What are the reasons behind the society’s objections to wind farm development? Are they justified and what do we need to do in order to change this attitude?

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SCHOOL OF SCIENCE & TECHNOLOGY
A thesis submitted for the degree of
Master of Science (MSc) in Energy Systems

DECEMBER 2016
THESSALONIKI – GREECE
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Abstract

This dissertation was written as a part of the MSc in Energy Systems at the International Hellenic University. The aim of this investigation is to list all the reasons that create social objections towards wind turbines, throughout the years. While many people are in favor of wind energy as a greener choice of electricity production, when the installation concerns neighboring areas, the objections tend to increase. Under this prism, there are several reasons as to why it is difficult to foster social acceptability in a new wind project, such as noise, visual impact, terrestrial or marine ecosystem disturbance, shadow flickering, safety concerns, land use and possible adverse health effects. A majority of the reasons are justified while others are not.

**Key words:** wind turbines, social acceptability, social opposition
## Table of contents

ABSTRACT .................................................................................................................................................. III

CHAPTER 1 – INTRODUCTION .................................................................................................................. 4
  1.1 Environmental Policy Framework ....................................................................................................... 9
  1.2 Feed-in tariffs (FiT), Feed-in Premium (FiP), Quota System & Tradable Green Certificates (TGC) .................................................................................................................. 11

CHAPTER 2 – WIND ENERGY: AN OVERVIEW ......................................................................................... 13
  2.1 Characteristics of a wind turbine ......................................................................................................... 17

CHAPTER 3 – LITERATURE REVIEW ....................................................................................................... 21
  3.1 Social objections ................................................................................................................................... 22
    3.1.1 Noise & Human Health ............................................................................................................... 28
    3.1.2 Not In My Back Yard (NIMBY) Syndrome ............................................................................... 34
    3.1.3 Visual impact ............................................................................................................................ 39
    3.1.4 Shadow flickering ..................................................................................................................... 45
    3.1.5 Safety & Icing .......................................................................................................................... 47
  3.2 Environmental impacts ......................................................................................................................... 50
    3.2.1 Impacts in ecosystems .............................................................................................................. 52
      3.2.1.1 Wildlife, birds & bats ........................................................................................................ 53
      3.2.1.2 Marine ecosystems .......................................................................................................... 59
    3.2.2 Use of land and landscape ....................................................................................................... 60
  3.3 Economic aspects ................................................................................................................................. 62

CHAPTER 4 – THE ROAD TO ACCEPTANCE ............................................................................................ 65

CHAPTER 5 – CONCLUSIONS ..................................................................................................................... 67

REFERENCE LIST ....................................................................................................................................... 69
# Table of figures

Figure 1: Total and relative gross avoided greenhouse gas emissions in European Member States (Source: European Environment Agency, 2016) ............................................. 5  
Figure 2: The progress in wind industry of European Union in a nutshell ....................... 6  
Figure 3: Annual Installed Capacity by region 2007-2015 (Source: Global Wind Energy Council, 2015) ........................................................................................................ 8  
Figure 4: Horizontal and vertical axis wind turbines (Source: Mathew, 2006) ....................... 17  
Figure 5: Schematic of a wind turbine (Source: Nelson, 2009) .................................. 18  
Figure 6: The evolution of wind turbines’ diameter during the past years .................. 19  
Figure 7: Evolution of wind turbines ........................................................................... 20  
Figure 8: Social acceptance of different type of electricity generation technologies (Source: European Commission, 2007) ................................................................. 23  
Figure 9: Factors affecting public opinion about wind projects (Source: Devlin, 2005) 23  
Figure 10: The triangle model of social acceptance of renewable energy innovation (Source: Wüstenhagen et al., 2007) ................................................................. 26  
Figure 11: Links between factors affecting the opinion of the public (Source: Devlin, 2005) ................................................................................................................. 27  
Figure 12: Opposition to wind turbines due to noise ................................................... 28  
Figure 13: Noise produced by wind turbines compared to household appliances .......... 31  
Figure 14: The NIMBY syndrome ................................................................................. 35  
Figure 15: the development of public attitudes towards wind projects (aka U-shaped curve) (Source: Wolsink, 1994) ................................................................. 37  
Figure 16: Opposition to wind turbines due to visual impact .................................... 39  
Figure 17: Wind park .................................................................................................. 42  
Figure 18: Wind offshore park ................................................................................... 43  
Figure 19: Shadow flickering effect .......................................................................... 46  
Figure 20: Ice on a wind turbine blade ........................................................................ 48  
Figure 21: Comparison of impacts between wind energy and conventional and renewable energy sources (Source: Saidur et al., 2011) ........................................... 52  
Figure 22: Cause of bird fatalities (Source: Kaldellis and Zafirakis, 2011) ................. 55  
Figure 23: Map of Natura 2000 areas in the European Union .................................... 57  
Figure 23: Birds passing by a stationary wind turbine ......................................................... 58
Table of tables

Table 1: European wind power capacity installed (in MW) ............................................. 7
“Of all the forces of nature, I should think the wind contains the greatest amount of power”

Abraham Lincoln
Chapter 1 – Introduction

Nowadays, emerging alternative technologies, which aim in confronting the issues of depletion of energy resources and environmental pollution that have arisen, have gained significant attention and importance. Energy consumption of a nation often mirrors the level of prosperity that it could achieve; subsequently, energy is one of the most crucial factors affecting the development of a nation (Mathew, 2006).

Petroleum-based fuels are derived from limited crude oil reserves concentrated in certain regions on the planet, creating energy security conflicts and entail in significant amounts of environmental emissions, causing air pollution. The lack of proper management of fossil fuels that leads to their depletion, increases concerns and debates regarding environmental impacts, health and safety issues, which are forcing the world towards new energy sources. Additionally, the excessive use of fossil fuels combined with the increasing demand and population of the world, impose a switch to other alternative energy sources (Nelson, 2009) that will ensure a more sustainable future. The development of these sources is an essential ingredient to the industrialized world. Debates on whether alternative sources could fully replace conventional ones, are at the forefront.

Renewable energy sources, which include wind, solar, geothermal energy, biomass, hydropower, oceanic and tidal power, provide clean energy for electricity generation, transportation, and heating, offering the potential of replacing fossil-based fuels. The reason they are called renewable is that they can naturally replenish on a human time scale, in comparison with fossil fuels that need thousands of years. This is the reason why they are highly recommended in order to transform the industrialized world into a more sustainable one.

The transition to renewable-based energy sources can provide many social benefits, such as improved health, due to lack of emissions in air and water, work opportunities and technological advances (Alkella et al., 2009). Additionally, investing in renewable energy can help a country’s economy as instead of depending on imports of conventional sources for energy supply (such as natural gas, oil or coal), which are not equally distributed in the world, numerous of different available sources exist depend-
ing on the particular location and its characteristics (wind, solar, biomass, etc.) (Alkella et al., 2012). Nonetheless, besides the valuable merits that renewable sources provide to energy consumption section, renewable energy facilities do not lack of impacts.

Figure 1 illustrates the reduction of greenhouse gas emissions in the European Union, because of the transition in renewable sources. Additionally, globally, emissions of carbon dioxide (CO$_2$) have increased by 50% since 1990 in comparison to 2015, according to the United Nations\(^1\), whereas according to Mathew (2006) three quarter of global emissions of CO$_2$ is due to the combustion of fossil fuels.

Figure 1: Total and relative gross avoided greenhouse gas emissions in European Member States (Source: European Environment Agency, 2016)

The European Union, as mentioned above, set mitigation measures that include the transition to renewable technologies, in order to reduce emissions. Concerning wind power, it has become, at present, the preferred option of energy for numerous planners, developers, energy researchers and national governments decision makers, who want to eliminate carbon dioxide emissions, provide new jobs and prevent the depletion of fossil fuels (Dai et al., 2015). Wind is the world’s fastest developing energy source nowadays, in tune with the continuous rate of energy demand and the development of modern technologies (Mathew, 2006). As with every other renewable source, wind energy is not

free of environmental impacts and a misreading of these impacts would result in deleterious consequences.

As shown in Figure 2, the European Union made significant progress towards the use of wind energy. More specifically, the total wind capacity added was 12,800 MW and the total number of turbines installed 74,000; in addition, 225,000 people were employed by the wind industry (Global Wind Energy Council, 2015). The large number of employment opportunities may create a very positive attitude towards wind turbines. However, social objections create very critical thresholds towards the operation of wind turbines in specific areas as many people are in favor of wind energy but they do not want installations “in their back yard”.

![2015 in a Nutshell](image)

Figure 2: The progress in wind industry of European Union in a nutshell
(Source: Global Wind Energy Council, 2015)

As shown in the table below, European wind power capacity installed, has increased since 2014, with Germany having the dominant position with the largest installations, followed by Spain. According to Global Wind Energy Council (2015), “Germany alone accounted for almost 50% of total EU wind energy installations with 6,013 MW”.
Table 1: European wind power capacity installed (in MW)

(Source: Global Wind Energy Council, 2015)

<table>
<thead>
<tr>
<th>Europe</th>
<th>End 2014</th>
<th>New 2015</th>
<th>Total End 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>39,128</td>
<td>6,013</td>
<td>44,947</td>
</tr>
<tr>
<td>Spain</td>
<td>23,025</td>
<td>-</td>
<td>23,025</td>
</tr>
<tr>
<td>UK</td>
<td>12,633</td>
<td>975</td>
<td>13,603</td>
</tr>
<tr>
<td>France</td>
<td>9,285</td>
<td>1,073</td>
<td>10,358</td>
</tr>
<tr>
<td>Italy</td>
<td>8,663</td>
<td>295</td>
<td>8,958</td>
</tr>
<tr>
<td>Sweden</td>
<td>5,425</td>
<td>615</td>
<td>6,025</td>
</tr>
<tr>
<td>Poland</td>
<td>3,834</td>
<td>1,266</td>
<td>5,100</td>
</tr>
<tr>
<td>Portugal</td>
<td>4,947</td>
<td>132</td>
<td>5,079</td>
</tr>
<tr>
<td>Denmark</td>
<td>4,881</td>
<td>217</td>
<td>5,093</td>
</tr>
<tr>
<td>Turkey</td>
<td>3,738</td>
<td>956</td>
<td>4,694</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2,865</td>
<td>586</td>
<td>3,431</td>
</tr>
<tr>
<td>Romania</td>
<td>2,953</td>
<td>23</td>
<td>2,976</td>
</tr>
<tr>
<td>Ireland</td>
<td>2,262</td>
<td>224</td>
<td>2,486</td>
</tr>
<tr>
<td>Austria</td>
<td>2,089</td>
<td>323</td>
<td>2,411</td>
</tr>
<tr>
<td>Belgium</td>
<td>1,959</td>
<td>274</td>
<td>2,229</td>
</tr>
<tr>
<td>Rest of Europe²</td>
<td>6,564</td>
<td>833</td>
<td>7,387</td>
</tr>
<tr>
<td>Total Europe</td>
<td>134,251</td>
<td>13,805</td>
<td>147,771</td>
</tr>
<tr>
<td>Of which EU-28³</td>
<td>129,060</td>
<td>12,800</td>
<td>141,578</td>
</tr>
</tbody>
</table>

However according to the same source, Asia over the years gained ground and has more installed capacity than Europe, Africa and Middle East, Latin and North America and Pacific region, as shown in the figure below (Figure 3) (Global Wind Energy Council, 2015). Nevertheless, at present there is not a single renewable technology that can be used as a panacea in every region. To this extent, a middle ground should be found combining different technologies.

² Bulgaria, Cyprus, Czech Republic, Estonia, Finland, Faroe Islands, FYROM, Hungary, Iceland, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Norway, Romania, Russia, Switzerland, Slovakia, Slovenia, Ukraine.
³ Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK.
Nonetheless, wind energy faces an array of objections concerning the site and the location of a wind park, the produced noise from wind turbines, the visual impact that it may create and the disturbance in the local ecosystem. The aim of the present investigation is to record the reasons behind local community’s objections towards a wind farm installation, and in extent examine whether these reasons are justified or not and to that extent suggest possible solution in order to meet a middle ground between local people and wind industry.
1.1 Environmental Policy Framework

Energy policy is a key component in order to mitigate the causes of global warming and crisis of energy availability (Saidur et al., 2010). Nowadays, environmental problems tend to be global instead of local. For instance, air pollution is not trans-boundary. This is the reason why it may be declared that without unambiguous energy policy, a country by itself would not be able to solve intense problems like mitigation of greenhouse gases (GHGs) emission, overuse of energy, etc. (Saidur et al., 2010).

