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A REVIEW ON ENVIRONMENTAL IMPACT OF WIND ENERGY

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Abstract. The environmental impacts due to technology application have been an interesting and environmentally issue for researcher and engineers worldwide. The environmental impact of wind power when compared to the environmental impacts of fossil fuels, is relatively minor. Compared with other low carbon power sources, wind turbines have some of the lowest global warming potential per unit of electrical energy generated. Wind energy, commonly recognized to be a clean and environmentally friendly renewable energy resources that can reduce our dependency on fossil fuels, has developed rapidly in recent years. Its mature technology and comparatively low cost make it promising as an important primary energy source in the future. However, there are potential environmental impacts due to the installation and operation of the wind turbines that cannot be ignored. The impacts of the wind energy on the environment are important to be studied before any wind firm construction or a decision is made. Positive and negative impacts of wind energy have been broadly explained as well as. It has been found that this source of energy will reduce environmental pollution and water consumption. However, it has noise pollution, visual interference and negative impacts on wildlife.

Keywords: wind energy; environmental impacts, clean energy

I. INTRODUCTION

Energy researchers, industrial professionals, and government decision makers have increasingly turned their attention to renewable energy sources in an effort to reduce reliance on fossil fuels. Energy technologies such as biomass, wind, and geothermal are developing very fast and are becoming more commercially competitive [1]. As one of the most mature renewable energy technologies, wind power has seen accelerated growth during the past decade. Wind power has become the preferred option of energy for planners and national governments, who are seeking to diversify energy resources, to reduce CO_2 emissions, to create new industries, and to provide new employment opportunities. According to the latest Global Wind Report, the total global wind power installation was 318.105 GW at the end of 2013 [2]. However, wind energy developments are not free of adverse environmental impacts. Wind energy is considered as a green power technology because it has only minor negative impacts on the environment. But a poor understanding of these environmental impacts is a serious concern for the wind energy industry especially in developing countries and ecologically vulnerable regions [3]. In this paper, the authors reviewed potential environmental issues caused by wind farm developments, summarized evidence collected through existing case studies, and identified methodologies to mitigate these adverse environmental impacts. This review study provides energy industry planners and developers with an understanding about how an inappropriate wind farm project design could adversely affect a local environment. Mitigation efforts should be completed during the design, construction, and operation phases of a wind farm in order to avoid damages to vulnerable ecological systems.

II. POSITIVE IMPACT OF WIND ENERGY

Energy produced by wind turbines does not produce pollutants like other sources of energy (i.e. coal, gas, and petroleum based fuel). Wind energy may help to reduce the air pollutions by replacing the current sources of conventional energy. As a result, emissions especially carbon dioxide, nitrogen oxide and sulfur dioxide can be reduced. It has been found in the literatures that the emission of these gases is responsible for acid rain and global warming which causes greenhouse gas effect, rise in sea-level, and fluctuating weather conditions. Wind energy is an infinite type of energy that can be harvested either in the mainland or on the ocean. It was estimated that a 2.5 kW system can save 1–2 tonnes of CO_2 and a 6 kW system can save 2.5–5 tonnes CO_2 [4].

In a suitable site, wind turbines represent a relatively low-cost method of micro-renewable electricity generation. They

can bring increased security for electricity supply to non-grid connected locations and give some protection against electricity price rises. Renewable Obligations Certificates (ROCs) can be received by generating electricity. These can then be sold to electricity generators to allow them to meet their targets to derive a specified proportion of the electricity they supply to their customers from renewable energy sources. A consumer can benefit from onsite generation of power by qualifying for exemption from the Climate Change Levy. One can also be paid for any surplus of electricity to supply to the grid. According to the fourth assessment report released by the Intergovernmental Panel on Climate Change (IPCC), the warming of the earth over the past half century has been caused by human activities. The main culprits are the greenhouse gases emitted by burning of fossil fuels, in particular carbon dioxide (CO_2). Wind power can provide energy while reducing the emission of CO_2. According to the World Energy Commission, use of one million kWh of wind power can save 600 tonnes of CO_2 emission. Therefore, massive use of wind power will help mitigate climate change. The use of wind power can also avoid regional environmental problems brought about by burning coal [5].

