The Real Truth About Wind Energy

A Literature Based Introduction to Wind Turbines in Ontario

August 18, 2011

Sierra Club Canada

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List of Abbreviations

AECL.. Atomic Energy of Canada Limited
APWRA...................................... Altamont Pass Wind Resource Area
CMA.. Canadian Medical Association
dB.. Decibel
dBA.. A-weighted decibels
DOE... Department of Energy
EIA... U.S Energy Information Administration
EMF.. Electro Magnetic Field
EREC.. Energy Efficiency and Renewable Energy Clearinghouse
EWEA... European Wind Energy Association
FIT .... Feed-in-Tariff
GWEC.. Global Wind Energy Council
HAWT....................................... Horizontal Axis Wind Turbine
Hz... Hertz
IEA... International Energy Agency
IESO... Independent Electricity Systems Operator
KW... Kilowatt
kWh... Kilowatt Hours
MOE... Ministry of the Environment
MW.. Megawatt
MWh.. Megawatt Hours
NRCan.. Natural Resources Canada
NRTEE....................................... National Round Table on the Environment and the Economy
OEE.. Office of Energy Efficiency
OPA .... Ontario Power Authority
POST .... Parliamentary Office of Science and Technology
RSPB.. The Royal Society for Protection of Birds
TVA.. Tennessee Valley Authority
VAWT.. Vertical Axis Wind Turbine

Foreword

Sierra Club Canada has, for many years, championed the cause of renewable energy with the goals of protecting Canadians from the dangerous health effects of hydrocarbons; protecting our environment from climate changing greenhouse gas emissions; and creating a sustainable economy. Toward these goals, Sierra Club Canada has supported the Ontario *Green Energy Act* and the resulting investment in the wind industry in Ontario and Canada. The *Green Energy Act* provides a springboard for the development of renewable energy through investment in small and large-scale projects, helping Ontario to move away from dangerous fossil fuels such as coal and oil.

Recently in Ontario, there has been backlash and opposition to wind power. As a leading Canadian environmental organization, Sierra Club Canada sees this reaction as an indication of the need to further evaluate the safety and value of wind turbines and wind farms. After a thorough review of the science we are confident in saying there is no evidence of significant health effects that should prevent the further development and implementation of wind turbines, wind farms and wind energy. In fact, the further development of wind energy as a growing portion of our energy supply will reduce direct carbon emissions, improve the quality of the air we breathe, and generally improve the health and well-being of Canadians, our families and the environment in which we live.

With a full review of available information Sierra Club Canada adds its voice to the overwhelming majority of governmental, non-governmental, scientific, and environmental groups in saying that a link between well-sited wind turbines and health concerns is unfounded. After a review of the pertinent information we hope that Ontario, and indeed all Canadian municipalities and citizens, can embrace wind power and the role it will play in a clean, safe, sustainable future.

A Literature Based Introduction to Wind Turbines in Ontario

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Introduction

In addressing wind power as a source of renewable energy a great many questions have been raised and concerns have surfaced. In the hopes of clarifying misconceptions and addressing the many questions posed, this document reviews available literature addressing wind turbines, the sound produced and health effects associated with them. Publications, journal articles, books and various studies have been reviewed and summarized to give an impression of wind as a part of the renewable energy sector in comparison with traditional electricity production.

This literature review approaches questions of the wind industry on a large scale analyzing available studies which look at all aspects of the industry. This is a review of the available scientific knowledge discussing the viability, safety and environmental impact of wind power. Scientific knowledge and study are constantly changing and increasing; this document shows the current state of available literature on wind turbines and associated issues.

In discussing the many topics associated with wind turbines, certain limits must be drawn. First we are unable to discuss individual installations, wind farms or wind turbines. Second we have chosen to discuss the situation in Ontario as it has become a central location for this debate. Toward this end each effect or issue has been approached through the lens of the Ontario Guidelines.

As mentioned above, this report does not deal with specific instances and installation. For anyone interested in these issues the Ontario Land Owners Guide 2005[1] released by the Ontario Sustainable Energy Association is recommended.

In approaching the topic of wind energy in Ontario this document begins by taking a large scope view of energy generation and consumption. The focus then narrows to discuss wind energy technology on a global scale. Finally the focus is shifted to the specific energy system in Ontario and the integration of wind power into that system. In doing so specific issues regarding human and environmental impacts are addressed.

[1] http://www.ontariosea.org/Storage/22/1377_LandownersGuideToWindEnergy.pdf

Contextualizing Renewable Electricity Generation

Anthropogenic climate change is now a well documented phenomenon. As stated in The Stern Review "*an overwhelming body of scientific evidence indicates that the Earth's climate is rapidly changing, predominantly as a result of increases in greenhouse gases caused by human activities*" (Stern, 2006, p. 4). This view has been substantiated in multiple documents, and is supported by many organizations.

It has been documented that average annual temperatures for Canada as a whole have increased 1.4°C between 1948 and 2007, with some Arctic regions experiencing a 2.1°C increase in annual temperature during this time (Statistics Canada, 2009). Seventy percent of greenhouse gas emissions are the result of energy generation in North America and Europe since 1850 (Stern, 2006, pp. 193).

In 2000, per capita greenhouse gas emissions in Canada were 22.1 tons $C0_2$ equivalent (Baumert et al., 2005, p.21). To put this in perspective 1 kg of CO_2 occupies a volume of 0.53 cubic meters (FieldCleggBradleyStudios et al., [No date]). Driving a medium sized car 5,000 km results in 1 tonne of CO_2 emissions (Statistics Canada, 2009). This ranks Canada as the seventh worst greenhouse gas emitter in the Organization for Economic Co-operation and Development following Qatar, United Arab Emirates, Kuwait, Australia, Bahrain and the United States (Baumert et al., 2005, p.21). Although home to only 0.5% of the world's population, Canada is responsible for 2% of world wide greenhouse gas emissions (Statistics Canada, 2009). Correspondingly, Canada has one of the highest rates of per capita energy consumption in the world, sitting at 17,030.83kWh in 2008 (The World Bank Group, 2011).

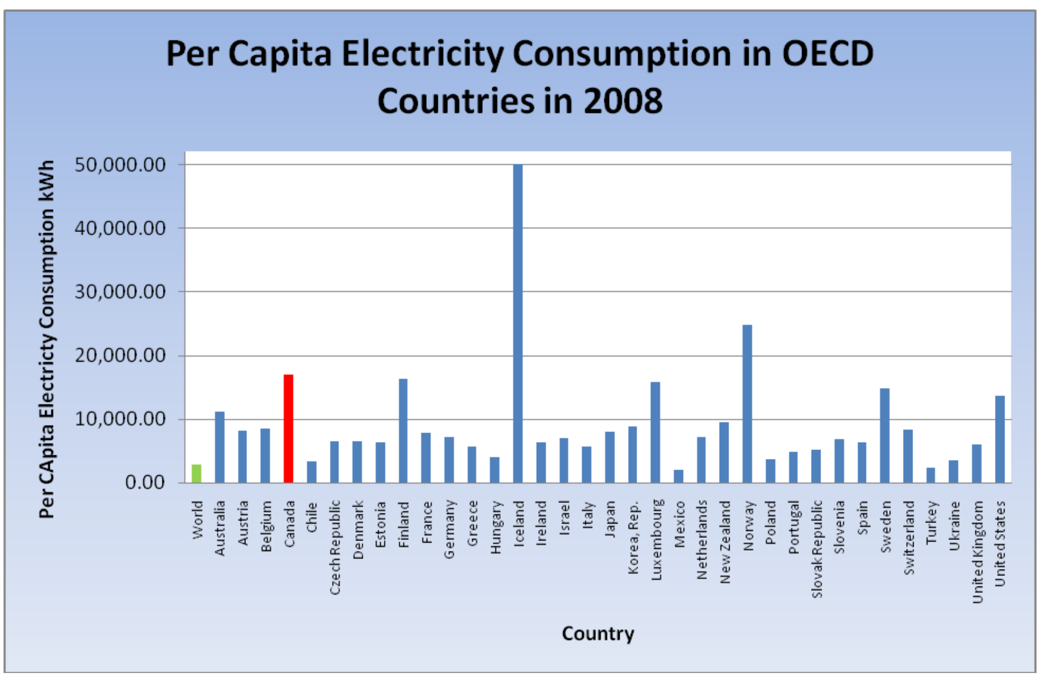

Figure 1: Per Capita Electricity Consumption in OECD Countries 2008 Information from (The World Bank Group, 2011)

In 2010, the majority of electricity produced in Ontario came from nuclear, followed by hydro, gas, and coal, with wind and other generation types making up the balance (IESO, 2011).

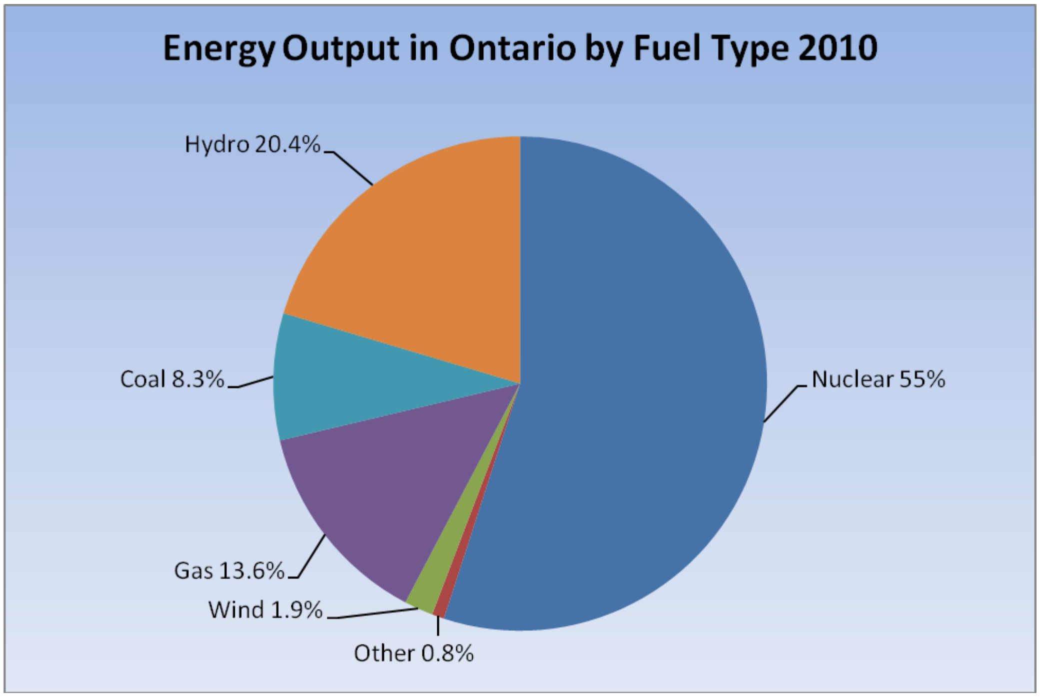

Figure 2: Energy Output in Ontario by Fuel Type Information from (IESO, 2011)

Renewable energy is one solution to a dependence on fossil fuels, and a corresponding reduction in greenhouse gas emissions. A renewable source of energy is derived from gravitational energy, solar energy or the earth's internal heat. This includes but is not limited to: wind, biomass, solar, hydro, geothermal or marine power. Wind power is an example of a renewable generation technique with tremendous potential. There are no direct greenhouse gas emissions from the generation of electricity from wind turbines, and every 1 MWh of electricity generated by a wind turbine equates to a reduction of 0.8-0.9 t in greenhouse gas emissions when compared to a power plant producing electricity from either coal or diesel (Statistics Canada, 2009).

The variability of wind is sometimes cited as a barrier to the proliferation of wind power, but no energy source produces at 100% capacity all of the time. Capacity factor is commonly discussed when referring to electricity generation techniques. It is the actual output of a generating facility over the theoretical output if generation was at the maximum level all the time. For example, a power plant working at 100% capacity 50% of the time would have a capacity factor of 50%, the same as a power plant working at 50% capacity 100% of the time. The U.S. Energy Information Administration, in their report entitled

Electrical Power Industry 2009: Year in Review, publish information on average capacity factors by energy source (EIA, 2011).

Table 1: Average Capacity Factors by Energy Source in 2009 (EIA, 2009)

Energy Source	Average Capacity Factors %
Coal	63.8
Petroleum	7.8
Natural Gas CC	42.2
Natural Gas Other	10.1
Nuclear	90.3
Conventional Hydroelectric	39.8
Renewable (Solar, Wind, Biomass)	33.9
Average	44.9

When reviewed over time the capacity factor for renewable energy can be seen to fall within the range of conventional energy sources, as seen in Figure 3 (EIA, 2009).

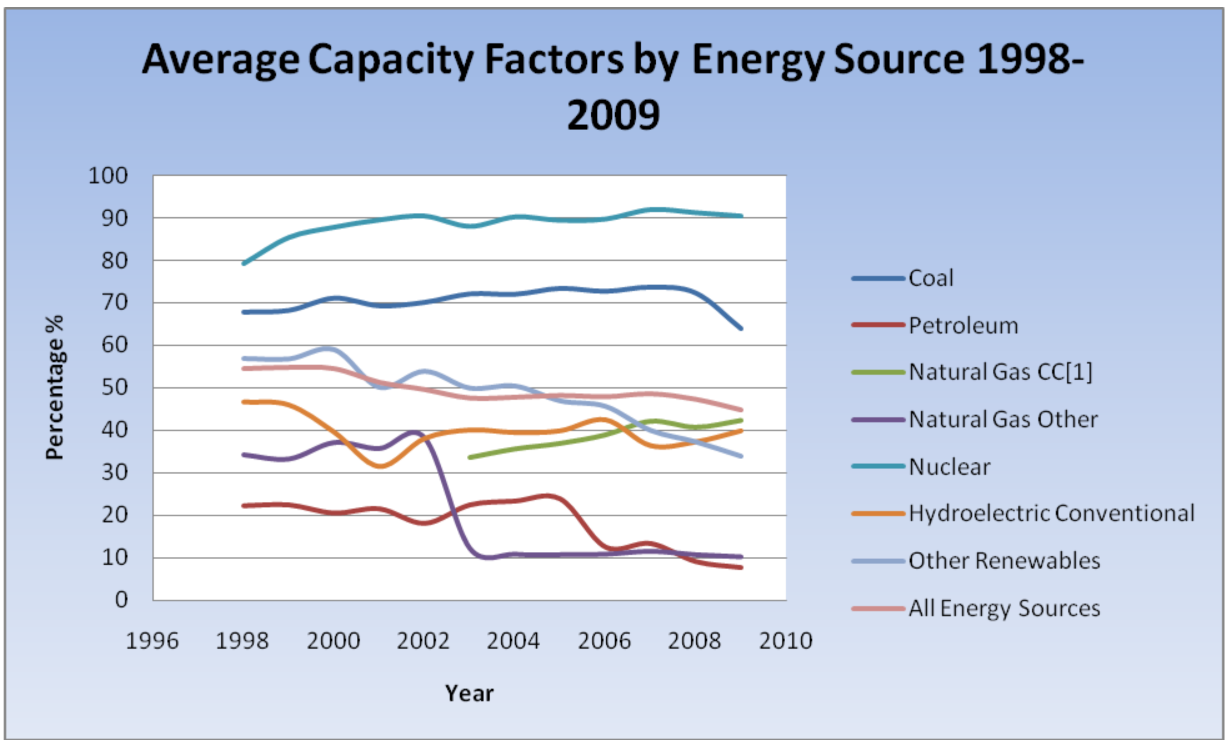

Figure 3: Average Capacity Factors by Energy Source from 1998-2009

When evaluating the total emissions from electricity generation technology, it can be seen that the emissions from wind turbines are low when compared to other methods of generation (Jacobson, 2009, p.154). The comparison shown in *Table 2* takes a holistic approach to the emissions associated with different forms of electricity generation. This analysis takes into account direct life cycle emissions, mining emissions, emissions associated with accidents, war and terror, as well as "opportunity-cost emissions" (Jacobson, 2009, p.154). This more complete accounting analyses the planning, approval, construction retrofit, and upgrades of different energy technologies and all associated delays (Jacobson, 2009, p.153-160).