Energy policy is the way and the strategy of a country in which a given entity (i.e. usually governmental) decides to apply issues of energy development in accordance with the development of the energy sector to sustain its growth including energy production, distribution and consumption (Saidur et al., 2010). Nevertheless, in modern societies, many countries do not address specific policies on wind energy. Subsequently, this means that wind energy, in some countries, has not yet been explored as an alternative (IEA, 2006; Saidur et al., 2010). According to Wolsink (2007b) “the success of national environmental policies on the implementation of renewable energy ultimately depends on the number of successful projects in which renewable sources are applied”.

The elimination of environmental pollution by reducing contaminants, such as greenhouse-gas emissions, is high on the political agenda of the European Union. To this extent, a communal EU energy policy has developed concerning the common objective to ensure the uninterrupted availability of energy products and services in the market, at a price which is affordable for all consumers (private and industrial), while contributing to the EU’s wider social and climate goals (European Commission, 2010)\(^4\).

The abovementioned framework programme is called ‘2020 Climate and Energy package’. The 2020 package is a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. The package sets three key targets:

- 20% reduction of greenhouse gas emissions (from 1990 levels)
- 20% of EU energy production from renewables
- 20% improvement in energy efficiency

The targets were set by EU leaders in 2007 and enacted in legislation in 2009\(^5\). In order to meet the targets by December 2008, the European Union had agreed in the ‘Renewable Directive’, to develop transmission and distribution infrastructure (EWEA, 2009b). However, more recently, the Conference of Parties (COP21) with 197 leaders from all around the world, under the supervision of the United Nations Framework Convention on Climate Change (UNFCCC) \(^6\), on December of 2015 in Paris reached an agreement (known as the Paris Agreement) to eliminate climate change, by holding the global temperature well below 2\(^\circ\)C\(^7\), in order to achieve a sustainable, low carbon future. In order to do so, it is advisable the use of renewable energy sources to produce energy by cleaner means.


\(^6\) http://unfccc.int/paris_agreement/items/9485.php [Accessed 17/08/2016]

\(^7\) http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf [Accessed 20/09/2016]
1.2 Feed – in tariffs (FiT), Feed-in Premium (FiP), Quota System & Tradable Green Certificates (TGC)

In recent years, support mechanisms have been adopted by the member states of the European Union to promote wind energy. Hence, there are various diverse support schemes for different member states concerning renewable technologies. Here Feed-in Tariffs (FiT), Feed-in Premium, Quota System and Tradable Green Certificates, that are mainly used, are discussed.

A Feed-in Tariff (FiT), according to Hiroux and Saguan (2010) guarantees that a price per KWh is fixed and is higher than the electricity market price, for the entire wind energy amount provided into the grid. According to Gonzalez Serrano and Lacal Arantegui (2015) “ideally, FiTs must include three key elements: (i) guarantee of dispatch, (ii) long-term commitment and (iii) payment levels based on the costs of the technology”. This instrument seeks to provide higher security for investors (Gonzalez Serrano and Lacal Arantegui, 2015). Thus, FiTs deal in the form of price and are “a form of supply-push policy” (Szarka, 2006). Nevertheless, the main bottleneck is the lack of market compatibility, since energy has to be obtained despite the demand level (Gonzalez Serrano and Lacal Arantegui, 2015).

Another category is the Feed-in Premium, which is “an additional amount paid for each unit of energy produced on top of the electricity market price” (Gonzalez Serrano and Lacal Arantegui, 2015). Hence, a FiP is regarded as a market-dependent tool as the final fee depends on the market price. FiP may be of high risk for potential investors, as they do not offer a guarantee of dispatch (Gonzalez Serrano and Lacal Arantegui, 2015). “Feed-in Premium has been preferred because the total income from market price and premium is usually higher than the fixed feed-in tariff” (Hiroux and Saguan, 2010).

As Gonzalez Serrano and Lacal Arantegui (2015) explain:

“Quota System and Tradable Green Certificates mechanism is market-based, since the price of the tradable green certificates is defined by market equilibrium between the supply and demand for certificates. Demand is driven by a determined target for renewable energy consumption, i.e. the quotas defined as a percentage of energy
generated by renewable energy sources. TGC have some disad-
vantages, mainly related to the risk that project developers have to
address under this support mechanism: (i) renewable projects face
uncertainty derived from both future evolutions of electricity prices
and of TGC prices” (Gonzalez Serrano and Lacal Arantegui, 2015).

Future global energy demand and climate change are issues that raise growing concerns. To limit this stress, current-day societies try to achieve energy generation from alternative resources. In this respect, wind energy development will contribute significantly to meet future energy demand and limit environmental pollution to some extent (Saidur et al., 2011).

A majority of experts claim that technologies such as wind, solar, and small-scale hydropower are not only economically feasible but are also ideal for rural areas (Paínuly, 2001) that might otherwise have more difficulty in access to energy sources. Renewable energy sources are easily accessible to humans around the world being comfortably available in a wide range and are abundant in nature (Saidur et al., 2010). To date, electricity can be derived from many sources. It is a widely accepted axiom that the generation of electricity from conventional sources (i.e. coal and natural gas), leads to considerable damage to human health, air and water quality, wildlife, and the environment (McCubbin and Sovacool, 2013).

The predominant technology upon which electricity generation is based, is the combustion of fossil fuels which is a market-ready sector. However, though the renewable sector is still considered an under-developed field, it is evolving at rapid pace and requires further research. From a technical and economic point of view, the most mature form of renewable and ‘clean’ energy is wind energy (Saidur et al., 2011). Wind energy, which as mentioned is one of the renewable energy sources, is one of the vital components in the generation of renewable electricity as wind is ubiquitous.

Wind power plays a significant role in the generation of electricity and has notably less serious environmental and social impacts than those arising from conventional energy technologies; nonetheless, they cannot be discounted to zero. As European Wind Energy Association (2009) highlights in each case of electricity production, a fuel is used to turn a turbine, which drives a generator, which feeds the grid. The turbines are designed to suit the particular fuel’s characteristics (EWEA, 2009b). The same applies to wind-generated electricity: the wind is the fuel, which drives the turbines, which generates electricity (EWEA, 2009b). However, unlike fossil fuels, it is free and clean...
(EWEA, 2009b). Small changes in wind speed produce greater alterations in the commercial value of a wind farm. For example, a 1% increase in the wind speed might be expected to yield a 2% in energy production (EWEA, 2009b).

Another reason why renewable wind energy is a better option is that wind turbines do not use a large amount of land in contrast with power plants. This implies that the area at the bottom of the turbine (i.e. in the bottom of the tower) can be used in agriculture, for example biomass agriculture. In this way, there could be a combination of two renewable energy sources (i.e. wind energy and biomass), resulting in a more sustainable production of energy.

Another advantage to wind energy is that wind itself is the fuel, which is clean and free, and this remains the case throughout the whole life cycle of the wind farm. In this respect, there is no extraction cost of the fuel being used for the production of energy. Wind energy has zero direct air pollution, (i.e. does not load the atmosphere toxic chemical and heavy metals (Mathew, 2006)), compared to emissions of its counterpart fossil fuels (i.e. gas, coal and petroleum), which release sulphur dioxide, carbon dioxide, and oxides of nitrogen, causing acid rain. Additionally, in electricity production from wind energy, there is an absence of greenhouse gases and other atmospheric emissions, at the point of generation due to the fact that no combustion takes place. To that extent, as observed by Saidur et al. (2011), wind energy may help to reduce air pollution by replacing the current sources of conventional energy. As a result, emissions, especially of carbon dioxide, nitrogen oxide, and sulfur dioxide can be eliminated.

As highlighted by Saidur et al. (2011) a small amount of CO$_2$ emissions is released by wind energy during its construction and maintenance phases. However, according to the same source, this amount of CO$_2$ is much less than other fossil fuel based power plants and can actually be absorbed by trees through the process of photosynthesis (Saidur et al., 2011).

In a water stressed world, water conservation is a vital component in modern societies. In comparison with coal power plants, where water is used to clean and process fuel (Saidur et al., 2011), there is no water consumption during electricity generation in wind turbines. Increased use of wind energy will create job opportunity, spur economic growth, achieve national security, and protect consumers from price spikes and fluctua-
tions (Saidur et al., 2010). Along with the abovementioned positive outcomes related to wind turbines, it is critical to examine the negative impacts as well. Before any decision is made, the worst-case scenario has to be determined and predicted to eliminate the damage to minimum (Saidur et al., 2011). Proper design and planning can diminish the impacts to the environment and human health.

The worst environmental impact of wind energy is avian mortality due to collisions of birds and bats with the turbines, which are not in global but in local level and can be controlled (Mathew, 2006), and are discussed in Chapter 3. However, wind energy protects the climate as every kilowatt-hour that is produced by wind energy is saved from combustion of conventional fossil fuels. Thus, it could be recommended by law that energy suppliers include a part of the energy from renewables in their supply mix (Painuly, 2001). RETs could be cost-competitive with conventional energy sources in several applications, but at present it is not possible to achieve their full potential (Painuly, 2001).

Wind energy is not an energy source completely free of pollution, as there are emissions released during the processes of manufacture, transportation and installation. Additionally, the problem of grid connection to decentralized areas can create opposition to this kind of technology. However, these oppositions can be counteracted by the fact that the lifetime of a wind turbine is 20 years of clean energy production. It is estimated that a modern wind turbine produces the energy that has been used to construct it, by operating three to nine months depending on the site and the characteristics of the turbine (Wizelius, 2007).

Moreover, wind energy is low density energy, and as Pryor and Barthelmie (2010) confirm “air density affects the energy density in the wind and hence the power output of wind turbines, and is inversely proportional to air temperature, thus increasing air temperature will lead to slight declines in air density and power production”.

The production of electricity from wind depends heavily on the location and its atmospheric conditions (i.e. air density, icing, and temperature), as well as the wind velocity. However, the energy derived from the wind is very susceptible to change of the climate, as differences in temperature can have as an outcome different load. As observed by Pryor and Barthelmie (2010), climate change may also alter not only the wind
resource, but also the environmental context, operation and maintenance and/or design of wind developments.

The function of wind turbines is intermittent (i.e. depends on the load of the wind that fluctuates during the day and the year, the location and the atmospheric conditions), which initiates problems during times of great demands and wind can be unpredictable. Wind resource depends on the solar radiation as well as the rotation of the earth and the circulation of atmosphere (Nelson, 2009). The seasonal variation is a result of the tilt of the earth combined with the earth’s movement around the sun (Nelson, 2009). Poor quality due to variations of weather is an undesirable consequence of wind-generated electricity (Havas and Colling, 2011). Generally, the barrier that arises is that of the adequacy of the produced energy in times of great demand. Wind energy might cause social conflicts (i.e. lack of social acceptance, hesitation and uncertainty of the consumers), and environmental constraints (i.e. disturbance of the ecosystems) which will be described in detail in Chapter 3.

In order to obtain trustworthy data (i.e. wind resource data, land use data, transmission lines etc.), digital maps are conveniently used as a general overview (Nelson, 2009). According to Nelson (2009) “if the wind speeds are known, then the average wind power or average wind energy per unit area can be estimated for any convenient time period, usually months, seasons, or year. In general, whatever the wind speed is at any point in time, over the next hour the behavior ought to be similar”. This is the reason why wind is very unpredictable and the need for data is crucial.
2.1 Characteristics of a wind turbine

A wind turbine is the main component that transforms the wind energy into electricity and a collection of interconnected wind turbines are called a wind farm or wind park. Wind turbines are classified based on the orientation of the axis of the rotor in respect to the ground in two broad categories, horizontal - axis turbines (HAWT), which have their axis of rotation horizontal to the ground and almost parallel to the wind stream, and vertical - axis turbines (VAWT), which have the axis of rotation vertical to the ground and perpendicular to the wind direction (Nelson, 2009; Mathew, 2006), as shown in Figure 4. The choice of wind turbines can be critical as it determines the quantity of energy produced. For optimum load, the operation of the wind turbine should be constant, in regard with safety considerations (Nelson, 2009), as safety is one of the main factors that should be taken into account.