A. Reduction of Water Consumption

In an increasingly water stressed world, water consumption is vital and is a great concern especially for countries like Singapore where clean water is highly valuable and scarce. It may be mentioned that conventional power plants use large amounts of water for the condensing portion of the thermodynamic cycle. For coal power plants, water is also used to clean and process fuel. Amount of water used can be millions of liters per day. By reducing the usage of water, water can be preserved and used for other purposes.

TABLE I
WATER CONSUMPTION OF CONVENTIONAL POWER PLANT AND RENEWABLE ENERGY BASED SOURCES

Technology	gal/kWh	l/kWh
Nuclear	0.52	2.30
Coal	0.49	1.90
Oil	0.43	1.00
Combined cycle gas	0.25	0.95
Wind	0.001	0.004
Solar	0.030	0.110

California energy commission estimated the amount of water consumption for conventional power plants as shown in Table 1. From Table 1, it has been found that water usage for wind turbine is lower than the conventional power plants and solar energy system. It was reported that the average amount of water consumption in Malaysia for conventional power plant was about 1.48 l/kWh while wind energy operated power sources used only 0.004 l/kWh for the year 2007 [6].

B. Reduction of Carbon Dioxide Emission

Generally, wind energy has zero direct air pollution. A small amount of CO_2 emissions is released by the wind energy during its construction and maintenance phases. However, this amount of CO_2 is much less than other fossil-fuel based power plants. This amount of CO_2 produced can actually be absorbed by the tree by the process of photosynthesis. Every unit (KWh) of electricity produced by the wind displaces a unit of electricity which would otherwise have been produced by a power station by burning fossil fuel [10]. It does not produce carbon dioxide, sulfur dioxide, mercury, particulates, or any other type of air pollution, as do fossil fuel power sources.

A study by the Irish national grid stated that "Producing electricity from wind reduces the consumption of fossil fuels and therefore leads to emissions savings", and estimated reductions in CO_2 emissions ranging from 0.33 to 0.59 tonnes of CO_2 per MWh [67. Amount of pollutants that can be reduced is shown in Table 2.

TABLE 2
REDUCTION OF DIFFERENT POLLUTANTS

Gases	CO_2	NO_x	SO_2
Reduction on emission per year (short-tonnes)	3251	20	421

According to data from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, approximately 67 million tonnes of CO_2 was avoided in 2006 by generating electricity through wind, biomass, photovoltaics and hydropower. Among these few types of electricity generation systems, wind energy plays the most important role. Emission reductions can be calculated using carbon emission factor 640 g CO2/kWh and following equation [8]:

$$CO_2 \text{ (in tonnes)} = \frac{A \times 0.3 \times 8760 \times 640}{1000} \qquad (1)$$

III. NEGATIVE IMPACT OF WIND ENERGY

Besides the positive impact, it is important to study the negative impact of a wind turbine technology. Before any decision is made, the worst condition has to be determined and predicted. By doing this, the damage can be reduced to minimum. The primary environmental impact related to wind turbine usage include wildlife safety, bio-system disturbance, noise, visual pollution, electromagnetic interference, and local climate change [9].

A. Effects on Animal

1) *Birds*: Wind turbines induce mortality and disturbance risks to birds. Birds can be killed by colliding with the rotating propellers of a wind turbine or can suffer lethal injuries because of collision with the turbine towers, nacelles or other structures in a wind farm such as guy cables, power lines, and meteorological masts. Loss et al. estimated that 234,000 birds on average were killed annually by collisions with monopole wind turbines in the U.S. In addition, wind turbine towers were found to have killed birds from some rare species such as golden eagles, swans, and Cantabrian Capercaillies [10]. The wind turbine induced bird mortality data in publications are summarized in Table 3.

TABLE 3
BIRD COLLISION MORTALITY CAUSED BY WIND TURBINE

Bird mortality /turbine/year	Location and time	Turbine information
24 birds	East dam, Zeebrugge (2001–2002)	200, 400, and 450 kW
35 birds	Boudewijn canal, Brugge (2001–2002)	600 kW
18 birds	Schelle (2002)	1.5 MW

Various factors contribute to wind turbine induced bird mortality, such as the wind turbine design and arrangement, bird species, and climatic variables. Orloff and Flannery [11] reported that bird mortality was higher for lattice turbines than for other turbine tower types. The location and layout of the wind farm also have influence on the bird mortality rate. Another negative impact of wind turbines on birds is disturbance, which includes habitat destruction, the barrier effect, and impact on the bird breeding and feeding behavior. Additionally, the majority of the birds either changed their flying direction to bypass the wind farm by a distance of 400 m or 1000 m or completely disappeared from the radar screen. Another research study found that, through 10 years of observation data on 47 eagle territories in western Norway, coastal wind farms affected the breeding success rate of the white-tail eagles.

