Elizabeth Garstin 0303976 ENV 2E02, Feb 2005
Adviser: Alastair Grant Work Set By: K.Tovey

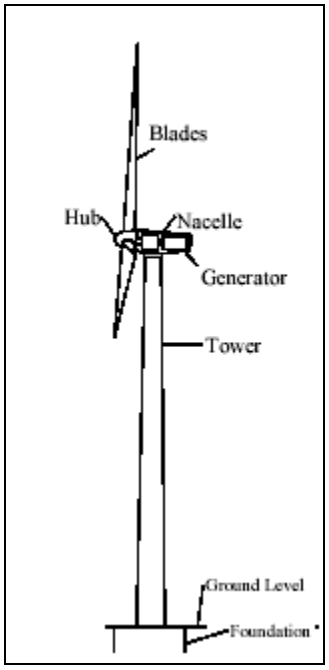
The Potential for Wind Energy in the UK

Introduction:

The UK's energy future is uncertain. Our energy demand is increasing, our traditional fuels of oil, coal and gas are running out, and we are threatened with the danger of climate change. However, wind is likely to prove vital in building a secure energy future for the UK. Wind is a clean, abundant and sustainable source of energy, and is currently the fastest growing source of electricity in the World[1]. The UK has the largest wind resource in Europe[2], but we are far behind other European countries such as Denmark and Germany. In this report, the basic technology of wind energy will be explored, the, pros and cons and the potential of the technology discussed, and projections made for how much electricity the UK could have being generated by wind by the year 2030.

Technology of Wind Turbines

Wind turbines generate electricity using the natural power of the wind to drive a generator. Three blades rotate around a horizontal hub, which is connected to the power electronics, located in the nacelle at the top of a steel tower (figure 1).



- The wind passes over the blades thus exerting a turning force
- The rotating blades turn a shaft inside the nacelle, which goes into a gearbox
- The gearbox increases the rotation speed for the generator
- The generator uses magnetic fields to convert the rotational energy to electrical energy
- The power output goes to a transformer which converts the electricity from the generator (~700Volts) to the right voltage for the distributor system (typically 33kV)
- Regional electricity distributor networks or the National Grid transmit the electricity around the country.

Figure 1: Components of a Wind Turbine (Source: New Zealand Wind Energy Association, 2004)

[1] BWEA, *Benefits of Wind Energy*, http://www.bwea.com/energy/benefits.pdf
[2] The Carbon Trust *The Future for UK Renewables?*
http://www.thecarbontrust.co.uk/carbontrust/about/press_releases/PressRelease_29_10_03.pdf

Most wind turbines start generating electricity at wind speeds of around 3-4ms^{-1}, and at around 15ms^{-1} they generate the maximum 'rated' power[3]. At wind speeds greater than 25ms^{-1} they shut down in order to prevent storm damage.

Offshore technology of wind turbines is based on the same principles as onshore technology. Piles are driven into the seabed with erosion protection at the base to prevent seafloor damage. The top of the foundation in painted a bright colour to make them more visible to ships. In offshore wind turbines, sub-sea cables take the power to a transformer, which converts the electricity to 33kV before running it back to connect it to the grid at a substation on land[4].

The amount of electricity produced from wind turbines depends on the following factors:

- **The windiness of the site:** the power available from the wind is a function of the cube of the wind speed (e.g. if the wind blows at twice the speed then the energy content increases eight-fold).
- **Wind turbine availability:** i.e. the capability of the turbine to operate when the wind is blowing.
- **The arrangement of the turbines:** in wind farms, the turbines are laid out so that one turbine does not take the wind away from another. There are also landscape issues to consider.

Currently, the most commonly used wind turbines have a capacity of 1-2MW, although some as large as 6MW are being developed[5].

Onshore Wind Versus Offshore Wind

Offshore wind speeds are higher and much less turbulent than those onshore (up to about 0.5ms^{-1} higher 10km offshore)[6]. However, wind over elevated land sites can have higher speeds. It is currently much more expensive to install wind turbines offshore and so offshore turbines are generally much larger so that their cost-effectiveness per unit of

[3] BWEA, *Wind Turbine Technology*, http://www.bwea.com/energy/technology.pdf
[4] BWEA, *Wind Turbine Technology*, http://www.bwea.com/energy/technology.pdf
[5] BWEA, *Annual Review 2004*, http://www.bwea.com/pdf/reviewsmall.pdf
[6] BWEA, *Annual Review 2004*, http://www.bwea.com/pdf/reviewsmall.pdf

electricity generated is greater. These larger, offshore turbines have taller towers that place the rotors in stronger winds.