Figure 4: Horizontal and vertical axis wind turbines (Source: Mathew, 2006)

The main components that a wind turbine includes (as shown in Figure 5) are: the blades and the hub (that combined, constitute the rotor), the tower, the brake, the low and high speed shaft, the gearbox (which increases the rotation speed of the generator), the controller, the generator (that altogether constitute, the nacelle which is the enclosure), the vane, the anemometer, the brake, yaw drive and yaw motor.
Whilst HAWTs are the most commercial turbines today, they are more complex and expensive structures (Mathew, 2006). VAWTs can accept the wind from any direction, and the generator in vertical axis wind turbines can be placed at ground levels, which are the main advantages. On the other hand, there are five crucial disadvantages that can oppose the use of vertical-axis turbines: the rotor is closer to the ground, and there is cyclic variation of power on every revolution of the rotor (Nelson, 2009). The low efficiency, the high cost and the fact that they are usually not self-starting, are the remaining disadvantages favored the horizontal turbines (Mathew, 2006; Kaldelis and Zafirakis, 2011).

Every wind turbine is type-certified for distinct external conditions. This certification, which is requested by developers and insurance companies, guarantees that the wind turbine will be secure and will be in operation for approximately 20 years for onshore and 25-30 years for offshore projects (EWEA, 2009a). Offshore wind turbines last more years as wind conditions at sea are less turbulent (EWEA, 2009a).

As shown in Figure 6 and 7, wind turbines as years pass by; tend to get bigger with higher height and bigger rotor diameter in order to yield more energy. This could
lead to more social objections due to the fact that they can be detected and create optical disturbance from greater distances. To this extent, visual impact of wind turbine is an issue that cannot be ignored anymore.

![Figure 6: The evolution of wind turbines’ diameter during the past years](image)

(Source: Kaldelis and Zafirakis, 2011)

The figure below (Figure 7) illustrates that wind turbines in 1980-1990, had a rotor diameter of 17 m., height less than 40 m. and yield energy of 75 kW. However, from 2010 until today, the rotor diameter is more than five times greater than the past, the height is doubled (80 m.) and the produced energy is 40 times bigger than the energy yield in the past. Moreover, future wind turbines will reach a capacity of 10,000 kW.
The great land use, noise, visual impact and impacts on wildlife, which are the main impacts of onshore wind parks, have forced energy industry to shift its focus to offshore installations. The major advantage of offshore installations compared to their onshore counterparts is that the wind blows harder and stronger, as it has greater turbulence, so that it can yield more energy (Leung and Yang, 2012). In addition, the turbines are installed in great distance of residential areas, eliminating the social objections about visual impact and noise to minimum. Nevertheless, offshore construction cost 1.5 – 2 times more than an onshore installation, as the equipment is more expensive and the cost rises sharply as wind tower is further away from the land; maintenance and repair are more challenging due to the fact that they are inaccessible being installed in great distance from the shore (Leung and Yang, 2012).

Concerning social acceptance, wind offshore projects are more acceptable by the public as they are thought to reposition the ‘problem’ of public objections due to lack of visual impact (Haggett, 2011). However, the installation of wind parks several miles away, does not eliminate the visual impact and consequently does not solve the visual problem. In general, prior negative experience of onshore parks often leads to opposition towards offshore installations (Haggett, 2011). In a nutshell, offshore installations are not a problem-free alternative (Haggett, 2011).

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Chapter 3 – Literature Review

In 1987, the Brundtland Commission published the document “Our Common Future, From One Earth to One World”, which defined Sustainable Development for the first time as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The three dominant pillars on which the sustainable development concept rests are social equality, environmental protection, and economic growth. The report highlights the perspective that environmental protection, economic growth, and social development are not contradictory but complementary goals. Furthermore, since renewables are viewed as ‘inexhaustible’, they contribute to progress towards sustainability (Szarka, 2006), following an alternative path of development.

Due to continuous technological developments, energy demand increases uncontrollably. As a consequence, the generation of energy by ‘greener’ means is a solution towards a more sustainable future. Wind energy enjoys significant public support as well as multiple oppositions about the location of an installation of a wind farm due to different social objections. In order to overcome these objections and foster social acceptability, a middle ground between policy, decision-makers and local people must be met. The factors that mostly affect people’s opinion about a wind park are aesthetic intrusion, noise and possible effects on human health, environmental concerns (i.e. disturbance in ecosystems), safety issues, shadow flickering and possible reduction in tourism and landscape’s value.

The goal of the present investigation is to list the reasons that lead to opposition towards wind energy installations, from every aspect of sustainable development (i.e. society, environment, economy) and suggest alternative solutions in order to overcome these bottlenecks, and eliminate the damage to minimum.
3.1 Social objections

Although wind energy has greener image than carbon-based sources, the location of wind farms faces serious obstacles (Gamboa and Munda, 2007). In general, social acceptability is a key issue concerning the construction of a wind farm on a sight. People’s attitude towards wind projects is influenced, according to Haggett (2011), “by the fear about harm to the environment, impacts on wildlife and sea life, the fishing industry, recreational activities such as boating, fishing and yachting, and the loss of tourist income”.

Social costs have attracted attention by many scientists and some politicians. It is evident in local communities that wherever a large facility is to be installed, causes of concern arise (Nelson, 2009). Public perceives wind power in a fundamentally different way than wind farms and this difference in perception causes the most misreading in public behavior (Wolsink, 2007b); while many people are in favor of wind energy they are opposed to wind industry and wind turbines.

The perception of people towards wind turbines divides them into two categories: on the one hand, some people view wind turbines as very beautiful, useful technologies that may be a landmark of green energy, whilst on the other hand, others consider them as installations that offend their environmental aesthetics and diminish the value of the landscape. These two fundamentally opposite points of view create debates, polarization and intense conflicts. In general, solar and wind energy, as shown in the figure below, seems to be more socially accepted, compared to other electricity generation technologies, whereas conventional energy sources mostly face opposition.
As shown in Figure 9, the factors affecting public opinion about wind energy projects are several, such as possible effects on birds and non-avian wildlife, proximity to turbines, level of related knowledge and information of local people, perceived need for wind power, noise annoyance, land use and perceived level of electromagnetic interference (i.e. affecting television) (Devlin, 2005). Although shadow flickering is not mentioned in the Figure below, it is nowadays common reason for opposition. Costs and benefits of wind power are often the factors counterbalanced by the public. In a nutshell, objections may arise from a combination of annoyance, noise, visual impact, shadow flickering, occupation of land and ecosystem disturbance (Bishop and Miller, 2007).
The problem that is created with public opposition is that the public is not a homogeneous group, which means that wind developers may face a group of people with different values, norms, age, roles and experiences (Haggett, 2011). Another problem is the background of the local people (whether they are educated, and in what level, or if they have a general environmental awareness attitude, and whether they have had any previous experience with wind farms etc.) and how the public forms its opinions (i.e. which sources local people trust, consult and are influenced by) so as to get informed. In other words, what is the source of information as in some cases the local residents do not have access to scientific resources in order to be properly informed and often the sources are not reliable and trustworthy (for instance, the Internet as a general source).

In line with the previous paragraph, general lack of awareness about the benefits and the usefulness of renewable energy sources, prejudice, misinformation, ignorance and hesitancy alongside with change may establish social barriers. In general, each individual’s web of belief varies a lot based on different experiences, age, education, underlying values, culture and norms and may create social gaps and difficulty in interpreting individual’s behavior. However, there is lack of scientific evidence concerning in which way values influence attitudes towards wind energy industry (Bidwell, 2013).

Additional constraints that lead to more reasons to object to a construction may be a possible belief of reduction of the tourism, the value of natural scenery, especially when it comes to archaeological regions of interest, as well as the value of real estate. However, the presence of heavy industry in an area of interest seems to make residents more likely to support wind parks as an upgrade of the image of the region (Van der Horst, 2007). As highlighted by Gamboa and Munda (2007) the policy process itself for choosing the siting of the installation of wind turbines may also create conflicts. There is no doubt that, given the size of a wind park, the biggest challenge that decision-makers face is that the wind turbines may interfere with norms, cultural heritages, and landscapes, especially for the residents who live in the surrounding area, resulting in discomfort (Firestone et al, 2015). Nevertheless, research is still needed to comprehend the issues concerning local communities’ opposition related to wind power (Szarka, 2006).

On the other hand, some local people are in favor of wind farms as they acknowledge them as a good opportunity for rapid, greener and more sustainable develop-
opment, as well as job opportunities, a source of income or improvement of social services and as electricity generation by cheap and clean means (Gamboa and Munda, 2007; Katsaprakakis, 2012). In many cases, local resources are used for the construction of a wind park (Gibbons, 2015). Additionally, engagement of society is needed in decision-making processes (Bell et al., 2005; Szarka, 2006), as involvement of local community tend to increase the acceptance levels (Spiess, 2015). In general, according to Molnarova et al. (2012) in order to foster social acceptability, the installation of wind turbines should above all respect the landscape and its particularities.

As Wüstenhagen et al. (2007) claims social acceptance is a combination of three sometimes, independent dimensions: socio-political acceptance, community and market acceptance. Figure 10 illustrates the triangle of the social acceptance. Socio-political acceptance, in a general level, refers to the social consensus of the benefits of technology and policy, which is expressed by supporting wind energy (see among others Wüstenhagen et al., 2007; EWEA, 2009b; Bidwell, 2013); whereas community acceptance refers to the acceptance of the projects by local stakeholders, particularly residents and local authorities (see among others Wüstenhagen et al., 2007; EWEA, 2009b). Community acceptance is the field where social debate around renewable resources arises and develops and the most attractive concerning social research in the wind energy field (EWEA, 2009b). Finally, market acceptance refers to the process that market parties adopt the energy innovation, which focuses on consumers as well as investors and has attracted the least attention of the three dimensions (Wüstenhagen et al., 2007; EWEA, 2009b).
In a nutshell, as shown in Figure 11, the reasons for support or objection towards wind siting are related with the type of landscape. In a more detailed approach, the level of existing regional industrialization affects negatively the aesthetic valuation of landscape, but positively the willingness to accept landscape alteration (Devlin, 2005). This may be justified by the perception of local people that the landscape change is an improvement.

According to Haggett (2011), five reasons for support or opposition have been established: “firstly, the aesthetic value of the site where the wind project will be installed, rather than the local nature of the installation, may arise concerns” (Wolsink, 2007 a, 2007b). “Secondly, social, political, and historical background as well as the sentimental attachment that local people may have towards the potential siting may create intense conflicts and thirdly, renewable energy technologies can divide the supporters and opponents in terms of whether the project will be local or global. The ownership and the trust that local people have towards the developers is the fourth reason” (Wolsink, 1996), while the engagement of local society during the decision-making process is the fifth reason (Haggett, 2011).

In line with the previous paragraph, the willingness to accept the project is based on a web of factors, such as the level of information about the project, the project pro-
posal, trust (or lack of it) towards the installation company. Additionally the personal participation in terms of local financial gain, as well as engagement in the decision-making process, general opposition towards turbine siting and perceived need for new wind turbines are an array of factors that influence acceptance. As Devlin (2005) states social acceptance of wind projects is influenced by four factors: need of the project, engagement of the society (which are both directly proportional to social acceptance), economic incentives and the visual impact, particularly on natural landscape.

Figure 11: Links between factors affecting the opinion of the public (Source: Devlin, 2005)
3.1.1 Noise & Human Health

Noise is defined by the Oxford Dictionary\(^9\) as “a sound, especially one that is loud or unpleasant or that causes disturbance”. Whether noise is a source of disturbance depends on the “level of intensity, frequency, frequency distribution, and pattern of the noise source, background noise levels, the terrain between emitter and receptor, and the nature of the noise receptors” (Morrison and Sinclair, 2004). The most common objection about wind turbines is the fact that they are noisy (Harrison, 2011). To that extent, the most crucial environmental effect of wind turbine is the noise pollution (Saidur et al, 2011). However, many wind farms operating in uninhabited regions and noise is not a concern (Harrison, 2011).