2) *Bats:* Bats are more likely to respond to moving objects than stationary ones. However, a high bat mortality rate close to wind farms has been observed. Wind turbine related bat mortalities are now affecting nearly a quarter of all bat species in the United States and Canada. Research revealed that wind turbines killed not only bats from local populations but also migratory bats. Other researchers proposed alternative explanations. According to Arnett et al., bats could be attracted by the ultrasound emissions and the lights of the wind turbines. Another possibility is that the bats treated the wind turbines as trees and tried to explore them as potential roosting sites. In addition, a large amount of insects attracted by the high heat radiation of the wind turbine nacelles could also cause the hunting bats to aggregate around the turbines. Kunz et al. observed that a large number of dead bats were found at utility-scale wind energy facilities located along forested ridge tops, although bat carcass search is easier in grassland areas compared to agricultural landscapes or forested ridge tops. Additionally, more bats were killed in autumn migration and during the two-hour period after sunset. According to Kerns and Kerlinger, weather conditions and bat mortality do not seem to be directly associated. The bat fatality rate did not change when the wind speed was faster, when the environmental temperature was lower, or during foggy conditions. The flashing red aviation lights on the top of the wind turbine towers were not a reason for the bat mortality. A study by Barclay et al. showed that the size of the rotor was not associated with the death toll of bats, but the height of the turbine tower was. The bat mortality rate increased exponentially as tower height increased. This brought up a new concern: future wind farms will have less wind turbines but each turbine will be higher; this may increase bat mortality. A comprehensive bibliography associated with the wind farm induced bat morality rate up to 2008 can be found in Ref. [12].

3) Marine Species: Offshore wind turbines may have impacts on marine species. Construction of wind turbine foundations and on-site erection of wind turbine towers make seawater turbid and introduce additional objects on the seabed, which may cause damages to the benthic fauna and flora and may block sunshine in the water. Wind turbines and their scour protection may change the nearby fish distribution. Wind farm construction creates an artificial reef, which also impacts biodiversity. The noise and the electromagnetic fields around wind turbines may lead to negative effects on fish. Marine mammals such as porpoises and seals may react to wind farms, especially during construction phase activities such as pile driving. At the Nysted Offshore Wind Farm, researchers observed a clear porpoise population drop during construction and operation of the wind farm, which persisted for two years. Wind turbine maintenance activities, such as parts replacement or lubrication, can cause oil or waste to enter and pollute the surrounding seawater. Although research results in literature claimed that the potential impacts of wind farms on marine life were mainly within the construction phase and the impacts during the operational phase were more local, marine wind farms should be carefully planned to avoid major habitats of local sea animals.

B. Deforestation and Soil Erosion

During construction of a wind farm, some activities such as foundation excavation and road construction, may affect the local bio-system. If surface plants are removed, the surface soil would be exposed to strong wind and rainfall, resulting in soil erosion. Wastewater and oil from the construction site may seep into the ground soil and lead to serious environmental problems. Areas with rich wind resources, including grasslands, moorlands and semi deserts, typically have weak eco-systems with low bio-diversity. Construction with heavy machinery may disturb the local eco balance, and the local environment's recovery may take a long time A Chinese wind turbine construction guideline suggested that excavation should involve human labor as much as possible in order to minimize the disturbance induced by the heavy machines. In addition, the guideline recommends that trees and grasses should be replanted as soon as possible after construction.

C. Noise

Noise is one of the major environmental hindrances for the development of the wind power industry. Two types of noise are produced by wind turbines: tonal and broadband noises. Tonal noise is defined by discrete frequencies (in the range of 20 Hz-100 Hz) and is generated by the non aerodynamic instabilities and unstable airflows over holes, slits, or a blunt trailing edge of a wind turbine. Broadband noise, a random, non-periodic signal with a frequency more than 100 Hz, contains continuous frequency distribution generated by the interaction of wind turbine blades with the atmospheric turbulence and by the airflow along the air foil surface. The noise of the wind turbines includes aerodynamic noise and mechanical noise. Aerodynamic noise comes from the turbine blades passing through the air. This noise, perpendicular to the blade rotation surface, varies with the turbine size, the wind speed, and the blade rotation speed. A strong wind with a big turbine is obviously noisier. Since modern turbines can rotate to face the wind upward direction, noises can come from different directions at different times. Some turbine blade

