less attractive reduce visual preferences for these landscapes much less, and this decrease was noted at just half the distance. A WT does not in less-attractive landscapes appear to be such an intrusive element in contrast to its surroundings, and at distances greater than 5 km its visual impact more corresponds with those of other landscape features. The observer can see the WT at this distance, but the visual impact is not determinative for the evaluation of the landscape scene. In contrast, a WT located in an attractive landscape of high aesthetic quality, and one regarded as more natural, acts as an extraneous and contrastive object and visual preferences are reduced by more than twice as much. That negative effect, meanwhile, is still perceived at up to twice the distance.

These findings will be useful for spatial planning of WTs as they can be used to determine circular visibility zones within which the intensity of WTs' visual impact differs and that impact is evaluated more or less profoundly [22]. From this viewpoint, the differentiated evaluation of visually affected landscapes can be defined in two or three visibility zones, as demonstrated in Table 2. Within zones thus identified, it is possible to classify in detail those landscape characteristics which might be negatively affected by WT placement. The effect on natural or cultural qualities of landscape will be more negative in a zone of strong impact than in zones of middle or weak impact. The level of WT impact can hereby be objectified depending on the distance of the evaluated area from the typical observer.

This spatial differentiation of affected landscapes is similarly supported by the work of other authors [22], although their approach to delineating visibility zones is based on subjective albeit expert estimates. In the manner of delineation discussed above, the resulting delineations are determined via quantitative analysis. We should emphasise, however, that the size and design of the WTs may well constitute an important variable. Our experiment involved a WT size (105 m high, 90 m rotor diameter) and type which is among the most frequently erected in Central Europe. Had the data been collected and processed regarding WTs having distinctively different parameters, then the results could have been different. Our specific findings, conclusions and recommendations should therefore be taken and applied with due care and consideration.

4.2. Effect of number of WTs

The score of visual preferences was generally from 1 to 2 points lower in the case of close distance (i.e. 1.5 km) for different numbers of WTs. It can be assumed that this evaluation with increasing distance would further rise, as other studies can affirm [21,36] and would accord with our findings discussed in the previous section. The decrease from 3 to 4 points between the evaluation of 1 WT and 25 WTs for both tested distances (1.5 and 5 km) was roughly the same and substantial. Lower ratings for higher numbers of WTs have also been reported by other authors [8,16,17]. The reason for this lies in the increasing proportion of negatively perceived elements within the landscape. Common natural features and those associated with the cultural landscape are visually stifled due to the WTs' expression, and those features' replacement by unoriginal geometrical objects of such size disrupts the scale of the landscape [29]. With the sole exception of one WT at a distance of 5 km, the evaluation of all WTs at both distances had negative ratings. This shows the tendency usually to assess a landscape negatively if it has WTs present, and this result corresponds with the findings of other authors [3,20,26].

Table 2
Indicative delineation of visibility zones to determine the level of visual impact on landscape for wind turbine (WT) planning using circular diameter with the central point in the position of assessed WTs. The visibility zones are proposed for WTs with hub height 105 m and rotor diameter of 90 m.

Landscapes of	Landscapes of high aesthetic quality (km)	Landscapes of low aesthetic quality (km)
Strong impact	0–1.5	0–1.5
Middle impact	1.5–7.5	
Low impact	7.5–10	1.5–5

The results of our study reliably confirmed the presumption that an increasing number of WTs reduces visual preferences. This indirect dependency was affirmed regardless of the distance from the observer and separately at two tested distances. The decrease in preferences, however, had a different behaviour at each distance. Although the accretive number of WTs at a distance of 1.5 km reduced scores significantly at the beginning, with further WT additions the dynamic of the score reduction declined and the decrease in score stopped at about 20 WTs (in as much as a presence of 25 WTs was perceived more or less the same). The relative tolerance to increasing numbers higher than 10 WTs might be determined by the observer's weaker ability to recognise individual WT structures but rather to perceive them as a compact group [37]. With respect to WT size and close proximity to the observer, respondents had a diminished ability to distinguish the number of WTs or to perceive the size of the group. The higher numbers of WTs already covered most of the view for the observer of the photograph, and their changing amount was more difficult to detect.

The decrease in visual preferences at a distance of 5 km was in all cases steep, although that decline came to a complete halt between 5 and 10 WTs. Generally, compared to the closer distance, the trend of decreasing preferences at a distance of 5 km indicated the ability of respondents to recognise changing numbers of WTs in larger groups at this distance. The assessment of increasing number of WTs had always a lower score in visual preferences, regardless of the landscape visual quality.

This part of the research did not confirm our presumption that abrupt decreases in preferences for higher number of WTs could be expected due to the cumulative effect, whereby the observer would cease to perceive individual structures but rather see only a visually compact group. Such presumptions have been discussed in some cases involving practical assessment of WTs' visual impact [17,27]. While this trend was not affirmed at the distance of 5 km, in the case of distance 1.5 km the decrease in preferences for higher number of WTs even decelerated and nearly ceased.

4.3. Effect of landscape visual quality

The results from this part of the study indicate a very interesting phenomenon not previously reported in any other study. Three tested landscapes without WTs were ranked with statistical evidence in order from the most to least attractive (A – B – C) based on visually relevant attributes of the landscapes. In the case of assessing the same landscapes with the presence of various numbers of WTs (1–25), this rank order of evaluation was reversed. The visual preferences for the most attractive landscape A were the most reduced after one or more WTs were added to the photograph (decrease from +5.52 to −2.42), whereas the diminution for the least attractive landscape C after adding WTs was the lowest (decrease from +1.93 to −2.00). Furthermore, this finding entailed not just the highest relative decrease in landscape A's evaluation, but a decrease from absolutely highest rating to absolutely lowest.

Apparently, respondents evaluated negatively the contrast of WTs with the most attractive and natural landscape A. This contrast or unsuitability of WTs location in such landscape outweighed even the positive landscape attributes in the respondents' assessments and they tended to penalise such contrastive combination by giving it the absolute lowest rating. The effect of different landscape types was demonstrated especially at the close distance of 1.5 km, where the negative impact occurred especially in evaluating the most attractive landscape A. On the contrary, the impact at this distance was smallest in preferences for the least visually attractive landscape C. At this distance, the evaluation of three edited landscapes (with WTs) simulated the overall evaluation of landscapes with added WTs, meaning without difference according to distances. At a distance of 5 km, the distinctions between the assessed landscapes with added WTs were negligible. At this distance, further increasing the number of WTs in landscape C had relatively the smallest negative impact on its assessment.

Taken as a whole, these findings underscore the role of landscape type in the process of evaluating WTs' visual impact. This has been confirmed by other authors [9,19,20,26,27], who emphasise the role of landscape in assessing the placement of WTs. None of the cited papers, however, mention such a dramatic decrease in the relative and, in particular, the absolute scores for visual preferences in a landscape of high aesthetic quality. In assessing WTs' visual impact, therefore, it is important to evaluate carefully the visual quality of the landscape itself. In considering the suitability of landscapes for possible placement of WTs, it is necessary to protect especially the visually attractive and natural landscapes whose visual qualities could be the most degraded. Conversely, it makes sense to concentrate WTs in landscapes with low visual qualities and possibly in landscapes which already are influenced by other objects bearing negative visual impacts [19,27].

5. Conclusion

This study's findings and approach, in combination with earlier, case-type studies and their findings, should stimulate new thinking and approaches in assessing WTs and planning their placement while focusing attention upon WT number, WT distance from a typical observation point, and the visual quality of a landscape. All these variables, and including their interactions, had highly significant effects on the evaluation of a landscape's visual quality. Number of WTs had the greatest impact, while the observer's distance from a WT had a smaller effect and landscape type had the smallest effect of all. The results confirmed the importance of landscape's aesthetic value and that WTs will face greater opposition in natural and visually attractive landscapes. The most attractive landscape with the most positive score initially was evaluated with the absolutely most negative ratings after WTs were added. This finding strongly suggests that placement of WTs in landscapes with natural character and high aesthetic value should be avoided. The landscape qualities – including both natural and cultural attributes – should be assessed before any WT placement and in the very earliest stage of any contemplated WT development. In the planning process, landscape visual quality should be evaluated and landscapes of high aesthetic value should be protected against development on such scale as constituted by wind farm projects.

Furthermore, we have determined the interaction between landscape visual quality and distance from the observer and found that distance thresholds varied according to landscape attractiveness. The visual impact of WTs in landscapes with high aesthetic values disappeared at a distance of around 10 km. In less-attractive landscapes with stronger human influences, this breakpoint was at around half that distance (about 5 km). The close proximity of WTs to any type of landscape was considered to be a very negative intrusion, regardless of the visual attractiveness of the landscape itself. Consequently, we have proposed the designation of visibility zones to objectify the intensity of WTs' visual impact on the landscape. The visibility zones should be applied in the planning process according to landscape type in order to mitigate the visual impact of WTs as much as possible.

An interesting finding was established for the interaction between the number of WTs and distance from the observer. The perception of WTs in a group was different at the close distance of 1.5 km compared to the middle-range distance of 5 km. The landscape of high aesthetic value was significantly more negatively influenced by the number of turbines at a close distance. Although cumulative effect was not significantly proven in this study, a rising number of WTs was determined to be perceived increasingly negatively for all tested landscapes. The dynamic of that diminution in score was lower, however, for the least attractive landscape which was already characterised by strong human impact and decreased naturalness.

The results of this study can make a substantial contribution to reducing negative visual impact in the WT planning process and thus to achieving higher public acceptance of these structures. The identified thresholds for distance from the observer and number of WTs may help to improve the methods for assessing WT impact and elucidate the reasons for why wind farm projects are rejected. To achieve higher public support, the placement of WTs must respect the aesthetic qualities of the landscape with consideration for its general character, natural and cultural attributes, observation points, and other factors. Towards this end, public officials may incorporate into their decision-making process visual impact assessment of renewable energy schemes and WTs planning that incorporate all these physical attributes.

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How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process

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ABSTRACT

Background

Three groups of stakeholders are mainly involved in the planning, assessment and approval processes for wind parks: planners, the public, and the responsible public authorities. These groups have varying aims, and there are various ways of looking at proposals to set up a wind park. In particular, the viewpoints of planners and government officers are likely to differ. Planners are likely to focus on technical aspects of a wind farm project, while the public authorities are likely to be oriented toward environmental considerations.

Methods

The effect of respondents' characteristics on landscape perception was analysed using generalized linear mixed models (GLMM). Set of various landscape images with and without wind turbines (WTs) was evaluated on a 15-points scale. The evaluation was accomplished with additional questions about general attitude toward wind energy, willingness to live close to WTs and presence of WTs near respondents´ homes.

Results

Using a questionnaire presented to university students in technical study programmes and to students in environmental study programmes, it has been determined that educational orientation substantially influences people's perception of wind turbines (WTs). Respondents pursuing technical studies evaluated landscapes with WTs more positively than did students in environmentally-oriented study programmes. In addition, the responses of students in environmental study programmes were influenced by their general attitude towards wind energy, unlike the responses of the technically-oriented students. We also examined the influence of respondents' other characteristics on their perceptions of WTs in the landscape, including their general attitude toward wind energy and their willingness to live near WTs, toward the presence of WTs in the vicinity of their place of residence, and interactions among these factors.

Conclusions

Our study indicates the importance of education in planning wind parks. Sanctioning bodies should be able to evaluate each proposed project adequately and impartially, and to assess the potential level of impact of the proposal on the landscape and on landscape values, including aesthetic values, and on the population, and also other impacts caused by the construction and the functioning of WTs. This kind of professional knowledge is also very important for planners. One way to raise students' awareness and their professional knowledge could be through interdisciplinary coursework on this topic.