![Figure 12: Opposition to wind turbines due to noise\(^10\)](http://www.madaketwind.org/Wind_turbine_noise_cartoon.jpg)

There is a vast literature that divides noise emitted by a wind turbine into two major categories: mechanical and aerodynamic type (see among others Pedersen and Halmstad (2003), Hau (2006), Oerlemans et al. (2007), Colby et al., (2009), European Wind Energy Association (2009), Chief Medical Officer of Health (2010), Saidur et al. (2011), Katsaparakakis (2012), Leung and Yang, 2012, Dai et al. (2015) and Firestone et al. (2015)). The abovementioned authors define mechanical noise, which does not increase with the dimensions of the wind turbine, as it is generated by the moving compo-


\(^10\) http://www.madaketwind.org/Wind_turbine_noise_cartoon.jpg [Accessed 08/10/2016]
tments such as gearbox, electrical generator, and bearings that due to improvement of turbine emit less noise. The recently constructed wind turbines eliminate the mechanical noise through proper insulation in the nacelle (EWEA, 2009b). Aerodynamic noise, which is the dominant sound source from modern wind turbines, is developed by the rotation of blades that create a flow of air over and past the blades (Chief Medical Officer of Health, 2010; Saidur et al., 2011; Dai et al., 2015; Firestone et al., 2015).

Wind direction may fluctuate the noise level of the wind turbine, making the nature of noise unpredictable (Harry, 2007), while the design characteristics of the turbine and the blade can influence noise emissions (Rogers et al., 2006). On top of that, the highest noise level is measured at the bottom of the wind turbine being installed perpendicular towards the receiver (Saidur et al., 2011). In a wind park, the noise level at a certain distance is also proportional to the number of turbines in operation (Dai et al., 2015). The model of the wind turbine can influence the produced noise as well. Additionally, background noise can play a significant role in the perception of noise by the receiver (Spiess, 2015). Due to the windy nature of the siting location, much of the sound produced by the turbines is masked by ambient or the background noise of the wind itself (NWCC, 2002; Rogers et al., 2006).

Whether noise from wind turbines is annoying, is a subjective issue and depends on personal characteristics of an individual. By the same token, the problem that arises is that it is very difficult to obtain scientific-based answers as to why the noise is annoying for some people. In addition, it is difficult to distinguish if the reason of annoyance is the noise itself or if other factors may have contributed to this (such as visual disturbance, background noise, shadow flickering etc.). Subjective annoyance is related to the sound level and frequency as well as to the physiological and mental factors of the receiver (Harry, 2007). Sensitivity to both sound and electromagnetic waves differs among individuals and this may explain why there are reported experiences with different effects (Havas and Colling, 2011). In other words, not everyone in the same home is going to have the same effects or the same sensitivity to disturbance.

Technological developments, research and improvement on design of wind turbines have led to noticeably quieter wind turbines in comparison to the past, as according to Rogers et al. (2006) “blade airfoils have become more efficient, as more of the
wind energy is converted into rotational energy and less into acoustic energy”. However, there are various factors worth researching regarding turbine noise and its actual impact on annoyance. Disturbance from noise may be resulted by the repetitive noise from the blades, and from components such as the gearbox and not the produced noise itself (Nelson, 2009). An important finding by Van Renterghem et al. (2013) is that the turbine noise is not more annoying than highway noise. Additionally, the dose received, which may result in effects to human health, is not often taken into consideration when measuring the characteristics of the sound (Frey and Hadden, 2007).

In a number of studies (see among others Wolsink, 2007a; Harry, 2007; Pedersen and Larsman, 2008; Knopper and Olson, 2011; Katsaparakis, 2012; Van Renterghem et al., 2013), noise annoyance is linked to visual attitude from people in neighboring regions to the wind farm, as wind turbines may be installed in residential locations, where they are unavoidably visible. Residents that could detect and identify the noise from the turbine are more disturbed, than those that could not detect it (Van Renterghem et al., 2013). To that extent, noise may be reported to increase proportionally to visibility, and convert into annoyance. However, the abovementioned relationship is not always clear (Pedersen and Larsman, 2008).

Another factor that could influence the annoyance from noise is the general attitude towards wind turbines, which is difficult to be measured quantitatively, but should be taken into account when exploring alternative solutions to unpleasant noise (Harry, 2007; Pedersen and Larsman, 2008). In order to control the noise annoyance, Dai et al. (2015) propose three measures: either improvement of the blade design or a minimum distance between populated regions and wind farms, or an upper limit of noise level set by national framework. For instance, in Greece a minimum distance of 500 m from residential areas is required by law11.

Figure 13 is provided by General Electric12, a manufacturing company that constructs wind turbines as well as air conditions, refrigerators etc., and compares the noise (in decibels) generated by an operating wind turbine to other household appliances with regard to the distance. As shown in the figure below, at 400 meters the sound drops at approximately 40 dB(A), which is the noise produced by a refrigerator. As the distance

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decreases heading towards the wind turbine, the figure reveals that the maximum noise that can be emitted is equal to that of a blender or a vacuum cleaner.

Figure 13: Noise produced by wind turbines compared to household appliances

As with the development of any new technology, multi-debated concerns about the impact of wind turbines to human health have been raised, especially in terms of audible and inaudible noise (Knopper and Olson, 2011). There are two diametrically opposite opinions that enjoy high acceptance: the first supports that there is no direct causal link to wind turbines and human health, while the second maintains the belief that wind turbines produce noise that can be correlated to impacts to human health (i.e. nausea, sleeping problems, anxiety, etc.).

In literature, there are plenty of sources that stand by either of those opinions. For example, supporting that there is no direct relation between turbines and human health, Knopper and Olson (2011) claim “To date, no peer reviewed articles demonstrate a direct causal link between people living in proximity to modern wind turbines, the noise they emit and resulting physiological health effects”. Additionally, and according to the same authors, health effects are more likely to be traced back to a number of environ-

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mental stressors that result in an annoyed and stressed state to a specific part of the population (Knopper and Olson, 2011). This opinion seems to have numerous supporters such as Pedersen and Halmstad (2003), Colby et al. (2009), Chief Medical Officer of Health (2010), Havas and Colling (2011), Merlin et al., (2013), Knopper et al. (2014) and Crichton and Petrie (2015).

As Chief Medical Officer of Health (2010) reports while some residents in neighboring areas (i.e. near wind turbines) may show symptoms such as dizziness, headaches and sleep disturbance, there is no solid scientific evidence that demonstrates a direct causal association between wind turbine noise and adverse health effects. To support this point of view, various reports highlight that even though the sound level from wind turbines at residential areas may lead to annoyance to some people, the sound level is not capable of creating hearing impairment or other direct health problems (see among others Pedersen and Halmstad (2003); Colby et al. 2009; Chief Medical Officer of Health, 2010). However, sleep disturbance should be further examined (Pedersen and Halmstad, 2003). Another interesting statement is that of Knopper and Olson (2011), who point out that the change in the environment has a causal link with health effects and not a turbine-specific variable. According to Colby et al. (2009) only a small amount of sensitive people may have sleeping annoyance.

In line with the previous paragraph, Colby et al. (2009) highlights that potentially the claim that wind turbines may result in adverse health effects may be resulted by the nocebo effect. As the aforementioned authors define the nocebo effect is “an adverse outcome, a worsening of mental or physical health, based on fear or belief in adverse effect. In other words, anti-wind farm activists may be creating with their publicity some of the problems that they describe” (Colby et al., 2009). In summary, the fear that wind farms may cause health effects, which may be created to local people by exogenous factors, may cause health effects. This is a factor that it is very difficult to quantify.

On the other hand, numerous sources such as Frey & Hadden (2007), Harry (2007), Havas and Collins (2011) and Onakpoya et al. (2015) state that turbine noise can have adverse health effects such as annoyance, sleep disturbance depression, aggressiveness, headaches, nausea, dizziness and stress. More specifically, Frey & Hadden
(2007) state that levels of sound may cause an adverse effect on health, not only psychologically, but also physiologically with medical consequences; whereas Harry (2007) states that the health effects are caused by the non-auditory sounds. Noise that is emitted by wind turbines, as Onakpoya et al. (2015) state, affects sleep and quality of life, but the correlation is unclear. Nevertheless, human health effect may take years to appear as a pattern when it may be too late to be corrected (Frey and Hadden, 2007).

In terms of noise, loud levels (i.e. high sound pressure) of audible noise and infrasound, “have been connected with sleep disturbance as well as learning, and cognitive disruptions, stress and anxiety” (Knopper and Olson, 2011). Nevertheless, as Frey and Hadden (2007) and European Wind Energy Association (2009) suggest the disturbance may be correlated with the distance of the wind turbines (source) to the populated neighboring areas (receiver), claiming that as the number of wind turbine installations near to residential areas augment, records of health effects have grown. To support the aforementioned opinion, Frey and Hadden (2007) highlight the fact that these effects do not appear where wind turbines are located at a safe distance from homes. In accordance with these statements, Havas and Colling (2011) suggest that wind park should be placed as far from residential regions as possible. In order to prevent adverse health effects, due to turbine noise, many health authorities have proposed to residents that the construction of the wind park be installed 1.5 to 2 kilometers from residential areas (Harrison, 2011).

Onakpoya et al. (2015) point out that people living near wind farm facilities have reported sleep disturbances and degradation in their quality of life and increased level of sleep disturbance. However, Onakpoya et al. (2015) state that the annoyance of the residents is strongly correlated with the fact that either they have visible contacts with the wind turbines or have the opinion that wind turbines interfered with the natural scenery. As resulting to the above-described situation, it is difficult to distinguish whether the noise itself actually leads to annoyance or sleep disturbance or whether subjective factors (i.e. visual impact and generally attitude towards wind turbines) cause the disturbance (Knopper and Olson, 2011; Van Renterghem et al., 2013; Onakpoya et al., 2015). It is, in fact, more likely for people who have balance problems, motion sickness, or ear or eye problems, to report such symptoms (Havas and Colling, 2011).
## 3.1.2 Not In My Back Yard (NIMBY) Syndrome

Whether a specific wind energy project will be implemented or not in a particular location, is based on many different elements that mainly concern the local populations’ attitude towards the project (Petrova, 2016). Whilst local society may benefit from a construction of a wind farm (i.e. by creating more employment opportunities, etc.), residents may oppose the project for several reasons such as visual disturbance, noise, shadow flickering, etc. This perspective is the so-called Not In My Back Yard (NIMBY) syndrome. In general, NIMBY concept implies that people view wind energy as beneficial to society, but by the time they are actually confronted with it, they oppose to the construction of wind farms for selfish reasons (Wolsink, 2007b; Bidwell, 2013). However, the NIMBY explanation is not reliable as it tells us little about the reason why someone opposes to a construction of a wind farm in his or her area (i.e. the reasons that lead to opposition) (Bidwell, 2013). To that extent, two or more people opposing wind turbine installations may be included in the NIMBY explanation for different reasons (i.e. NIMBY is not specific explaining one certain reason).

Nevertheless, Dear (1992) defines NIMBY as the “incentive of habitants who want to protect their neighborhood”. Moving from global to local, the basic concept of the syndrome is that while people theoretically support wind energy, the supposed adverse effects from the parks lead to opposition towards a construction of a wind farms (Dai et al., 2015). As a consequence, open dialogue and decision-making, participation and involvement of the residents of the neighboring areas is needed before any construction begins.

While NIMBY syndrome is intended to clarify local opposition, it fails to mirror the complexity of human incentives (Bell et al., 2005). Local opposition that is included in NIMBY concept is cited as one of the fundamental challenges and social dilemmas that wind industry should face in order to be developed (Smith and Klick, 2007). While local people justify their opposition and complaints towards local wind energy projects by objecting on the impacts on scenery or environment, their real concern is far more personal (Bell et al., 2005). By the same token, one of many explanations about this complex phenomenon is the ‘selfish’ element to defend their back yard (van der Horst, 2007). In order to overcome self-interest objections, the best path is to discover ways of
increasing personal profits that local people will gain from a wind energy project (i.e. offer financial compensation or shares of the project) (Bell et al., 2005; Spiess 2015). Nevertheless, before policy makers choose to adopt a financial incentive strategy, they need to be sure whether they are dealing with either NIMBYs or people whose ‘values are for sale’ (Bell et al., 2005).