pitches also can automatically adjust with the change of wind direction which produces different levels of noise. Aerodynamic noise contains different frequencies and is considered to be a broadband noise. Mechanical noise comes from the turbine's internal gears, the generator, and other auxiliary parts. These noises are noticeable and irritating, especially for wind turbines without sufficient insulation. Contrary to the aerodynamic noise, mechanical noise does not increase with the turbine dimensions, and it can be controlled through proper insulation during manufacturing. The total noise, measured by the sound pressure level dBA, is a combination of the mechanical and the aerodynamic noises. The low frequency noises (10-200 Hz) are considered as the substantial part of the noises when the modern turbines become larger. Early acoustic noise testing was performed on several small-size wind turbines. Many other factors contribute to noise propagation and attenuation, including air temperature, humidity, barriers, reflections, and ground surface materials. For example, inside a building, the wind direction and the building material sound absorption ability have influence on the attenuation of the noise. Another important factor is the background noise. At night, noises can be perceived differently. The whooshing (amplitude-modulated noise from wind turbines) can be perceived with increased intensity and can even become thumping. This is due to the ambient noise or background noise being low at night as a result of low human-made noise and the stable atmosphere [56]. Therefore, when analyzing wind turbine noise, the measured noise pressure level of wind turbines should be modified by the background noise [13].

D. Visual Impact

Shadow flicker, an effect caused by the movement of the turbine blades through the sunshine, becomes a human impact when a number of parameters converge, including distance from turbine, operational hours, and interactions with the sunlight. Besides the flickering shadows, the negative visual impact of wind farms on landscapes is another factor that makes people have a negative opinion of the wind energy industry. Some may consider wind energy as a useful alternative to reduce the conventional energy induced negative consequences on the environment while others may look at the wind turbines as machines that are changing a beautiful landscape into an industrial environment. Evaluating the visual impact of a wind farm is a difficult task.

Factors influencing the intensity of visual impacts of wind turbines include scenic backgrounds, local topographies, and local landscapes between viewers and turbines. When idle, a wind turbine looks like an abandoned machine. If a wind turbine is located near a scenic spot or an archaeological area, people are more likely to view the turbine as visual pollution. If a wind turbine is built in narrow or closed areas such as valleys, its visual impact appears to be more intensive. The number of blades and the blade rotating directions of a wind turbine can influence its visual impact. According to Sun et al., a wind turbine with three blades is more acceptable to people who are sensitive to visual impacts than the one with two blades. The reason could be that the turbines with three blades tend to give a stronger sense of balance. Wind turbines with counter-clockwise rotating blades generated stronger visual disturbance to viewers. The wind turbine layout in a farm can be categorized into regular layout and irregular layout. Generally, the regular layout created a better sense of visual regularity and consistency than the irregular layout, which may lead to a sense of chaos. However, even with the regular layout such as a grid, the intensity of the visual impact may change as the viewer moves across the landscape and observes the turbines from different directions and elevations .

E. Reception of Radio Waves and Weather Radar

Although the electromagnetic field of a wind turbine itself is extremely weak and is confined in a small range, it can still create electromagnetic interferences. Bacon found three degradation mechanisms that can interfere with waves: the nearfield effects, the diffraction effects, and the reflection or scattering effects. Studies carried out by Randhawa and Rudd showed that the diffraction in the Fresnel zone and the reflection or scattering effects created by wind turbines are the main mechanisms which degrade the radio performance. Wind turbine towers and blades can be an obstacle and can cause interference for wireless services. Wind turbine blades modulate radiowave signals strongly enough to affect many electromagnetic systems such as televisions, FM broadcast radios, microwave communication systems, and navigational systems. This interference can induce ghosting effects (also named video distortion), which are pale shadows on a television screen. Interference also can cause errors in navigational systems and disrupt the modulation in typical microwaves. Wind turbines sometimes can create a shadow zone that blocks waves mitted from a transmitter. They can also induce a diffraction effect with a predictable interference pattern around the turbine towers. In addition, wind turbine towers sometimes can reflect radio waves because of reflective materials used on the towers. For instance, steel tubes for the turbine towers are good reflectors. However, the blades of more recently constructed wind turbines are exclusively made of synthetic materials, which have minimized the impact on the transmission of electromagnetic radiation [14].

