

# VISUAL PREFERENCES FOR WIND TURBINES

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Department of Land Use and Improvement

# **VISUAL PREFERENCES FOR WIND TURBINES**

DISSERTATION

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The dissertation entitled “Visual preferences for wind turbines” has been created within doctoral studies at the Department of Land Use and Improvement at the Faculty of Environmental Sciences of Czech University of Life Sciences at Prague.

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## 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 Eiffel 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, 2006; 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 though 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.

## 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

## ARTICLE 1

### **Wind turbines location: How many and how far?**

#### **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.

## KEYWORDS

Visual impact, Landscape quality, Visual preference, Wind power, Renewable energy planning

## HIGHLIGHTS

- Negative impact of wind turbines (WTs) diminished with distance from observer.
- Impact disappeared at 5 to 10 km regardless of 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.

## CITATION

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

## ARTICLE 2

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

### 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

### CITATION

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

## ARTICLE 3

### **Futuristic Wind Power Systems Suitable as Artistic Sculptures**

#### **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

## CITATION

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

## SUMMARY

This work suggests at once three improvements or opportunities to help higher public acceptance. First (Article 1), 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 (Article 2), how to improve respondents', sanctioning authorities' and planners' knowledge regarding environmental and technical issues via, for example, interdisciplinary courses. Third (Article 3), 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. 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. 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 of 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.

## SHRNUTÍ

Disertační práce je souborem tří vědeckých článků, které spojuje tematicky problematika vizuálních preferencí větrných elektráren (VE). První článek se zabývá hodnocením vhodného umístění VE v krajině a zkoumá tři aspekty, které mají vliv na toto hodnocení: typ krajiny, vzdálenost VE od pozorovatele a počet VE. Druhý článek je postaven na hodnocení vlastností respondentů a možnostech zlepšení znalostí a povědomí této problematiky z hlediska provázání technických a environmentálních znalostí pomocí interdisciplinárních kurzů. Třetí článek je založen na návrhu alternativního vizuálního řešení VE, která by svým vzhledem zvýšila vizuální atraktivnost těchto konstrukcí.

Typ krajiny včetně jejích estetických, přírodních a kulturních hodnot by měl být posouzen před tím, než začne samotné plánování VE. Právě krajinný typ v interakci se vzdáleností od pozorovatele a počtu VE byl určen první studií jako významný faktor, který má vliv na celkové vizuální hodnocení. Studie poukázala na zajímavý jev, že i atraktivní krajina může být hodnocena po umístění určitého počtu VE velmi negativně a hůře než ty, které nejsou vnímány jako hodnotné. Takovéto plánování by mohlo vést k fatální degradaci právě chráněných a cenných území. Na druhou stranu, umístění VE ve velmi blízké vzdálenosti, tj. 500 m, může být vnímáno negativně v každém typu krajiny. Vzdálenost je tedy důležitý faktor pro hodnocení vlivu VE na krajinu, také v interakci s počtem VE. V první studii byly navrženy zóny viditelnosti, které se liší dle typu krajiny a technických parametrů VE (výška aj.).

Plánování větrných farem a schvalovací proces může být zlepšen hlubší znalostí environmentálních a technických aspektů týkajících se výstavby VE. Komplexní vzdělání a znalosti jsou důležité jak pro úředníky plánovacích a schvalovacích orgánů, tak pro plánovače a techniky (developery). Převážně technicky nebo environmentálně orientované myšlení může způsobovat konflikt mezi zúčastněnými stranami v plánovacím procesu. Vedle toho také obecný postoj k větrné energii byl určen jako významný faktor mající vliv na vnímání respondentů. Má především vliv na možné přizpůsobení se po určitém čase od výstavby. Na druhou stranu respondenti s pozitivním přístupem k větrné energii mohou být výraznými oponenty z důvodů jejich neochotě se přizpůsobit nové situaci vzhledem k plánované výstavbě VE. Zahrnutí lokálních residentů a komunit má tedy velmi důležitý vliv na celkový průběh schvalovacího procesu. Stejně tak vzdělání a povědomí o této problematice u všech zúčastněných stran (místní obyvatelé a komunity, plánovací orgány a developer).



Přestože vizuální vliv VE je často diskutován v literatuře jako jeden s nejvíce signifikantních faktorů pro další vývoj a plánování VE, další alternativní a vizuálně odlišné typy VE nejsou prozatím zmiňovány. Je to způsobené pravděpodobně efektivností současných typů VE (HAWT), které tvoří hlavní zdroje získávání energie z větru. Třetí studie proto předkládá řešerši pro VE typu „wind concentrator“ dle literatury a současných forem nabízených na komerčním trhu. Tyto větrné turbíny, založené na vytvoření tunelu pro zrychlení proudění vzduchu, mají jednu obrovskou výhodu oproti tradičním VE. Jelikož je rotor umístěn uvnitř tunelu, exteriér této turbíny může být navržen dle představ architekta a možností daných místem a dalším kontextem. Možnost navrhnout jakýkoli design této technické infrastruktury otevírá možnosti v kombinování estetické a industriální funkce.

Shrnutο na závěr, na základě řešerše a výsledků studie, vizuální vliv způsobující nesouhlas veřejnosti s výstavbou VE a související estetickou degradaci krajiny musí být řešen nějakým způsobem. Všechny závěry v této práci jsou užitečné z hlediska plánování VE a mohou být uplatněny v praktickém plánování a posuzování umístění VE.

## CURRICULUM VITAE

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### Education

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

Czech – native speaker, C3

English – advanced, C1

German – A2

Spanish – A1

## Computer skills

Adobe Photoshop

CAD programmes – Revit, Autocad

MS Offices – Word, Excel, Powerpoint

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:

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