According to Jones and Eiser’s (2010) findings “an individual’s ‘backyard’ is apparently defined by the extent to which development is anticipated to be directly visible”. In order to comprehend and overcome the NIMBY syndrome, decision makers should take into account the reason and nature of local opposition arguments and find a way to come to an agreement with the local community (Dear, 1992). There is a trend to name all opposition to spatial developments as NIMBY opposition (Wolsink, 2007a), which is not realistic. As shown in the figure below (Figure 14), NIMBY syndrome is the local tension towards the construction of wind turbines, due to the fact that they are big installations perceived as eyesore.

NIMBY syndrome becomes more frequent as people oppose the siting only when the wind park is going to be located in their own backyards (Wolsink, 2000; Wolsink, 2007a). If the wind turbines were to be located somewhere else, the same people would

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13 Source: http://ramblingsdc.net/Australia/Energy/ArgumentsAgainst.jpg [Accessed 15/08/2016]
be in agreement with a wind installation and would not emphasize on the actual characteristics of the site (Wolsink, 2007a). Unfortunately, there are theoretical and practical barriers in evaluating landscape beauty (Gamboa and Munda, 2007).

Wind turbines should be placed in open, exposed areas in order to gain high velocity and yield more energy (Drewitt and Langston, 2006). The distance of wind farms to the closest populated area is one of the major reasons that people tend to oppose to the installation of wind turbines (Bidwell, 2013). The concerns are purely local and are based mainly on visual disturbance, health and safety issues as well as distrust of decision makers (Smith and Klick, 2007). “Those who make the decisions regarding wind farms are not the same people who must live with them on a daily basis” (Pasqualetti et al., 2002). However, on the other side of the coin, surveys reveal that the closest the wind farm is to the populated areas the higher the acceptability because opposition is an aftereffect of ignorance of the benefits that wind turbine can provide to local communities (Strachan and Lal, 2004).

Counter to the NIMBY syndrome, researchers claim that often opponents react negatively towards wind farm projects due to relevant and detailed knowledge of their region (Haggett, 2011) or place-protective feelings (Devine-Wright, 2009). However, local opposition may be a result of mistrust towards the private company and not the wind project itself (Ek, 2005).

Wolsink (1994; 2007b) distinguishes six assumptions, “based on the assumption that opposition is a result of NIMBY:

i. Decision-making as regards wind development tends to be laborious.
ii. The wind farm represents ‘higher’ interests than those of the local population.
iii. Everyone is agreed on the usefulness of wind power developments.
iv. No-one wants a wind development facility in his own backyard.

From the third and fourth assumptions, we can logically assume that if we suppose that everyone wants to pass on any inconvenience to someone else.

v. Everyone would prefer to have wind development facilities situated in someone else’s backyard.
vi. The attitudes and opinions, which make up the NIMBY phenomenon, can be regarded as static. The NIMBY theory does not appear to allow for the possible alteration of insights regarding usefulness and location, something that already has proven to be faulty”

Wolsink (1994; 2007b)

Figure 15 shows the development of onshore projects, also known as U-shaped curve. It is evident that the type of installation plays a significant role since solitary turbines are generally more accepted than wind farms. Initially, attitude is very positive, during “no-plan” phase (i.e. when people do not face the possibility of a wind project in their neighborhood), while the minimum point is when project plans are announced, mostly due to doubts, fear of impacts and undesirability of large scale structures, and high acceptance appears sometime after construction (Wolsink, 1994; Haggett, 2011). “The conclusion is clear: opinions on a technology alter as soon as people are confronted with an application” (Wolsink, 1994). The nature of attitudes is not static over time, but fluctuates depending on the phase of the installation.

![Figure 15: the development of public attitudes towards wind projects (aka U-shaped curve) (Source: Wolsink, 1994)](image)

In order to solve the NIMBY problem, the obvious solution suggested by Bell et al. (2005) and Spiess (2015) is to alter the decision-making process, by demanding a
direct democratic public vote on wind farm developments. Nonetheless, it is unclear whether a direct public vote would solve the problem (Bell et al., 2005).
3.1.3 Visual impact

People’s opposition or acceptance of wind farms may depend on their overall perception and feeling towards wind farms, as well as how well informed the residents are, former use of the potential site, possible effects on human health and surrounding environment, and visual disturbance of the landscape (Jobert et al., 2007; Dai et al., 2015). However, visual impact on the landscape is a particularly controversial and subjective issue that plays a significant role in the implementation of wind park siting. This subjectivity makes it very difficult to measure quantitatively the visual impact wind parks can have on people.

Visual impact is considered the dominant factor that influences public attitudes towards wind farms (Wolsink, 2007b; EWEA, 2009b; Kaldellis et al., 2013). While some people perceive wind turbines as objects blended with the natural landscape that reduce the reliance on conventional energy sources generating electricity in a clean and cheap way, others consider them as ‘aesthetic (i.e. visual) pollution’ that spoils and alters the beautiful scenery and converts it into an industrial one. The latter aspect creates opposition to wind energy industry by the local people. Hence, a wind farm may be perceived by different individuals as a positive or a negative addition to the existing landscape (Kaldellis et al., 2013). There is lack of scientific research as to the factors influencing the visual preferences of the public (Molnarova et al., 2012).

Figure 16: Opposition to wind turbines due to visual impact14

14 Source: https://pbs.twimg.com/media/Cd3ctIzW0AE74SW.jpg [Accessed 17.08.2016]
When it comes to deciding about the visual impact of wind turbines, supporters and opponents pay attention in different details (Maehr et al., 2015). Whilst supporters focus is on benefits (i.e. environmental gains, reduction of GHG emissions, creation of job opportunities, greener energy production etc.), opponents mostly see the negative effects (i.e. ugly constructions that will spoil natural landscape, local environmental impacts of the construction) (Maehr et al., 2015). Nevertheless, prior experience that people may have with wind turbines does not seem to influence the perception of the visual impact on them (Ladenburg, 2009). Additionally, people may diverge as some of them may perceive wind turbines as optical disturbance and simultaneously as a more environmental and green way to generate energy (de Vries et al., 2012).

Specific locations for wind parks tend to attract major opposition, as for instance, scenic areas or parks, Natura 2000 and archaeological areas create great conflicts as to whether farms should be installed. On the other hand, a wind turbine that is placed on a hill may reduce direct visual impact (Dai et al., 2015). This is the reason why distance between the installation and regional areas plays a significant role in energy project development (Bishop and Miller, 2007). Moreover, when turbines are placed out of sight, they tend to be more acceptable by local people (Jones and Eiser, 2010); whereas closeness to residential areas attract more negative comments by the people as they view them as negative man-made structures (de Vries et al., 2012). The surroundings of the siting region play a significant role as well; the area should be as open as possible (Wizelius, 2007).

Along with the location of wind farms and the type of landscape, characteristics of the wind turbine such as the size, number and direction of blade of the wind turbines, spacing between turbines, color, height and material have an impact and are strategic keys on how the local community reacts towards them (Nelson 2009; Katsaparakakis, 2012; Molnarova et al., 2012). For instance, different types of turbines seems to have different effects on aesthetic, wind farms have different visual impact comparing to small wind turbines (Nelson 2009; Katsaparakakis, 2012; Molnarova et al., 2012). In addition, according to the findings of Molnarova’s et al. (2012) research, the number of wind turbines is inversely proportional to the public acceptance (i.e. the smaller the number the higher the acceptability), since as it is noted by the aforementioned authors “where the supporters of wind power saw a single turbine as an improvement to the
landscape scene, four turbines were perceived as a deterioration”. The height of the turbines placed as well as the installation position (i.e. distance) influence the visibility and consequently the opposition (Pasqualetti et al., 2002; Nelson, 2009; Katsaprakakis, 2012).

According to Mathew (2006) “turbines of same type, size and equal number of blades are preferred for clean, simple and repetitive view, and uniform tower height, as well as uniform color to the blades are advisable”. In addition, the same author suggests that “all the turbines should be functional with rotors rotating preferably in the same direction and at the same speed; whereas mismatch between the turbines in a cluster may result in chaotic effect” (Mathew, 2006). While color may play a significant role minimizing the visual impact of the wind farm, there is a disagreement as to which is the most acceptable color as different colors may create different contrast in diverse landscapes (Pasqualetti et al., 2002).

In line with the previous paragraph, the number of blades and the directions that the blade is rotating are important factors on visual impact (Dai et al., 2015). Moreover, the turbines with three blades are more acceptable from people as, according to Dai et al. (2015) they give a stronger sense of balance. In addition, the installation of bigger turbines minimizes the number of installed turbines; however, bigger turbines may not be the optimum solution as stress may occur by the blades’ own weight (Leung and Yang, 2012).

The color of the blades and the tower of a wind turbine is an important factor in terms of visual impact that should be considered. According to Mathew (2006), European Wind Energy Association (2009), Saidur et al. (2011) and Katsaprakakis (2012) the color used is green at the base (i.e. closest to the Earth) gradually transitioning into white, or off-white or light grey at the top to make the turbine look like it is part of the skyline, or well blended in the natural landscape, in order to reduce the visual impact, as shown in the picture below.

In general, same color to the blades, nacelle and towers, is advisable as it avoids color contrast between the components (Mathew, 2006). “Another suggested, but untested solution is to paint blades with UV paint, which may enhance turbine’s visibility to birds” (EWEA, 2009b). Young et al. (2000), disagree with the abovementioned
statement by EWEA (2009b) and reach the conclusion that UV painted turbines increase the number of avian fatalities; whereas Long et al. (2010) hypothesize that the reason is that UV attracts more insects and subsequently the birds are attracted by the insects. Nevertheless, up to date, there is no scientific knowledge as to “whether birds can detect man-made objects painted with UV-reflective paint more easily than objects with conventional (non-UV-reflective) paint” (Young et al., 2003).

![Wind park](https://upload.wikimedia.org/wikipedia/commons/2/25/F%C3%A2nt%C3%A2nele_Cogealac_Wind_Farm_2011.jpg)

Figure 17: Wind park

In order to quantify the visual impact in terms of distance, Katsaprakakis (2012) suggests that visual impact is viewed noteworthy in distances “lower than ten times its tower height”. European Wind Energy Association (EWEA, 2009b) distinguish the zones of theoretical visibility into four categories: 1) zone I, is the visual dominant zone, where the blades’ movement is obvious, 2) zone II, is visually intrusive, where the turbines are important elements on the landscape but are not the dominant points in the view, 3) zone III, is noticeable, where the turbines are clearly visible but do not disturb as they appear small and the wind farm is noticeable as an element in the landscape, and 4) zone IV is the element within distant landscape, where the apparent size of the turbines is very small and the movement of blades is indistinguishable (EWEA, 2009b). To this extent, Petrova (2016) proposes two measures to mitigate the visual disturbance: the first is to scale the turbines so as to blend into the landscape in a better way and the second is to use “separation zones” that will set the minimum required distance between turbines and neighboring area.

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15 Source: [https://upload.wikimedia.org/wikipedia/commons/2/25/F%C3%A2nt%C3%A2nele_Cogealac_Wind_Farm_2011.jpg](https://upload.wikimedia.org/wikipedia/commons/2/25/F%C3%A2nt%C3%A2nele_Cogealac_Wind_Farm_2011.jpg) [Accessed 17/08/2016]
Weather conditions may play a significant role as well, as the visibility of the atmosphere when it is clear, is higher from greater distances, than when it is foggy. Moreover, the contrast that is created between the wind turbines and the background (i.e. sky) are crucial parameters that should be quantified (Bishop and Miller, 2007). The operation of the wind park is a significant parameter in social objections and more specifically in terms of visual impact: when a wind turbine is inactive, it may be perceived as an abandoned machine (Dai et al., 2015), whereas when it operates properly it is perceived to serve a purpose so it is useful and beneficial (Pasqualetti et al., 2002; Katsaprakakis, 2012). When particular locations are proposed, GIS and visibility analysis can help define the proposed sites and determine the degree of the visual impact (Bishop and Miller, 2007). According to Pasqualetti et al. (2002) a wind turbine should not be considered only as its components but rather as a “visible addition” to the existing scenery.