Keywords: Wind energy; Educational orientation; Visual impact; Distance; Decision-making process

Background

In the past two decades, wind energy has become a primary renewable energy source. This is demonstrated not only by the prominent construction of a large number of wind parks, but also by the development of modern wind turbines (WTs). WTs now exceed 100 meters in height and achieve outputs of 2–3 MW [1]. While renewable sources are generally perceived positively and sympathetically, specific wind farm projects are very frequently considered undesirable by the public. Projects are often be rejected, and construction may be halted [2,3,4,5,6].

A number of studies on the acceptability of WTs have been published, dealing not only with respondent characteristics but also with the types of landscape where WTs are located. Analyses of respondents' perception of WTs have focused on the impact of characteristics such as age, gender, education level, and distance of the home or place of frequent sojourn from WTs, as well as the so-called NIMBY (not-in-my-back-yard) effect. Strong opponents of WTs appear to be older and more highly educated [7,8], and differences in attitudes between genders are often minimal [7]. No NIMBY effect has been demonstrated as a motivation for a negative response to the construction of WTs [9,10,11]. The results of certain studies have demonstrated that people living in the vicinity of WTs paradoxically perceive them more positively than do people living further away from them[6,12]. However, it is not entirely clear to what extent people can become accustomed to wind parks, and what causes people who frequently spend time in the vicinity of WTs to have a positive perception of them. There are conflicting results on the extent to which the perception of WTs is influenced by living in their vicinity. A study by Eltham et al. [13] demonstrated a more positive evaluation by respondents in 2006 that there called opinions of 1991. However, a study by Groth and Vogt [14] reports the opposite findings. A negative perception of WTs can last for several years after construction is completed. The main causes are higher prices for electricity, and noise from the operation of turbines. Similar results can be found in a study from Texas, where the people living closest to WTs were the least supportive of wind parks [15].

The NIMBY effect has become an implicit phenomenon when planning most large investment proposals, including wind parks. Present-day research sometimes indicates that respondents are concerned about being labelled as NIMBYs [16]. The literature has therefore established more acceptable explanations for opposition to the construction of WTs, namely place attachment [17,18,19], sense of identity [16], and confidence in the structure itself and in its benefits [20]. Place attachment is very important in forming a positive environment for local inhabitants [21,22]. Landscape is perceived not merely as scenery, but also as a dwelling space [23].

Research has also demonstrated that financial participation and profit for municipalities is a relevant factor, and that it may increase the acceptability of planned wind farms in the vicinity [24]. This goes together with fair communication and with participation in the planning process. Huebner [24] suggests visits to wind parks, moderated workshops, and the use of local expert knowledge to discuss suitable areas and to mitigate the visual impact on the landscape.

Other studies have confirmed that WTs are perceived very negatively in aesthetically valuable and natural landscapes [25,26,27],as opposed to landscapes already more markedly influenced by human activities. Nevertheless, planning organizations and development companies continue to attempt to construct WTs in these valuable landscapes, predominantly in mountain and coastal areas with a very marked morphology and rich natural cover. These are of course areas with a high wind potential. This issue was examined in a study carried out in the Netherlands [28], which compared the attitudes of environmentalists and the government architect when the proposed large wind energy park in the Wadden Sea area, a protected area in the Netherlands, was halted following a lengthy debate. The influence of knowledge from a certain professional orientation on the perception of WTs is therefore evident. To date, however, there has been no study examining the possible influence of the type of university education and subsequent professional development on the perception of WTs as new technological structures in the landscape. This situation is analogous to the perception of post-mining areas, where the way in which respondents with a professional focus on landscape ecology perceive post-mining landscapes differs markedly from the perceptions of respondents of other orientations [29]. Another study testing the opinion of university students on the placement waste dumps demonstrates that the differing perceptions of respondents are influenced by their level of environmental knowledge [30]. In another study, the level of professional knowledge about natural fires contributed markedly to an increase in support among local inhabitants when planning strategies after naturally occurring fires [31].

Is education important for wind park planners? What education should members of a sanctioning body have in order to make an objective assessment of the suitability of WTs, and not to be biased by their educational backgrounds? To answer these questions, we analysed the perception of several different landscape scenes without WTs and with various numbers of WTs at various distances from the observer in a sample of university students in environmental study programmes and in technical study programmes. A further objective was to determine the influence on the respondents of their general attitudes towards wind energy, the proximity of their homes to WTs, and their willingness to live near WTs, and also whether people can to a certain degree become acclimatized to WTs.

Methods

Study design

In order to analyse perceptions of the aesthetic value of landscapes with and without WTs, WTs were visualized in three different types of landscape, in different numbers, and at varying distances from the observer. Students of two universities with different educational orientations were selected as respondents: students of the Faculty of Environmental Sciences at the Czech University of Life Sciences in Prague, and students of the Faculty of Civil Engineering and at the Faculty of Architecture at the Czech Technical University in Prague. The students were selected with a view to comparing the perception of WTs in the landscape by students of engineering and students of environmental studies. Students form a relatively homogeneous group, differentiated mainly by their field of study. This is advantageous from the perspective of filtering out the potential influences of level of education and of age [30]. Three different landscapes with various levels of human influence, located in the territory of the Czech Republic, were selected for evaluation. One objective of this study was to measure the effect of various levels of human influence on the landscape. The inclusion of multiple landscape types reduced the effect of any relationship that a respondent might have to a specific area (i.e. a place attachment; [18,19]). Landscape A depicts the Bohemian Central Uplands, a protected landscape area located in north Bohemia and characterized by a distinctive morphology and diverse cover. Natural features are predominant, forming an aesthetically valuable scene with a harmonious scale. Landscape B is from the Želiv area of the Bohemian–Moravian Highlands, which is morphologically not very distinctive. There is a higher level of visible human influence, but it is in balance with the natural and landscape features. Landscape C is located in central Bohemia, near Neratovice. It represents a landscape type that is markedly influenced by human activities. The natural features are suppressed, and the landscape does not have a marked morphology or cover.

For the evaluation, a set of 39 images was created. In each landscape type, various numbers of WTs were visualized (1, 5, 10, 15, 20, and 25) at two different distances (1.5 km, 5 km). Vestas 90-type WTs (height 105 m, rotor diameter 90 m) were selected for the visualization. A combination of three landscape types with visualizations of six varying numbers of WTs at two distances formed a set of 36 images. Images of each landscape without WTs also added, making a total of 39 images for evaluation. Respondents were asked to evaluate the images. The images were presented in random order, so as to prevent any influence on the rating, for example, due to an increasing number of WTs within the landscape scene. Simple questionnaires were used for the rating, with each respondent allocating a score ranging from +7 to −7 to each numbered picture (+7 being the most positive rating,

−7 the most negative, and 0 as neutral). Before the ratings were made, the pictures were projected for the respondents without the presence of WTs and with a visualization of 1 WT and 25 WTs for each landscape type. This enabled the respondents to acquire a context for the ranking scale.

After they had evaluated the pictures, the respondents were asked to provide answers to three questions: 1) What is your general attitude toward wind energy? Possible answers: P – Positive, O – Neutral, N – Negative. 2) Would you be willing to live near WTs? Possible answers: Yes, willing (W);No, not willing (NW); I am indifferent or have no opinion (X). 3) Do you live near a wind power plant (i.e. within 10 km)? Possible answers: Yes, No. The distance of 10 km was set on the basis of previous experience as a level at which a WT still has an impact on the aesthetic evaluation of a landscape [25,32]. In order to prevent any preliminary influence on the respondents' ratings, these questions were presented only after they had rated the set of images. The rating was performed in large lecture rooms using screen projections. The same period of time (10 seconds) was allotted for rating each image.

Data processing

The effect of respondents' characteristics (see Table 1) on landscape perception was analysed using generalized linear mixed models (GLMM). Within GLMM, we used the *glmer* function, which is a part of the *lme4* package of R statistical freeware, version 3.0.2 [33]. Each of the 39 landscape photographs with a specific combination of the number of WTs (1, 5, 10, 15, 20, and 25) and the distance of the observer from the WTs (1.5 and 5 km) was evaluated by 285 respondents. Landscape perception (i.e. respondents' ratings of the photos; $n_{resp.}$= 285×39 ratings = 11,115 rows) represented in our model a semiquantitative response variable on a 15-point assessment scale (from −7 to +7 including zero). This variable was converted into a variable with a binomial distribution comprising two vectors – the real landscape assessment value of each respondent, and the supplement to the maximum evaluation value. For example, if a certain landscape assessment awarded by any respondent was +5, the supplement to the maximum evaluation (+7) was 2. The value of +5 represents here the degree of success (i.e. how much the particular respondent liked the landscape), and supplement 2 represents the degree of failure (the higher the value, the more negative the assessment is). Following the rules for modelling with binomial errors (according to [34]), we used the *cbind* function, and we bound together the two above-mentioned vectors of the response variable into a single object *y*. This object *y* was then used in the GLMM analyses as the response variable with abinomial distribution.

The respondents' attitude towards wind energy (attitude: positive × neutral × negative), the presence of WTs within10 km of the respondent's home (yes × no), the response to the question

“Would you be willing to live near WTs?” (willingness: willing × not willing × no opinion), the type of study programme that the respondent had chosen(technical × environmental),and the interactions between these variables, comprised the explanatory variables in our model. As was mentioned above, each photo was evaluated by 285 respondents. To avoid pseudoreplications, identification of the photo was included as a random factor in the model. GLMMs were used for this. Using GLMM and photo identification as a random factor, we also solved the potential problem of differing evaluations of scenes according to the different numbers and distances of WTs.

Variable	Abbreviation	Df	Chi	P
Type of education	Education	1	673.94	$<10^{-6}$
Willingness to live near WTs	Willingness	2	267.86	$<10^{-6}$
Presence of WTs within 10 km of the respondent’s home	Presence	1	55.46	$<10^{-6}$
General attitude toward wind energy	Attitude	2	17.86	$<10^{-4}$
Education: Attitude		2	187.26	$<10^{-6}$
Presence of WTs: Attitude		2	60.31	$<10^{-6}$
Willingness: Attitude		4	11.98	0.02
Willingness: Education		2	4.59	0.10

Table 1

Effects of respondents’ characteristics and their interactions (last four rows) on their perception of landscapes with wind turbines (WTs). Df – degrees of freedom, Chi – value of test statistic, P – obtained probability (levels lower than 0.05 indicate a significant result (i.e. effect of a variable on landscape perception).

The significance of each explanatory variable in both models was analysed using deletion tests and a backward selection procedure. The final model, consisting of only significant variables, was finally checked using standard statistical diagnostics [34].

Results

Type of education – orientation the study programme

A significant difference was detected in the evaluations of landscapes with WTs according to students’ school affiliation. This is the most significant factor among all those monitored (Table 1). Students with a technical orientation awarded markedly higher ratings to landscapes with WTs (mean evaluation ± SD: −1.46 ± 3.11) than did students with an environmental orientation (−2.77 ±

3.77). An interesting relationship was found in the interaction between the factors *Type of education (education)* and *General attitude toward wind energy (attitude)*. While technical students' ratings were practically unaffected by their attitudes toward wind energy, the ratings awarded by environmental students were strongly influenced by their attitudes towards wind energy – the ratings increased with the respondent's more positive attitude towards wind energy (Fig. 1). Further interactions between the education variable and other factors were inconclusive.