There are many restraints to building onshore wind farms, which are reduced with offshore wind farms, such as planning, and local opposition.

Offshore wind farms may be the way forward, but it is currently much more cost effective to build onshore. However, the costs involved with constructing wind farms are likely to decrease greatly as the technology is improved and moneylenders gain more confidence in the technology so that the cost of financing decreases[7].

Advantages of Wind Energy

There are many benefits to be gained from the increased use of wind energy to generate electricity in the UK. Wind-generated electricity replaces generation from conventional, polluting sources, which cause the emission of several greenhouse gases such as carbon dioxide and sulphur dioxide. Wind turbines in the UK currently prevent the emission of 1¾ million tonnes of carbon dioxide each year[8]. Wind power is clean, with no chemical or radioactive emissions, and has minimal impacts on the local ecosystem. When, and if needed, decommissioning of wind farms is easy and leaves no toxic residues or environmental damage[9]. The average working life of a wind turbine is 20 to 25 years and at the end of this period the materials have a scrap value and can be sold on[10].

Wind energy is one of the safest energy technologies. It is also the fastest growing energy sector in the UK, providing many vital jobs in the manufacturing, construction and maintenance of wind farms. A new local wind farm can bring contracts worth several million pounds to companies in areas where wind energy is developed[11], bringing direct economic benefits to communities.

There are also no direct fuel costs, and the cost of extracting the power from the resource is expected to fall as technology improves[12].

[7] BWEA, *The Economics of Wind Energy*, http://www.bwea.com/ref/econ.html
[8] BWEA, *Benefits of Wind Energy*, http://www.bwea.com/energy/benefits.pdf
[9] NATTA, *Renewable Energy in the UK*, http://www-tec.open.ac.uk/eeru/natta/natta-guide.html#wind
[10] BWEA, *Wind Turbine Technology*, http://www.bwea.com/energy/technology.pdf
[11] BWEA, *Wind Energy and the UK's 10% Target*, http://www.bwea.com/energy/10percent.pdf
[12] NATTA, *Renewable Energy in the UK*, http://www-tec.open.ac.uk/eeru/natta/natta-guide.html#wind

The current cost of generating electricity from onshore wind is 3.1pKWh^{-1}, expected to fall to 2.7pKWh^{-1} by 2010[13]. This is favourable to the recent figures produced for the DTI on new nuclear build, of 3.7pKWh^{-1}. The average wind farm in the UK also takes around 3-5 months to pay back the energy used in its manufacture[14], compared to about 6 months for coal or nuclear power stations. So this demonstrates how wind-generated electricity is proving to be relatively cost-effective compared to conventional methods.

Wind turbines are not only confined to wind farms on hilltops in remote areas. They can also be found at many different locations such as remote rural homes, schools and hospitals, and even urban city centres[15]. There are many benefits for households, communities or farmers and agricultural businesses that want to generate their own electricity, such as various supporting funding schemes ("Clear Skies", "The Scottish Community and Householder Renewables Initiative" and DEFRA's "Rural Enterprise Scheme" in Scotland). Rent payments and maintenance contracts for wind farms can represent an income of hundreds of thousands of pounds per year for the local economy[16].

Disadvantages of Wind Energy

The main disadvantage of wind-generated electricity is the local opposition that wind farms create, although many of the grounds for protest often appear to be uninformed. For example, the protested-against local impacts such as noise disturbance are completely unfounded as modern wind turbines are actually very quiet. As long as the turbines are well designed and well sited, they can be quiet enough to cause no disturbance to people living just an few hundred metres away[17]. At these distances, any noise they do create usually blends into background noise. There are also similar unfounded concerns over the visual impact destroying areas of 'natural beauty', and also the danger to birds[18].

---

[13] OXERA, *Results of Renewables Market Modelling*, http://www.dti.gov.uk/energy/renewables/policy/oxeraresults.pdf
[14] BWEA, *Wind Turbine Technology*, http://www.bwea.com/energy/technology.pdf
[15] BWEA, *Wind Energy and the 10% Target*, http://www.bwea.com/energy/10percent.pdf
[16] BWEA, *Wind Energy and the 10% Target*, http://www.bwea.com/energy/10percent.pdf
[17] Yes to Wind, *Debunking the* Myths, http://www.yestowind.com/noisy_debunk.html
[18] US Department of Energy, *Advantages and Disadvantages of Wind* Energy, http://www.eere.energy.gov/windandhydro/wind_ad.html

Another problem is that good onshore wind sites are often located in remote areas, away from the towns and cities where the most electricity is needed[19]. This means that there is an additional expense and complication in connecting the wind farms to the National Grid so that the electricity can be distributed to the appropriate areas.