The findings of Jones and Eiser (2010) are of great importance as they claim that “on average, respondents demonstrated a clear preference for offshore development over onshore development”. According to the aforementioned authors, the approval in offshore locations may be driven by the transposition of the visual impact to a location that is not directly visible (Jones and Eiser, 2010). Impacts of offshore installations are different from onshore structures (Pasqualetti et al., 2002). As shown in the figure below (Figure 18), offshore parks are in great distances away from residential areas neutralizing the visual impact.

![Wind offshore park](https://www.elsevier.com/__data/assets/image/0020/31466/Wind-farm.jpg)

Figure 18: Wind offshore park

16 Source: [https://www.elsevier.com/__data/assets/image/0020/31466/Wind-farm.jpg](https://www.elsevier.com/__data/assets/image/0020/31466/Wind-farm.jpg) [last access: 16/08/2016]
On the contrary, Ladenburg (2009) suggests that lower levels of objections (i.e. higher acceptability) on offshore wind farms may be the consequence of lower development of offshore parks, which is not by any means representative. According to Bishop and Miller (2007), offshore facilities are immune to the oppositions against onshore installations. Moreover, the general opposition of local people towards onshore wind turbines in terms of visual impact has shifted the attention of wind industry on offshore installations (Bishop and Miller, 2007). However, offshore structures still gain objections in respect to visual impact when placed near the coast (Bishop and Miller, 2007; Ladenburg, 2009). In this respect, further research should be conducted on the parameters that affect visual impact of on- and offshore windfarms.

Visual impact is an emblematic topic concerning wind turbines; hence, the effects of visual impact should be one of the basic priorities in wind turbine siting agenda. However, it is very difficult to measure and quantify the visual impact of a landscape (EWEA, 2009b). In order to minimize or neutralize the effects of visual impact and reduce the social objections, Brusa and Lanfranconi (2006) recommend various preventive mitigation measures. For instance, the selection of a wind turbine’s characteristics (size, color, tower, number) should be according to landscape’s specific features and the siting of the wind farm should be at least in a certain distance from residences (Brusa and Lanfranconi, 2006).
3.1.4 Shadow flickering

Social objections are also based on shadow flickering that residents in neighboring areas may suffer for certain seasons during the year. As defined among others by Morrison and Sinclair (2004), Chief Medical Officer of Health (2010), Saidur et al. (2011), Tabassum-Abbasi et al. (2014), and Dai et al. (2015) shadow flickering is a unique effect caused by the movement of the rotating blades cutting through the sunlight, in sunny conditions, and becomes a human impact when a number of parameters converge, including distance from turbine, operational hours, flicker frequency and hub height.

According to Tabassum-Abbasi et al. (2014) “depending on the angle of the incident light and its intensity the flicker may cause feelings ranging from undesirable to unbearable”. Hence, the possibility for suffering from shadow flickering is higher when wind farms are located near populated areas (Katsaprakakis, 2012). Nevertheless, due to rules of maximum sound emission, the minimum distance to the closest neighboring region is usually six to ten rotor diameters and at that distance, shadows will occur only during some limited periods during the year (Wizelius, 2007). This distance may reduce shadow flickering impacts (Tabassum-Abbasi et al., 2014).

Shadow flickering is produced in two ways: the first is the movement of the blade and the second the reflection of the sunray on the wind turbine (Saidur et al, 2011). In both cases, shadow flickering produces visual pollution (Saidur et al., 2011). The intensity of shadow flickering, according to Mathew (2006) depends on the rotor speed and direction, number of bright sunshine hours and the geographical location of the installation. Proper design of wind farms can predict and prevent shadow flickering in order to overcome social objections referring to shadow flickering (Katsaprakakis, 2012). The problem with reflections from turbine’s blades has been diminished already, since the rotor blades on modern turbines are designed with an anti-reflection coating (Wizelius, 2007).

Shadow flicker opposes a problem, mainly in Northern Europe, as the latitude and the angle of the sun is low across the winter sky and as well as the closeness of inhabited buildings and wind turbines (Manwell et al., 2009). One approach to prevent shadow
flickering is shown in the picture below, where a minimum distance is required between the wind turbines and the wind farm in order to eliminate shadow flickering effects.

![Figure 19: Shadow flickering effect](http://www.betenenergy.com/sites/default/files/image/aofe.png) [last access: 18/08/2015]
3.1.5 Safety & Icing

Inadequate maintenance or inappropriate design of blades may create crucial safety problems as they may lead to separation of moving parts of the turbine. The reasons of some of the accidents, as explained by Abe et al. (2016), may be natural weather phenomena, such as thunderbolts and hurricanes. These accidents may pose a serious threat to safety if the wind farm is located near a residential area.

According to Manwell et al. (2009) safety issues are divided into two categories: public and occupational safety. Concerning public safety there are many critical considerations such as blade throw (major safety concern), tower failure (i.e. the total collapse of the tower to the ground based on poor design of the tower), attractive disturbance (i.e. observation of a turbine for the first time may raise the curiosity to try to climb tower and be injured) (Manwell et al., 2009). Additionally, fire hazard (due to the fact that the perfect site for a wind farm (i.e. high average speed, low vegetation, few trees) pose the most dangerous conditions for a fire hazard) is crucial issue regarding public safety (Manwell et al., 2009). Occupational safety concerns mainly the worker on the construction of wind projects, mainly during installation and maintenance phases, due to very strong wind, climbing in slippery surface, no use of work belt and the death is most of the times instantaneous (Gipe, 1995).

Wind farms operating in high elevations or cold regions face frequent icing effects, which is a major challenge with different types and causes. Ice is a very dangerous aspect of wind turbines, especially when it forms on the blades of the wind turbine and may be thrown by the rotation (also known as ice shedding or cast ice) (Chief Medical Officer of Health, 2010; Homola et al., 2006). This may lead to reduction of power, damage or harm to the components (Homola et al., 2006), safety concerns, and decrease of the turbine’s efficiency. In response to these concerns, Pryor and Barthelmeie (2010) claim that wind turbines can be manufactured to withstand extreme weather conditions.

Parent and Ilinca (2011) classify the techniques to avoid icing into two categories: anti-icing and de-icing systems. Anti-icing prevents ice to form on turbine’s blades, while de-icing removes the ice layer from the surface (Parent and Ilinca, 2011). Another categorization proposed by the same authors is passive and active methods; passive methods benefit from the physical properties of the surface of the blade to reduce or
prevent the formation of ice, which is a low-cost method; whereas active methods use external systems to supply energy that is thermal, chemical or pneumatic (Parent and Ilinca, 2011).

Homola et al. (2006) classify detection of ice into two categories: directly (that detects the alteration caused by the ice) or indirectly (that detects the weather conditions that cause the icing (i.e. humidity and temperature) and use a model to predict when icing is occurring). The optimum spot for the detection of icing on a wind turbine is on the blade (close to the tip) (Homola et al., 2006).

The operation of wind turbines should be stopped during bad weather conditions to minimize risk (Chief Medical Officer of Health, 2010). Another measure to diminish the threat is the active heating of blades to avoid icing effects, by using black paint that absorbs the sunlight during the day (Parent and Ilinca, 2011). Ice may be formed in the sea as well, affecting the performance and the output of the farm and remains a critical issue. As shown in the picture below, ice may create crucial problems in the operation of the blades.

Figure 20: Ice on a wind turbine blade

Source: http://www.s1106835.crystone.net/sites/default/files/image006_small_0.jpg [Last access: 16/08/2016]
Data of wind and weather conditions should be collected before and during the operation of the wind park in order to prevent hazards. However, as referred by Parent and Ilinca (2011), measurements may be affected by ice, leading to wrong data collection.
3.2 Environmental impacts

The constant and thoughtless use of fossil fuels will reduce the stock available for future generations. However, fossil fuels are the dominant sources of energy generation, which contribute currently to the most crucial environmental problems: air pollution and climate change. In the case of fossil fuels, environmental damage can arise throughout the whole life cycle (i.e. extraction (drilling and mining), transportation, combustion, management of the disposal unwanted by-products).

Nowadays, following an alternative path of development, the use of renewable energy sources has gained excessive interest, in order to eliminate reliance and dependency on fossil fuels. There is a great argument concerning how clean the renewable technologies are. Nonetheless, as noted by Lee (2002) “there is no such thing as a ‘clean’ energy source with respect to the environment, but some energy conversion technologies are friendlier to the environment than others”. The reason why lately accelerated focus and interest have gained ground concerning the environmental impacts of wind energy is the fast-growing pace and rapid expansion of wind energy (Pasqualetti et al., 2002).

Wind energy is one of the most mature technologies with a continuous growth rate and has become more commercially competitive (Dai et al., 2015). However, with the current growth rate, concerns have augmented about the long-term environmental impacts that may be created by the installation of wind parks. In general, as claimed by Saidur et al. (2011) wind energy is considered as a green power technology as it has only minor environmental footprint (mainly in the operated area) compared to conventional fuels; nonetheless, they should not be overlooked due to the considerable growth of wind energy (Leung and Yang, 2012).

According to Saidur et al. (2011), the energy consumed to manufacture and transport the materials used to build a wind farm is equal to the new energy produced by the plant within a few months of operation (Saidur et al., 2011). While the negative impacts appear to be few, the environmental footprint of wind farms should be studied independently before any installation or decision-making takes place as the evaluation of a site should not be based on previous experience of another site, but on up-to-date measurement for the specific site. In line with that, in some cases, potential environ-
mental impacts raise environmental concerns that can prevent the implementation of the wind project (Kaldellis et al., 2013).

As mentioned above, wind power plants have relatively little environmental footprint compared to fossil fuel power plants. Nevertheless, there are concerns over the noise produced by the rotor blades, visual impacts, which were described in the previous chapters, and mortality of birds and bats that fly into the rotors (Saidur et al, 2011) that will be described in the upcoming chapters. These issues attract an array of concerns that create polarization and serious conflicts among society and should not be ignored.

The aim of the present chapter is to understand and identify the reasons of disruption in habitats and biodiversity, which is an important task as it is the basis for making qualified decisions with respect with the environment.
3.2.1 Impacts in ecosystems

Evident to date shows that a proper well-designed wind park siting should not pose major threats to biodiversity (European Commission, 2011). In literature, specific species, such as birds, bats and marine animals, may be vulnerable to impacts of wind structures on their ecosystems (European Commission, 2011; Abe et al., 2016). Impacts that can create vulnerability to the aforementioned species include the potential disturbance that may be caused throughout the life cycle of the wind turbine (i.e. road to access for installation, maintenance and construction, electrical cabling to access the grid) with the degree of impact depending on the characteristics of each species (European Commission, 2011; Abe et al., 2016). In general, as suggested by Pasqualetti et al. (2002) wind industry should minimize or eliminate construction of roads, by using existing roads, as new roads may result to soil erosion.

However, the impacts on biodiversity are not only specific to each species but site-dependent as well. Therefore, an Environmental Impact Assessment should be conducted before any installation plant and should focus on the diverse characteristics of each district and biotope as a different case study.

Figure 21 presents the comparison in terms of impacts in habitats between conventional and renewable resources. In the figure below, it is evident that wind power has impacts only in the construction of the plant, whereas fossil fuels (i.e. coal, oil and natural gas) have negative impacts to almost all the habitat categories (i.e. air and water pollution, global warming, mining and drilling and construction of plants).

<table>
<thead>
<tr>
<th>Habitat impacts</th>
<th>Coal</th>
<th>Natural gas</th>
<th>Oil</th>
<th>Nuclear</th>
<th>Hydropower</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air and water pollution</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Global warming</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
</tr>
<tr>
<td>Thermal pollution of water</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Flooding of land</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mining and drilling</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Construction of plants</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Figure 21: Comparison of impacts between wind energy and conventional and renewable energy sources (Source: Saidur et al., 2011)
3.2.1.1 Wildlife, birds & bats

Whilst wind turbines are more environmentally friendly than fossil fuels, their negative impacts on the ecosystems should be minimized (Saidur et al. 2011). The effects of wind turbines on wildlife depend on an array of factors, such as the topography of the area, the variety and the number of species that have their habitat or their migratory route (for birds) in the region of the potential installation of the wind farm (Drewitt and Langston, 2006). Potential impacts due to an installation of a wind park that entails adverse effects on biodiversity should be neglected. In this respect, each case of wind farm should be examined individually considering all the parameters that could minimize the damage in the ecosystem’s balance (Drewitt and Langston, 2006).