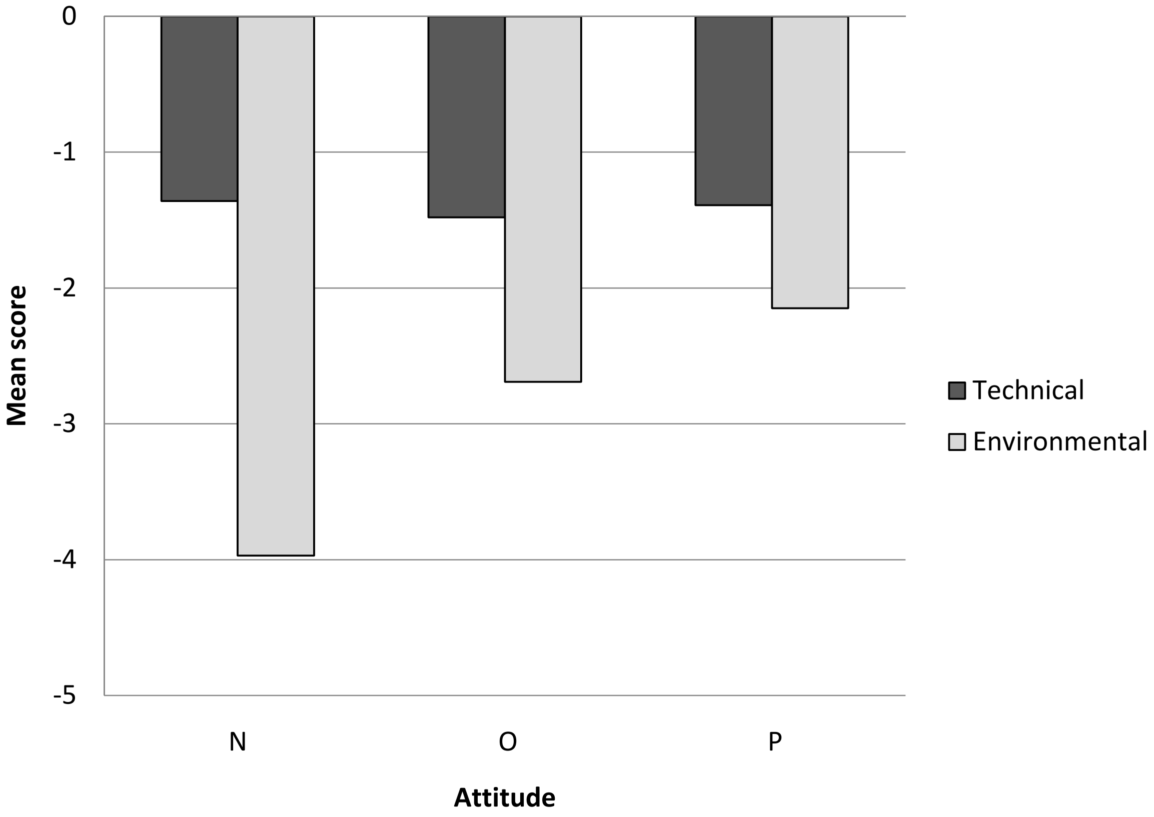

Fig. 1. Mean score of landscape evaluations according to type of education (environmental versus technical) and according to the respondent's general attitude toward wind energy (N – negative, O – neutral, P – positive).

Willingness to live near WTs

Willingness to live near WTs had a strongly significant influence on the ratings (Table 1). Respondents who were unwilling to live near WTs (NW) awarded the lowest ratings (mean ± SD: −2.62 ± 3.35), while there was practically no difference between the ratings awarded by respondents who were willing (W) and by respondents who were indifferent (X) (W: −1.62 ± 3.90; X: −1.63 ± 3.46). A similar trend was found among respondents from each of the university faculties. This indicates that the interaction between the variables *willingness* and *education* was inconclusive (Table 1). On the other hand, the interaction between the variables *willingness* and *attitude* was shown to be conclusive. Within the group of respondents with a positive attitude toward wind energy, those willing to live near WTs (category W within willingness) awarded the highest ratings. The average ratings among respondents with a neutral or negative attitude did not differ markedly in this respect (i.e. the ratings awarded by those unwilling to live near WTs and the ratings awarded by those willing to live near WTs were similar) (Fig. 2).

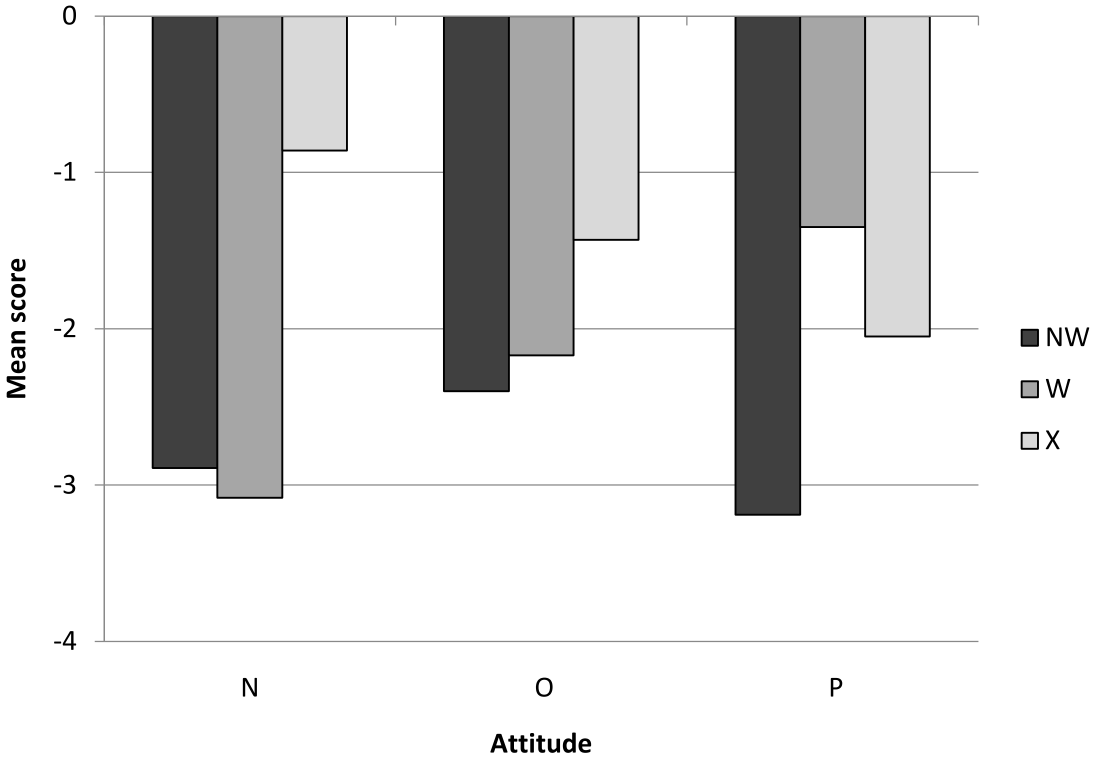

Fig.2. Mean score of landscape evaluations according to the respondent's willingness to live near wind turbines (W – willing, NW – not willing, X – no opinion) and according to general attitude toward wind energy (N – negative, O – neutral, P – positive).

Presence of WTs within 10 km of the respondent's home

Respondents living near WTs (within 10 km) evaluated landscapes with WTs more positively (mean ± SD: −1.65 ± 3.65) than did respondents with no WTs in the vicinity of their place of residence (mean ± SD: −2.20 ± 3.50, Table 1). Furthermore, the interaction between the variables *Presence of WTs within 10 km of respondent's home (presence)* and *General attitude toward wind energy (attitude)* proved significant. While the average ratings among respondents with a neutral attitude

(O) were not influenced by the presence of WTs near their place of residence (the average ratings of the two groups differed only slightly), the average ratings awarded by respondents with clear attitudes (negative or positive) were always higher for respondents living near WTs (Fig. 3).

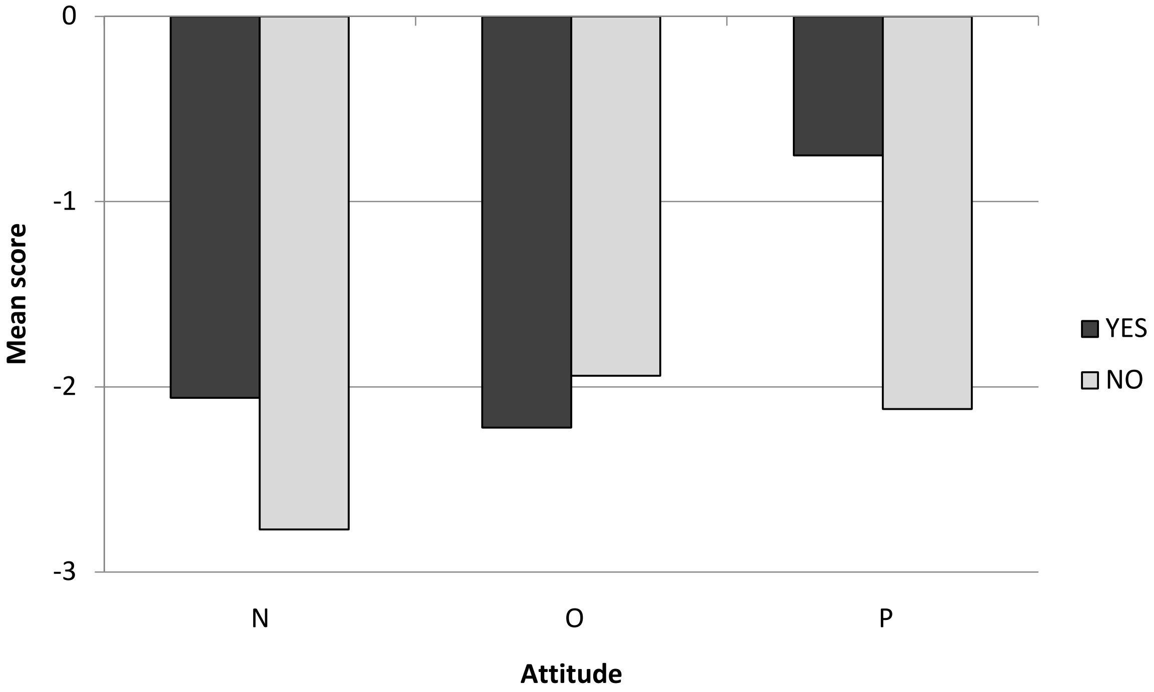

Fig.3. Mean score of landscape evaluations according to the presence of wind turbines within 10 km of the respondent's home (Yes × No) and according to the respondent's general attitude toward wind energy (N – negative, O – neutral, P – positive).

General attitude toward wind energy

Respondents' ratings of WTs were markedly influenced by their attitude toward wind energy. Not surprisingly, those respondents with a negative attitude toward wind energy awarded the lowest ratings for WTs (mean ± SD: −2.67 ± 3.27), while respondents with a neutral attitude and respondents with a positive attitude awarded very similar ratings (−1.96 ± 3.25 vs. −1.62 ± 4.06, respectively). Respondents' attitudes toward wind energy were also evident in all assessed interactions (see explanations above).

Discussion

The results of the study are focused on four main characteristics of the respondents: their general attitude toward wind energy, their willingness to live near a wind power plant, the presence of WTs near their place of residence, and the orientation of their university studies. In the past 20 years, the authors of this study have processed assessments of more than 1,500 WTs for the purposes of sanctioning their installation (more than 180 individual construction projects in the Czech Republic, Germany, and the United States). On the basis of practical experience, the discussion here is divided into three subsections according to the three types of authorities involved in the approval process (also taking into consideration the importance of educational orientation): (i) authorities who plan WTs, (ii) authorities who represent the affected public, and (iii) those who make decisions as public administration authorities.

Importance of educational orientation for planners

What kind of education is most relevant for planners dealing with wind farms? This is a question that has until now not been discussed in detail in the literature. Our study is the first to provide results based on respondents' differing perceptions of WTs according to the orientation of their studies (i.e. their professional orientation). The results obtained by comparing attitudes of respondents from universities with different orientations (in this case, environmental studies versus technical studies) reveal a distinct difference in how WTs are perceived within a landscape. Students with a technical orientation award a markedly higher rating to WTs in the landscape than do students studying environmental sciences. Furthermore, it was determined that, among technical students, a respondent's general attitude toward wind energy (positive, neutral, negative) does not influence his/her ratings of landscapes with WTs, whereas it markedly influences the ratings awarded by students of environmental sciences. However, students with a positive attitude toward wind energy awarded higher ratings to landscapes with WTs.