One common objection to wind energy is the belief that wind is an unreliable source of energy as it cannot be stored and so it would be irresponsible to rely on it very much. However, the wind is not unreliable. Wind turbines generate electricity for about 80% of the time, although not always at full output[20].

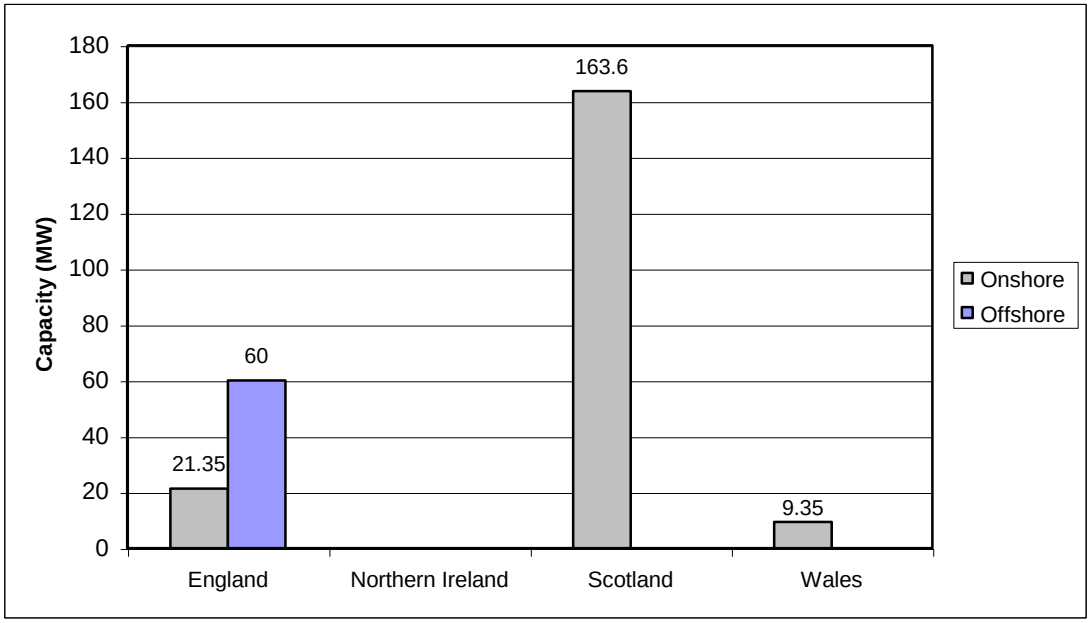
A large problem arises from the fact that so far in the UK, projects have been developed by conventional medium to large-scale companies. This has generated a great deal of mistrust by the general public of the companies and thus the technology they are promoting. In Denmark, around 70% of the 3000 or so wind farms are owned locally, dispelling this issue[21]. This raises the question of whether new UK wind farms should be increasingly more locally owned, to try to improve the acceptance of such a valuable method of electricity production.

Projections for Wind Energy in the UK

My projections were based on the build rate of wind turbines in the year 2004. In this year over 250MW of wind power was installed in the UK (figure 2), an increase of 40% on the previous year. This is the equivalent of about one 1.5MW turbine being built every two days. The total installed capacity by the end of 2004 was just in excess of 900MW[22].

[19] US Department of Energy, *Advantages and Disadvantages of Wind* Energy, http://www.eere.energy.gov/windandhydro/wind_ad.html
[20] BWEA, *Wind Turbine Technology*, http://www.bwea.com/energy/technology.pdf
[21] NATTA, *Renewable Energy in the UK*, http://www-tec.open.ac.uk/eeru/natta/natta-guide.html#wind
[22] BWEA, *Annual Review 2004*, http://www.bwea.com/pdf/reviewsmall.pdf