F. Climate Change

Wind turbines can impact local weather and regional climate. Zhou et al. studied eight years satellite data in regions of west-central Texas equipped with 2358 wind turbines and reported a temperature increase of 0.724^{o}C in the area. The study also showed that at night, the temperature increase was even more obvious. Wind farms may also change the global distribution of rainfall and clouds. However, this warming effect caused by wind turbines is still much weaker than that generated by the emission of greenhouse gases on the global scale. Research indicated that the recovery rate of the wind speed, after the wind passed through a wind farm, is a decreasing curve. The turbulence created by wind turbine blade rotations can affect the regional climate as well.

The regional climate change can induce a longterm impact on wildlife and regional weather patterns. In contrast, some other studies reported that wind farms were able to alleviate adverse climates, even though the effect was very limited. Studies have found that the wind farms in Gansu Province of

China were effective in decreasing the local wind speed and mitigated the hazards of sand storms [15].

IV. Mitigation of Wind Energy Environmental Risks

The negative environmental impacts from wind energy installations are much lower in intensity than those produced by conventional energies, but they still have to assessed and mitigated when necessary. Mitigation strategies are discussed in the following sections in order to involve more researchers and engineers in this campaign.

A. Limiting the Effects on Birds and Bats

To reduce bird fatalities, several strategies could be considered. Restricting construction activities to non-breeding periods could help reduce the negative effects of bird disturbance.

Turbine design optimization is another effective way to reduce bat mortality. Long et al. proposed a methodology based on fundamental analytical models that optimizes turbine designs in order to maximize the chances of bats being able to detect the presence of the blades. Site selection of a wind farm is also important . The monitoring and modeling methodology proposed by Liechti et al. is an effective approach to select a suitable location. The methodology suggested building wind farms far from important bird habitats and bird migration routes. It is helpful to work with ornithologists to consider possible impacts on birds when designing a wind farm layout. Bird flight activities in a zone of 200-500 m surrounding the planned wind farm should be recorded and analyzed. Fight heights, directions, species, and behaviors of birds should be studied systematically. Sensitivity analyses are also helpful when selecting a wind farm location. Clarke pointed out that wind farms should be located at least 300 m away from any nature conservation site. Spatial distribution and aggregation activities of vulnerable species should be assessed before a wind farm construction in order to minimize bird disturbances. After wind turbine locations are finalized, the direction of tower layout should be properly designed to reduce the effects on bird migration. In addition to the computer modeling and mapping, field inspections and monitoring are also useful. Modern instruments such as video, radar, and acoustic and thermal imaging equipment have been successfully applied to study bat mortality under different weather conditions and in different landscapes. Infra-red video cameras, as well as pressure and vibration sensors, have been integrated into automated recording systems to perform the environmental assessment of wind turbines and collect information on bird movements.

B. Reducing Influence on Marine Environment and Climate

To mitigate meteorological impacts of wind farms, the rotor generated turbulences should be reduced. Through improved rotor and blade designs and a proper design of turbine spacing and pattern, the turbulences can be mitigated, and the hydro-meteorological impacts can be reduced. It is also suggested to locate wind farms in regions where wind energy is abundant and the frictional dissipation is high. In this way, the wind energy will be harvested instead of losing as frictions. The purpose of this strategy is to increase the efficiency of wind farms. Preliminary research showed that the noise caused by the offshore wind turbine operation could not be heard at 20 m below the water's surface [96]; studies also indicated that visual impacts of wind farms could be negligible at eight km away from the shore.

With the increasing height of the wind turbine towers and the increasing size of the offshore wind farms, the environmental impacts of wind farms such as habitat fragmentations, noises, vibrations, electro-magnetic interferences, the impacts on fish, marine mammals and benthos are becoming significant. Therefore, the construction of offshore wind farms should be strictly managed to avoid ambient water pollution. Pile driving should not be conducted during the migrating seasons of porpoises to minimize disturbances. Through modeling and analysis, offshore wind farms should be spatially allocated to maximize revenues while protecting marine fish populations .