The lack of significant influence of general attitude toward wind energy on the perception of landscapes with WTs among respondents with a technical background implies that they perceive wind power plants only as technical structures designed for a certain use [35]. Respondents with an environmental orientation, on the other hand, perceive WTs not only as structures but above all as components of the landscape. A similar divergence in the perception of WTs was demonstrated in a study on a planned wind park in the Wadden Sea [28]. It is apparent that assessments of the suitability of a landscape for the placement of WTs are not to be ignored, and should form an integral part of the decision-making process [25,27].

This begs the question: Who, in that case, should plan the construction of wind parks and propose where WTs should be placed in the landscape, while taking into the account the landscape type and its natural, aesthetic, and historic values? Technically-educated planners are likely to give greater consideration to construction technologies and to functionality than to landscape values. This entails a risk that these functionally-based proposals will be opposed and overturned during the subsequent environmental assessment process. Insensitive placement within the landscape may not be identified until the landscape impact assessment. This will result in time delays and financial losses for the investor, and potentially also for the planner. Alternatively, insensitively placed WTs may be approved, leading to negative impacts on landscape values. At the same time, it should be recognized that some results among groups of environmentally-oriented students point to an excessively conservative, uncompromising commitment to landscape preservation and protection. Our results have adumbrated these tendencies primarily among those environmentally-educated respondents with negative attitudes towards wind energy.

While education in a certain field leads to increasing knowledge in the field of specialization, this can be accompanied by neglect for and ignorance of knowledge from other fields of study. Specialists in environmental fields, for example, incline toward protecting the landscape and its values, rather than toward developing new technologies, such as the construction and development of renewable energy sources (including wind parks). Specialists in technical fields, on the other hand, are more focused on the development and implementation of technology, and they often disregard or underrate landscape values. This statement may seem ideologically based, but the results of our study and many others [28,29,31,35] have demonstrated considerable differences in landscape perceptions between respondents from technical fields and respondents from environmental fields. Such perceptions and opinions may be shaped by the personality of each individual, even before he or she registers as a student. Personal ideas, attitudes and objectives are an important factor in the choice of a study programme, and these initial opinions are likely to be further shaped and entrenched in the course of the study programme.

The perception of WTs may be influenced by a lack of knowledge about the subject, or by unwillingness to accept other values and opinions. Whatever influences there are on individual students, a melding of technical and environmental knowledge among experts from different fields can be achieved only in part. One way to deal with this issue, which is not trivial, would be to provide special interdisciplinary courses in this subject area. These courses may provide technical knowledge to environmentalists and expand the knowledge of environmental issues among engineers and planners. By acquiring basic knowledge and an appreciation for the landscape values which are at risk of being disturbed by the construction of WTs, planners will be better able to judge at the very outset of planning whether a proposal will or will not be successful. At the same time, environmentalists can learn more about technological (and economic) considerations.

Public opposition to/acceptance of wind parks

This subsection expands on the results of WT perception ratings from the perspective of the distance of proposed WT structures from the place of residence of respondents who may be affected by them. The discussion also indicates which respondents should be included in the planning and approval process on the basis of their proximity to proposed WTs.

As expected, respondents not willing to live near WTs awarded lower ratings to landscapes with WTs than respondents who are willing to live near WTs, or who expressed a neutral opinion. Surprising results were obtained, however, for the interaction between the factors *Willingness to live near WTs* and *General attitude toward wind energy*. It had been expected that respondents with a negative general attitude to wind energy would award low ratings to landscapes with WTs, regardless of their willingness to live near WTs. Surprisingly, the highest ratings came from respondents with a negative attitude, but who expressed indifference about living near WTs. Respondents with a positive attitude toward wind energy and also willingness to live near WTs awarded much lower ratings. Nevertheless, an expected trend was found in the ratings awarded by respondents willing to live near WTs. Their ratings correlate positively with their attitudes toward wind energy. By contrast, those unwilling to live near WTs unexpectedly awarded the lowest rating in combination with a positive attitude towards wind energy. We had anticipated that they would award the worst ratings in combination with a negative attitude. A positive attitude toward wind energy was apparently entirely eclipsed by the unacceptability of living near WTs. Even though they were proponents of wind energy, they would not accept living near WTs. This result is an example of to the NIMBY effect, which has become the topic of a number of studies, though none of them has clearly confirmed that the NIMBY effect in fact exists [e.g. 9,10]. The ratings awarded by respondents with a neutral attitude to the possibility of living near WTs have an inverse character. The highest ratings are awarded by respondents with a negative general attitude to wind energy, while respondents with a positive general attitude to wind energy awarded the lowest ratings.

Interesting results were registered for the interaction between the factors *General attitude toward wind energy* and *Presence of WTs within 10 km of respondent’s home*. Those with a negative attitude to wind energy and who did not live near WTs awarded the lowest ratings, while respondents with a positive attitude and living nearing WTs awarded the highest ratings. This supports the hypothesis that people can to a certain degree become accustomed to WTs. This finding has also been demonstrated by other studies [6,13].

Who should be included in the planning and decision-making process?

A general clear-cut attitude (positive or negative) toward wind energy has an important influence on the perception of new wind farm projects. It can be assumed that people with a negative attitude will tend to remain rather negative, even after WTs have been constructed, as demonstrated in this study and also by Read et al. [32]. Read et al. found that a negative attitude toward wind farms tends to be based on a past attitude, and that the tendency to oppose wind farm developments is strongly associated with past oppositional behaviour (i.e. past behaviour is the best predictor of future behaviour in this matter). Choice experiment methods [36] have proven effective in planning WTs. In this method, respondents are asked which location out of a number of options they consider most suitable. Ek and Persson [36] demonstrated, for example, the importance of three main considerations: avoidance of recreation areas, co-ownership of WTs by the community, and community involvement in the decision-making process. Many other studies have concluded that it is crucial to involve the local population in the process [5,10,18,24]. An important question is therefore: What group of respondents should be included in the assessment process? The authors' own experience, also supported by results, shows that there are three such groups. The first group consists of inhabitants living in the immediate vicinity of the proposed location (i.e. within 1.5 km) and who are thus directly affected acoustically and visually by the WTs. The second group should include inhabitants of indirectly affected areas between ca 1.5 km and 10 km distant. This group is affected only by the visual impacts of WTs [25,32]. According to several studies, place attachment has considerable influence on perception [17,18,19]. The third group should comprise respondents generated from vacationers and other occasional visitors to the area. While Frantal and Kunc [37] found no significant influence of WT construction on the number of visitors to recreation areas in the Czech Republic, other studies have highlighted marked opposition and disagreement among the general public concerning popular recreation areas [8,10].

Educational orientation of sanctioning bodies

In this subsection we come to a classic scenario when a wind park is sanctioned. A wind park with a certain number of WTs is proposed in a specific location. There are objections from environmentalists, the public, and the local inhabitants. The proposal is awaiting assessment by a competent public administration authority as to whether the project will be sanctioned and, if so, under what conditions. This presents the situation in a very simplified way, but it leads essentially to a single question: What professional knowledge should the responsible employee of the planning and sanctioning public administration authority have in order to ensure that the proposal is assessed adequately and impartially?

More than 85% of wind farm proposals are rejected in the Czech Republic. This suggests that the planning and sanctioning bodies have no clear objective or methodology for approaching the construction of WTs. The results of our study have indicated that students in technical study programmes and students in environmental study programmes form very different camps as regards their perceptions of WTs. This can have a crucial influence on the processes of planning, evaluation and final approval. It can be inferred that the planning and sanctioning authorities and their representatives should not be inclined to only one camp. The members of these bodies therefore need to have both environmental knowledge (i.e. about impacts on the landscape and its values, noise, etc.) and technical knowledge. An impartial assessment is best achieved by a neutral general attitude towards wind energy. The results of this study show that respondents with a neutral general attitude award very similar ratings, whether or not there are WTs near their homes. Other studies have also demonstrated the influence of general attitude on the perception of specific projects [27,38].

A large proportion of projects are rejected on the basis of non-acceptance by the public, rather than on the basis of an adequate assessment by the planning and sanctioning bodies [6,28]. Although environmental impact assessments have been provided by independent experts, proposed projects are often stopped in response to strong opposition by the public. It would therefore be only a modest overstatement to say that a proposal that will have a great impact on the landscape and its values can be approved as long as there is no considerable public opposition. To put it another way, as long as there is no major public opposition to a proposal, no other considerations will make it unacceptable. In practice, this points to an ineffectively-functioning system.

The fact is that developers often do not discuss their proposals with the public or with local communities. Instead, they take the course of “stealthy” construction, hoping that no large wave of protests against the proposal will arise. As has already been mentioned, this approach is ineffective in practice, and leads to delays in the project or to its outright cancellation [2,3,4,5,6]. The sanctioning body should play the role of mediator, directing the entire process and thereby facilitating communication between the main stakeholder parties – the developers and the affected inhabitants. Members of the sanctioning body should also know the location in question very well, including the landscape and its values, in order to make an adequate assessment of possible negative impacts.

If a developer proposes the construction of a new wind farm, the sanctioning body should lead the entire process. Locations where the impact would be smallest can be identified on the basis of an expert landscape analysis. A similar process is mentioned, for example, in a study from the UK that assesses several locations from the perspective of suitability for construction [39]. Although the topic is different, a study on finding a suitable location for a landfill site presents a similar case [40]. Out of 20 technically suitable locations, only 5 were selected as socially acceptable. The procedures of the sanctioning body can be summarized in three basic steps. First, the sanctioning body should inform the developers and planners about possible locations and landscape values, and should indicate suitable locations. During this process, it should inform the local communities about the planned project, and should monitor communication with the developers. Finally, it should make an adequate assessment of the proposed project, and should suggest design modifications, in the event that only part of the project can be sanctioned. Thus, at the very start of the process, there is a procedure for steering clear of unsuitable locations and thereby preventing the loss of time and money. Communication with the concerned inhabitants and with the public should be stipulated by the sanctioning body in such a way that developers are not able to avoid participating, or participation should be required by law. This planning and decision-making process should be directed by an impartial person, by someone with a neutral attitude towards WTs. If this director has a markedly positive or negative attitude, there is a risk that his or her attitude will influence the authority's decision.

Conclusions

This study has contributed new knowledge about respondents' perception of WTs within the landscape on the basis of four respondent characteristics: general attitude toward wind energy, educational background, presence of WTs near the respondent's home, and willingness to live near WTs. All four monitored characteristics were evaluated as being very significant for the overall rating. Our study has also analysed the practical application of the results on the basis of distinguishing three main groups involved in the planning process: planners, the affected public, and sanctioning bodies. It also proposes how the results may be applied.

Our study is the first to have demonstrated the importance of respondents' educational orientation. It has shown clearly that students with a technical education are likely to perceive WTs rather as functional structures, while students with an environmental education are likely to give greater weight to the impact of WTs on the landscape and its values. Professional knowledge therefore distinctly influences perception. Thus, environmental knowledge and environment protection have an important place in evaluating WTs within a landscape. These topics are not studied in depth in engineering study programmes, and technical students therefore normally do not perceive the need for landscape protection so strongly. Professional knowledge about environmental matters is very important for planners, and it should also be considered relevant for representatives of the sanctioning authorities. One way to raise awareness and knowledge of environmental issues would be to provide interdisciplinary coursework dealing with this topic.

Our study has also confirmed the hypothesis that people can to a certain degree get accustomed to WTs. However, this was demonstrable only among respondents with a positive attitude toward wind energy generally. There is a less marked tendency for respondents with a negative attitude toward wind energy to get accustomed to the presence of WTs, and the situation is entirely unclear in the case of respondents with a neutral attitude. The general attitude toward wind energy therefore plays a very important role in the perception of WTs, even after WTs have been constructed in the vicinity of a respondent’s home. On the basis of experience and accumulated findings, the authors have designated three main groups of concerned people who may be affected by the construction of WTs, and who should therefore be included in the planning process. These are: inhabitants living in the immediate vicinity (i.e. within 1.5 km), who are affected visually and acoustically; inhabitants living within 10 km and who are thus affected visually; and people who are vacationers and/or occasional visitors to the area. A neutral attitude towards wind energy is a desirable basic characteristic for sanctioning bodies and relevant authorities, as neutrality is necessary for an adequate and impartial assessment of proposals.

Willingness to live near WTs also has a significant influence on the perception of WTs in the landscape, especially among the affected public. Although wind energy is generally viewed positively by respondents, most of them nevertheless evaluate specific projects negatively. Among affected respondents, therefore, it is not so much how they perceive wind energy that is important – what really matters is their willingness to adjust. Open presentation of a proposed project by the developers, communication with the local communities, and including them in the decision process are very important for the successful development of the entire project.

Finally, this study has indicated the importance of adequate education for planning wind parks. Sanctioning bodies should be able adequately and impartially to evaluate each proposed project, to assess the level of impact on the landscape and its values, including aesthetic values, and on the population, as well as other impacts caused by the structure and the activities of WTs. Likewise, it is important for the public and the local communities to be aware of these issues. Awareness can ensure that there is only sensible opposition to projects, and that developers have no justification for claiming that opposition merely reflects NIMBYism. Planners need to be well educated in the area of environmental protection. This will enable them from the very outset to prevent developers proceeding with proposals that would have an unnecessarily large impact on the landscape. Project proposals that would lead to loss of money and wasted time, and other unfavourable outcomes, need to be dropped as early as possible in the proceedings. Communication between developers and local communities, mediated by the sanctioning bodies, is crucial for creating transparency and more efficient planning of wind park construction.

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Futuristic Wind Power Systems Suitable as Artistic Sculptures

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ABSTRACT

The current generation of traditional wind turbines have experienced a high degree of public opposition, often resulting in un-built projects. This is ironic, given popular trends for achieving sustainable energy independence from traditional fossil fuel power plants. However, in some countries there are a vocal majority of citizens who do not want to live near or see the traditional wind turbine in the landscape. Therefore, new public-friendly solutions are needed for the continued growth and development of sustainable wind energy. This paper discusses possible alternative designs for combining funnel-based wind turbines with artistic sculptures and other aesthetic interventions. Three options are presented, each with its own unique design solutions. These alternative wind turbines encompass a broad variety of technical ideas and transform them into artistic sculptures. This distinctive approach can be incorporated into a wide variety of possible scenarios, from undeveloped landscapes to public spaces in urbanized built-up areas.

Keywords:
Architectural design; Artistic Sculptures; Channel based technology; Landmark; Visual impact; Wind turbine

Introduction

Harnessing the wind to generate power is a proven technique for nearly 3000 years when the first windmills (vertical-axis mills) were constructed to provide mechanical power for milling of grain (Ackerman, 2005; Burton et al., 2001). This novel invention actually originated in the Middle East and the Afghan highlands, later making its way to western Europe, predominantly into the Netherlands. It was there where this “new” technology for milling grain gained popular acceptance throughout the region and continued to evolve becoming more efficient in the coming centuries. The traditional and characteristic look of these iconic elevated wooden devices grew to become a significant cultural icon associated with the Dutch vernacular landscape. Nevertheless, the twentieth century brought many changes and most noteworthy a great expansion in the development of wind energy (Kaldellis and Zafirakis, 2011). Toward the latter half of the 20th century, the public increasingly realized the limited resources and finite energy potential of fossil fuel as source for energy. Renewable energy sources have since increasingly become a serious and realistic source of future energy production. A little-known fact was that the first wind turbine used for generating electrical energy was constructed in 1891. Other devices using modern airfoils were developed as early as the 1940s. The characteristic and recognizable modern wind turbine became popularized in 1970s and 1980s in both Western Europe and North America. Since that time, the development of wind turbines has grown exponentially with many new wind parks being constructed on a regular basis. In 1980s, when the phenomenon of the modern appearing wind turbine was relatively new (Ackermann, 2005; Burton et al., 2001), there were a limited number of implemented projects; a large number of the general public were in favour of these projects (Thayer, 1987). However, 1990s brought a tremendous boom in the development of “wind parks”, and many enjoyed social acceptance (Gipe, 1993; Wolsink, 2007). Krohn (1999) conducted surveys to determine public acceptance for wind energy in Canada, the United States, Denmark, Sweden, Britain, the Netherlands, and Germany. In 1990s these countries were generally in favour of wind energy with nearly 80% of people surveyed advocating for further development alternative energy generation from wind.

The new millennium brought a great increase in the development of alternative wind energy generation devices (Moller, 2011). These developments were predominantly associated with the European Community Directive 2001/77/EC stipulating the promotion of electricity produced from renewable energy sources in the internal electricity market. The construction of wind turbines has grown significantly since 2001 due in part to the on-going financial support from European governments. This exponential growth in wind energy has resulted in an increased impact upon natural landscapes based upon their placement. Many of these newer devices stand nearly 160 metres tall from the ground plane to the centre of their impellor, the result being increased visual impacts of wind turbines in the landscape (Moller, 2006). If one were to draw a chart with an X and Y axis, with development of wind turbines represented on one side and social acceptance for them on other, it would illustrate an inverse relationship. Specifically, the increase in the number of constructed (or planned) wind parks has resulted in greater public opposition, in spite of public desire for renewable energy generation. The size, height, and moving blades of modern wind turbines are directly related to their perceived visual impact in the landscape (Sklenicka, 2006).

Nowadays, the pros and cons of wind energy are strongly debated, and many proposed projects are cancelled due to the perceived visual impact that will result from installation. Visual impact upon the landscape and the associated negative aesthetic characteristics is a very real and significant issue that will not "go away" in the near future (Betakova et al., 2015; Vries et al., 2012), followed closely by the associated environmental impacts such as noise (Pederson, 2008), light flickers, and their inherent danger to birds and bats (Drewitt and Langston, 2006). Specifically, it is the stark appearance of three very large moving blades coupled with a device of enormous size – many standing 160 metres tall – which have rendered many installation projects unsuitable to be erected in a variety of different landscape scenarios – both scenic and ordinary. Although many new wind energy projects are either cancelled or delayed for indefinite periods, the potential for energy generation from wind is still not as effectively utilised as it could be. Surveys conducted by teams of university research scholars have tested how respondents´ rated the visual impact and associated characteristics of traditional three-bladed wind turbines (Ladenburg, 2008; Ek, 2005), and the perceived physical attributes of these structures. Recent studies have emphasized the visual impact and/or appearance of modern wind turbines as the principle problem (Lothian, 2008; Molnarova et al., 2012). The review of Nymbism (Not In My Back Yard) by Petrova (2013) concluded that the visual presence of turbines in the landscape should be evaluated. The question remains if it is possible in our modern society to reach a sustainable (wind) energy target while there is often strong public opposition to their placement; people like them but don't want to see or hear them. Could a fundamental redesign of the physical appearance of the wind turbine result in a change in public acceptance or preference for them? If so, what might a new generation of wind turbines actually look like, and, is this goal actually possible from an engineering and efficiency point of view?

At present, there have been some new innovative engineering and design technologies that entirely change the way that a wind turbine functions. This includes wholesale changes to the visual appearance and overall improvements to the efficiency and performance for generating electrical energy (Manwell et al., 2009). What typically are found today are two distinct families of wind turbines; (1) horizontal axis wind turbines (HAWT) and (2) vertical axis wind turbines (VAWT). Specifically, it is the placement of the rotor – the central shaft that spins and generates electricity – that separates the two styles of wind turbines. The most commonly used device is the three-bladed turbine from the HAWT family. It is important to mention that large number of other types of devices have been proposed, and in some cases successfully built (Manwell et al., 2009). With regards to the HAWT, there are a greater number of variations based on the number of blades, i.e. single and double bladed, and multi-bladed. Turbines can also vary by their orientation of pitch – up-wind and down-wind – which is associated with the angle of the blades. Other approaches incorporate the use of a diffuser or concentrator to channel airflow from an intake collector and then direct the airflow across the blades. Additional types of HAWT are illustrated in Figure 1.

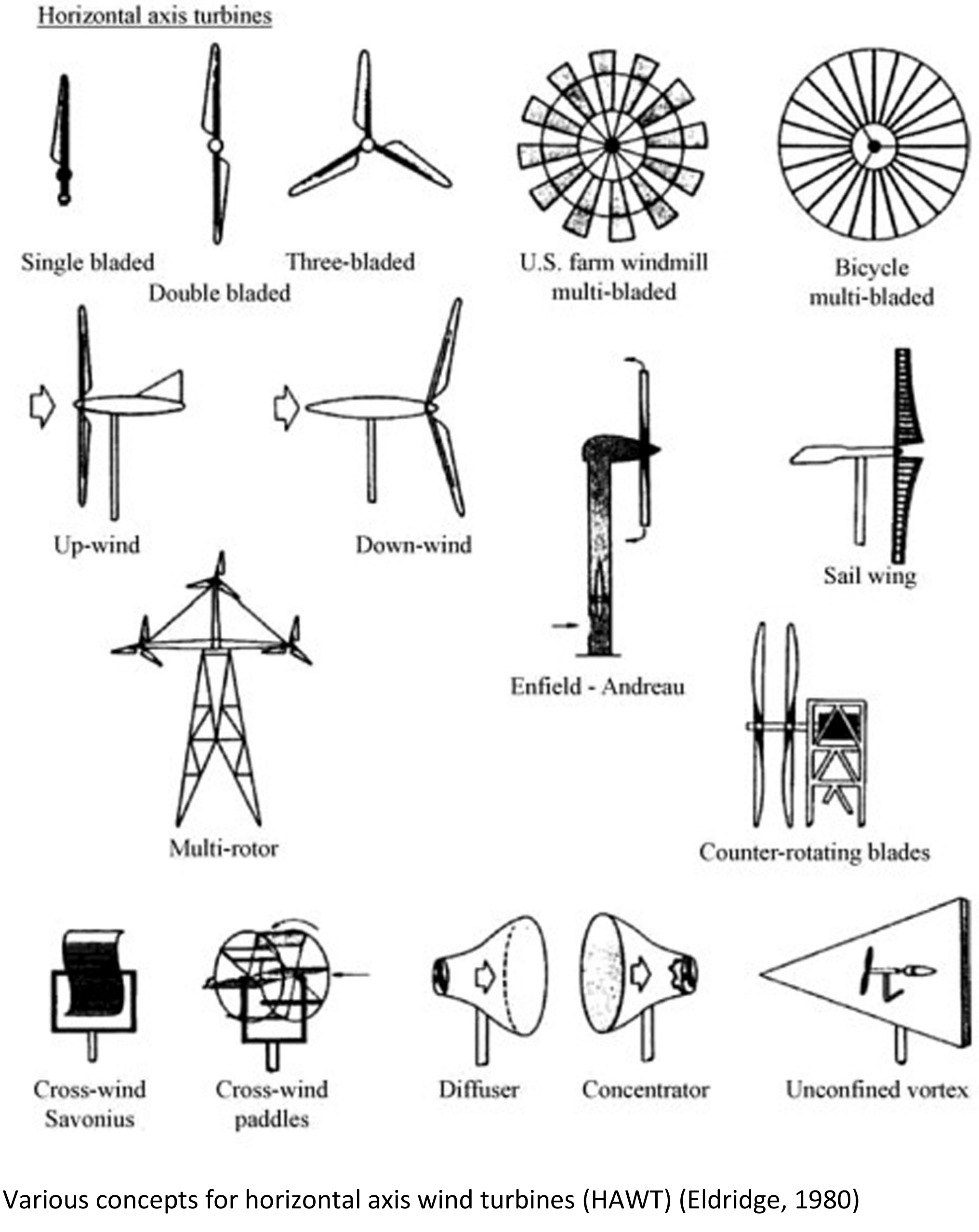

Fig. 1. Various concepts for horizontal axis wind turbines (HAWT) (Eldridge, 1980)

From a visual perspective, some of VAWT seem to be very unique in their appearance and layout, primarily because they do not resemble what one might consider to be a "typical" appearing wind turbine. However, none of these have experienced a similar degree of success as those with a horizontal-axis, lift-driven rotor (Manwell et al., 2009). The closest device that rivals the efficiency of a HAWT was the Darrieus VAWT; this concept was studied in Canada and the United States in 1970s. Despite the appealing design, this turbine has some reliability issues and as such has never become the leading type in the wind energy industry. Another type, the Savonious, is based upon a rotor using drag instead of lift; however, these rotors are inherently inefficient. Recently there are some new designs where the principal idea is to channel the captured wind across the spinning rotor thus increasing the productivity of energy output from the rotor. The literature explains that to build such effective rotor which could withstand very strong wind speeds is very expensive and therefore the turbine is not cost efficient (van Bussel, 2007). Other VAWT types are shown in Figure 2.

To explore the architectural methods and thinking, this paper presents three guiding concepts that should be considered for new wind power generation systems: 1. Harmony with the natural landscape; 2. Symbol or iconic landmark of the place; and 3. Artistic performance. This research proposes architectural designs that will achieve a greater level of public acceptance while simultaneously achieving a sustainable and renewable energy future. In addition, the study explores several design options that might be applicable in different scenarios with minimal visual and environmental impacts and variable artistic appearance. In most instances, designs strive to be vernacular in character to the location and cultural of their intended placement.

Study design and principles

The appearance of a traditional wind turbine is very strict based on its design and engineering and thus cannot be significantly modified in a stylish or architecturally refined manner. Similar limitations apply toward the Savonious and Darrieous wind turbines, both of which are based on strict and specific design guidelines for their functional efficiency. As such, another type of wind turbine had to be chosen in accordance with new and conceptual architectural designs and practices. From the types of wind turbines described above, the turbines with an air intake channel have been chosen for the architectural model experiment. In the market today, there are currently several devices available with such technology, sometimes labelled as wind concentrators. These unique channel-based wind turbines include the BAT, Flo Design, Invelox, Next-Gen Wind, and Wind Tamer - all are copywritten names of each manufacturer. All turbines have the rotor located inside of an enclosed device (i.e. channel or just simply the body) while a structural channel is formed around that space. These new and innovative designs provide many unique opportunities for changing the visual appearance or character of the wind turbine since the actual moving parts or blades are enclosed and not visible as a central moving part. As stated, these wind turbines have no visibly moving parts on the surface, thus, eliminating the commonly associated impacts to flying animals (birds, bats, etc.); reduced noise and light-flickers caused by rotating blades; and most importantly great variability in the proportion, height, and other design parameters. As such, this opens many possibilities for architectural and aesthetic designs with virtually unlimited characteristics for how an air-intake channel for the turbine will appear. An analogy to this design approach is that yes, you are designing a building, but its appearance entirely up to the creativity of the individual designer.

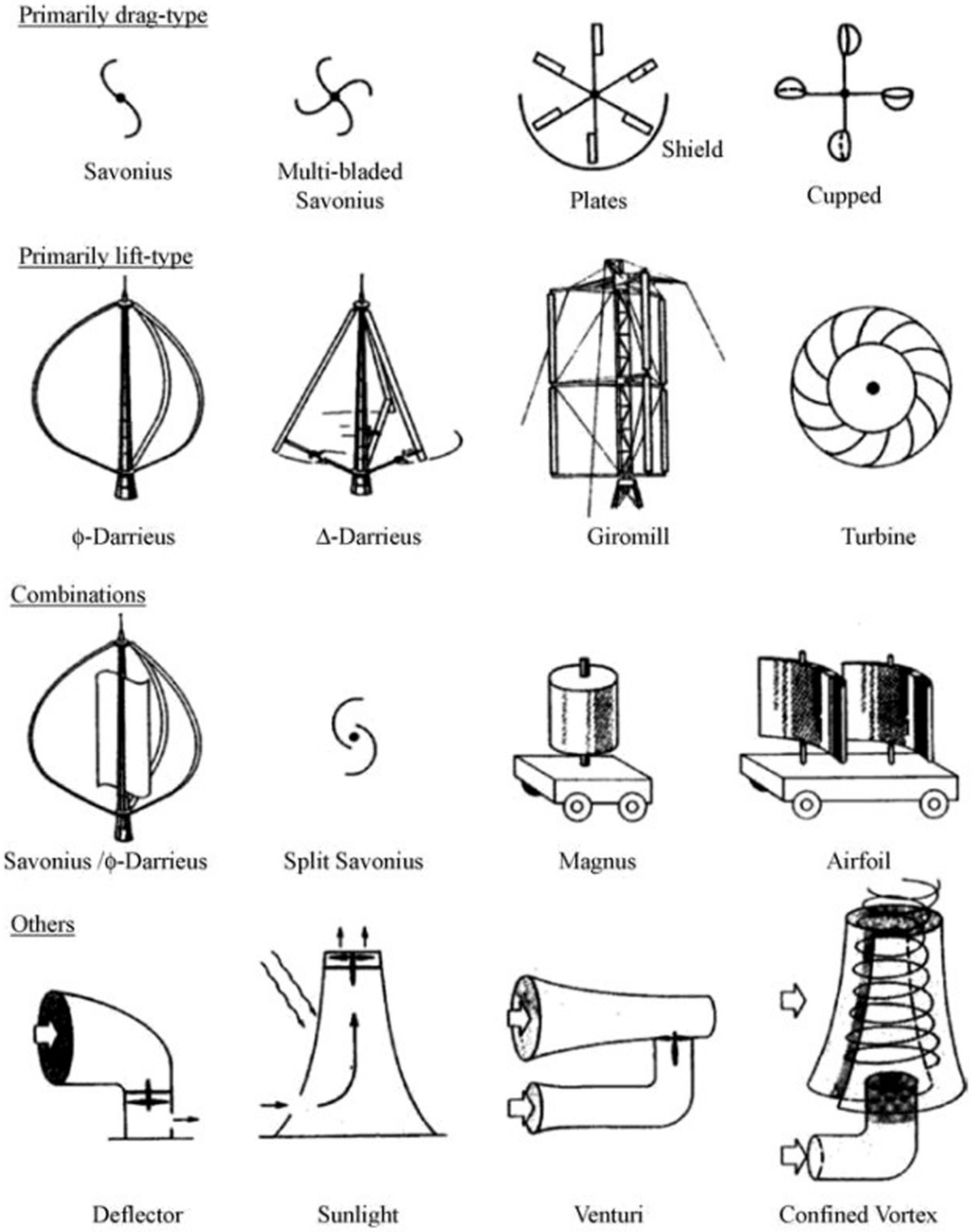

Fig. 2. Various concepts for vertical axis wind turbines (VAWT) (Eldridge, 1980)

BAT (the Buoyant Airborne Turbine) was developed by Altaeros Energies (Glass, 2012). It integrates four main components: a proprietary helium filled shell, lightweight conventional three-bladed turbine, high strength tethers holding turbine on its place, and portable ground station. FloDesign turbine developed by Flodesign Wind Turbine, Inc. is visually similar to conventional wind turbines with a rotor mounted on the top of vertical column; however, it is aerodynamically contoured by a shroud that creates an inlet for air (Presz and Werle, 2011). Invelox (Allaei, 2010a, 2010b) is developed by the Minnesota-based USA company known as Sheerwind, Inc. This system is based on capturing the wind through an inlet or air intake and then accelerating, directing, and concentrating it through a funnel and nozzle where it is then directed toward a turbine-generator system installed inside of a venturi channel. Conventional wind turbines use massive turbine generator systems mounted on top of a very tall tower. Invelox, by contrast, funnels wind energy to ground-based or rooftop generators (Allaei et al., 2015; Allaei and Andreopoulos, 2014). Next-Gen Wind is a ground-based wind turbine developed by the Oklahoma City, Oklahoma, USA-based company NextGen Wind LLC. According to literature provided by the company, the funnel shape that is specific to the wind collection unit increases the volume density of the air mass, forcing it through a smaller tunnel (channel) where multi-blade wind energy collection rotors and generators are located (Journal Record, 2012). The principle is very similar to above-mentioned Invelox. What is unique about a funnel system is that the <u>height of wind turbine</u> is not one of the key factors in energy production; rather it is the <u>volume of captured air</u> that is the main factor for successful energy generation. This allows much greater flexibility to develop designs that best fit in a greater variety of location-scenarios, meaning that such device with its air intake could be situated within an urbanized or developed area with the intake appearing to be part of a building facade. WindTamer diffuser-augmented wind turbine utilizes patented technology for the production of electrical power (Brock, 2010). Arista Power, Inc. is the developer of this design and its principle is similar to that of the FloDesign wind turbine.

Accordance with nature

Many traditional wind turbines are located in naturalistic landscapes with favourable topography, low human impact, and high proportion of natural elements such as indigenous and migratory wildlife. Mountainous landscapes, for example, are characteristic by their sensitiveness to any intrusion associated with visual impacts to the greater landscape beauty and aesthetic characteristics of the setting. Ironically, these areas have a tremendous potential for generating wind energy, as many are located in high mountain regions or where broad expansive slopes exist. Note however that these naturalistic areas are not typified by development or the demand for electrical energy; developed areas are often located far away from these naturalistic settings. Thus, the challenge is to create a structure that is visually sensitive and appropriate to the place (location), respects the aesthetic and natural values of the surrounding landscape, has low impact upon wildlife, and is not recognizable as wind turbine to appease the general public who are typically in opposition to wind turbines for reasons described earlier in this paper. In another words, the device must coalesce with its surrounding environment.

The alternative design proposals presented in this paper present a variety of solutions, use natural and vernacularly appropriate materials such as structural walls constructed from large cut stone, wooden beams or girders, bricks, and green surfaces. The shape and mass or size of the air intake device is designed to evoke appropriate architectural character and cultural values of the place (or region). The concept(s) utilize recognized and acceptable natural and cultural characteristics and then incorporates each into a design proposal for sustainable energy technology. The first concept for the system of alternative wind energy generation can be applied by simply retrofitting historical view towers, which stand approximately 45 meters in height. Similarly, new towers could be built in the same physical character as those historical icons that exist today and are typical for the area. The size of the tower depends on the specific requirements for energy production, power output, and wind conditions, etc.

Sense of Place: establishing appropriate landmarks

This concept can be applied in a variety of scenarios in the landscape by retrofitting existing structures or creating new ones that evoke historic characteristics of a known location. These new or retrofitted structures have the potential to become a symbol or landmark for small villages, an architectural motif for a building (incorporated to the building structure or as free-standing device), or new symbolic icon of a city. The number of visual shapes and characteristics that can be incorporated into the system is limited only by the imagination of the designer (architect, engineer, sculptor, etc.). The design proposal can take any representative concept or idea and convert it into a functional sculpture that is both a display of public art while simultaneously functioning as the air intake for a wind turbine such as the Invelox. It can become such a symbolic element in the landscape, such as the Statue of Freedom in Washington, DC, the Eiffel Tower in Paris, France, or any other symbolic monument such as the Azadi Tower in Tehran, Iran, the Turning Torso in Malmo, Sweden, or various statues of Jesus in Lisbon, Portugal and Rio, Brasil, or the Ještěd Tower in Liberec, Czech Republic. The unique advantage that the alternative designs presented in this paper emphasize is how energy production can be hidden behind artistic or cultural symbolism. Such symbolic memorials, towers, statues and sculptures, with the addition of wind power generation could become a visually sustainable model for electrical energy generation.