Table 2: Total eqCO_2 Emissions from Various Electricity Generation Technologies (Jacobson, 2009, p.154)

Technology	Total Emissions in g CO_2e/kWh^{-1}
Solar PV	15-59
CSP	8.5-11.3
Wind	2.8-7.4
Geothermal	16.1-61
Hydroelectric	48-71
Wave	41.7-62.7
Tidal	34-55
Nuclear	68-180.1
Coal-CCS	307.8-571

A report by the Canadian Medical Association (CMA) outlines the grave impact that air pollution has on human health, as well as the large financial costs associated with air pollution related illnesses. This report states that in 2008, air pollution was responsible for 21,000 deaths in Canada (CMA, 2008, p.iii). 90,000 people will have died from acute effects and 710,000 will have died from long-term exposure to air pollution by 2031, with the highest number of deaths from acute exposure in Quebec and Ontario (CMA, 2008, p.iii). In 2008 air pollution was responsible for 620,000 visits to doctors offices, and 92,000 emergency room visits, while these numbers are expected to rise to 940,000 and 152,000 respectively in 2031 (CMA, 2008, p.iii). In 2008 the cost of air pollution was $8 billion, and by 2031, the cumulative cost of air pollution will be $250 billion (CMA, 2008, p.iii). There are no emissions directly associated with energy produced from wind turbines (Andersen, 2008, p.11).

Gipe has noted two deaths of members of the public from wind turbines; the noted deaths were *"a crop-duster pilot in Texas who struck a guy wire on a meteorological mast and a female parachutist who drifted into a large turbine in Denmark on her first solo jump*" (Stankovic et al., 2009, p. 85).

Wind Power

While it is not precisely known when wind first began to be used as a source of power, it is likely that some form of windmill was used in Japan and China 3000 years ago (Wizelius, 2007, p.7). The first wind mill to be well documented had a vertical axis, and was located in Persia, dating to 947 AD (Wizelius, 2007, p.7). Horizontal axis wind mills were built in Europe by the later part of the 12th century (Wizelius, 2007, p.7). Windmills were one of the dominant forms of power in Europe until the close of the 19th century, with the number of windmills peaking in the mid-19th century, numbering 9,000 in the Netherlands, 18,000 in Germany, 8,000 in England, 3,000 in Denmark and 20,000 in France (Wizelius, 2007, p.9). Early mills provided significant mechanical energy which was used in a variety of industries from flourmills and water pumps to lumber mills and the processing of various foodstuffs, spices and grains.

Wind power has since developed in its efficiency and its ability to produce electricity, the form of energy we most commonly associate with wind turbines today. Windmills of all sorts use the energy from the wind and the principles of aerodynamics to produce energy in many forms. Modern turbines add the use of a generator to produce electricity. In 1892 the first wind turbine used to produce electric power was build in Denmark by Paul la Cour (Wizelius, 2007, p.15).

The familiar windmill has evolved, and in our age of growing energy consumption, is becoming an increasingly common feature, appearing on hilltops, across plains, and on the coasts, shores and banks of oceans, lakes and rivers. New technologies are allowing the installation of wind turbines at increasingly greater distances off shore. Modern wind turbines are designed and installed in multiple ways.

There are two main types of wind turbines, horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). Turbines can further be classified based on whether they depend mainly on lift or drag forces to move their rotors (Stankovik et al., 2010, p.117). The primary types of lift based turbines are the Propeller (double-bladed and three-bladed), the Darius, the Cyclogiro, the Chalk Multiblade and the Sailwing, and the primary types of drag based turbines are the Fan, the Savonius and the Dutch (Walker and Junins, 1997, p.21). From the orientation and the number and type of blades, to the construction materials, all design aspects are variable (France Énergie Éolienne). In Ontario most wind turbines are three bladed horizontal turbines placed atop a tower of 80-120m, facing into the wind.

The structure of wind turbines can be broadly broken up into three parts, the rotor system, the nacelle and the support structure, including the tower and foundation (Jain, 2011, p.169).

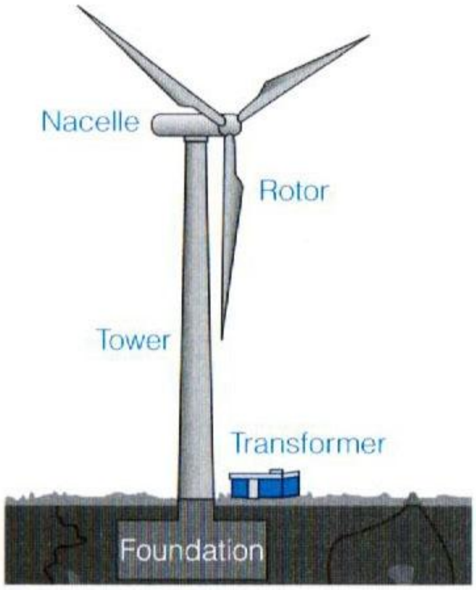

Figure 4: Diagram of Wind Turbine Components (EREC,2010, p. 94)

Wind turbines work by transforming kinetic energy from the wind into electricity. The rotor system, composed of the blades, the hub and the pitch mechanism, *"captures wind energy and converts it into rotational kinetic energy"* (Jain, 2011, p. 169). The tower and the foundation are structural elements, and the primary consideration when designing these elements is potential turbine loads and site soil conditions (Jain, 2011, p. 169, 180-181). The diagram in Figure 5 illustrates the main components of a nacelle, with a description of these components following.

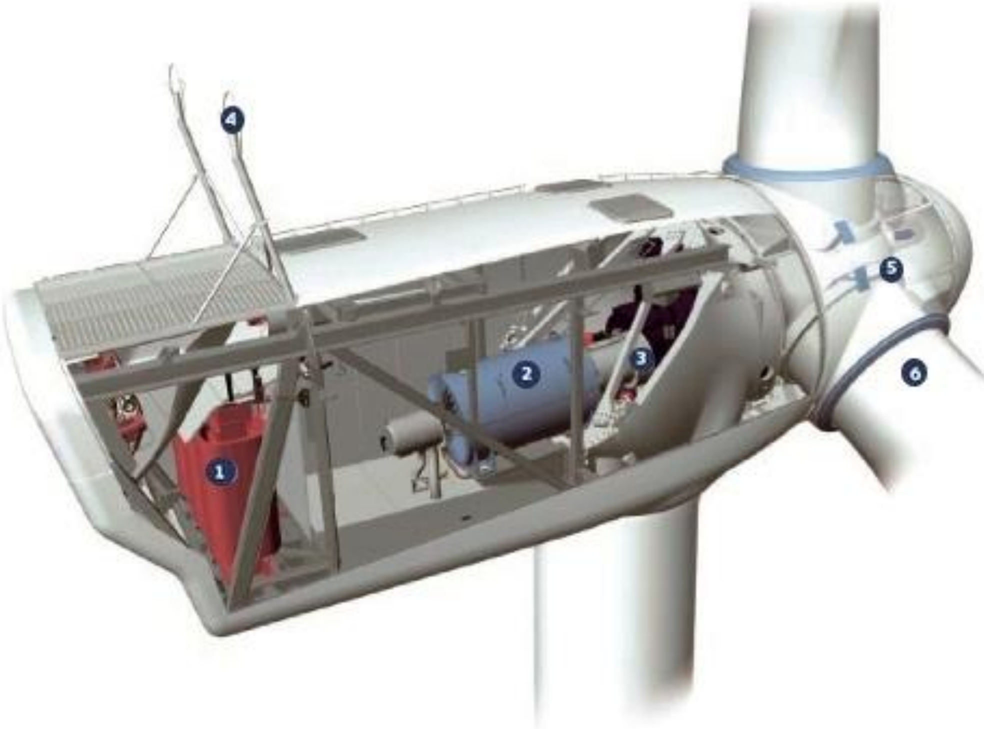

Figure 5: Diagram Showing the Main Components of a Wind Turbine (FEE, [No Date])

1) Transformer

The transformer steps-up the electricity generated by the alternator to a voltage compatible with the transmission system in place.

2) Alternator

Energy from the wind is transformed into mechanical energy through the sweeping of the blades and the turning of the turbine hub. That mechanical energy is then transformed into electrical energy by the alternator.

3) Mechanical Break

For various reasons the wind turbine may need to be shut down or stopped. This may be for maintenance or due to adverse weather conditions. The mechanical break holds the blade and hub in place, protecting the internal mechanics. Usually in this case the blades are also rotated to allow the wind to pass through with minimal force applied.

4) Anemometer

Constant monitoring of wind speed and direction is an important part of most wind installations. With constant monitoring in real time of wind speeds better prediction of wind speeds and future electricity generation becomes available. Cut in and cut out speeds are also usually linked with the wind speed registered at the anemometer.

5) Rotor Hub

The rotor provides the structure to connect the blades to the nacelle. It also turns with the blades and transfers that rotation to the alternator.

6) Blade

The three blades shown on the model of a wind turbine are aerodynamically designed to maximise the capture of wind energy and transform it into mechanical energy. Built like a wing, the blades rely on the principles of lift to function and collect energy.

It is typically expected that the life span of a wind turbine will be between twenty and thirty years (Crawford, 2009, p.2655). The major structural components, for example the base and the tower, can potentially last for many years beyond this range, while moving parts may require more frequent replacement (Crawford, 2009, p.2655). A study on wind turbines by Crawford has shown that "*The life cycle energy requirements were shown to be offset by the energy produced within the first 12 months of operation"* (Crawford, 2009, p.2653). Many of the materials wind turbines are made of can be recycled, and no decommissioning issues are associated with wind turbines (Andersen, 2008, p.11).

In discussing wind energy, and electricity in general, two units of measure are often used. In order to understand the conversations surrounding the topics, these units must be understood in the context. A watt itself is a rate of power, joules per second (j/s) (Wizelius, 2007, p.47). Kilowatt denotes the power output of electricity equal to one thousand watts. A kilowatt hour (kWh) is the quantity of electricity equivalent to one hour of electricity at one kW.

Wind turbines do not have any direct emissions. They have the potential to reduce overall CO_2 emissions. Table 3 shows the typical reduction in CO_2 emissions that are possible based on the size of the wind turbine when compared to coal and gas fired power stations. It should be noted that "*The amount of carbon a turbine saves also depends on how a project has been designed as well as the lifetime/reliability of the turbine*" (Stankovik et al., 2009, p.21).

Table 3: Typical Available Energy and Reductions in CO_2 Emission from Various Sizes of Wind Turbines (Stankovik et al., 2009, p. 21)

HAWT	Energy Capture			Carbon Savings	
Blade Diameter (m)	Mean Wind Speed 5.5 m/s			Coal Fired Power Station Tonnes CO_2/year	Gas Fired Power Station Tonnes CO_2/year
		Power from Turbine (kW)	Annual Turbine Energy (kWh)		
1		0.02	374	0.4	0.1
2		0.09	1496	1.5	0.4
5		0.56	9350	9	3
10		2.24	37,401	37	10
15		5.03	84,153	82	23
20		8.94	149,605	147	40
25		13.97	233,758	229	63
30		20.12	336,611	330	91
35		27.38	458,166	449	124
40		35.77	598,420	586	162
50		55.88	935,032	916	252
60		80.47	1,346,446	1320	364
70		109.53	1,832,662	1796	495
80		143.06	2,393,681	2346	646

The cut in speed of a wind turbine, which is dependent on the design of the blade and the friction of the components, refers to the wind speed at which enough force is provided by the wind to turn the blades (*Stankovik et al., 2009, p.72).* The cut-out wind speed refers to the speed at which the wind turbine will cease to spin to prevent the turbine from damage (Stankovik et al., 2009, p.72). The rated wind speed is the speed at which the wind turbine is extracting a maximum amount of energy from the wind (Stankovik et al., 2009, p.72). Annual mean wind speed is simply the average wind speed at a site over the course of a year, while the minimum annual mean wind speed is the speed at which "*there will be enough energy in the wind on an average basis to begin to consider the idea of installing a wind turbine on the corresponding site. Although there is no definitive point at where the technology will move from unfeasible to feasible, a useful value to keep in mind is a minimum annual mean wind speed of 5.5 m/s* ", with the measurements taken at the hub height of the proposed turbine (Stankovik et al., 2009, p.72). Table 4 shows the typical wind speeds required for wind turbines to perform.

Table 4: Typical Wind Speeds for Wind Turbines Actions (Stankovik et al., 2009, p.73)

	Wind Speed	
	m/s	km/h
Possible Cut in Speed	3	10.8
Typical Cut in Speed	4	14.4
Minimum Annual Mean Speed	6	21.6
Typical Rated Speed	12	43.2
Typical Cut-out Speed	25	90

Wind power has the advantage of not being land intensive. Wind farms generally require 0.08-0.13km^2/MW of generation capacity (Andersen, 2008, p.12). The land surrounding the wind turbines can remain as natural habitat or agricultural land (Andersen, 2008, p.12).

Canada has 0.5% of the world population, and 20% of the world supply of fresh water, 7% of which is considered to be renewable (NRTEE, 2010, p.15). Due to this ratio it may seem that Canada will be immune to water issues, but this may not be the case moving forward. A report by the National Round Table on the Environment and the Economy, entitled *Changing Currents*, states:

> *Between now and 2050, Canada's population is expected to increase by 25%, the Canadian economy is predicted to grow approximately 55% by 2030, and climate change is anticipated to increase temperatures, change precipitation patterns, and increase the frequency of extreme weather events such as floods and droughts. These stresses will impact Canada's watersheds and create new pressures on the long-term sustainability of our water resources.*
> (NRTEE, 2010, p.15)

In the NRTEE report gross water consumption is considered to be "*the total amount taken from surface water bodies or aquifers*", while consumptive water use is "*the amount of water intake that is not returned to the source, and which is generally lost to evaporation or contained within wastewater or products*" (NRTEE, 2010, p.29). It is stated that thermal power generation, account for 64% of gross water consumption in Canada (NRTEE, 2010, p.61). While thermal power generation can be considered to be nuclear power, electricity from fossil fuels such as coal, oil and natural gas, and electricity generated from biomass, biogas, municipal waste and industrial bi-products, the NRTEE report only considered fossil fuels and nuclear, as other types of generation make up a very small percentage of thermal generation in Canada (NRTEE, 2010,p.73).