Figure 2: Wind Turbines Built in 2004



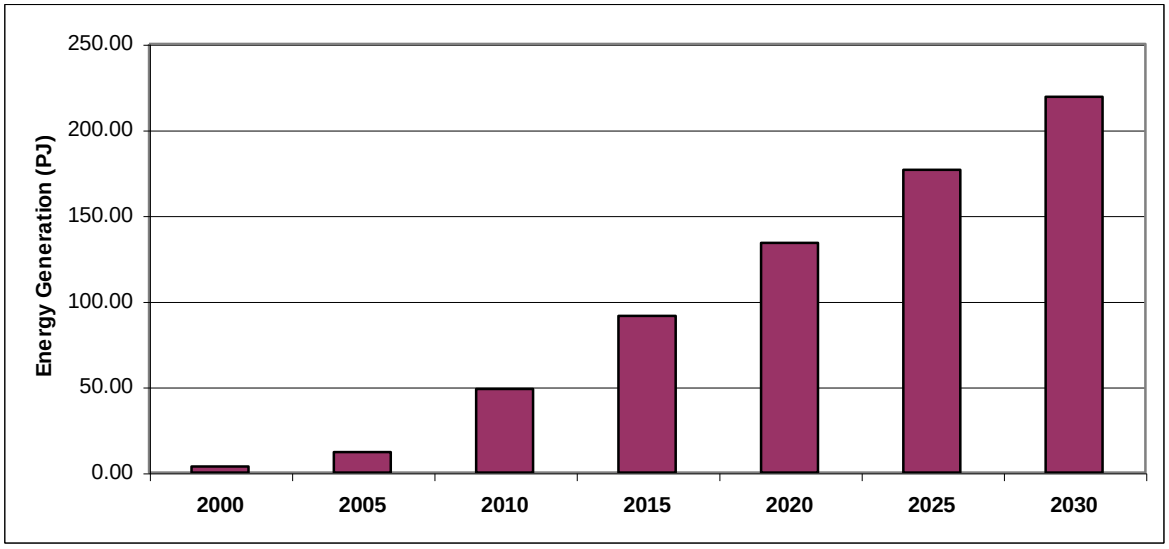
(Adapted from BWEA, Annual Report 2004)

For my projections, I assumed an increase in installation of 40% each year until a maximum build rate of 900MW is achieved. From that point, the level of an additional installed capacity of 900MW per annum is sustained until the year 2030. In order to convert these figures into Petajoules I assumed an average load factor for the turbines of 30%. Table 1 shows my figures for these calculations, and figure 3 demonstrates them on a graph.

Table 1: Projections up to 2030 in PJ

Year	Capacity (MW)	Power (MWh)	Energy generated (PJ)
2000	380.00	998640.00	3.60
2005	1260.89	3313618.92	11.93
2010	5157.12	13552911.36	48.79
2015	9657.12	25378911.36	91.36
2020	14157.12	37204911.36	133.94
2025	18657.12	49030911.36	176.51
2030	23157.12	60856911.36	219.08

Figure 3: Projections for Wind Energy Generation in PJ up to 2030



In order to have 219PJ of energy supplied by wind power by the year 2030 (as my projections predict), about 15,000 wind turbines of 1.5MW capacity would need to be built over the next 26 years. This equates to an average of 3 turbines being built every 2 days.

I have taken the assumption that the level of total electricity generation remains constant with the 2003 figure of 379TWh in order to present these projections as percentages of total current electricity generation (Table 2 and Figure 4).

Table 2: Projections up to 2030 Expressed as Percentages of Total Current Electricity Generation

Year	Proportion of Current Electricity Generation (%)
2000	0.26
2005	0.87
2010	3.58
2015	6.70
2020	9.82
2025	12.94
2030	16.06

Figure 4: Projections Expressed as a Percentage of Total Current Electricity Generation