The size, shape, and aesthetic characteristics for these systems depend upon the selection of an appropriate site where they shall be erected. For example, a freestanding device in an open urban public space would be designed to respect the character of that particular space while providing power demands and requirements. Design characteristics would be different, for example, at location near the edge of a city from one located within the urban core. The size of the air intake structure (also known as the wind concentrator) is also dependent upon the motivation or idea it shall symbolize: for example the specific type of business organization or institution, such as a museum, a manufacturing plant, or shopping centre. What is particularly unique and exciting is that as stated, each design installation would be distinctive to each specific location, in stark contrast to the "one size fits all locations" design technique employed in the placement of traditional wind turbines.

Artistic performance

The ability to perform an engineered task and do it with artistic and aesthetic design integrity places alternative wind power technology on par with a level of variability and design options not afforded to traditional wind energy devices. The design manufacturers (SheerWind, FloDesign, BAT, etc.) claim that the wind-concentrator design is efficient with wind speeds as low as 2 m/s. Not only is this a significantly higher level of energy generation efficiency, it offers unlimited possibilities to artists and architects to create functional and visually aesthetic design solutions. What this means is that with the increased level of efficiency for wind energy generation, the air intake structures, as presented in this paper, have a much greater level of design variability than does a traditional wind turbine. To date, a variety of distinctive design installations have been realized, such as tree-like sculptures in Vail, Colorado and London, England, "giant ducks" in Sydney, Australia, "giant people" in Budapest, Hungary and Hamburg, Germany, and fountains and many other statues, sculptures, and artwork occupying public spaces, squares, promenades, pedestrian pathways, in front of shopping galleries and administrative centres. The difference now is that the sculpture, such as Budapest's "giant people" can provide multiple services: the production of energy while also allowing people enjoy and admire the artistic installation. However, it is the industrial function, i.e., wind power generation that may not be realized by the public. Thus, artistic performance will have new dimension: the visual beauty that brings 'clean' power, and thereby contributing to the reduction of air pollution often associated with coal-fired power plants or visual pollution associated with traditional wind turbines. In another words, the main functions of such sculptures will be not just aesthetic, but also allow for the production of electrical energy from a globally available clean source of energy: wind.

The size of the air intake is tremendously variable when the key design factors are the requirements for energy production and perhaps the specific conditions of the place where the device is to be located.

Proposals and concepts

The proposed case study concepts described below are based on a wind turbine with an air intake on the top and an enclosed rotor with an air exhaust port located at ground level. This design approach uses the Invelox (SheerWind) with an Omni-directional intake to illustrate possible design solutions (see Figure 3).

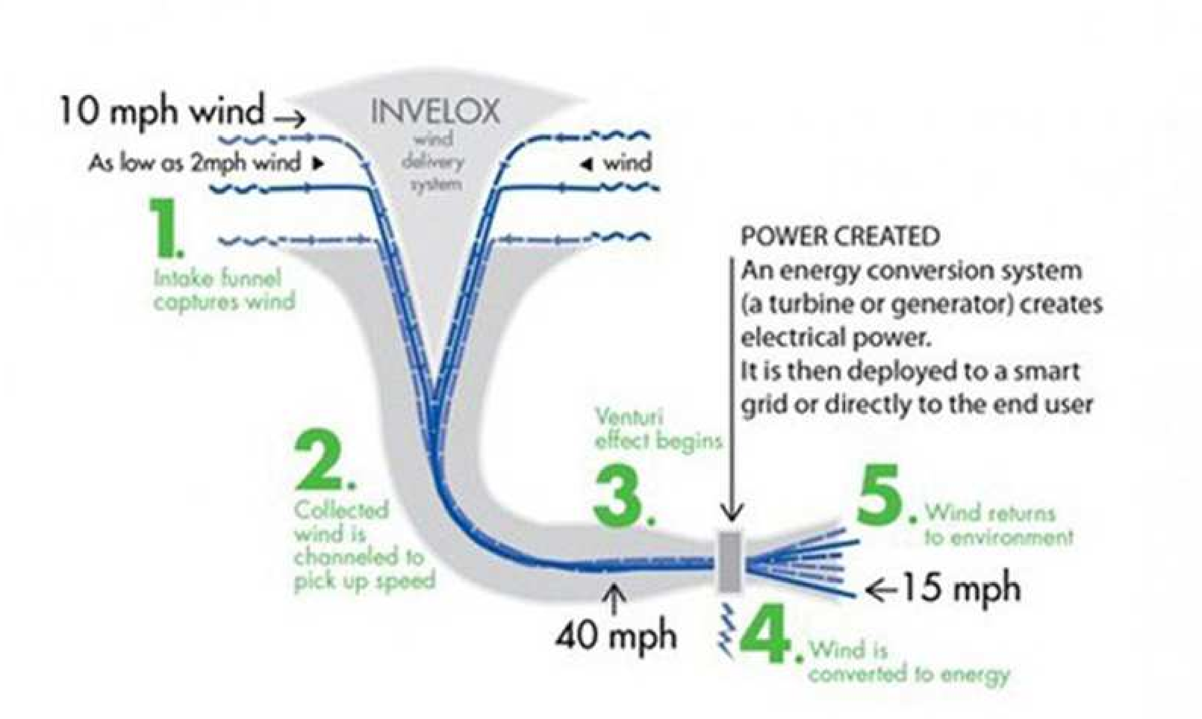

Fig. 3. Concept of Invelox wind turbine (source: http://sheerwind.com)

Case Study #1: Design in accordance with nature

This first proposal is designed in the spirit of 19th century historical towers typically located in a rural mountainous region of the northern Czech Republic (Bohemia). The height may vary from 15 to 50 metres depending on the intended power output and specific location of the Invelox style wind turbine. Construction materials and exterior facade surfaces may be selected to maintain the traditional rural character of the structure, in particular the vertical walls of the towers would be assembled from native stone that integrate well in this landscape and are characteristic to other built towers commonly found in this region. Wooden support beams or planks serve as the structural columns for the tower. Such a structure would also serve as the load-bearing system of the enclosed wind turbine device. This landscape reflects typical mountainous areas in central Europe, with characteristic strong wind conditions. Specifically, Figure 4 represents landscapes located in “Jizerské hory” mountains of the northern region of Bohemia, and in Giant Mountains, in the northeast of Bohemia, Czech Republic. With the design goal to minimize the visual impact as much as possible, the proposed structure would be partly placed under ground or below grade, significantly reducing the overall design height (see Figure 5: ‘Earth Flower’ design). Nevertheless, this solution may introduce two competing cost items: on one hand site excavation will increase the cost of construction due to the requirement for earthwork. However, earth can be used as part of the structure of the wind turbine system (placement of the turbine sub-surface) and thereby reduce cost of material used. The visible components of this design are the air intake located at the hill top and air exhaust located at a lower elevation near the bottom of the hill. As stated, the entire body of device can be covered by earth and housed inside of a structural shell. In all cases, this type of wind capturing and delivery system exhausts the captured wind into the atmosphere while converting a portion of the wind to electrical energy and into the electrical grid.

Fig. 4. Wind turbine presenting the structure of historic view tower, located in “Jizerské hory” region and in “Krkonoše” region, Northern Bohemia, Czech Republic.

Fig. 5. Wind turbine presenting the structure partly hidden in the ground. The illustration shows intake built above the ground and the channel in the ground with exhaust revealing at the lower part of the hill.

Case 2: Symbolism of a specific place or institution

This approach illustrates how a design element, which is both artistic and functional, can be a symbolic representation of a specific place – genius loci. Symbolism is represented as a commonly known object, often typified by ordinary daily use, or it can be representative of living things found in local or national fauna and flora.

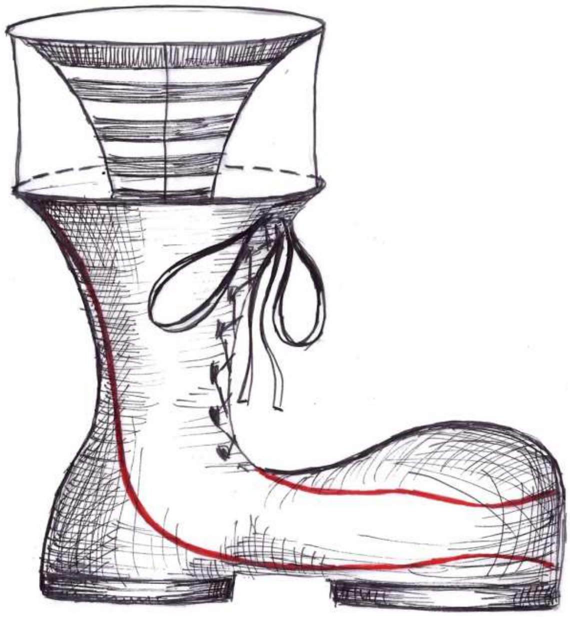

Fig. 6. Wind turbine presenting the idea of symbolising the 'shoe' object. The proportion of such design responds to the omni-directional wind turbine Invelox (see figure 3).

This case study presents two proposals, briefly described as follows: The symbol of 'shoe' (see Figure 6) is proposed for a well-established shoe manufacturing company, known worldwide. Assume that this company wishes to highlight its image as business focused on sustainability and their support for clean energy production. The idea is based on a vision that upper part of the shoe (such as the top of a boot) would constitute the air intake and the lower part above the sole would cover the body of wind device. The wind turbine would be completed installed inside the 'shoe' envelope.

The second concept, the flower (see Figure 7) symbolises the importance of nature and the need for its protection. The purpose of this installation is to represent an organization dedicated towards conservation of nature as a means to demonstrate the need of sustainable energy. In this case, the blossom would function as the air intake at the top and the stalk as the channel directing air towards the enclosed turbine below grade. The flora motif is further inspired by a Hawaiian flower (see Figure 7), with the blossoming leafs serving as the load-bearing system for the structure.

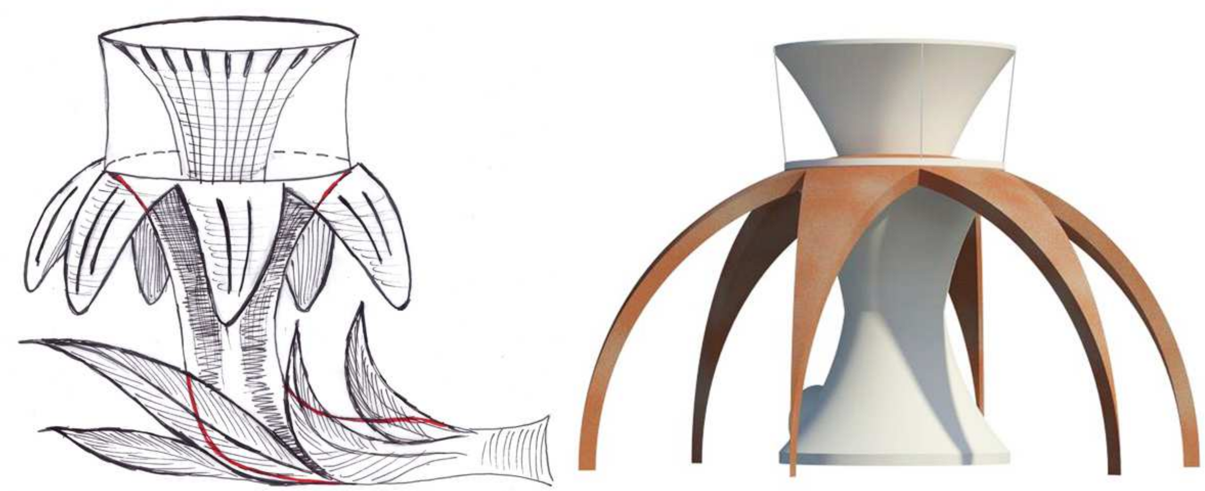

Fig. 7. Wind turbine presenting the idea of symbolising the flower. The proportion of such design responds to the omni-directional wind turbine Invelox (see figure 3). The ‘leaves’ of the blossom can be designed in varied proposals, for example creating the shelter for people against sun light or rain.

Case 3: Artistic performance

This proposed structure is designed to utilize a simple conical structure with circular or elliptical openings as the air intake (see Figure 8).