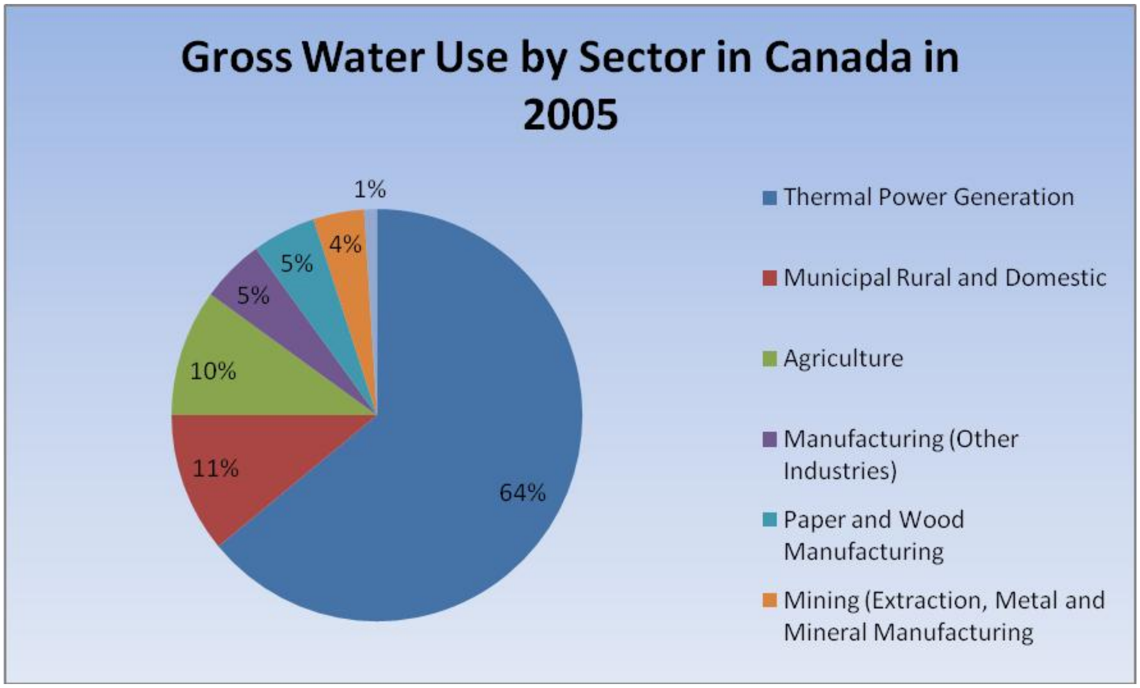

Figure 6: Gross Water Use by Sector in Canada in 2005(NRTEE, 2010, p.61)

Thermal power generation accounts for 12% of consumptive water use in Canada (NRTEE, 2010,p.62). Thermal power plants primarily use water for cooling, and for the creation of steam to operate turbines (NRTEE, 2010, p.75). Wind turbines do not use water when in operation, though small amounts of water may be used to clean the blades (DOE, 2006, p.17).

It has been estimated by the International Energy Agency that by 2030, due to increased demand and the necessity of replacing existing generating plants, 74 gigawatts of new electrical generation capacity will be required in Canada (NRTEE, 2010, p. 68).

<u>**Wind Power Internationally**</u>

All around the world countries are moving aggressively to increase their wind generation capacity. This increase in installed generating capacity is documented in the Global Wind Report Annual Market Update, with Europe and Asia leading (GWEC, 2010, p.14).

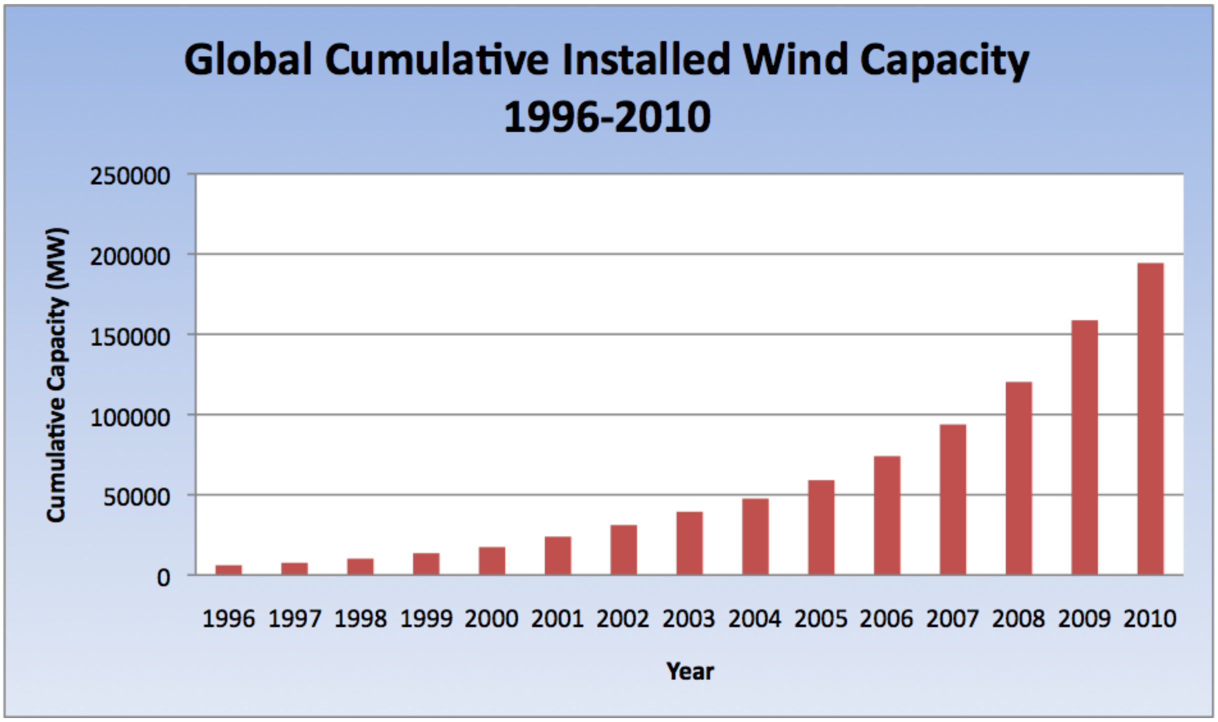

Figure 7: Global Cumulative Installed Wind Capacity 1996-2010 Information from (GWEC, 2010, p.14)

Over the course of 2010 many countries, most notably China, have dramatically increased their number of wind installations (GWEC, 2010, p.11).

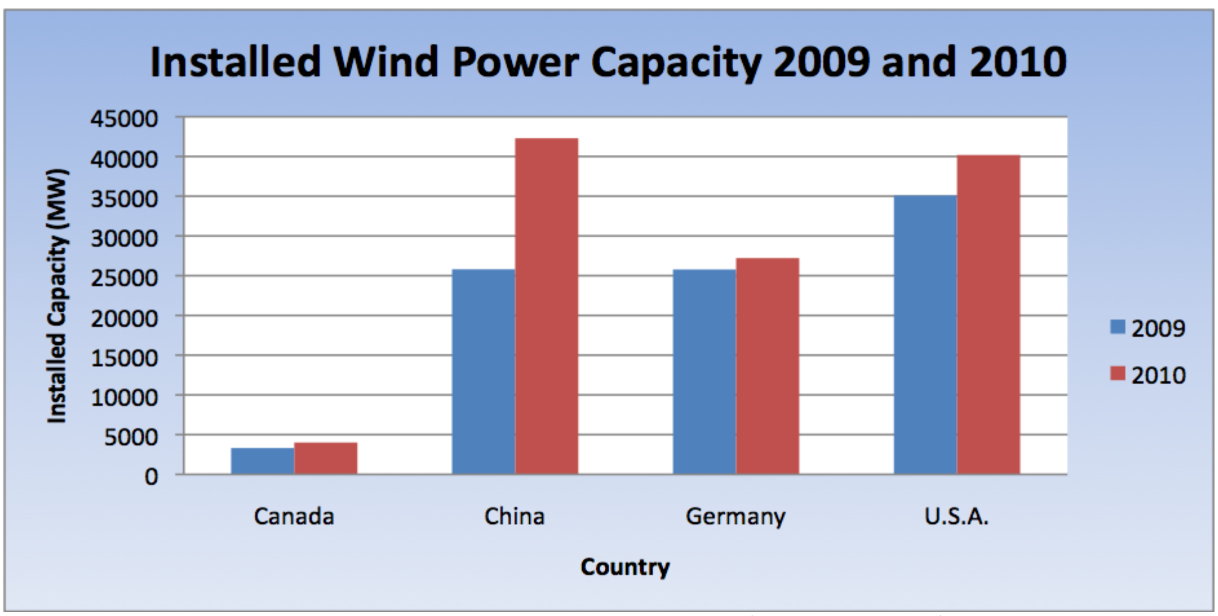

Figure 8: Installed Wind Power Capacity in 2009 and 2010 Information from (GWEC, 2010, p.11)

Canada and Wind Energy

Canada remains behind the rest of the world in installed wind generation capacity, despite the fact that there are tremendous benefits to be gained from renewable electricity generation. If Canada continues to delay involvement in the renewable energy industry, it will become increasing difficult to be competitive, as other countries will have substantially more knowledge, skill and development.

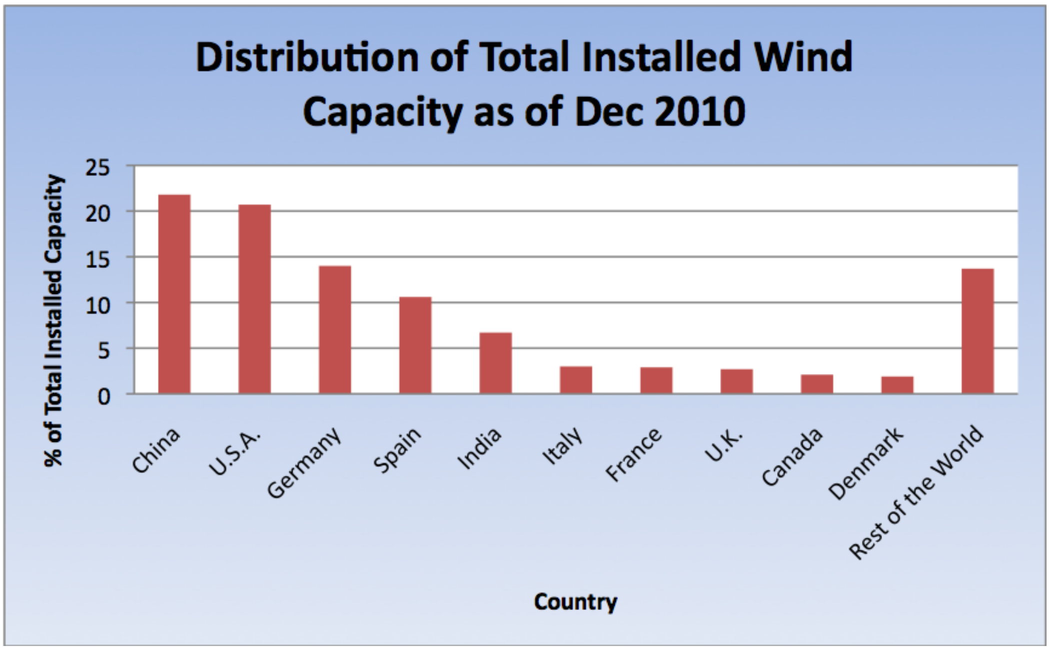

Figure 9: Distribution of Total Installed Wind Capacity as of Dec 2010 Information from (GWEC, 2010, p.12)

According to Bloomberg New Energy Finance, in 2010 worldwide investment in wind power increased 31% to an all time high of 96 billion USD (GWEC, 2010, p.18). It would seem prudent to capitalize on the influx of capital and interest in this sector. Investment in wind energy would create jobs in many sectors, including communications, business, marketing, meteorology, many streams of engineering, mechanical and electrical technology, research and the construction trades (EREC, 2001, p.2).

Since 2009 the United States has made substantial investment in clean energy. If Canada were to match these investments on a per capita basis, an additional $11 billion would need to be set aside for renewable energy development (Campbell et al., 2010, p.2). It is anticipated that this would lead to the creation of 66,000 jobs in the clean energy sector, with the potential of additional job creation in the energy efficiency and transport industries (Campbell et al., 2010, p.2).

Wind Energy and Jobs

The Conference Board of Canada has estimated, based on a 2000 MW generating capacity, that the development and operation of offshore wind farms in Ontario has the potential to create 3 900- 4 000 jobs during the construction phase, from 2013-2026 (Conference Board of Canada, 2010). This development would contribute between $4.8 and $5.5 billion to Ontario's economy for this period (Conference Board of Canada, 2010).

The development of wind energy in Europe has created many new jobs. In 2007 in the European Union the wind energy sector directly employed 108 600 people, and indirectly employed over 150 000 (EWEA, 2008, p.13). It is expected that by 2030 the number of people employed by the wind energy sector will have risen to 375 000 (EWEA, 2008, p.11).

The Cost of Wind

In Europe, as wind turbines have become increasingly common, the cost of producing energy from wind has decreased by over 50% over the last 15 years (EWEA, [No date], p.5). Manufacturers estimate the cost of generating electricity from wind turbines will fall 3-5 % for each new generation of turbines developed (EWEA, [No date], p.5).

It has been estimated that if the environmental externalities associated with generating electricity from fossil fuels was included in their cost, the price of electricity generated from coal and oil would double, and the cost of electricity generated from gas would rise 30% (EWEA, [No date], p.6).

If subsidies to the fossil fuel and nuclear sector were removed the renewable energy sector would not require any subsidies to be competitive (EWEA, [No date], p.6). It has been estimated that in Canada, annual government subsidies for the oil sector in Newfoundland and Labrador, Alberta, and Saskatchewan were $1.38 billion in 2009 (Enviro Economic Inc., et al, 2010, p. 40). A report from Atomic Energy Canada Limited states that they received $321 million in parliamentary appropriation, a form of taxpayer subsidy, during the 2009-2010 period(AECL, 2010, p. 24).

In 1999 Ontario Hydro was separated into five companies, and its $20.9 billion debt was transferred to the Ontario Electricity Financial Corporation (Gibbons, [No date], p.14-15). This debt was effectively transferred from the power company to the taxpayers and electricity consumer of Ontario (Gibbons, [No date], p.14-15). In 2007 the average electricity consumer in Ontario paid $377 to the

Ontario Electricity Financial Corporation, to pay off this debt (Gibbons, [No date], p. 14-15). As of December 31st 2007, the debt was at $18.3 billion (Gibbons, [No date], p. 14-15).

Wind Power Integration

The integration of wind power into our supply mix will have some challenges and obstacles to overcome. In respect to power distribution, questions of connecting to the electrical grid have lead to further questions concerning the variability and stability of renewables. In order to approach these questions electrical grids (specifically Ontario's), the role they play and the technology involved must first be discussed and understood. From there, how renewables, specifically wind, connect and interact as part of present and future grids can further be analysed.

The Grid

"*The electrification of developed countries has occurred over the last 100 years*" (IEA, 2011, p. 13), and the electrical grid was brought into existence as a means of transferring electricity from generators to consumers, both residential and commercial. Over that period in Ontario the grid has grown and developed though it is still based on a centralised system overseeing the entire workings of an increasingly large and complex grid. The following diagram shows the basic workings of a classic grid.