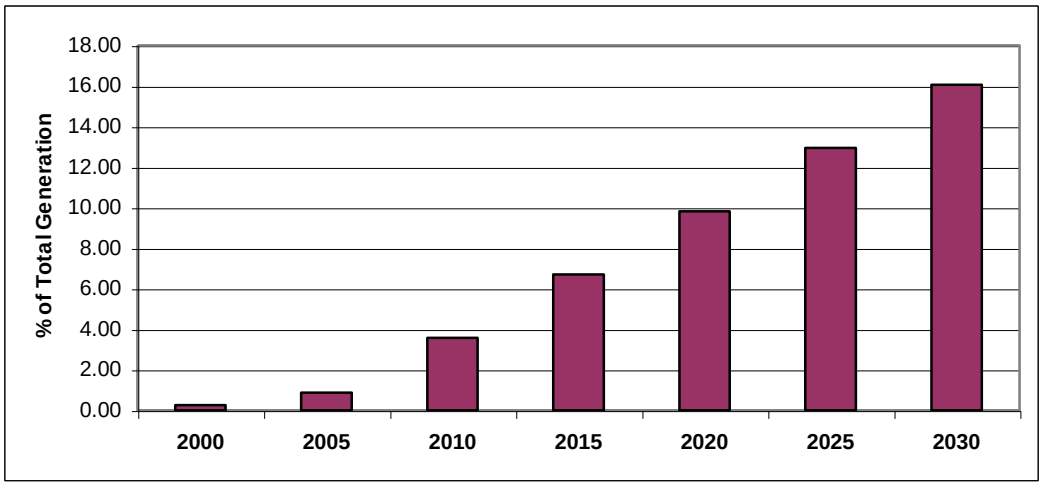
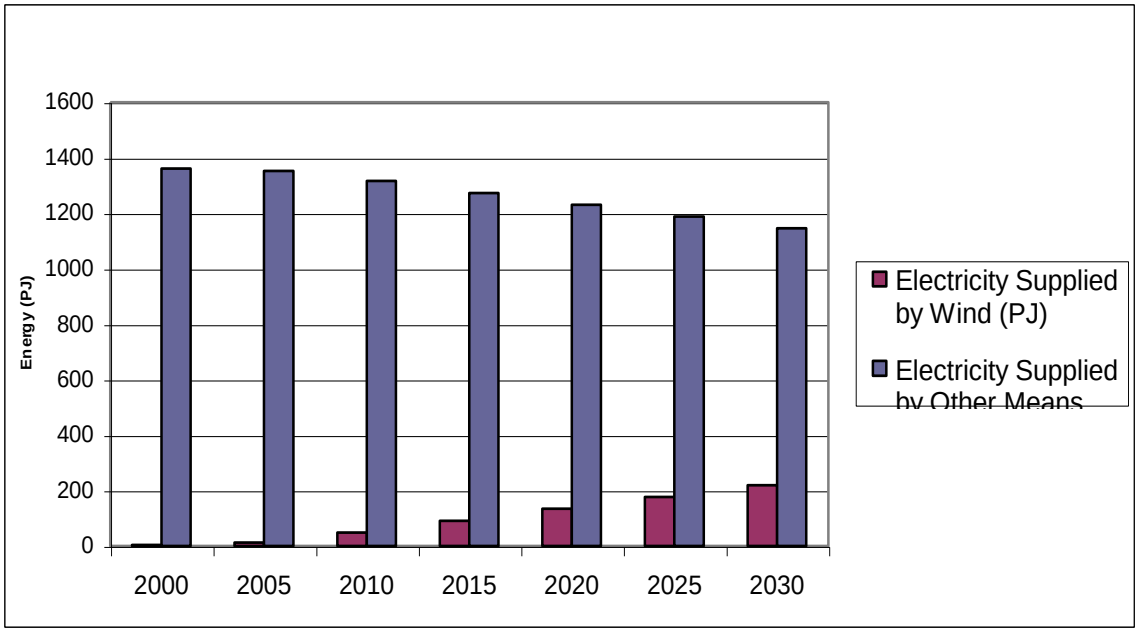


Figure 5 below shows how, as more and more electricity is being supplied by wind power over the years, the proportion supplied by other means (conventional and other renewable sources) decreases. This graph demonstrates the fact that wind energy simply isn't enough on its own to secure our energy future. It will make a very big impact into the work that the UK needs to do in order to reduce its use of conventional, depleting fuels, but other renewable technologies will also need substantial investment and development in order to make a difference in the UK.

Figure 5: Projections for the Change in Proportion of Electricity Supplied by Wind Energy



Conclusion:

Wind energy is sustainable, clean and increasingly competitive economically. The local impacts of wind farms are relatively small compared with the global impacts of using conventional fuels. As technology of wind farms has improved, the cost of electricity from wind projects has decreased, and continues to do so. Wind farms can greatly improve the economy of areas by providing jobs and injecting money into communities via land rental and so on. Many of the objections to wind farms are unfounded and so education of communities or schemes such as community-owned projects could help to dispel them.

However, although wind energy is viable and beneficial, the projections shown here demonstrate that wind energy is not capable on its own of securing a sustainable energy future for the UK, but that other technologies need funding and development. Therefore, when devising an energy policy for the UK, there needs to be an integrated approach of a combination of different renewable sources of energy as well as schemes and policies to reduce consumer demand and make more energy efficient technologies.