Fig. 8. Wind turbine as artistic sculpture located in the urban landscape in London (Great Britain) and Lisbon (Portugal). Both locations are located either at river bank (London) or sea coast (Lisbon), i.e. at places with typical constant wind conditions.

It could also include additional openings as different flow channels depicted as names or letters or even other cut-out motifs and symbols completing the entire performance idea of the exterior. The construction material for the cover or conical structure is proposed from COR-TEN steel, preferable for its high resistance to wind and other environmental effects such as rain, snow, ice, hail stones, UV rays; the actual body of the wind turbine will be enclosed within the structure, consistent with Invelox and Next-Gen wind turbines. The manufacturing of the vertical conical structure is fairly simple and does not require complicated construction methodologies. This proposed design concept is intended to be located in an urban context or setting, for example on the riverbank in London, or on the coastal area in Lisbon, Portugal where wind velocity at the air intake is assured due to at least one open direction oriented towards the water (i.e. river, coast side). The example locations – such as pedestrian promenades – are often embellished by artistic sculptures. For this reason, the image simulation has been portrayed in this type of a location. The simulation design for this case study symbolises the goblet of fire – a symbol of freedom and peace in society – including the message in graphic form (figures, patterns, abstraction, letters and other motifs).

Discussion and perspective

This paper demonstrates how architecture can transform a highly technical device, such as a wind turbine, into an attractive and aesthetic element in both undeveloped landscapes and urbanized built up areas. It is important to point out that wind turbines are typically located in undeveloped open landscapes, often far away from where the energy generated will be used or consumed. Thus, there is an inherent inefficiency in the relationship between energy generation and energy consumption. Perhaps only solar panels or photovoltaic arrays avoid this pitfall. The alternative wind generation devices described in this paper can be placed in locations that are not typically thought to be possible. With this advantage of locating high efficiency enclosed turbines where the air intake, or 'wind concentrator' as they are often referred to in the literature, can be incorporated into the architecture features of a building such as vernacular stone observation towers or modernist architectural schemes, the possibilities are very exciting. The selection of a 'wind concentrator' (air intake), for this purpose, is purely based on the possibility to fashion a wide variety of exterior covers for the air intake shaft that then funnels wind and directs it toward the turbine itself. The schematic examples proposed in this paper serve to illustrate a range of possible structures might and their appearance.

It is important to clarify that this paper does not calculate or further explain the functionality or energy efficiency of the new generation of wind turbines described herein; this is best left to research by others. Note that detailed explanations and calculations of alternative wind turbines with enclosed moving impellors are described in the literature and specifications for each of the different manufacturing companies or inventors. Detailed information about the Invelox systems, for example, can be found in published papers by Allaei et al. (2015) and Allaei and Andreopoulos (2014). Although mentioned earlier in this paper, the wind turbines in section 'Study Design and Principles' are based on concentrating the wind; actual designs may vary in their visual appearance. For example, BAT has the shroud typically fashioned from a helium-filled shell and more importantly, it is intended to be placed nearly one hundred metres above the surface of the ground. The visual impact of this device has not been tested in any known social science literature. Other types, such as FloDesign and WindTamer, are intended to incorporate a specific shroud for the intake to be mounted on the top of a load-bearing column. The appearance of these two devices is more closely related to that of traditional wind turbines and as such is very difficult for further architectural modifications. The funnel-based type devices, such as Invelox and Next-Gen Wind, offer greater options for design variability, mainly because the exterior appearance is not important for the functionality of the device; the difference between these two devices is the location of an air intake. Whereas Invelox has an intake on the top of the structure and exhaust at the ground level (in most applications however both can be located on a roof top), Next-Gen Wind places both intake and exhaust at the ground level.

Present and future energy demand, increased consumption, finite resources for fossil fuels, and other global issues point toward a future based increasingly upon renewable energy targets, in particular wind energy; a world-wide subject for discussion due to its potential for innovation in the design and efficiency of the turbine devices. Environmental impacts (visual intrusion in the landscape, noise, light flickers, danger to birds etc.) and thus strong public opposition happen to be a critical obstruction in some locations for greater expansion of traditional wind farms (Wolsink, 2007). This paper presents three possible schematic concepts for how to utilize wind and produce energy for communities while offering alternative solutions for the physical aesthetic appearance in several scenarios – natural landscapes, cityscapes and other public spaces.

Because the wind concentrators (air intakes), of the Invelox and Next-Gen Wind devices do not have any visible moving blades and place generator or turbine(s) at ground level or enclosed on the top of a building, it suggests that it both should be harmless to birds and other wildlife. Furthermore, the noise impact is presumed to be at a lower level (based in literature provided by both manufacturers) since there are no exposed blades producing a “swooshing” sound or light flickers. This allows for the construction of an enclosed wind turbine style device in developed urbanized areas, public spaces, or near residential districts. The increased design flexibility inherent in this style device includes reduced requirements to dig long underground channels for electrical wires to connect to the electrical grid. Such advantages go together with reduced costs associated with device erection, location (positioned closer to where energy will be consumed), maintenance, and operation. The visual impact or wind turbines, being the most negative impact considered by public, (Betakova et al., 2015), is discussed in following paragraph.

The proposals described in this paper demonstrate the physical design variability possible with Invelox and Next-Gen wind energy devices. There are an infinite number of variations in the overall height, width, and size of the air intake, the variety of materials used in the construction, position, location, and air exhaust. Each factor suggests that each site installation and design allow for modification and design for a great number of site-specific solutions to fulfil energy demands of a community. These devices provide new possibilities in how the external appearance of the air intake and wind concentrator can be adapted to fit to many different scenarios. Natural and scenic landscapes have the potential to no longer be impacted by a large moving object, such as a traditional wind turbine (Vries et al., 2012). With this exists the potential for communities to have their own source of 'clean energy,' without local opposition regarding its visual appearance. Public spaces in built up areas can be enhanced by beautiful sculptures that are an integral part of the energy production for the electrical grid. With this, many other possibilities are opened.

Renewable energy production no longer has to simply be the system of "build and produce" without site-specific solutions to mitigate their visual character in the landscape and physical environment. Managing the impacts upon landscape character should be considered distinctive for such structures (Vorel et al., 2006). Channel-based turbines (Invelox, Next Gen Wind, and others) have many advantages, relative to the design variability and site accommodation. Thus they can be used to create effective economical and aesthetically attractive systems with a variety of benefits specific to their aesthetics character upon landscape (Nohl, 2001). However, the total energy output may not be on par in comparison with traditional wind turbines at this stage of their engineering evolution. Nevertheless, the critical factor to remember is that a device designed in accordance with the surrounding landscape can find its appropriate utilization. See the summarized pros and cons of traditional wind turbines and alternative wind turbines (Invelox, Next-Gen and other) contained in Table 1.

Alternative wind turbines	Traditional wind turbines
Advantages	
• Attractive design and therefore higher public acceptance • Alignment with surroundings • Possible design for cityscape and public spaces • Retrofitting to existing structures • Possible lower impact on wildlife and people • Possible noise reduction • Variable design applied to specific situation	• Tested and known efficiency • Tested and known durability and productivity • Developed technology during decades • 'Simple' design • Accompanying studies
Disadvantages	
• New alternative method without long-term testing • Each situation may require specific design solution to its conditions • Unknown behaviour in strong weather conditions (storm, hurricane, etc.) • Unknown noise data and other • Costs dependent on conditions of each place	• Visual impact – public opposition • Impact on wildlife – danger to bird and bat populations • Noise annoyance and light flickers • Danger risk to human – not possible to build up in cityscape • Very high costs • Frequently built in places far away from locations which need energy supply

Table 1. Summarization of pros and cons of traditional wind turbines and alternative wind turbines (Invelox, Next-Gen and other)

Channel-based wind turbines should be considered just as any other built structure that is designed in accordance with the landscape, the historical and cultural development of a region, targets and goals for sustainable energy production, and other requirements. All are due to the elimination of environmental impacts, dangers, and risks to humans. The uniqueness pertains to the possible accommodation and adjustment to any environment where it might be built, i.e. a mountainous landscape, a coastal seascape, or urbanized areas and public spaces. This type of wind energy producer can be sensitive to places with respect to natural and cultural attributes, can be retrofitted to unused industrial structures, or can be used to create beautiful pieces of public art.

The described systems in this paper allow for the development and installation of wind turbines in locations where traditional devices were previously thought to not be possible, primarily due to their associated visual and environmental impacts. It is the design variability that is perhaps the greatest advantage of channel-based wind turbines specifically because these systems allow for their development with many visual design variations. Finally, it is the ability to develop a system of energy production that also achieves many other simultaneous benefits, such as development of public art or renovation and retrofitting forlorn industrial sites, minimizing impacts to birds and bats, and elimination of visual clutter in the landscape which makes ideas and concepts presented in this paper unique and appropriate for the future of sustainable energy generation.

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CURRICULUM VITAE

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Dissertation topic: **Visual preferences for wind turbines**

Education

2012 – present	Doctoral programme Applied and Landscape Ecology Czech University of Life Sciences, Faculty of Environmental Sciences, Department of Land Use and Improvement
2010 – 2012	Master in Architecture and urbanism Czech Technical University in Prague Faculty of Civil Engineering, Department of Town and Landscape Planning
2006 – 2010	Bachelor in Architecture and Engineering Czech Technical University in Prague Faculty of Civil Engineering, Department of Architecture
1998 – 2006	Gymnasium Trutnov

Professional experience

2012 to present	Artiga REIM, Terronska 49, Prague, Czech Republic – project manager, architect
2010 to 2012	atelier Doubner, Wenceslas square 15, Prague, Czech Republic – project architect
2011	Secretary of the Committee for urban planning and city development in Prague – Prague City Assembly

International experience:

2008 - 2009	Erasmus study in Denmark in English, VIA University Horsens – Programme: Constructing Architect (2 semesters)
Autumn 2010	ATHENS programme – 1 week in Milano – course The Art of Urban Composition
Spring 2011	Project at Prague institution of NCSU (North Carolina State University) – landscape architecture (1 semester)

Language skills	**Computer skills**
Czech – native speaker, C3	Adobe Photoshop
English – advanced, C1	CAD programmes – Revit, Autocad
German – A2	MS Offices – Word, Excel, Powerpoint
Spanish – A1	3D Modelling – Revit, 3DMax

Teaching experience at CULS

2013 to 2015	Landscape planning
2014	Spatial planning

Grants

2013/14	Visual preferences for wind turbines IGA FES 20134279 (Internal grant of Faculty of Environmental Sciences)
2014/15	Visual preferences for wind turbines IGA FES 20144220 (Internal grant of Faculty of Environmental Sciences)

PUBLICATIONS

Articles published in scientific journals with IF:

Betakova V, Vojar J, Sklenicka P. (2015). Wind turbines location: How many and how far? Applied energy 151: 23-31

Articles published in journals in SCOPUS database:

Betakova V, Vojar J, Sklenicka P. (2016). How education orientation affects attitudes toward wind energy and wind farms: implications for the planning process Energy, Sustainability and Society (accepted)

Articles submitted in journals in SCOPUS database:

Betakova V, Kumble P. (2016). Futuristic wind power systems suitable as artistic sculptures. Design Issues (submitted)

Abstracts at conferences:

Betakova V. (2016). Wind turbines – Most visible cultural elements in natural landscapes. In Nature & Culture: heritage in Context. 7th Annual Conference on Heritage Issues in Contemporary Society, 16 – 19 May 2016, Czech University of Life Sciences, Prague

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Conference papers:

Betakova V. (2016). Artistic wind turbines along greenways: The concept. In Jombach, S., Valánszki, I., Filep-Kovács, K., Fábos, J. Gy., Ryan, R. L., Lindhult, M. S., Kollányi, L. (Eds.) 2016: Landscapes and Greenways of Resilience – Proceedings of 5th Fábos Conference on Landscape and Greenway Planning (Budapest, 01 July, 2016)

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