C. Noise Reduction

To reduce noise from wind turbines, improved blade design is the key. A balance between the noise radiation and the energy production should be explored during the blade design phase [98]. An appropriate design of blades can significantly reduce the aerodynamic noise. The application of upwind turbines is also useful to reduce low frequency noise. The insulations inside the turbine towers can effectively mitigate the mechanical noise during the course of operation. The special gearboxes for wind turbines introduce less noise than standard industrial gearboxes. The steel wheels of the special gearbox have semi-soft and flexible cores with hard surfaces to ensure strength, to extend the lifetime of the equipment, and to muffle noise. Direct drive wind turbines without any gearbox or high-speed mechanical component can operate more quietly.

Variable-speed turbines create less noise at low wind speeds than the constant-speed turbines. Besides technical measures, another way to avoid noise-induced problems is to build wind farms close to noisy areas. For example, road traffic can mask wind turbine noise if the traffic noise exceeds the turbine noise by at least 20 dBA. This method is effective for fairly quiet wind turbines with 35-40 dBA noise level. Different criteria on the noise levels and the standoff distances between wind farms and habitations have been provided by different countries or regions. Suitable criteria should be followed with a comprehensive consideration of specific local conditions for a wind farm development.

D. Mitigating Visual Impact

The planning guidelines from the Ireland Department of the Environment, Heritage and Local Government (DEHLG) suggested four factors to limit a wind farm's visual impacts on landscapes during the design phase: (1) whether it is acceptable to change the landscape; (2) how visually dominant are the wind turbines on the landscape; (3) what is the relationship between aesthetics and the wind energy development; and (4) how important is the impact. The shadow flicker issue from wind turbines can also be predicted and avoided with an appropriate sitting design of a wind farm. To encourage local residents to have a positive perception of wind farms, public participation in the early stages of the planning and implementation of wind power projects are

recommended, such as working together to seek solutions to the visual impact issues. Early communication is crucial to avoid conflicts with the public. Devinee Wright suggested that a project should go beyond the NIMBY label and incorporate social and environmental psychological aspects. The 'backyard' motives are dominated by the feelings about equity and fairness rather than selfishness, and institutional factors can play a more important role than the public acceptance of wind power projects. Involvement of local residents and good communication can help decrease the public resistance to wind energy projects. Wind turbine tower layouts can be categorized as regular and irregular formats. Generally, the fewer the number of wind turbines and the simpler the layout, the easier it is to create a visually balanced, simple and consistent image. For regular landscapes such as an open or leveled space, a regular layout, such as a double line, a triangle, or a grid, is preferred. Irregular layouts are more suitable for the landscapes with variable elevations and patterns. Selecting an appropriate color for a turbine is important to mitigate its visual impact. Rather than painting turbines in a color to camouflage them against their background, it is more suitable to choose a color to engage the turbines to the backdrops at different views and in different weather conditions. White, off-white or light gray gives people a feeling of cleanliness and efficiency. Dark or metallic colors, typically for industrial elements, may not be suitable for wind turbines.

E. Reducing Electromagnetic Interfence

In Greece, construction of wind farms within a certain distance of a telecommunication, radio, or television station is forbidden. However, in other European countries, wind turbine towers are commonly used for the installation of antennas to improve communication services, such as mobile phone services. With regards to the compatibility and interference with telecommunications, Binopoulos and Haviaropoulos argued that the electromagnetic radiation and interference of wind turbines are very limited. However, there are scenarios when the electromagnetic interference causes problems. For these situations, various measures can be used to minimize the problem. Blades made from synthetic materials, compared to steel blades, produced less interference. Wind farms could be planned and constructed at locations without blocking broadcast signals. The installation of extra transmitter masts could also be a solution, with a little extra cost for investors. In regions where the wind turbine induced electromagnetic interference already occurred, deflectors or repeaters could be installed to overcome the problems.

V. CONCLUSIONS

Renewable energy is one solution for the global energy problem. It has been found that wind energy is clean, environmental friendly, and cheaper compared to other sources of renewable energy. As such this source of energy will protect the earth from the atmospheric contamination. It was also found that water consumption can be reduced with the usage of wind energy compared to petroleum based power plants that produce energy. It was also found that wind energy has minimal impacts on the habitat compared to other sources of energy.

However, energy produced by wind turbine is not free from negative impacts. It has been found that wildlife is killed with the collision of wind turbines in many cases. This source of energy also creates sound noise which is annoying to the vicinity of wind turbine installation project. Visual performance is also interfered by the wind turbine. If wind turbines are designed and planned carefully, many of these negative impacts can be minimized.

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