Saidur et al. (2011) distinguish the impacts of wind turbines to wildlife into two categories: direct, i.e. the mortality from collisions with turbines, and indirect impacts, such as, according to the authors, “avoidance, habitat disruption and displacement”. Impacts on birds and bats are the issue most studied in literature as they attract an array of concerns (Morrison and Sinclair, 2004). In general, there is a conflict met, as well as extensive debates as to whether wind turbines are dangerous or not. On the one hand, some support the opinion that wind turbines may be very dangerous for the local biotopes, as they may result (if not sited properly) to mortality and collision with specific species (Katsaprakakis, 2012), while, on the other hand, researchers point out that birds can detect wind turbines and avoid them in time (Larsen and Guillemette, 2007).

Morrison and Sinclair (2004) explain the paradoxical issue of collision of birds with slow rotating blades, given the excellent vision of most birds:

“Optical analyses indicate that as a bird approaches the rotating blades, the retinal image of the blades (which is the information that gets transferred to the bird’s brain) increases in velocity until it is moving so fast that the retina cannot keep up with it. At this point, the retinal image becomes a transparent blur that the bird probably interprets as being safe to fly through, with potentially catastrophic consequences. This phenomenon is called ‘motion smear’ or ‘motion blur’ and is well known in human perception” (Morrison and Sinclair, 2004).
The mortality of birds due to wind turbines is an essential cause of environmental concern that often creates social objections. The design of the blade, and more specifically, the rotation of the blades, may lead to collision with birds and can cause mortality or fatal injuries (Dai et al., 2015). Additional factors that may increase mortality rates are bird species, climatic conditions, landscape topography, direction and strength of local winds (EWEA, 2009b; Dai et al., 2015). Fatality rates for birds fluctuate in accordance with the biological characteristics of the area where the wind farm is installed (Nelson, 2009). Highest mortality rates could be seasonal (for instance, during migratory seasons (i.e. spring and autumn)) or during prenuptial season or while searching for food for the nestlings (European Commission, 2011). However, according to Dai et al. (2015) “the accurate bird fatality rate is difficult to estimate due to variations in search area, searcher efficiency and predator removal rates”. In accordance with the previous statement, the European Wind Energy Association (2009) claims that bird mortality is a sporadic event.

To wider debates, National Research Council (2007) and Kaldellis and Zafirakis (2011) claim that the number of bird and bat deaths (as a result of wind turbine structures) is much smaller compared to mortalities due to collisions with buildings, towers, pesticides, communication towers, vehicles, power lines and other manmade installations, as shown in Figure 22. McCubbin and Sovacool (2013) shift the emphasis to the comparison of effects of wind energy to fossil-based resources and conclude that carbon-based power generation has greater effect on bird populations after taking into account all impacts, particularly climate change.
The mortality of bats does not seem to have a correlation with the wind speed, the environmental temperature or the flashing red aviation lights on the top of the towers (Dai et al., 2015). However, mortality increases proportionally as the height of the tower increases, which creates new concerns about the future wind turbines that will be higher (Dai et al., 2015).

Injuries and mortality are the results of collisions of the birds with the blades or associated structures (European Commission, 2011). Levels of collision depend on an array of factors, such as bird species (i.e. age, behavior, etc.), species flight height, number of species and behavior (Drewitt and Langston (2006); European Commission, 2011). Additional factors that affect the levels of collision are topographical bottlenecks (sight location), the nature of the wind farm itself (i.e. the scale and design of the wind turbine), including lightning, as well as weather conditions (for instance poor visibility, rain or fog) (Drewitt and Langston, 2006; European Commission, 2011; Dai et al., 2015).

Nevertheless, it is difficult to identify the causal link between collisions and poor weather as for the inconvenience of tracking birds under these circumstances (Dai et al., 2015). In addition, when poor weather conditions (i.e. fog, rain, strong wind or dark nights) occur, there is bad or lack of visibility and flying height, and more birds collide with the wind turbines (Erickson et al., 2001; Dai et al., 2015). Moreover, the red warning light on the top of the tower in poor weather conditions may attract more birds and
increase the rate of collisions (Dai et al., 2015). Although the collision risks are generally low, they should be taken into account notably for endangered species. Susceptible species (i.e. low reproductive rate or living under vulnerable conservation condition) should be under continuous monitoring (European Commission, 2011).

Disturbance to the local biodiversity may be caused by wind turbines themselves as physical barriers, or during the construction or operational phases of wind farms. Displacement of birds and bats may occur due to intrusion and disturbance to their natural habitat (i.e. vibration, noise, or use of transportation means such as boat, vehicle or helicopter etc.) (European Commission, 2011); however, the level of disturbance fluctuates depending on the species, seasons and locations involved (i.e. how important is the site) (Drewitt and Langston, 2006; European Commission, 2011).

In line with the previous paragraph, displacement of bats may occur if the wind turbines are located in or near a forest (occupied by bats), where trees are removed for the installation of the wind park. There are many hypotheses about why bats are attracted by wind turbines but researchers are not in agreement about the main reasons (Dai et al., 2015). The two most dominant explanations are that insects are attracted under certain weather conditions to the turbines and subsequently they bring bats and birds or that the heat radiation of wind turbines attracts the bats (European Commission, 2011).

Specific species may follow different migration flyways in order to avoid contact with the turbines, which is a form of displacement and creates constraints; while other species lower their flight height in particular locations increasing the risk of collision (Drewitt and Langston, 2006; European Commission, 2011). Large birds with difficulty in maneuvering (such as swans and geese) generally have higher possibilities of risk of collision with structures (Brown et al., 1992). Another reason for an ecosystem’s disturbance is the construction of roads for easy access to the site narrowing the fauna’s and flora’s territories.

In most cases, wind parks should not be placed in a Natura 2000 site. According to the European Commission19, Natura 2000 site is defined as “a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types

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which are protected in their own right”. In Figure 23, a map of all the recorded Natura 2000 sites in Europe is illustrated.

![Map of Natura 2000 areas in the European Union](image)

**Figure 23: Map of Natura 2000 areas in the European Union**

*Source: European Commission, 2011*

Flora is affected as well as fauna. The installation of a wind park or the construction of a road to access a wind park may alter the balance of the ecosystem and local biotope through the soil disruption and deforestation or regional vegetation that may lead to habitat loss for some species (Katsaprakakis, 2012). By vegetation removal, wind and rainfall may lead to soil erosion (Dai et al., 2015). In addition, if there are any leaks of wastewater or oil on the soil, serious environmental problems will emerge (Dai et al., 2015).

A conflict between the best areas for installing a wind park and the conservation of the local biodiversity is often met (Katsaprakakis, 2012). Before a construction of a wind park, developers should consider a web of environmental factors. These factors are the ecosystem’s safety, the migratory routes that may pass through the wind farm to avoid the risks of collision and mortality, the flight heights and directions. Additionally, disturbance and displacement of ecosystems, regions with significant levels of raptor activities, breeding, wintering or migrating populations of species that may be endangered are factors that should be examined (Drewitt and Langston, 2006).
In order to diminish the impacts on the habitats, preventive measures should be taken into consideration. For instance, appropriate space between turbines should be measured and preserved in order to facilitate animal movements or no travel permitted along roads during specific times of the year (i.e. migration periods) (Morrison and Sinclair, 2004). In addition, radars can be set to detect birds’ behavior in the area that the installation is going to be located. Potential constructors should consult professional wildlife surveys or scientists, in order to understand the breeding and feeding behaviors of local birds (Leung and Yang, 2012). For birds and bats, manual or automatic operation of wind turbines that will shut down when birds approach is an option that may eliminate the risks of collisions and fatalities (Dai et al., 2015). In this way as shown in the picture below, collisions may be reduced.

![Figure 24: Birds passing by a stationary wind turbine](http://vogeltalksvrving.com/wp-content/uploads/2013/12/wind-birds_shutterstock.jpg)

Appropriate planning and siting over a broad geographical region in a strategic manner are critical, and are the most effective ways to limit the impacts on wildlife and should be essential goals of the planning process (European Commission, 2011). Up-to-date sensitivity maps for valuable wildlife should be used in order to determine the optimum area for siting (European Commission, 2011) and siting in sensitive areas should be avoided. Before, during and after construction an environmental program should monitor the whole area and inform about possible impacts on the biotope (EWEA, 2009b).

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3.2.1.2 Marine ecosystems

Offshore turbines gain significant ground nowadays in order to avoid the disturbance of terrestrial ecosystems, as “as water has less surface roughness than land offshore wind speeds are considerably higher than onshore” (EEA, 2009). However, offshore installations are more complex and costly than their onshore counterparts (European Commission, 2011) and might increase concerns in relation to marine species. It should be kept in mind, that offshore installations might be noisier than onshore structures as sound propagates readily over water (Harrison, 2011).

The construction of an offshore wind park creates an artificial reef, also known as ‘reef effect’, which impacts the local marine animals directly and indirectly as it might alter the physical characteristics of the seabed (European Commission, 2011; Dai et al., 2015). The mapping and monitoring of the seabed is a very complex issue, due to limited or lack of knowledge about several marine species, and this has as well created a major gap in the determination of marine Natura 2000 sites (EWEA, 2009b; European Commission, 2011). The limited research in offshore installations claims that fish movements or populations do not seem to be disrupted; however, the impact on fish mammals should be further clarified (Morrison and Sinclair, 2004). Additionally, the impacts of boat and air traffic on marine ecosystems constitute a major concern with offshore wind park developments (Morrison and Sinclair, 2004).

Marine noise pollution is another cause of concern as it may displace marine ecosystems or interfere with their normal behaviors (European Commission, 2011). Leaks of oil or wastes during maintenance could also accelerate the water pollution (Dai et al., 2015). Increase of temperature around cables should be neglected because normally, the cables should be buried at a maximum depth of 3 meters in the seabed (European Commission, 2011). Unfortunately, lack of information and reliable knowledge about mortality of birds at offshore wind parks is due to the difficulty of detecting collisions and the difficulty in recovering dead birds from the sea (EWEA, 2009b). Further research is needed to gain relevant knowledge as offshore installations are under researched.
3.2.2 Use of land and landscape

Land use, as well as the scarcity of proper landscapes is a major argument towards the siting of a wind farm. Nevertheless, wind turbines not only do they occupy small regions but they can coexist with agriculture and animals as well. Additionally, using the land under the wind turbines for cultivating biomass can produce renewable energy more efficiently and in a greener way. One claim against the construction of wind parks in relation to other counterpart energy sources is that wind parks hypothetically require more land than thermal and nuclear power plants, even though they might produce the same amount of power (Katsaprakakis, 2012). However, this is not a valid argument if addressed in its total (Katsaprakakis, 2012).

The size of conventional power plants ranges across greater areas of land (though not in a single location) as it requires several procedures to generate such power (Katsaprakakis, 2012). To be more specific, a fossil-based power plant uses additional land and space for the generation of energy as the land they use also includes processes such as mining or pumping of fuel, transportation across distances to other plants, production and storage space, and disposal of waste generated in the process to name a few (Katsaprakakis, 2012).

Not only do conventional power plants utilize more land, but also they negatively and considerably affect greater area that includes fauna, flora, and humans, a very extreme contrast to the impact of wind parks (Katsaprakakis, 2012). According to Manwell et al. (2009), “in general, the variables that may determine land-use impacts include: site topography, size, number, output, and spacing of wind turbines; location and design of roads; location of supporting facilities (consolidated or dispersed); location of electrical lines (overhead or underground)”. The cornerstone of all social objections is the type of landscape where the wind farm will be installed, as local people may raise their voice about a wind park in their area, while being supporters of wind power in general. Many definitions of the term landscape have been proposed throughout the years. While according to Duncan (1995) “landscape is a portion of a natural and cultural environment - it is material landscape”, EWEA (2009b) states that the term ‘landscape’ is very difficult to be defined as it is a very wide and broad term that changes throughout the time. On top of that, Wolsink
(2007a) claims that the type of landscape is the dominant factor for opposition and overshadows all the other factors that can lead to social objections. To that extent, Molnarova et al. (2012) reach the conclusion that “landscapes containing wind turbines are perceived as less attractive than the same landscapes without these structures”.