References:

- **BWEA Website: http://www.bwea.com**

BWEA, 2004, *Benefits of Wind Energy*, http://www.bwea.com/energy/benefits.pdf, visited 13/02/05.
BWEA, 2004, *Wind Turbine Technology*, http://www.bwea.com/energy/technology.pdf, visited 13/02/05.
BWEA, 2004, *Annual Review 2004*, http://www.bwea.com/pdf/reviewsmall.pdf, visited 05/02/05.
BWEA, 2004, *The Economics of Wind Energy*, http://www.bwea.com/ref/econ.html, visited 22/02/05.
BWEA, 2004, *Wind Energy and the UK's 10% Target*, http://www.bwea.com/energy/10percent.pdf, visited 13/02/05.
BWEA, 2004, *BWEA Statistics Reporting 1st Quarter* Success, http://www.bwea.com/planning/1Qbriefing.html, visited 10/02/05.

- **EWEA Website: http://www.ewea.org**

EWEA, *Wind Energy – The* Facts, http://www.ewea.org/documents/Thefacts_Summary.pdf, visited 10/02/05.

- **DTI Website: http://www.dti.gov.uk**

DTI, *Energy Consumption in the United* Kingdom, http://www.dti.gov.uk/energy/inform/energy_consumption/ecuk.pdf, visited 01/02/05.
DTI, *DUKES Energy* Projections, http://www.dti.gov.uk/energy/inform/energy_projections/ep68_final.pdf, visited 02/02/05.
DTI, 2004, *UK Energy in Brief*, http://www.dti.gov.uk/energy/inform/energy_in_brief/energyinbrief2004.pdf, visited 02/02/05.
DTI, *Energy White Paper*, http://www.dti.gov.uk/energy/whitepaper/ourenergyfuture.pdf, visited 02/02/05.
DTI, *Renewable Forms of Energy*, http://www.dti.gov.uk/energy/inform/dukes/dukes2004/07main.pdf, visited 13/02/05.
DTI, *Capacity of, and Electricity Generated From, Renewable* Sources, http://www.dti.gov.uk/energy/inform/energy_stats/renewables/dukes7_4.xls, visited 13/02/05.

- **The United Kingdom Parliament Website: http://www.parliament.the-stationery-office.co.uk**

The House of Lords, 2004, *The target of 10 percent of electricity from renewable energy by 2010* http://www.parliament.the-stationery-office.co.uk/pa/ld200304/ldselect/ldsctech/126/12626.htm, visited 13/02/05.

- **The Carbon Trust Website: http://www.thecarbontrust.co.uk**

The Carbon Trust, 29/10/03, *The Future for UK Renewables?* http://www.thecarbontrust.co.uk/carbontrust/about/press_releases/PressRelease_29_10_03.pdf, visited 12/02/05.

The Carbon Trust, 2004, *The Carbon Trust and DTI Renewables Impact Network* Study, http://www.thecarbontrust.co.uk/carbontrust/about/publications/Renewables%20Network%20Impact%20Study%20Final.pdf, visited 12/02/05.

- Cabinet Office, 2002, *The Energy Review*, http://www2.env.uea.ac.uk/gmmc/energy/pdf_files/energy_review_full_document.pdf, visited 20/02/05.

- *Embrace the Revolution*, http://www.embracewind.com/myths.html, visited 20/02/05.

- NATTA, *Renewable Energy in the UK*, http://www-tec.open.ac.uk/eeru/natta/natta-guide.html#wind, visited 31/01/05.

- OXERA, 2004, *Results of Renewables Market Modelling*, http://www.dti.gov.uk/energy/renewables/policy/oxeraresults.pdf, visited 20/02/05

- Yes to Wind, *Debunking the* Myths, http://www.yestowind.com/noisy_debunk.html, visited 13/02/05.

- US Department of Energy, 2003, *Advantages and Disadvantages of Wind* Energy, http://www.eere.energy.gov/windandhydro/wind_ad.html, visited 20/02/05.

- *Renewable Energy Systems*, 2003, http://www.res-ltd.com/meikle/intro.htm, visited 13/02/05

- The New Zealand Energy Association, 2004, *Wind Energy – an* Introduction, http://www.windenergy.org.nz/documents/040621-NZWEA-Intro_WindEnergy.pdf, visited 13/02/05