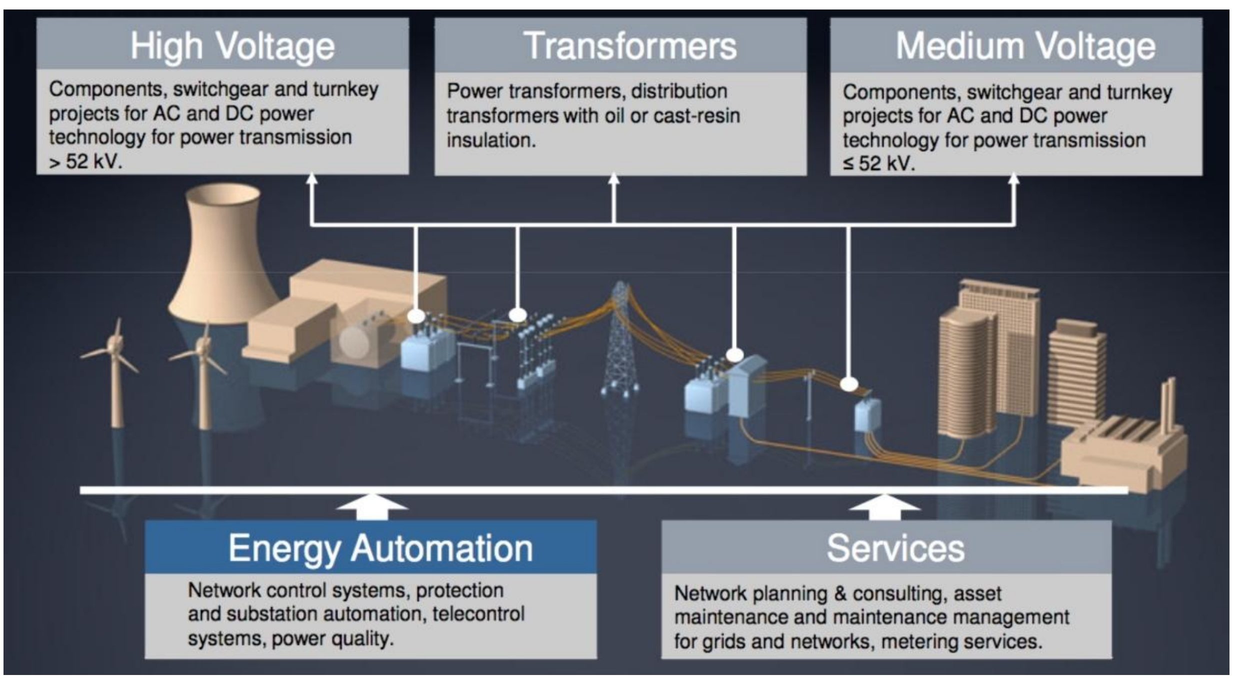

Figure 10: Basic Workings of a Classic Grid (Lilien, 2010 p.14)

As can be seen, communication is more or less one way, in that energy automation is executed without direct feedback from the grid. Due to this configuration the response to power outages can be delayed and the area affected is often larger. Power flow is also one way, in that large generating stations produce electricity that is fed into the grid and sent to consumers (Lilien, 2010).

Smart Grid

Ontario's grid, and most electricity grids across the world, were designed and built upon the assumption of large scale, centralised generation. With the introduction of renewable sources of energy, including wind, to the power generation capacity, upgrades and adaptation is necessary to have the grid continue to provide the high quality service expected. With the introduction of renewables comes smaller scale production of electricity, either connected to the grid individually and in groups/farms, often much closer to residential areas where the electricity will itself be used. As stated by the International Energy Agency:

> *As demand grows and changes (e.g. through deployment of electric vehicles), and distributed generation becomes more widespread, ageing distribution and transmission infrastructure will need to be replaced and updated, and new technologies will need to be deployed.* (IEA, 2011, p. 13)

Toward the end of upgrading the grid, taking advantage of major technical advances since its inception, the Ontario Government and Ontario Power Authority are in the process of transforming Ontario's grid into a smart grid. This will allow better monitoring of demand, usage and peak hours, as well as the input of various renewable sources. This will also create a grid that functions in multiple directions instead of simply one. Traditionally the grid has power running from power generation stations to customers, being controlled by energy automation. The smart grid will allow a two way flow of both energy and communication. With a smart grid in place better prediction and balance will become available allowing for further development of a grid which will continue to meet the needs of the electricity sector well into the future (Curtis et al., 2008).

Better predication and distribution will come as a result of developments largely in communication. The installation of smart meters will allow monitoring, in real time, of energy usage in specific residential and commercial locations. There are a host of other technologies being implemented into the grid to allow for better communication and transmission. These technologies are implemented at various portions of the grid, allowing for better transmissions in both directions as well as allowing consumers to feed into the grid. The following diagram shows the potential for a smart grid, with multi-directional communication and movement of energy allowing for greater flexibility, stability, and the integration of a variety of electricity generation technologies (Bertolo and Gross, 2008).

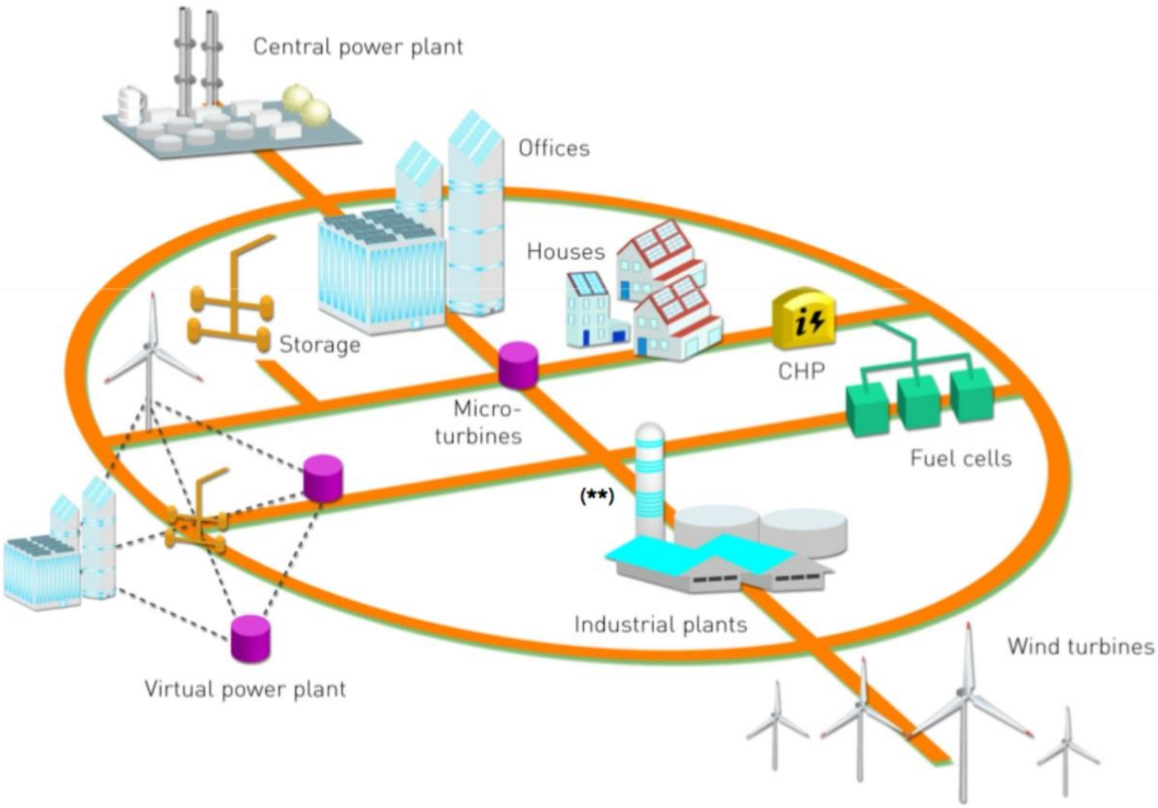

Figure 11: Diagrammatic Representation of a Smart Grid System (Lilien 2010 p. 21)

Variability

When approaching wind power the first logical question asked is simply: how can a variable source of energy (the wind) provide a stable, constant supply of electricity? This question, firstly, is applied only in a situation where wind and other renewables provide the base load of electricity. Though this isn't the situation now, it is the hope of those working with renewable energy that it will be. Thus, the question of how consistency and stability can be achieved using renewables must be discussed, not for the present but for the future.

How to integrate renewables as a large portion of electricity production on a smart grid has been well researched and discussed, providing a plenitude of possibilities. The strategies which allow for a consistent supply of energy to consumers fall into two large categories: management and technology. Obviously these two categories are not mutually exclusive for implementation; rather, they can be decided and implemented in a fashion which is deemed appropriate.

Management

When managing wind as part of a system of electricity production and distribution it must first be understood as part of a larger system. Wind power has never, and probably will never be, promoted as a single solution to our energy needs. Rather, wind is put forward as part of a mix of renewables including solar, biomass, tidal, wave and geothermal. In our present situation a mix of energy sources is used, each source being managed and integrated into the system. In Ontario we currently have a diversity of energy sources, including nuclear, hydro, coal, gas and a mix of renewables. The short term goal of those promoting renewables is to increase their share of the electricity produced, thus decreasing the need for the use of heavily polluting sources of electricity.

Sources of electricity are usually placed into three categories: base load generation, peaking generation and standby generation. Base load generation is usually supplied by large power plants fuelled by nuclear energy, coal or oil which have large generating capacity, but very little flexibility, in that they are not easy to start up and shut down. They provide the base needs of electricity which are constant regardless of the time period. Hydro-electric is also capable of providing the base load as it is consistent and can be installed at very large scales. Peaking generation is also often large scale with more flexibility, kicking in to provide electricity during regular peak hours; it is often filled by natural or bio-gas, oil or hydro plants. Standby generation is quite flexible, starting up and shutting down quickly depending on demand. It fills in the unexpected peaks in demand over time. Wind power has the capacity to provide standby and peaking generation with present technology and planning (Farret, 2006). To transfer to a grid relying completely on renewables, further planning and development needs to be done, though it is well within present technological capabilities. This integration has been seen on a small scale on island communities such as El Hierro (Spain)[2] or Samso (Denmark)[3].

In the early development of renewable energy the question of variability must be addressed. An individual wind turbine does vary in its output of electricity depending on available wind; however, with the development of wind (and other renewable sources of energy) over large geographical areas feeding into the same grid evens out variability. *"Just as consumer demands are smoothed by aggregation, so is the output from wind plants, and geographic dispersion dramatically reduces the wind fluctuations"* (Fox et al., p.14). The larger the installation of renewable energies, the greater variety of sources and locations the more stable supply. To further the stability of the electricity supply using renewables the ability to predict wind speeds

[2]http://www.insula.org/index.php?option=com_content&task=view&id=19&Itemid=33
[3] http://www.islepact.eu/html/index.aspx?pageid=1112&langID=3

and electricity generation in real time is necessary

<u>Prediction</u>

Prediction of wind speeds has increasingly become important for the electrical grid. Understanding when and where large winds will be allows for a variety of benefits for the distribution of electricity. First and foremost it allows planning for peaks and valleys in supply ensuring a steady supply to the customer by increasing or decreasing the load of other energy sources. It also allows for real time adjustments, either sending excess energy or requesting extra energy from connected grids (Usaola, 2009).

Currently Canada, like most other countries has a wind map, showing average wind speeds for specific areas and heights (Canadian Wind Map). This is a tool, which can be used by wind farm developers, which allows one to see the potential for wind farms before doing an installations. For real time measurements and predictions, many tools are already available and the technology is constantly improving. Prediction tools already exist, providing reasonable predictions both externally and integrated into the system. The next generation of prediction tools is, however, well on its way to deployment. The UK has recently upgraded its prediction systems for wind and expects to increase efficiency using the SpiDAR system. With integrated sensors across the region, using a decentralised approach, the improvements in efficiency are expected to be significant. While wind speed can vary, it "*can be quite accurately forecast in the appropriate timeframes for balancing electrical supply*" (Sustainable Development Commission, 2005, p.22).

Out of the implementation of renewable energy projects has come the discussion of energy storage. Debate continues to surround this topic as a future based on renewable energy becomes the goal of many groups, organisations and even governments. The use of energy storage would have three major benefits to the electrical grid: added stability allowing distributed generation to provide a stable output; the provision of a source of energy to fill in instantaneous lacks of primary energy; plus, the ability for distributed power generation to perform seamlessly as one unit. Often wind power installations are in fact connected into the grids nodes, as is seen in Spain; this allows for less imbalance and greater predictability (Usualo, 2009). Though these benefits would add greatly to the promise of a wholly renewable electricity system, further questions and debate continues.

Storage

A major question for a completely renewable electricity system is that of storage. There are many who think that planning and strong prediction capabilities will not allow for enough reliability in the system. To solve this problem the idea of storage is often proposed. If storage capacity for renewables was implemented the question remains of what form the storage system would take.

Energy storage has already been put into place both in test facilities and in full scale installations. The potential for energy storage can come in many forms, depending on the local resources and characteristics of the system. For large scale installation a mix of all possibilities would likely need to be used.

Batteries are a means of energy storage with which we are all familiar. The ability to store energy using chemical means is a system that has become so ubiquitous it is no longer discussed. From lead/acid batteries in cars to lithium-ion batteries in cell phones, portable electronics and now electric vehicles; batteries are ubiquitous. The use of batteries for energy storage is often the first option discussed. Batteries are a tested and well understood means of energy storage allowing for significant production without major technological innovation (Farret, 2009, p.263-296). In order for batteries to function as a stable energy storage system for the electrical grid, both size and cost would have to decrease. As can be seen in the electric car debate today, these two characteristics are limiting factors in their implementation.

Another energy storage solution is the stocking of energy as gravitational energy. Pumped-hydro electric is a solution favoured by many proponents of the storage of energy. Essentially, using the excess electricity produced during peak periods, water would be pumped into a reservoir above a generating station. When the power is needed the water is released, turning a turbine, transforming that potential energy into mechanical energy and back into electricity (Farret, 2009, p. 263-296).

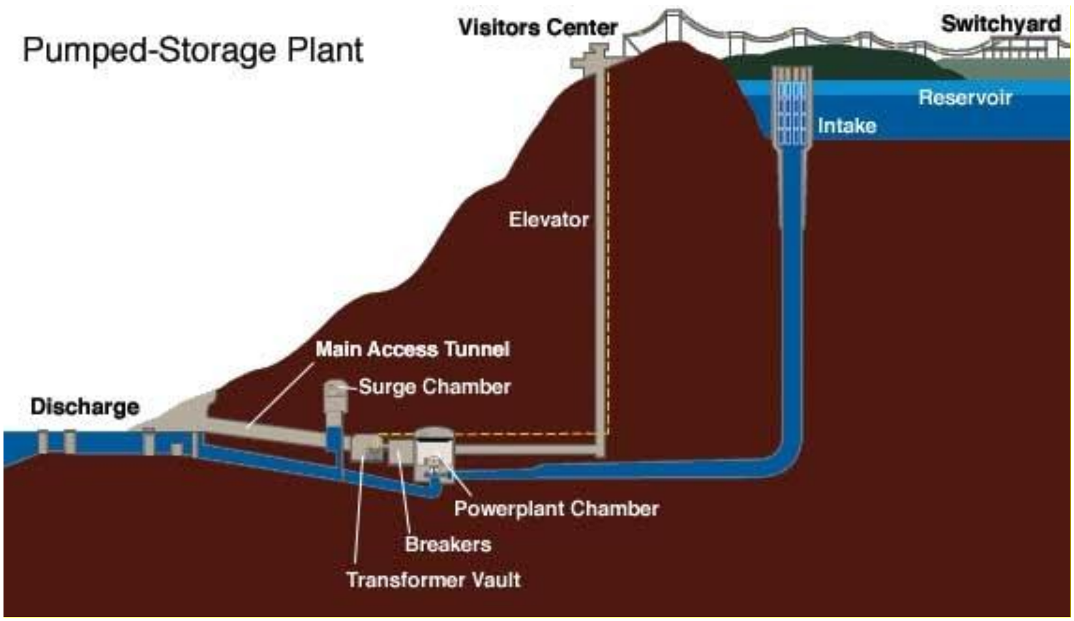

Figure 12: Diagram Illustrating a Pumped-hydro System (TVA, 2011)

Aside from batteries and pumped storage, there is also the use of compressed air, fly wheels and a collection of new ideas emerging as potential storage options for electricity. Though many options exist major discussions also focus on the use of hydrogen as a source of stored energy.

Hydrogen

For those working in the field of renewable energy, hydrogen is often a major talking poin. Many argue that it is the future of energy storage in that it offers an affordable, portable energy-dense method of storage. Those against it argue that using hydrogen for the storage of energy is too expensive, the technology is not fully mature and it could potentially be dangerous. As this topic is highly debated the basic system will be discussed here. Essentially the use of hydrogen for the storage of energy follows three basics steps. Using pure water and electricity, the water is broken into its constituent elements, hydrogen and oxygen (this is usually done using an electroloyzer, though other methods exist). The hydrogen is then safely stored either as a liquid or gas for future use. When that energy is needed the hydrogen is then sent through a fuel cell where, when recombining with oxygen to create water, electrons are released in the form of electricity (Swan, 2009). The technology involved in this process is well understood and offers a range of energy efficiency; the debate has only just begun as to its feasibility on a large scale.

Wind and the Grid

In discussing the grid in relation to renewable energy, specifically wind energy, the issues are clear and well understood. Where the debate remains is not in whether it is feasible to integrate renewables into the present and developing grid but rather how? The development of the smart grid is necessary for the efficient integration of renewables. Good quality, well researched predictions tools can and will add further stability to the grid, while the integration of more and more diverse renewables may in the future do the same. The necessity of a smart grid is clear; the investment is already being put in. This new system, combined with intelligent decisions made with the installation of wind farms, will allow for a smooth transition into a better energy electricity generation and distribution system.

Pricing

The increase of electricity bills over the last few years has caused concern across the province. Unfortunately this increase in pricing has been associated with the increase in renewable energy. However, this is a simplification of the state of the electrical system in Ontario.

By the beginning of the 2000s Ontario's energy grid was outdated. Ontario was a net importer of electricity relying on coal from the US for our energy needs, and there was a general lack of stability. Since that time Ontario has invested heavily in the infrastructure to ensure strong supply of energy and a better system for the future of our energy needs.

Over the last 20 years the prices of water, fuel, oil and cable television have all grown more quickly than the price of electricity. Over the next 20 years it is expected that electricity prices will continue to rise at a rate of 3.5% every year. This increase in price will cover the improvements and maintenance of a system in need of upgrades, the restructuring of Ontario Hydro's debts and the integration of renewable sources of electricity. These are all necessities to maintain a reliable system of electricity supply.

Feed-in-Tariff

The Feed-in-Tariff program in Ontario is a program, modeled on international feed-in-tariffs, used to encourage the growth of the renewable energy sector. In understanding the debate surrounding the wind industry one must understand the FIT program as well. The FIT program is actually broken down into two programs: the FIT program and the microFIT program.

The FIT program is applied to commercial sized installations (greater than 10kW) while the microFIT program is applied to individual or community owned installations (less than 10kW). Essentially both programs provide the same function: guaranteeing a set price for electricity produced using renewable methods. Both programs have set prices depending on the type of renewable energy. The following chart compares Ontario's FIT pricing to similar programs across Europe. The European prices are as of April 1 2010, and have been converted from Euro's to Canadian dollars using the exchange rate from the same date.

Table 5: Feed in Tariff Prices in Canadian Dollars (Europe's Energy Portal, 2011)

Jurisdiction	Wind Power 'On-shore'	Wind Power 'Off-shore'	Solar PV	Biomass	Biogas
Denmark	0.047	n/a	n/a	0.053	n/a
Estonia	0.069	0.069	0.069	0.069	n/a
Ireland	0.08	0.08	n/a	0.098	n/a
Austria	0.100	0.100	0.397 - 0.630	0.082 -0.219	n/a
Spain	0.1	0.1	0.438- 0.465	0.146- 0.216	n/a
Portugal	0.101	0.101	0.424 - 0.616	0.137- 1.480	n/a
France	0.112	0.424- 0.794	n/a	0.171	n/a
Ontario	**0.135**	**0.190**	**0.443-0.802**	**0.130-0.138**	**0.104-0.195**
Lithuania	0.137	0.137	n/a	0.109	n/a
Czech Republic	0.148	0.148	0.623	0.105 - 0.141	n/a
Latvia	0.15	0.15	n/a	n/a	n/a
Netherlands	0.161	0.254	0.629 - 0.798	0.157 - 0.242	n/a
Cyprus	0.227	0.227	0.465	0.185	n/a
Italy	0.411	0.411	0.493 - 0.602	0.274 - 0.411	n/a
United Kingdom	0.424	n/a	0.575	0.164	n/a
Germany	0.068 - 0.123	0.178 - 0.205	0.397 - 0.753	0.109 - 0.164	n/a
Slovakia	0.068- 0.123	0.068- 0.123	0.37	0.098 - 0.137	n/a
Bulgaria	0.095 - 0.123	0.095 - 0.123	0.465 - 0.520	0.109 - 0.137	n/a
Greece	0.095 - 0.123	0.095 - 0.123	0.753	0.095 - 0.109	n/a
Luxembourg	0.109 - 0.137	0.109 - 0.137	0.383 - 0.767	0.141 - 0.175	n/a
Slovenia	0.119 - 0.128	0.087 - 0.119	0.365- 0.567	0.101 - 0.306	n/a
Belgium	n/a	n/a	n/a	n/a	n/a
Finland	n/a	n/a	n/a	n/a	n/a
Hungary	n/a	n/a	0.132	n/a	n/a
Malta	n/a	n/a	n/a	n/a	n/a
Poland	n/a	n/a	n/a	0.052	n/a
Romania	n/a	n/a	n/a	n/a	n/a
Sweden	n/a	n/a	n/a	n/a	n/a

Table 5 shows the guaranteed price of electricity produced by onshore wind turbines in Ontario as 13.5¢ regardless of the scale of the installation. This program gives specific prices for renewable energy toward the goal of the growth of the industry. These prices are based on the scale of installation and the type of the technology being used. As the various technologies further mature and drop in cost the FIT program will adapt and progress with them (OPA).

<u>**Current Regulations**</u>

In order to understand the debate behind wind turbines today we must first approach the standards presently in place. This review focuses on Ontario, as a great deal of investment is being put into wind in this province. The strictest standards in North America are already in place in Ontario for the protection of citizens from any potential harm due to wind turbines (MOE, 2011). Most of these regulations are in the form of specific setbacks (the distance a wind turbine must be from homes, roads etc) and noise thresholds. These standards apply to any turbine over 50 kW (industrial scale wind turbines) and are as follows:

- A 550 metre setback from any building used by people (Ontario, Environmental Protection Act, *359/09*).

- A setback distance equal to the height of the tower from any properties not involved in the project (unless there are no land use concerns, in which case it can be reduced to the length of the blades of the windmill) (Ontario, Environmental Protection Act, *359/09*).

- A setback of 10 metres plus the length of the blades of the wind turbine must be allowed from the right of way of roads and railways (Ontario, Environmental Protection Act, *359/09*).

These regulations were put in place with the intention of eliminating any disturbing noise from wind turbines by keeping sound levels below 40dBA in all nearby residences. They are also designed to provide adequate distance to avoid any damage or injury due to malfunction, regular maintenance or blade icing (Copes et al.).

<u>**Sound and Noise**</u>

We are constantly surrounded by various types and levels of sound whether we live in rural areas with agricultural soundscapes or urban areas filled with the fluctuating sounds of city life. With recent increases in the installation of wind turbines in both rural and urban environments it is important to understand the potential impacts of their sound. In order for research on the sound levels of wind farms and wind turbines to be comprehensible it is necessary to understand how the volumes and types of sound we experience every day are measured, studied, and understood.

Sound levels are generally measured in decibels (dB), and for the purpose of studies on windmills expressed in A-weighted decibels (dBA), a measurement specific to human hearing. This chart shows typical sound levels in various situations.

TYPICAL SOUND PRESSURE LEVELS MEASURED IN THE ENVIRONMENT AND INDUSTRY

Noise Source At a Given Distance	A-Weighted Sound Level in Decibels	Qualitative Description
Carrier deck jet operation	140	
	130	Pain threshold
Jet takeoff (200 feet)	120	
Auto horn (3 feet)	110	Maximum vocal effort
Jet takeoff (1000 feet) Shout (0.5 feet)	100	
N.Y. subway station Heavy truck (50 feet)	90	Very annoying Hearing damage (8-hour, continuous exposure)
Pneumatic drill (50 feet)	80	Annoying
Freight train (50 feet) Freeway traffic (50 feet)	70 to 80	
	70	Intrusive (Telephone use difficult)
Air conditioning unit (20 feet)	60	
Light auto traffic (50 feet)	50	Quiet
Living room Bedroom	40	
Library Soft whisper (5 feet)	30	Very quiet
Broadcasting/Recording studio	20	
	10	Just audible

Figure 13: Typical Sound Pressure Levels (Colby et al., 2009, p.12)

As seen in *Figure 13,* most sound in our lives ranges from approximately 10 to 140 decibels. We need to strain to hear anything below this decibel level, for example the sound of leaves or snowflakes falling. Anything above 130 decibels can become painful and cause permanent hearing damage. On this scale wind turbines fall at approximately 45 decibels; somewhere between the quiet of a bedroom and a calm house. Decibels are used to measure volume, though sound is much more complex, also having a large range of pitch.

Sound is produced as a wave. The pitch of a sound is measured by the frequency of the wave, measured in Hertz (Hz). The higher the frequency of the sound, the higher the pitch perceived. Human hearing is generally sensitive to sound between 20Hz and 20000Hz, depending on many variables including age, locale, nature of work and previous sound exposure. The limits of human hearing and the effects of sound on the human body depend on a combination of both decibel level and wavelength. Although we are sensitive to low frequency sound, any sound at these levels must be at a significantly higher volume to be heard. It is understood that sound below the threshold of hearing has little if any effect on people (Howe, 2006, p.5). *Figure 4* shows the decibel levels perceptible by human hearing according to frequency and it shows several curves of perceived sound levels in phons. It is clear that with lower frequency sound human hearing becomes progressively less sensitive.

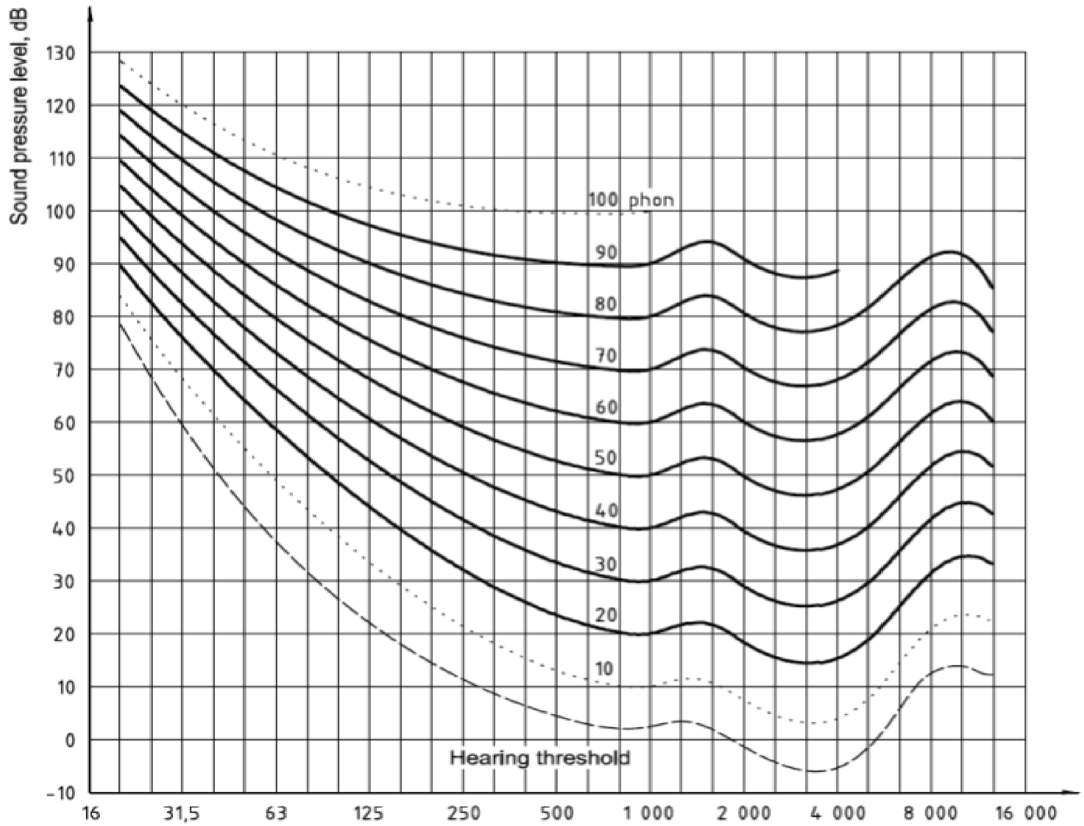

Figure 14: Hearing Threshold Graph (Agence Française de sécurité sanitaire de l'environnement, May 2010)

Wind Turbines and Noise

A great deal of study has been done on the effects of noise on the human body, though there is always need for further research. The Agence Française de Sécurité Sanitaire de l'Environnement is one of many organizations confident in the existing science to address the questions of sound produced by wind turbines.

> "*Perceptible noise at the foot of a wind turbine is of either mechanical or aerodynamic origin; mechanical noise which was audible with early wind turbines has more or less disappeared. Aerodynamic noise, initiated by the passage of wind over the blades in front of the tower, has equally been reduced by the optimization of blade design and the materials used in their production.*"
> (Agence Française de Sécurité Sanitaire de l'Environnement et du Travail, 2010)

A large number of studies and literature reviews have all concluded that noise (audible, low frequency and infrasound) from wind turbines is minimal and has no significant effect on the health of nearby residents. To better address this question, sound produced by windmills must be discussed in two categories: audible sound and low frequency/infrasound.

Audible Sound

As with any moving thing, wind turbines do produce audible sound. Sound from wind turbines comes primarily from two main sources, aerodynamic sound, which "*is radiated from the blades and is mainly associated with the interaction of turbulence with the surface of the blades*" and mechanical sound, which is "*normally associated with the gearbox, the generator and control equipment"* (Stankovic et al., 2009, p. 89). For the most part, as discussed above, this sound comes from the interaction of wind and the turbine's blades. The sound profile for wind turbines has been well studied and is quite complex; for the sake of clarity, generalization will suffice.

At the base of a wind turbine the noise level can vary depending on wind speed, the size of the wind turbine, and the angle at which the blades are set, amongst a host of other variables. This sound level is generally in the audible range (1000 to 20 000 Hz) and diminishes with distance: no more than 50dBA at 350 metres, and not exceeding 40dBA at 500 metres (Rideout, 2010). These levels of sound elicit various reactions depending on the present background sound of the particular environment.

In many cases, especially urban installations, background sound already exceeds the sound produced by a wind turbine. In this case, the sound from the wind turbine blends into the background sound, simply becoming part of the present soundscape without the notice of residence. It is generally accepted that in order for a noise to be audible and noticeable it must exceed the background noise of a given environment by approximately 5dBA (Rogers, 2006, p.5-6).

In rural environments, where most wind farms are located, the sound profile tends to have much lower levels of background noise, varying from 25-42 decibels (Rogers, 2006, p.19). In this situation, in buildings located at the minimum mandated set back distance, most people would be able to hear the wind turbines, but annoyance would be minimal.

Studies done in Sweden have found interesting results in the relationship between proximity to wind turbines, perceived sound and accompanying annoyance. These studies were done using several groups and methods; questionnaires, letters, and interviews for those living within set distances of industrial sized wind turbines. This included homes both closer to wind turbines than Ontario regulation allow, as well as homes placed well beyond these regulations. This research used decibel levels and questionnaires to determine general reactions. Decibel levels were separated into five groups: less than 32.5 dBA; 32.5-35 dBA; 35-37.5 dBA; 37.5 - 40 dBA; and, above 40 dBA (Pederson, 2008; Pederson, 2007). For our purposes we will look at the groups around the limits in Ontario.

In this self-reported study, for levels between 37.5-40 dBA, 73% of respondents noticed the noise of wind turbines while approximately 6% were annoyed. At 40 dBA and above 90% of people noticed the sound while 15% were annoyed. By maintaining the limit of 40 dBA most people will hear the sound of a wind turbine, but very few if any will be annoyed and there are no negative health effects (Pederson, 2008).

The same study found an interesting correlation between those who benefited financially from windmills and reduced perception/annoyance levels even with closer proximity and higher sound levels. It also found that those who did not like windmills to begin with, or who found them to be unattractive were more likely to notice and be annoyed by the sound of the wind turbines (Pedersen, 2008).

These results are not unique. Several studies have similar findings, showing perception and annoyance occurring around the 40dBA threshold, the limit set by the Ontario government. For the studies themselves, and more detailed analysis, please consult the works cited and the accompanying quotes and documents (Pederson, 2010).

Low Frequency and Infrasound

As discussed earlier, not all sound can be heard by the human ear. Both low frequency sound and infrasound, though different types of sound, will be dealt with here in one section as most research applies to both. Low frequency sound is generally defined as sound at a frequency of less than 200Hz. This sound, though still audible, is very much at the limits of human perception. Infrasound is considered to be the sound frequencies often below our audible range, below 20hz, because of this it is discussed in dB instead of A-weighted decibels (dBA) (Copes, no date)(Howe, 2006 p.5).

Low frequency sound is produced all around us and is a constant part of our lives, but at such low frequencies, and with such a low volume, that much of it is unheard by the human ear. Infrasound, usually inaudible, is only heard at extremely high decibel levels. Both of these kinds of sound are produced naturally and by man made sources such as waves, wind, waterfalls, industrial processes, vehicles, and indeed wind farms. In the case of wind farms however, several peer-reviewed articles conclude that infrasound is inaudible and thus has no noticeable effect on people (Colby, 2009)(Howe, 2006).

> "*Specific International studies, which have measured the levels of infrasound in the vicinity of operational wind farms, indicate that levels are significantly below recognized perception thresholds and are therefore not detectable to humans.*"(Sonus Pty Ltd. 2010)

In this report infrasound from two Australian wind farms is shown with the internationally recognized Audibility Threshold and measurements taken from a beach.

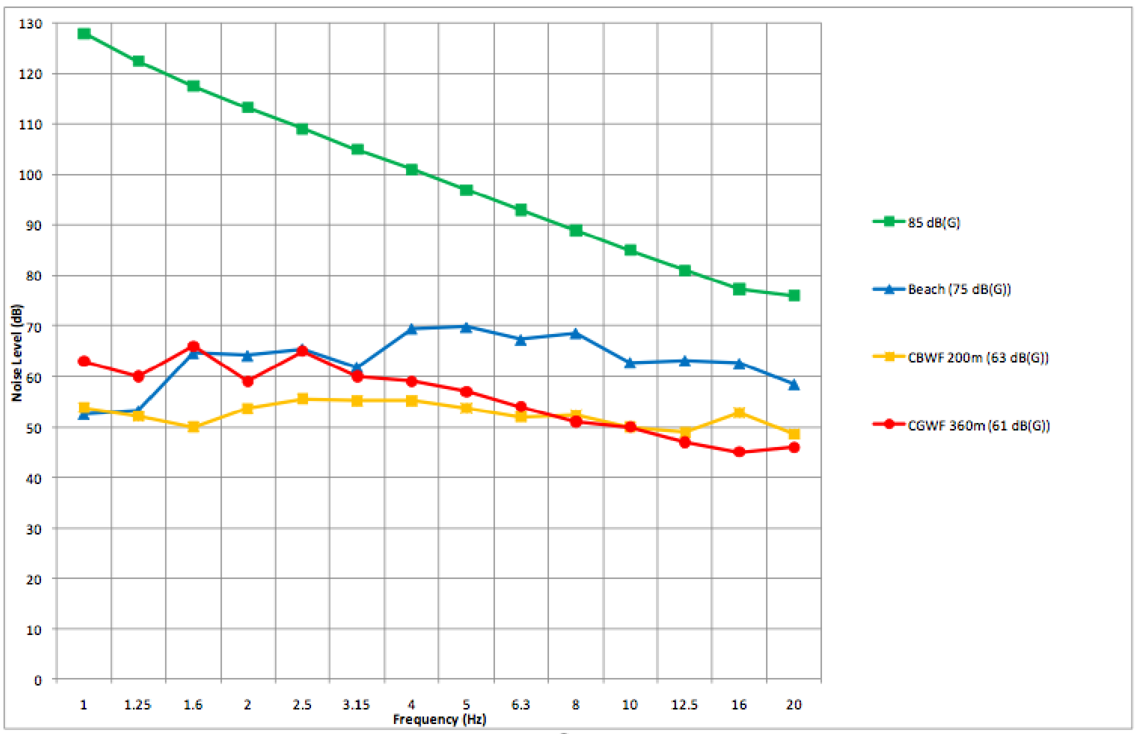

Figure 15: Audibility Threshold (Sonus Pty Ltd. 2010, p.4)

The threshold for human hearing of low frequency sound, shown in Figure 15 in green, is well above both that of the wind farms and the beach itself. This is not to say that sound from these sources is unheard; simply, low frequency sound and infrasound from these sources are not heard. The similarity in wind farm infrasound levels to that of a natural source of infrasound such as a beach is seen very clearly in this study.

In examining the evidence in regard to infrasound most researchers and organization involved in wind power come to the conclusion that infrasound below the level of hearing poses no threat.

Studies completed near Canadian wind farms, as well as international experience, suggest that the levels of infrasound near modern wind turbines, with rated powers common in large scale wind farms are in general not perceptible to humans, either through auditory or non-auditory mechanisms. Additionally, there is no evidence of adverse health effects due to infrasound from wind turbines. (Howe, 2006, p.11)

<u>The Effects of Windmill Sound</u>

The studies examining wind turbine sound repeatedly come to the same conclusion: the effects on health, if any, are minimal and affect only a very small portion of the population. For levels of sound under 40dBA wind turbines may be audible to the general population, and at the very worst may be perceived as annoying. This annoyance may cause sporadic waking throughout the night, though no effects beyond this are seen to be the results of wind turbine noise (Copes, no date). Several publications have linked the negative perspective toward wind turbines with adverse reactions to sound: those who don't like wind farms, or the look of wind turbines tend to notice and be annoyed by the sound of windmills significantly more than anyone else (King, 2010).

It is generally agreed among several levels and branches of Canadian and international government, research institutions and environmental groups that sound from properly sited wind turbines pose no adverse health effects to the general population. This consensus is based upon thorough review and interpretation of scientific data with the health and well being of the population in mind. The reassurance of the Chief Medical Officer of Ontario comes amidst a crowd of voices supporting wind energy:

"*The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects...*"

(King, 2010 p.2)

<u>Ice and Blade Icing</u>

Due to a combination of freezing temperatures and fog there is the potential for wind turbine blades to freeze and develop ice layers. Studies have shown that when the blades are stationary, ice will fall within 50 metres of the windmills and, while turning, ice could be thrown up to 250 metres. Though both of these distances are well below Ontario's setback regulations Ontario's public health agency recommends the shut down of wind turbines when ice forms on the blades. This can be done either manually or automatically (Copes, no date).

On the whole, blade icing of wind turbine is seen as a very preventable, minor problem. There have been no documented injuries due to ice falling or being thrown from wind turbines. As long as regulations are followed this reputation for safety should be maintained.

Visual Effects

Wind electricity generation does have visibility in the landscape. Work by Bishop suggests that in some circumstances it can be reasonable to do visibility modeling of wind turbines to a distance of twenty to thirty kilometres, but that in "*normal*" circumstances wind turbines located ten kilometres from the viewer will only be recognized by one out of five viewers. (Bishop, 2002, p.718). Figure 16 shows the proportional visual impact a wind turbine will have at various distances away from the viewer.

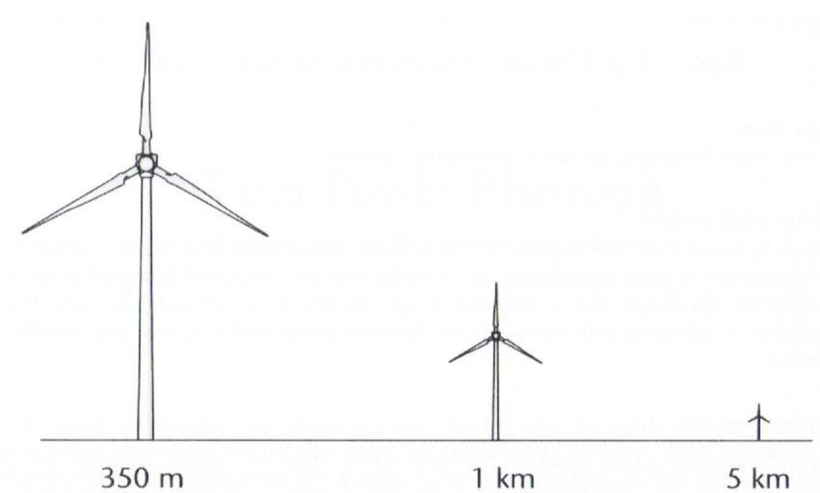

Figure 16: Wind Turbine Visibility (Wizelius, 2007, p. 165, taken from Typofrom/Gipe)

Bishop also concludes that *"Visual impact remains 'in the eye of the beholder' but may well become minimal beyond 5 km - 7 km, even in clear air"* (Bishop, 2002, p.718).

The light effect caused when the sun is positioned behind a rotating wind turbine has been described as shadow flicker. This effect generally lasts no more than 30 minutes and only appears in very specific situations. The geographic situation: lay of the land, the placement of the wind turbine and the position of the sun all have to line up perfectly (Rideout et al., 2010). If this situation occurs, the probability of shadow flicker being noticed in a building depends upon a variety of conditions including: the angle between the turbine and the building; the distance between the building and the turbine; the length of the blades and the height of the hub; the time of the year; the wind direction; the number of daylight hours the turbine is in operation, and the number of days with clear and cloudless skies (Office of the Deputy Prime Minister, 2004, p.176). In locations north of the equator there will be a zone to the south of the wind turbines where shadow flicker will not happen (Stankovik et al., 2009, p. 96).The area where shadow flicker can occur is limited by the size of the turbine. The maximum distance from a turbine that its shadow will be visible is dependant on both the diameter of the rotor and the height of the hub (Wizelius, 2007, p. 163). The maximum length of shadows from a wind turbine, as calculated by Freund, is shown in Table 6 (Wizelius, 2007, p. 163).

Table 6: Maximum Length of Shadows from Wind Turbines (Wizelius, 2007, p. 163)

Hub Height (m)	Rotor Diameter (m)	Summer		Winter	
		Horizontal	Vertical	Horizontal	Vertical
25	25	200m	350m	300m	700m
50	50	300m	700m	600m	1250m
75	75	500m	1100m	850m	1800m
100	100	600m	1375m	1100m	2300m
125	120	700m	1650m	1300m	2700m

The greater the distance between the turbines and the observer the less noticeable the shadow flicker will be (Office of the Deputy Prime Minister, 2004, p.177).

1.3% of Canadians are affected by epilepsy and there is some concern over a potential link between epilepsy and shadow flicker. 5% of those with epilepsy are light sensitive though this sensitivity is restricted to frequencies around 16-26Hz, occurring occasionally as low as 10Hz (Epilepsy Canada). A wind turbine producing shadow flicker would do so between 0.5 - 1Hz, well below the sensitivity level of the few people affected. There have been no documented cases of epileptic seizures brought on by shadow flicker.

Shadow flicker is a real effect of wind turbines. With the sun in the background, large moving shadows can be produced which some people may find distasteful. Table 6 shows the approximate sensitivity to shadow flicker at different RPM for three blade turbines, according to Stankovik et al.

Table 7: Sensitivity to Shadow Flicker at Different Rates (Stankovik et al., 2009,p.96)

Flicker Rate (Hertz)	Human Perception	Equivalent RPM Rate for a 3-Bladed Turbine
< 2.5	Negligible Effect	<50
2.5 - 3	May Affect 0.25% of the Population	50-60
3 - 10	Effect is Perceptible	<200
10 - 25	Greatest Sensitivity	200-500
>50	Continuous Light Source	1000

Larger turbines generally operate between 18 and 45 RPM, while smaller turbines generally operate below 150 RPM (Stankovik et al., 2009,p.96). This effect can however be prevented with proper placement of wind turbines to avoid the particular setup necessary to create this effect.

Electro Magnetic Fields (EMFs)

An electromagnetic field is a physical field containing electric and magnetic aspects which is caused due to the movement of an electrical charge. Electro Magnetic Fields surround us in modern society. All electronic devices, power lines, and generating stations produce EMFs. They are ubiquitous. As wind turbines are producing electricity they too create an EMF and when power is then transferred from a wind farm via hydro lines EMFs are once again present. The danger of EMFs is constantly under analysis as they are something that each and every one of us encounters on a regular basis. This constant research will help us to continue to evaluate EMFs and learn more about any safety issues.

Though wind power produces EMFs like any other source of power and power transmission there are two major benefits to wind power in respect to safety. First, as wind turbines are 80 to 100 metres above the ground the EMF created by the production of energy is generally well above any people who may be in the area. Second, most power from wind farms is transmitted to the grid by underground cables which, being below ground, effectively produce no EMF (Rideout, 2010).

There is constant research into EMFs, and safety issues are constantly being re-evaluated. For the time being safety issues are considered minimal. Certainly in the case of wind turbines EMFs are of little concern, producing as much or less of an EMF than other forms of energy production and transmission.

Impacts on Wildlife

Wildlife can be impacted by all forms of electricity generation. In 2008 the New York State Energy Research and Development Authority commissioned a report to look at the comparative impacts of different types of electricity generation on wildlife, including mammals, birds, reptiles, amphibians and fish

(Newman and Zillioux, 2009, p.1-1). This report looked at the levels of death and injury, degradation and destruction of habitat and the disturbance of typical behaviours (Newman and Zillioux, 2009, p.2-2). The types of electricity generation studied were coal, oil, natural gas, hydro and wind (Newman and Zillioux, 2009, p. 1-1). While acknowledging that all forms of electricity generation will have some impact on wildlife, it can be seen when comparing generating types that wind generation is less damaging to wildlife populations throughout the entire generation cycle (Newman and Zillioux, 2009, p.3-1).

Table 8: Comparative Wildlife Risks Levels for Various Electricity Generation Methods Information from (Newman and Zillioux, 2009, p.3-1)

Source	Resource Extraction	Fuel Transportation	Construction	Power Generation	Transmission and Delivery	Decommissioning
Coal	Highest	Lower	Lower	Highest	Moderate	Lower
Oil	Higher	Highest	Lower	Higher	Moderate	Lower
Natural Gas	Higher	Moderate	Lowest	Moderate	Moderate	Lowest
Nuclear	Highest	Lowest	Lowest	Moderate	Moderate	Lowest
Hydro	None	None	Highest	Moderate	Moderate	Higher
Wind	None	None	Lowest	Moderate	Moderate	Lowest

Birds

It has been stated that wind turbines can have a negative impact on bird populations, but wind turbines actually have a comparatively low impact on the number of birds that die every year from human causes (Erickson et al., 2005. P 1029). It has been estimated that, in the U.S. 500 million to over 1 billion birds are killed every year due to human intervention in the environment with wind turbines contributing an estimated 28.5 thousand deaths a year to this total (Erickson et al., 2005. P 1029).

Table 9: Avian Mortality by Source (Erickson et al., 2005. P 1039)

Mortality Source	Annual Mortality Estimate	Percent Composition
Buildings	550 million	58.2%
Power Lines	130 million	13.7%
Cats	100 million	10.6%
Automobiles	80 million	8.5%
Pesticides	67 million	7.1%
Communication Towers	4.5 million	0.5%
Wind Turbines	28.5 thousand	<0.01%
Airplanes	25 thousand	<0.01%
Other Sources	Not calculated	Not calculated

In a 2006 work, Drewitt and Langston found that annually there were 0.01-23 incidents of bird collisions per wind turbine (Baldock et al., 2009, p.9). A 2008 work by the same authors found that annually power lines were responsible for 2.95 to 489 collisions per km of line (Baldock et al., 2009, p.9).

The National Audubon Society in the United States has voiced its approval of electricity generated by wind, stating: "*Audubon strongly supports properly-sited wind power as a clean alternative energy source that reduces the threat of global warming*" adding that "*Scientists have found that climate change has already affected half of the world's wild species' breeding, distribution, abundance and survival rates.*" (National Audubon Society, 2011). Ruth Davis, the head of Climate Change Policy at The Royal Society for Protection of Birds has also shown support for renewable energy projects, including properly situated wind generation, stating,

> *The need for renewable energy could not be more urgent. Left unchecked, climate change threatens many species with extinction. Yet, that sense of urgency is not translating into action on the ground to harness the abundant wind energy around us.*
>
> (RSPB, 2011)

Bats

The impacts of wind turbines on bats are a fairly recent discovery which came about by accident while studying impacts on birds. It was found that at certain sites there was a higher then expected numbers of bat fatalities. Though the research on bat deaths is still preliminary, estimates say that approximately 15.3 – 41.1 bats/MW of installed capacity are killed each year (Kunz, 2009). This number varies greatly, however, from site to site. Most of these deaths (approximately 75%) are tree bats and because of this, a large portion of research has been restricted to this group of bats (Kunz, 2009). What is curious is that bat fatalities tend to be lower than that of birds at tall structures; it seems that bats do not have a tendency to fly into tall buildings and structures as birds do. This has lead to questions regarding the causes of bat fatalities and has further inspired research in this area (Arnett, 2008). That being said, "*No study reported a species of bat listed as threatened or endangered under the endangered species act killed at wind facilities."* (Arnett, p. 64)

Most studies undertaken to determine possible reasons why a higher number of bat deaths are occurring at wind farms have come to a few conclusions. First, after the recording of bat deaths, the collection and dissection of bat carcasses, there are two major causes of bat deaths. One, collision with wind turbines or wind turbine blades though these numbers are extremely low when the wind turbines are not in operation. The other is barotrauma: injury to the abdominal and thoracic cavities as well as the lungs due to the pressure difference caused by the sweeping of a wind turbine's blades (Cryan, 2009).

With an understanding of how bats are being injured by wind turbines, research has also focused on why bats are colliding with turbines; the questions of attraction and avoidance are being asked. It has been theorized that some bat fatalities are due purely to chance. Bats can however, be attracted to windmills leading to injury and loss of life. It has been posited that bats may be attracted for a variety of reasons including: an attraction to the high wind areas that are also prime locations for wind turbine development, attraction to the large number of insects in the area which are in turn attracted to the white colour of wind turbines, and attraction to the lights or sound produced by wind turbines, as well as a host of other hypotheses (Cryan, 2009, Long, 2010). Studies on bat fatalities seem to indicate that the problems with the interaction between bats and wind turbines are restricted to certain sites. Where some sites are seeing surprising numbers of fatalities others are seeing minimal deaths, similar to those at other tall structures; this indicates that proper monitoring needs to be done at individual sites in order to implement the most appropriate mitigation techniques.

As studies continue, the understanding of bat behaviour and their interaction with wind turbines will increase. For the moment current research and understanding is leading to a variety of methods for the mitigation of bat death. These advances in understanding are already improving bat fatality rates and will continue to improve them (Baerwald et al. 2009).

Prevention and Mitigation

The impacts of wind turbines on bird and bat species are a priority for those in the environmental and renewable energy fields. Mitigation techniques are now at the point where improvement is being seen and fatality numbers are dropping. This section will discuss mitigation techniques being proposed, tested or put in place now on a large scale, as well as, techniques specific to individual sites.

In Ontario, the Ministry of Natural Resources, as part of the Green Energy Act, requires certain procedures to be followed during the pre-construction, construction and post construction phases of wind turbines and wind farms in order to mitigate bird and bat deaths. Most of these regulations apply to both, while others are specific to either birds or bats themselves. These regulations can be found in the MNR documents: "Bird and Bird Habitats Guidelines for Wind Power Projects" and, "Bat and Bat Habitats, Guidelines for Wind Power Projects".

For both birds and bats pre-construction studies must be done to determine species in the area, activities undertaken in the area and any critical habitat components.

> *"The PPS specifically identifies wildlife habitat as:*
> *areas where plants, animals, and other organisms live, and find adequate amounts of food, water, shelter, and space needed to sustain their populations. Specific wildlife habitats of concern may include areas where species concentrate at a vulnerable point in their annual or life cycle; and areas which are important to migratory or non-migratory species.*
>
> *Wildlife habitat is considered significant where it is:*
> *ecologically important in terms of features, functions, representation or amount, and contributing to the quality and diversity of an identifiable geographic area or Natural Heritage System. Criteria for determining significance may be recommended by the Province, but municipal approaches that achieve the same objective may also be used."* (MNR March 2010)

This definition is further explained and laid out in detail in the "Significant Wildlife Habitat Technical Guide" produced by the Ministry of Natural Resources. With this in mind the wind industry is required to allow a buffer of 120m from any SWH. This is seen in Figure 18 below.

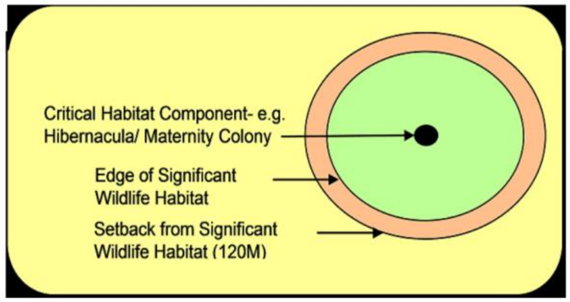

Figure 17: Significant Wildlife Habitat Setbacks

These two documents require monitoring of the wind farms for a period of 3 years of the completion of the projects. During this 3 year monitoring period the following fatality thresholds are laid out.

Birds:
18 birds/ turbine/year at individual turbines or turbine groups;
0.2 raptors/turbine/year (all raptors) across a wind power project;
0.1 raptors/turbine/year (raptors of provincial conservation concern) across a wind power project; or
2 raptors/wind power project (<10 turbines) (MNR March 2010)

Bats:
10 bats/turbine/year (MNR March 2010)

If these thresholds are then surpassed further monitoring and mitigation techniques may need to be put into place (MNR March 2010).

With the understanding that the government of Ontario requires mitigation techniques if the mortality thresholds above are exceed, effective techniques must be put into place. New studies in the last few years have highlighted the potential to decrease fatality rates of bats and birds. The best technique to avoid wildlife fatality and loss of habitat is good siting and placement of wind turbines. This is an imperative step in the development of a wind turbine project. By following ministry guidelines wind farms should give space to "*significant wildlife habitat*" allowing for the development of the project with minimal impact upon wildlife. If, however, during the 3 year monitoring period significant mortality rates are found, mitigation techniques and monitoring must be undertaken (MNR March 2010). Some well understood techniques are already in place while new techniques are being developed and tested to further improve mitigation practices.

When discussing bird mortality and wind turbines it is necessary to approach the topic of the Altamont Pass wind farm in California. This installation, now almost 30 years old, has had many problems with regard to bird deaths and has motivated research into wind turbine effects on wildlife. It has been concluded that this installation was poorly sited to begin with, being put in a bird migratory route, with many small turbines placed closely together (USGAO 2005). Toward mitigating the effects of this poorly sited installation, many of the older turbines are now being replaced with fewer, larger, new wind turbines. This replacement strategy is part of a larger strategy to reduce environmental impact: the Altamont Pass Wind Resources Area (APWRA) Conservation Plan. This new plan should increase bird monitoring as well as decrease bird fatalities in the area (APWRA, 2011).

The Altamont Pass wind farm is often sited both as an example of the negative impacts wind farms can have on wildlife as well as an example of improvements from poorly sited installations. For the prevention of environmental impact good siting prevents impact and the need for mitigation. Where mitigation is necessary the most common technique is intermittent shutdown of wind turbines depending on the life cycle of birds being affected in the area. Using bird migratory and behaviour data, turbines can be shut down at certain points to allow for the protection of certain species. This type of mitigation does, however, lead to questions of loss of profit.

As to bats, new research is coming out and many strategies are being put into place to reduce bat deaths. It has been well documented that bat deaths tend to occur under low wind conditions and that as winds increase bat activity decreases (Baerwald et al., 2009). Due to this aspect of bat activity, an increase of the cut in wind speed (the speed at which wind turbines begin to produce electricity) from 4 m/s to 5.5 m/s has seen decreases of bat deaths by 57.5%-60%. This change is cut in wind speed was put in place as part of research in south western Alberta where large numbers of bats were being killed (Baerwald et al., 2009). "*It is estimated that over the 1-month experiment, total revenue lost from the 15 turbines with increased rotor start-up speed was between $3,000 and $4,000*" (Baerwald et al., p. 3) this cost could have been further lowered if the start up speed was only changed at night and weather variables and high risk times could be taken into account (Baerwald et al., 2009). Though this technique is quite effective, new techniques and theories are arising too. It has been proposed that the colour of the wind turbines attracts more insects and thus more bats. A simple change of the colour of wind turbines could decrease bat attraction to wind farms and thus the number of bat deaths.

In all, most studies conclude that the most important aspect of wildlife protection is good siting practices during the pre-construction of wind farms. This focus on siting should then be followed up with consistent, high quality monitoring ensuring the protection of the wildlife and surrounding environment.

Conclusion

It would seem that the disconnect between resources and their end point of consumption becomes greater and greater as time progresses. Advances in technology and transportation allow the consumption of resources from places never personally experienced, shielding the consumers from the impact of their choices; "*a commercial pattern has emerged that has increasingly separated, or distanced, consumers from the consequences of their behaviour*" (Luna, 2008, p.1278). This would seem to hold true for most forms of consumption, including electricity use. Pasqualetti states that

> *"One of the most important spatial consequences of the dispersed processing that characterizes most generation of electricity is the resulting visual and absolute dilution of the aggregate impacts that result. It is the reward of such dilution that no single place must absorb or suffer cumulative environmental-including aesthetic insults. Unfortunately, this "out of sight, out of mind" pattern misleads the public by suggesting that the environmental costs of electricity are less than they actually are."*
>
> (Pasqualetti, 2000, p.384).

This separation has perhaps played some role in the rise in per capita electricity consumption that has been seen in Canada since the mid twentieth century.

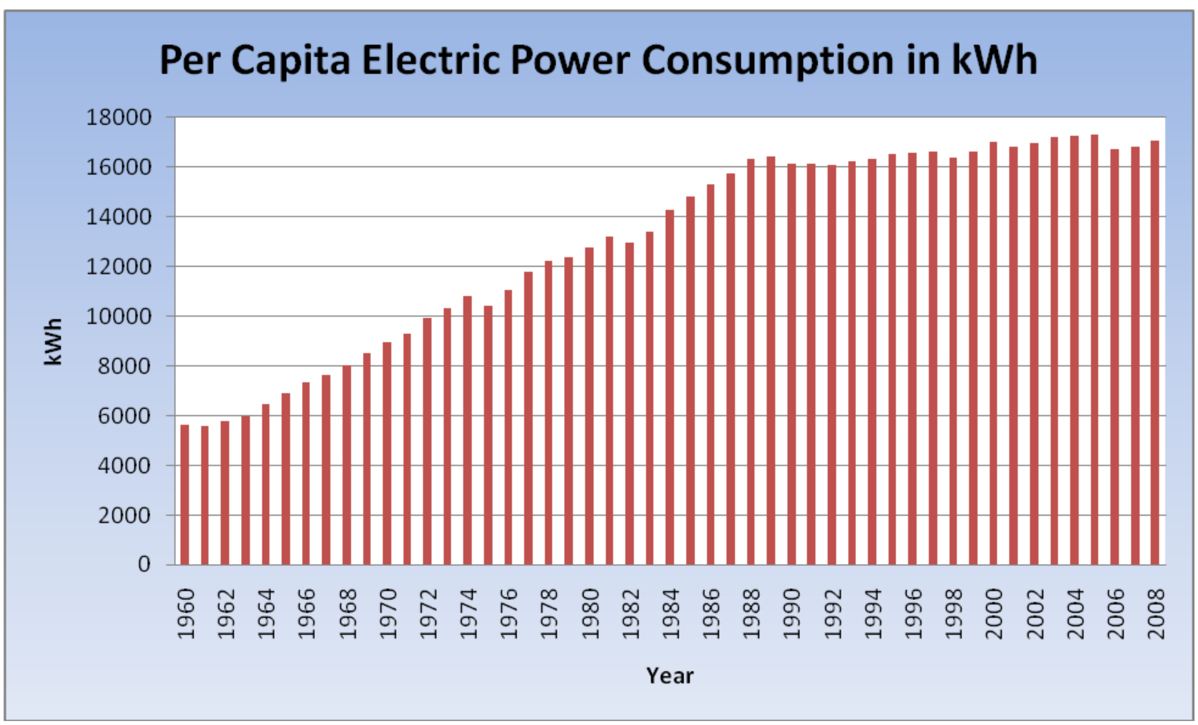

Figure 18: Per Capita Electric Power Consumption in kWh (The World Bank Group, 2011)

This separation between source and consumption has perhaps allowed a lack of awareness, either innocent or purposeful, to permeate understanding of the true impact of consumption on both people and the environment. People and places, no less valuable then those personally known, have been allowed to bear the burden of others' needs and wants simply because of geographical separation.

> *"As distance between consumption and production increases, we can expect a breakdown in the flow of information, creating misperceptions of scarcity and damage, resulting in unrestrained or excessive consumption. No less important, the pursuit of distancing as a method of cost externalization, either by producers or consumers, leads to displacement of environmental problems. Worse, this displacement often appears as a solution to environmental problems when ecological feedback is severed and price is the only information available to consumers."*
>
> (Luna, 2008, p.1278).

Renewable electricity generation may have the potential to reverse this trend. No longer will electricity generation be entirely concentrated and remote, it may very well be present and visible. It must be acknowledged that all forms of electricity generation will have an impact on some location, and the comparative close proximity of renewable generation should not be seen as a deterrent to its acceptance.

It has been shown that properly sited wind turbines are a low impact source of electricity, and have the potential to minimize the use of environmentally detrimental electricity sources.

A number of municipalities have passed motions calling for a moratorium on the installation of wind turbines until the time when appropriate proof of their safety has been set forward. We present this document, along with all accompanying reports, as reassurance not only of the safety, but of the many advantages of wind power. The same strength of opinion comes from the following individuals, groups and organisations.

<u>The Chief Medical Officer of Health (CMOH) of Ontario Dr. Arlene King:</u>

> *"The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct adverse health effects. However, some people might find it annoying ... Low frequency*

sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects."
(King, Dr., 2010, p.9)

<u>Ontario's Public Health Agency:</u>

"Based on best available evidence, any identified risks can be addressed through siting (setbacks) and operating practices."(Copes)

<u>The Ontario Ministry of the Environment:</u>

"A panel of three judges has ruled that Ontario's approach to wind turbines protects human health and the environment. The province's 550 metre setback for wind turbines is the strictest in North America and based on peer-reviewed science.

The Ministry of the Environment consulted 122 scientific journals in developing noise guidelines and protocols for wind turbines. This includes 15 peer-reviewed journals, eight conference presentations and 34 policy papers." (Ministry of the Environment, 2011)

<u>Natural Resources Canada/Canmet Energy</u>

"Harnessing the natural and renewable energies of the sun, wind, moving water, earth and biomass improves the sustainability of our energy production and delivers benefits to the environment and to human health." (Canmet Energy, 2009)

The National Medical Academy of France:

"It is understood that the worries and fears have largely been spread because they serve as supplementary arguments for Associations which oppose the installation of these turbines for ecological, aesthetic or economic motives, put forward, generally, politically and not with the competence of the Academy. Presently in the scientific literature, there is little proof of the potential dangers of windmills on man." (Auquier, Louis. Et al., 2006)

"On comprend que ces doléances et ces craintes aient été alors largement diffusées, parce qu'elles servaient d'arguments supplémentaires aux Associations qui s'opposent à l'installation de ces engins pour des motifs écologiques, esthétiques ou économiques, qui, eux, relèvent de la politique générale, et non des compétences de l'Académie. Actuellement, dans la littérature scientifique, on retrouve très peu de données sur les dangers potentiels des éoliennes pour l'homme." (Auquier, Louis. Et al., 2006)

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Appendices

Appendix 1: Quotations by Subject

	Source	Quotation
General	(King, 2010)	« …the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects, although some people may find it annoying. »
Sound and Noise	(King, 2010)	« The sound was annoying only to a small percentage of the exposed people; approximately 4 to 10 per cent were very annoyed at sound levels between 35 and 45dBA. Annoyance was strongly correlated with individual perceptions of wind turbines. Negative attitudes, such as an aversion to the visual impact of wind turbines on the landscape, were associated with increased annoyance, while positive attitudes, such as direct economic benefit from wind turbines, were associated with decreased annoyance. »
	(Rideout & Bos, 2009)	« No published data that confirm the claims of adverse health effects for low-frequency sounds of low pressure (i.e. below 20 Hz and 110 dB) »
	(Colby et al., 2009)	« There is no evidence that the audible or sub-audible sounds emitted by wind turbines have any direct adverse physiological effects. » « The sounds emitted by wind turbines are not unique. There is no reason to believe, based on the levels and frequencies of the sounds and the panel's experience with sound exposures in occupational settings, that the sounds from wind turbines could plausibly have direct adverse health consequences. »

	(Colby et al., 2009)	« As the annoyance of a given sound increases as loudness increases, there is also a more rapid growth of annoyance at low frequencies. However, there is no evidence for direct physiological effects from either infrasound or low frequency sound at the levels generated from wind turbines, indoors or outside. Effects may result from the sounds being audible, but these are similar to the effects from other audible sounds. » « It is important to note that although annoyance may be a frustrating experience for people, it is not considered an adverse health effect or disease of any kind. Certain everyday sounds, such as a dripping faucet—barely audible—can be annoying. Annoyance cannot be predicted easily with a sound level meter. Noise from airports, road traffic, and other sources (including wind turbines) may annoy some people, and, as described in Section 4.1, the louder the noise, the more people may become annoyed. »
	(Pedersen et al., 2008)	« There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dBA) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or *vice versa* or whether both are related to another factor. »
	(Health Canada, 2005)	« In a typical community, noise starts to make people highly annoyed when the sound level outside their home is around 55dbA. In comparison , the sound level on the shoulder of the major highway is between 80 and 90 dbA »
	(Leventhall, 2006)	«The fluctuations of wind turbine noise (swish – swish) are a very low frequency modulation of the aerodynamic noise, which is typically in the region of 500 - 1000Hz. The modulation occurs from a change in radiation characteristics as the blade passes the tower, but the modulating frequencies do not have an independent and separate existence. » (p.33) «Fear of a source is not the same as fear of the noise itself, but it is understandable that those who fear the effects of a noise upon their health will be less tolerant of the noise than those who do not fear it. » (p.33)

Infrasound	(Sonus Pty Ltd, 2010)	« Specific International studies, which have measured the levels of infrasound in the vicinity of operational wind farms, indicate the levels are significantly below recognised perception thresholds and are therefore not detectable to humans. »
	(Howe, 2006)	« Studies completed near Canadian wind farms, as well as international experience, suggest that the levels of infrasound near modern wind turbines, with rated powers common in large scale wind farms are in general not perceptible to humans, either through auditory or non-auditory mechanisms. Additionally, there is no evidence of adverse health effects due to infrasound from wind turbines. »
	(King, 2010)	« There is no evidence of adverse health effects from infrasound below the sound pressure level of 90dB »
	(Leventhall, 2006 p.34)	«It has been shown above that there is insignificant infrasound from wind turbines and that there is normally little low frequency noise. Turbulent air inflow conditions cause enhanced levels of low frequency noise, which may be disturbing, but the overriding noise from wind turbines is the fluctuating audible swish, mistakenly referred to as "infrasound" or "low frequency noise". Objectors uninformed and mistaken use of these terms (as in Fig 3), which have acquired a number of anxiety-producing connotations, has led to unnecessary fears and to unnecessary costs, such as for re-measuring what was already known, in order to assuage complaints. »
	(Syndicat des énergies renouvelables, 2010)	« Windmills, just like the wind in the trees or the circulation of traffic emit infrasound, that's to say low frequency sound below the audible limit of the human ear, but the impact of infrasound on human health has only been observed in very rare situations and never in the case of a wind farm. » « Les éoliennes, tout comme le vent dans les arbres ou la circulation automobile, émettent des infrasons, c'est-à-dire des sons de basse fréquence, au dessous du seuil audible par l'oreille humaine. Mais l'impact des infrasons sur la santé humaine n'a été observé que dans très rares situations et jamais dans le cas de parcs éoliens.» "The production of infrasound by wind mills is at close proximity well analysed and very moderate: it is without danger for people." « …la production d'infrasons par les éoliennes est, à leur voisinage immédiat, bien analysée et très modérée : elle est sans danger pour l'homme ; »

Vibration	(Colby et al., 2009)	« Vibration of the body by sound at one of its resonant frequencies occurs only at very high sound levels and is not a factor in the perception of wind turbine noise. »
	(Colby et al., 2009)	« The ground-borne vibrations from wind turbines are too weak to be detected by, or to affect, humans. »
EMFs	(King, 2010)	« Wind turbines are not considered a significant source of EMF exposure since emissions levels around wind farms are low. »
	(Rideout & Bos,2009)	« Lower exposure than other electricity generation / Underground cables bury electrical field »
Shadow Flicker	(King, 2010)	« About 3 per cent of people with epilepsy are photosensitive, generally to flicker frequencies between 5-30Hz. Most industrial turbines rotate at a speed below these flicker frequencies »
	(Rideout & Bos, 2009)	« • Most pronounced at distances from wind turbines less than 300 m (1,000 feet) • No evidence of health effects • Aesthetic or nuisance effect »
	(Académie nationale de médecine, 2006)	« The fear of an epileptic effect from windmills has often been brought up. However, if in other circumstances the epileptic reaction to a repetitive light stimulation has been demonstrated, we have not found any observation incriminating windmills in this pathology; this fear is not supported by any reviewed case. » « La crainte d'un effet épileptogène des éoliennes a été souvent évoquée. Cependant, si dans d'autres circonstances le rôle épileptogène d'une stimulation lumineuse répétitive est bien démontré, nous n'avons retrouvé dans la littérature aucune observation incriminant les éoliennes dans cette pathologie: cette crainte n'est étayée par aucun cas probant. » « There is not a risk of the stroboscopic visual stimulation from the rotation of windmill blades. » « qu'il n'y a pas de risques avérés de stimulation visuelle stroboscopique par la rotation des pales des éoliennes »
Ice Throw and Ice Shed	(King, 2010)	« Depending on weather conditions, ice may form on wind turbines and may be thrown or break loose and fall to the ground. Ice throw launched far from the turbine may pose a significant hazard. Ice that sheds from stationary components presents a potential risk to service personnel near the wind farm. Sizable ice fragments have been reported to be found within 100 metres of the wind turbine. Turbines can be stopped during icy conditions to minimize the risk. »

Structural Hazards	(King, 2010)	« The maximum reported throw distance in documented turbine blade failure is 150 metres for an entire blade, and 500 metres for a blade fragment. Risks of turbine blade failure reported in a Dutch handbook range from one in 2,400 to one in 20,000 turbines per year (Braam et al 2005). Injuries and fatalities associated with wind turbines have been reported, mostly during construction and maintenance related activities. »
	(Académie nationale de médecine, Groupe de Travail, 2006)	« … the risks associated with the installation, functioning and disassembly of these turbines are anticipated and taken into account by the vigorous regulations for industrial sites, which apply to this phase of installation and to the demolition of obsolete wind.» « …les risques traumatiques liés à l'installation, au fonctionnement et au démontage de ces engins sont prévus et prévenus par la réglementation en vigueur pour les sites industriels, qui s'applique à cette phase de l'installation et de la démolition des sites éoliens devenus obsolètes. »
Setbacks	(King, 2010)	« The minimum setback for a wind turbine is 550 metres from a receptor. The setbacks rise with the number of turbines and the sound level rating of the selected turbines. For example, a wind project with five turbines, each with a sound power level of 107dB, must have its turbines setback at a minimum 950 metres from the nearest receptor. These setbacks are based on modelling of sound produced by wind turbines and are intended to limit sound at the nearest residence to no more than 40 dB. »
	(Syndicat des énergies renouvelables, 2010)	«The volume of a windmill functioning at a distance of 500 metres rises to 35db, the equivalent of a whispered conversation. So, to eliminate all sound for those living nearby, the developers of wind projects should respect a certain distance from the nearest residence. » «Le volume d'une éolienne en fonctionnement à 500 mètres de distance s'élève à 35 décibels, soit l'équivalent d'une conversation chuchotée. Afin d'éliminer tout de gêne sonore pour les riverains, les développeurs de projets éoliens respectent un éloignement et les premières habitations. »

	(Académie nationale de médecine, Groupe de Travail, Mars, 2006)	«It is understood that the worries and fears have largely been spread because they serve as supplementary arguments for Associations which oppose the installation of these turbines for ecological, esthetic or economic motives, put forward, generally, politically and not with the competence of the Academy. Presently in the scientific literature, there is little proof of the potential dangers of windmills on man. » «On comprend que ces doléances et ces craintes aient été alors largement diffusées, parce qu'elles servaient d'arguments supplémentaires aux Associations qui s'opposent à l'installation de ces engins pour des motifs écologiques, esthétiques ou économiques, qui, eux, relèvent de la politique générale, et non des compétences de l'Académie. Actuellement, dans la littérature scientifique, on retrouve très peu de données sur les dangers potentiels des éoliennes pour l'homme. »
Impacts on Wildlife	(Newman and Zillioux, 2009)	«Acidic deposition, climate change and mercury bioaccumulation are identified as the three most significant and widespread stressors to wildlife from electricity generation from fossil fuel combustion in the NY/NE region. Risks to wildlife vary substantially by life cycle stage. Higher risks are associated with the resource extraction and power generation stages, as compared to other life cycle stages. Overall, non-renewable electricity generation sources, such as coal and oil, pose higher risks to wildlife then renewable electricity sources such as hydro and wind. Based on the comparative amounts of SO_2, NO_x, CO_2 and mercury emissions generated from coal, oil, natural gas, and hydro and the associated effects of acidic deposition, climate change and bioaccumulation, coal as an electricity generation source is by far the largest contributor to risks to wildlife in the NY/NE region. » (Newman and Zillioux, 2009, p.iii)
	(The Royal Society for Protection of Birds, 2011)	Ruth Davis, the head of Climate Change Policy at The Royal Society for Protection of Birds has said: «The need for renewable energy could not be more urgent. Left unchecked, climate change threatens many species with extinction. Yet, that sense of urgency is not translating into action on the ground to harness the abundant wind energy around us. » «The solutions are largely common sense. We need a clear lead from government on where wind farms should be built and clear guidance for local councils on how to deal with applications. We must reduce the many needless delays that beset wind farm developments. »

Appendix 2: List of Works Consulted

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