The threat of wind farms to landscape is more complex, as often the landscape has symbolic value (Bidwell, 2013). In other words, people with a solid bond to their local community may perceive wind farms in their region as a form of “alien invasion” (Cass and Walker, 2009). However, socially accepted landscape types include industrial, harbor, and military areas as well as agricultural landscapes (Molnarova et al., 2012). Wind turbines can be a sort of annoyance, in different levels, for different people; the challenge is then to distinguish which is the main source of annoyance and whether the reason is justified.
3.3 **Economic aspects**

Rapid economic growth has led to a tremendous increase in need for energy. Nevertheless, conventional fossil fuels, which have been key energy sources and valuable commodities up to now, possessing the world’s greatest amount of electricity generation, are facing depletion, environmental and safety concerns (Leung and Yang, 2012), as well as intense conflicts that might entail war as they are concentrated in specific regions of the world. Hence, renewable energy sources should bridge the gap between the constant need for energy. Nevertheless, concerning wind energy ‘it is likely that as in other components of climate change there will be ‘winners’ and ‘losers’, i.e. regions where wind energy developments may benefit from climate change, and regions where the wind energy industry may be negatively impacted’ (Pryor and Barthelmie, 2010).

Wind energy is one of the most mature renewable technologies and is applied in large-scale electricity generation (Leung and Yang, 2012), minimizing the dependence of economies to fuel price volatility (EWEA, 2009a), and being competitive with natural gas and coal, as it is cheaper than all other renewables like solar, hydro, biomass and geothermal (Mathew, 2006). The development of wind technology (i.e. turbine’s efficiency, size of wind turbines, etc.) has decreased the cost of generating electricity (Martin and Ramsey, 2009). Wind is the fuel, which is abundant and free, hence too valuable, and subsequently, the economics of wind farm installation depend heavily on the characteristics of the location of the installation (i.e. wind speed, wind direction, wind load). While the fuel costs nothing, the capital investment is high (Mathew, 2006).

Without a doubt, wind energy developers are very interested in the energy that can be obtained from the wind and how it varies by location (EWEA, 2009a). More specifically, the cost of wind energy fluctuates inversely proportional to the average wind speed of the site (Martin and Ramsey, 2009). The three most substantial factors for the development of a wind farm project are land, with good to excellent wind resource, contract to sell electricity produced, and access to transmission lines (Nelson, 2009).

Wind energy offers a variety of employment opportunities to local people helping the development of local and global economy. Although wind power does not require constant exploration for new sources (Martin and Ramsey, 2009), human power is needed to install, check an installation for proper operation, and maintain a wind farm.
In order to determine whether a wind farm installation is financially worthwhile the most crucial factors that should be taken into account are the initial cost of the installation and the annual energy production (Nelson, 2009). However, EEA (2009) and EWEA (2009a) add to the aforementioned factors: upfront investment costs, the costs of wind turbine installation, the cost of capital, operation and maintenance (O&M) costs, other project development and planning costs, turbine lifetime and electricity production, as well as the cost of grid connection and the cost of land. In addition, the produced energy should be economically competitive to the existing technologies (Nelson, 2009).

Wind is cheaper in generating electricity than other renewable sources (Nelson, 2009). The problem, according to EWEA (2009a) is, that “many participants in the energy policy debate fail to realize that the economics of wind power is fundamentally different from, say, the economics of gas turbine generation units. A gas turbine plant converts a storable, dispatchable and costly energy source into electrical energy. Wind turbines convert a fluctuating and free energy source, into electricity”.

Not all the electricity can be derived from wind energy because of the variability of wind (Nelson, 2009), which causes intermittency in wind turbines’ operation. Nevertheless, if cheap storage becomes possible, the market may alter for all new technologies (Nelson, 2009). As Nelson (2009) highlights “a wind project is economically feasible only if its overall earnings exceed its overall costs within a time period up to the lifetime of the system”. EWEA (2009a) points out that wind energy generation may fluctuate from hour to hour, ‘as electricity demand from electricity customers will vary from hour to hour; this means that other generators on the grid have to provide power at short notice to balance supply and demand on the grid’.

The payback time (i.e. how long it takes for a wind turbine to depreciate the initial investment) is a cause of concern for many investors. Usually, banks and finance institutions require a payback of 7-10 years (EWEA, 2009a). The investment is more profitable the longer the wind turbine operates after the payback period (EWEA, 2009a).

Economic issues of wind energy projects are multidimensional, with numerous aspects affecting the unit cost of generated electricity by a wind turbine, which may fluctuate from country to country and from region to region (Mathew, 2006). Figure 25
illustrates that the total cost of wind energy per KWh is a function of an array of factors. These factors include the lifetime of the project, the cost of capital and the price of turbines, road construction etc. (that combined constitute the capital cost per year), the rotor diameter, hub height and other characteristics of the turbines (EWEA, 2009a). Additional factors are the mean wind speed and the general characteristics of the site (that combined constitute the annual energy production), the operation and maintenance costs per year (which combined with the capital costs per year constitute the total cost per year) (EWEA, 2009a). The largest cost component of a wind project derives from wind turbines themselves, including the costs associated with blades, towers, transportation and installation, accounting for around 75% of the capital cost (EWEA, 2009a).

![Diagram of the cost of wind energy](image)

Figure 25: The cost of wind energy (*Source: EWEA, 2009a*)
Wind energy is known as an important mitigation measure for climate change, an opportunity measure for job creation, and a clean alternative for electricity generation (Petrova, 2016). However, social acceptability of wind energy fluctuates in respect to the country, for instance, in Denmark generally enjoys a high public acceptance, because of the ownership (Saidur et al., 2010). Nevertheless, there is no quantitative approach as to whether a development is culturally accepted (Pasqualetti et al., 2002).

Economic incentives (i.e. compensation or a share of profits from the wind project or reduction in electricity price to local communities), involvement of community members (i.e. good communication and participation) in decision-making process, planning and implementation phases will be the driving force to foster social acceptability (Szarka, 2006; Dai et al., 2015). Petrova (2016) claims that communities that receive financial motives express less concern about noise disturbance, visual degradation, or environmental pollution, and they tend to be much more positive towards the installation of wind farms in neighboring areas. As resulting from the above described situation, the abovementioned author concludes that project acceptance of renewable energy installations at local level increases proportionally with the financial involvement of local people (Petrova, 2016).

Wind farms have a major advantage, which is that they are not permanent, so the siting area can fully reclaim with proper design and return to its original state (EWEA, 2009b). EWEA (2009b) suggests a series of measures to ensure that the wind project will create the least impacts on the surrounding area. These measures include “key areas of conservation importance and sensitivity should be avoided; adequate and specialized personnel should be present and particularly in sensitive locations, employing an on-site ecologist during construction; siting turbines close together to minimize the development footprint; where possible” (EWEA, 2009b). Additional measures proposed by the same source are “installing transmission cables underground, timing of the construction phase to avoid sensitive periods; and for offshore projects, carefully timing and routing maintenance trips to reduce disturbance from boats, helicopters and personnel etc.” (EWEA, 2009b). In addition, total reclamation of the area after the end of a wind project is recommended in order nature to be in its previous condition and disturbed surfac-
es to be repaired (Pasqualetti et al., 2002). As Pasqualetti et al. (2002) suggest the technology of the wind turbines should be in harmony with nature, and as well-blended as possible.

In line with the previous paragraph, Katsaprakakis (2012) suggests additional considerations in order to attain the optimum selection of installation sites, such as: the minimum distance should be in compliance with the relative law, in order to eliminate visual impact, noise and shadow flicker. Nevertheless, this distance may not guarantee the local acceptability; however, in combination with a statistical survey may foster social acceptability (Katsaprakakis, 2012). Additional and specific measures in sensitive areas (i.e. Natura 2000 site or Special Protected Area for fauna and flora) should be taken to ensure the protection of sensitive biotopes, forested areas, rare species and their natural habitat, and migratory routes of birds (Katsaprakakis, 2012). By law, the wind project should be located 2000 m. away from historical or cultural value areas (Katsaprakakis, 2012).

The success of wind projects and, in extension wind industry, heavily depends on how much the public feels involved during the whole project (Wolsink, 2007b). As a consequence, lack of involvement may raise opposition (Haggett, 2011). The driving force to achieve the optimum public engagement is an open discussion between the local community and the developers (Wolsink, 2007b). However, different groups may have different opinions into discussions about the need of the project, which can be the source of an array of conflicts and debates (Haggett, 2011). Even if the wind project is accepted by the majority of the public, this does not ensure that it will be approved, as a minority of dedicated opponents will object and try to shake down the whole project (Pasqualetti et al., 2002).

Environmental degradation may lead to the thought (by the policy makers) that the public knowledge should be improved; however, improved knowledge does not imply positive attitude towards wind farm, since, according to Wolsink (2007b) and Ellis et al. (2007) studies show that there is lack of evidence proving any relation between knowledge and attitudes. Nevertheless, the levels of public acceptance might increase if the public is educated about the environmental gains of wind energy (Pasqualetti et al., 2002).
Chapter 5 – Conclusions

Wind energy is a mature and promising technology that can be utilized in order to achieve lower carbon emissions and a more sustainable future. However, wind energy, as well as all renewable sources, is not a panacea to solve the increasing energy demand problems. As with every big and visible construction, there are many different objections towards wind turbines. Whilst a majority of people may be in favor of wind energy, when the project concerns a neighboring area people tend to oppose to that, also known as NIMBY syndrome.

The reasons for objecting an installation of a wind farm are many with noise and visual impact being the dominant. Nevertheless, as described above modern wind turbines are quieter and noise is proportional to the distance of the receiver and wind turbines. Additionally, it is not clear whether noise is an effect of wind turbines or visual impact. Beauty of landscape is a subjective issue and this subjectivity makes it difficult to quantify it. As a result, whether a wind turbine is perceived as a well-blended with the natural landscape and it is a symbol of green energy or whether it is perceived as visual pollution remains a very subjective issue. Unfortunately, there is not a ‘perfect’ site for siting as every case study has different characteristics and should be examined as a unique one.

Shadow flickering, possible adverse health effects and concerns for ecosystem disturbance (terrestrial, marine and avian) are other reasons for opposition. Shadow flickering is a serious problem that can create dizziness and in order to be solved minimum distance is required between wind turbines and populated areas. It is not yet scientifically proved either that wind turbines can cause health effects, sleep disturbance, dizziness or nausea, or that they do not. Fear or possible belief about adverse health effects may lead to the ‘nocebo effect’ mentioned by Colby et al. (2009).

Ecosystem disturbance creates serious environmental concerns as to where is the best place to install a wind farm to prevent collisions with birds. However, as shown in Figure 22 bird fatalities are mainly caused by high buildings. In order to protect avian species, sensitivity maps should be used and during migratory periods the wind turbines could remain inactive. Additionally, continuous monitoring before, during and after the wind park operation is suggested. Marine ecosystems may be annoyed in different phas-
es of the construction. Further research on the impacts of offshore installations to the marine population is needed. There is lack of scientific data concerning the avian collisions and offshore installations, as it is very difficult to find and retrieve the body from the sea. Leak of oil is a very crucial effect of the maintenance phase of the construction.

Safety concerns about throwing ice in cold climate regions, as well as human safety by blade throwing is included in the reasons for opposition. Nevertheless, modern turbines may have heated blades. In order to achieve a safe environment about the people that are dealing with wind turbines, proper maintenance and monitoring is needed. Wind turbines may be accused for use of land but in reality conventional power plants uses additional land, as it needs to extract fossil fuels and affect the local fauna and flora. The land where the tower of a wind turbine is installed can be used for cultivation or grazing of animals.

Social acceptability can be a serious bottleneck in the process of a wind project. As a result, wind industry should involve local people in an open dialogue and in the decision-making process, as well as provide financial incentives or lower electricity price in order to deal with a more supportive society reducing existing negative attitude. To conclude, as Wolsink (2007b) suggests “the fact that a minority does not support wind energy is not surprising because there is hardly anything in life that is universally accepted”.

68


Chief Medical Officer of Health (2010). The potential health impact of wind turbines. Retrieved from:


