SUBMISSION FROM JANET GIBSON

TARGETS
Unrealistic, uneconomic in terms of carbon saving and finance, and unnecessary—see attachments. Targets should therefore be revised down.

CO2 emissions targets should be addressed with a new approach. Start with the simple. Examples include
USE REDUCTION
1. reduce use of electricity- e.g. Lower ambient temperature settings in public buildings, and public transport to 16-20deg C with average of 18deg C
2. introduce an electric appliance tax for frivolities such as hairdryers, except in swimming pools and hairdressers.
3. ban outdoor heaters
4. ban shops using heating whilst leaving the door open

EXTEND INSULATION
Think outside the box
Include sweaters- get the dress designers onside.
Houses could be designed with unheated glass corridors, conservatory etc on their outside walls.

DEVELOP A CULTURE OF EFFICIENCY
Do this by consensus instead of frightening people with doom and gloom statements – READ the book “COOL IT” by Bjorn Lomborg.

Reduce demand except for public transport. Stating an expected increased demand is not useful. Give people an allowance based on current demand and a higher charge if electricity use is increased, except for the elderly and infirm.

The public are paying for the targets. The carbon calculations are out of date and based on false premises being too reliant on models instead of on fact. More facts are now available – Please see references attached.

CHALLENGES
a) Technology
Not affordable. Lower the targets and stop trying to take the moral high ground. A large percentage of wind energy is not compatible with security, even when spare parts are still available from abroad, owing to constraints from the grid network – see attachments. We need nuclear energy for another generation to assist the National Grid if we are to save fossil fuels and reduce CO2 emission. Political constraints need to be addressed, including those from civil servants who are supposed to be neutral. Civil service knowledge is probably out of date. Carbon calculations need to be done again. As research using real data, as opposed to modelling, shows, wind energy is not as efficient as once thought.

Universities and research institutes should not be commercialised. Short term research involving vested interests always runs the risk of reducing standards. This is inadvisable in such a key area as energy. Instead the institutions high standards and findings should be used in a training and advisory capacity and as a desired
‘good example’. Add to this the building of Energy Research and Development Parks, campus style but away from the university research areas, which could be built and funded by the industries themselves, resulting in a synergistic environment.

b) Supply
What makes people believe that other countries will need energy from Scotland when those other countries have nuclear energy?

c) Planning
The planning system is not adequately resourced and is not fit for purpose because the Scottish Government overrules the democratic decisions and wishes of the population at regional level at appeals. All wind farm applications should include the route of National Grid connection saving time, energy (CO2 saving) and stress (CO2 health saving)

The increase in ill health due to the various attributes of wind energy should be included in the carbon dioxide calculations. This cause of ill health will increase owing to current policies and political ambition resulting in the dismissal of health concerns.

The gathering research on health issues connected to wind turbines being placed close to dwellings should be investigated and not dismissed, as is happening currently. In a similar fashion to the research and awareness raising which occurred in the tobacco industry the people will eventually discover the truth. Unfortunately the people are not being given the choice of avoidance of health hazards in the instance of wind energy. Litigation is increasingly being sought and it is all adding to the carbon cost. An instant 2km setback distance for turbines over 80m high would alleviate the position. Please see references attached.

Political ambition and status is the cause of much ill health in many countries of course. WHO guidelines and The Hippocratic Oath need to be enacted.

National Priorities & Local Interest
Local interests are also often national interests eg Tourism. Socially acceptable alternative energy sources should be developed eg photovoltaic solar power and ground source heat pumps, including a strong Scottish manufacturing, research and development base for socially acceptable technology in the suggested Energy Park. This would reduce the cost and increase efficiency and provide export.

d) Finance
Businesses in the Energy Park

e) Skills
Charge fees for fringe courses such as Media Studies and divert money to Science courses.

f) Subsidy
Reduce the socially unacceptable wind energy budget and tariffs and transfer financial support to other energies.
THE TARGETS SHOULD BE CHANGED. THERE IS TOO MUCH PANIC. IT IS UNNECESSARY. LISTEN TO THOSE CHALLENGING THE TARGETS AND THE REASONS WHY.

Civil servants, without a science and technology background, biased to the political ambitions of a government, undermines the finding of sensible solutions. Employing some ex-power company workers could help.

Janet Gibson
February 2012
A) EXECUTIVE SUMMARY.

a) The generation of electricity by onshore and offshore wind turbines is a major part of the U.K.’s drive to reduce carbon emissions.
b) The output from wind turbines is highly variable in the short term, and this intermittency of total wind output is accurately metered and recorded by the National Grid.
c) The UK Government, (D.E.C.C.) only record the electricity output produced by wind in a once monthly average figure. This completely ignores the major issue of intermittency, which produces the requirement for back up generation or storage, to effectively utilise the wind energy.
d) D.E.C.C. have no mechanisms in place to measure the actual carbon dioxide savings being achieved from generation by wind turbines, although there is growing evidence that the inefficient cycling of back up generators causes additional emissions of carbon dioxide, which may exceed the savings achieved by wind generation.
e) As short term output is not recorded, and onshore and offshore outputs are not separated in the National Grid data, it is not possible to determine whether offshore wind output is less intermittent and will produce more carbon savings than onshore.
f) In the absence of economical and practical large scale methods of energy storage, fossil fuel generators are required to cycle inefficiently to balance the variable wind load. and ensure a steady supply of electricity. A fall in efficiency of 5%, which will often result, produces additional carbon dioxide emissions, which will more than offset any reduction from wind generation.
g) Wind output in the U.K. frequently falls below 10% of installed capacity, requiring back up capacity of at least 90% of wind capacity to be readily available.
h) Spreading wind turbines over wide areas does not reduce variability. Experience over long periods from Germany, Western U.S.A. and U.K. indicate that wind and weather systems do not vary significantly over very large geographic areas.
i) A detailed study of data in Ireland of wind contribution, electricity demand and carbon dioxide emission figures shows that if no energy storage is available, carbon dioxide savings decrease with increasing wind contribution. This is confirmed by a major study in the U.S.A.
j) Major onshore wind developments have a major effect on the environment. To install 8GW of onshore wind capacity in Holland (to provide 10% of the required electricity ) would require 3 to 4,000 turbines and make 2,000 square km. or 6% of the Dutch land surface unfit for habitation.

B) INTRODUCTION.

The primary objective in the drive to increase the U.K. production of energy from renewable sources is to reduce carbon dioxide emissions, and hence arrest climate change. A major thrust in meeting this objective has been to encourage generation of electricity from renewable sources by providing subsidies (by Renewable Obligation Certificates) which are paid by electricity consumers through electricity prices.
Whilst the prime objective may be entirely desirable, it is incumbent on any government which pursues such an objective to put in place adequate provisions to measure the progress being achieved by its policies, relative to the costs borne by the consumer. In the case of wind energy, the U.K. Government has no measures in place to measure the actual reductions in carbon dioxide emissions being achieved by its costly (in both economic and environmental terms) support of wind generation installations. D.E.C.C. appears to hold the highly theoretical view that all electricity generated from wind turbines reduces carbon dioxide emissions equivalent to that which any displaced fossil fuel generator would have produced.

Whilst such an assumption may be valid for some renewable energy sources, the natural variability of wind results in very short term intermittency in the output of the installed wind capacity. In the absence of any suitable method of storing electricity, this requires equivalent “back up” or “spinning” fossil fuel capacity to be continuously available. This capacity is required to cycle up and down, following the rises and falls in wind output, and in doing so, has to operate outside its optimum steady state mode, producing significantly more carbon dioxide than when operating at its designed steady state.

The extent of the short term intermittency of wind output can be readily determined from the half hourly data posted on the NETA website www.bmreports.com, which covers the 4,006MW of wind capacity currently metered by the National Grid. (renewableUK claim a total of 5,970MW of wind capacity currently operated.) However, the D.E.C.C. persist in relying on a once monthly figure of wind output, obtained from surveys of producers and the claims for R.O.C.s submitted to OFGEM. Such a figure does, of course, totally miss the point, being an average of some 1460 half hourly pieces of data each month. This data graphically demonstrates the massive swings in wind output (e.g. a swing from 2,500MW to 500MW in 10 hours is not uncommon.) and that there are significant periods when total wind output is low (for 57 days in 2011, wind output was less than 10% of capacity). At the current time, the data does not distinguish between onshore and offshore, and it is not possible, therefore, to verify whether there are any differences in load factor or variability between onshore and offshore wind.

We, therefore, have a major element in the Government’s energy policy, intended to achieve significant reduction in carbon dioxide emissions, with the responsible Government Department making no attempt to measure how effective wind generation is in reducing such emissions. Further, there is a major initiative to greatly increase the number and size of offshore wind installations, without any meaningful evaluation of the likely saving in carbon emissions from such a major investment. Without clear data on the short term intermittency of both onshore and offshore wind, it is not possible to make any meaningful projection of the carbon savings from these forms of energy. It is unclear why a Government Department could so totally fail to measure one of its key objectives.

This note provides summary data on the variations in wind output in 2011 and summarises some recent work, which provides more realistic estimates of the likely carbon savings from wind generation. The work is, of necessity, technical, but the conclusions are clear and far-reaching, and it must be stressed that its conclusions
are based on firm data and some well established principles, and not on some newly developed and untried theory or model.

It is vital that the essential messages from this note are got over to a much wider body of policy makers, so that reviews and future decisions on energy policy, particularly any further use of wind energy, are based on sound science based evidence, rather than well meaning but highly theoretical dogma.

C) VARIATIONS IN WIND OUTPUT.

The extent to which the U.K. total wind output varies in the short term is well illustrated by the graph below, which shows the half hourly wind output throughout 2011 as metered by the National Grid and recorded on the web site www.bmreports.com

The extent to which total monthly average wind output varies, and falls below 5% and 10% of installed capacity is shown by the following table, which again uses the half hourly data from the National Grid. for 2011.

<table>
<thead>
<tr>
<th>Month</th>
<th>Installed Capacity MW (averaged over month)</th>
<th>Average Output MW</th>
<th>% Average Output</th>
<th>% Output &lt;5% Installed Capacity</th>
<th>Hours when Output &lt;5% Installed Capacity</th>
<th>% Output &lt;10% Installed Capacity</th>
<th>Hours when Output &lt;10% Installed Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2490</td>
<td>758.1</td>
<td>30.4%</td>
<td>2.7%</td>
<td>20.0</td>
<td>15.9</td>
<td>118.5</td>
</tr>
<tr>
<td>February</td>
<td>2662</td>
<td>973.2</td>
<td>36.6%</td>
<td>0.1%</td>
<td>1.0</td>
<td>6.0%</td>
<td>40.5</td>
</tr>
<tr>
<td>March</td>
<td>2862</td>
<td>709.0</td>
<td>24.8%</td>
<td>10.4%</td>
<td>77.5</td>
<td>26.1%</td>
<td>194.5</td>
</tr>
<tr>
<td>April</td>
<td>3226</td>
<td>917.7</td>
<td>28.4%</td>
<td>3.9%</td>
<td>28.0</td>
<td>20.8%</td>
<td>150.0</td>
</tr>
<tr>
<td>May</td>
<td>3317</td>
<td>1416.7</td>
<td>42.7%</td>
<td>0.1%</td>
<td>1.0</td>
<td>0.5%</td>
<td>4.0</td>
</tr>
<tr>
<td>June</td>
<td>3402</td>
<td>701.0</td>
<td>20.6%</td>
<td>4.4%</td>
<td>31.5</td>
<td>16.9%</td>
<td>122.0</td>
</tr>
<tr>
<td>July</td>
<td>3402</td>
<td>551.2</td>
<td>16.2%</td>
<td>20.5%</td>
<td>152.5</td>
<td>45.8%</td>
<td>341.0</td>
</tr>
<tr>
<td>August</td>
<td>3544</td>
<td>738.6</td>
<td>20.8%</td>
<td>11.2%</td>
<td>107.0</td>
<td>28.8%</td>
<td>238.5</td>
</tr>
</tbody>
</table>
Further details on metered wind output in 2011 are available from the author of this note.

D) WORK TO ASCERTAIN ACTUAL CARBON SAVINGS.

Examination of the graphs of wind output as metered half hourly by the National Grid (as summarised in C above ) clearly indicate that fossil fuel back up capacity will be required to run intermittently to balance out the wind output variations and ensure a steady supply of electricity. The random, wide variations in wind output in no way match the well recorded and largely predictable variations in total demand for electricity. The back up fossil fuel generators will thus produce significantly more carbon dioxide than they would if allowed to operate in the steady state mode for which they are designed.

Work has been carried out recently by three Dutch Scientists, Ir.Kees de Groot, Dr.Kees le Pair and Dr. Fred Udo, who have published five papers, in which they demonstrate that carbon savings from wind generation have been grossly exaggerated. All three are now retired and have had long and distinguished careers as scientists in industry, public technical organisations and academia, and are now independent of any organisation or pressure group. They argue for a much more realistic approach to evaluating the real carbon savings from the production of electricity by wind turbines.

The five papers are :-
1) The Hidden Costs of Wind Generated Electricity.
2) The Impact of Wind Generated Energy on Fossil Fuel Consumption
3) Wind Turbines as a Source of Electricity
4) Wind Energy in the Irish Power System
5) Electricity in the Netherlands

Further to these papers, the well respected Bentek Energy Consultancy of U.S.A. has recently (July 2011) produced a paper "The Wind Power Paradox" whose findings show that claims of carbon dioxide savings from the use of wind power are significantly overstated.

E) SUMMARY OF MAIN FINDINGS OF THE PAPERS.

The scope, source and the main findings of each of the papers is summarised, Further details may be obtained from the authors or by following the given link.

E.1. The Hidden Costs of Wind Generated Electricity.
http://www.clepair.net/windsecret.html
a) This study was based on publicly available data from German wind electricity production 2000 to 2008, where wind output was an average 17.5% of design capacity, spread over a large geographic area.
b) In one year, 2004, daily wind power varied from 0.2% to 38% of total power delivered to the German Grid, and as wind power always has priority when produced, to deal with low wind output, there must have been significant conventional power generators in stand by mode.
c) To cope with very low wind output, alternative generation capacity equivalent to at least 90% of the wind turbine design capacity must be provided. For now and the foreseeable future, these generators will be existing coal or gas, or new gas generators.
d) In Germany, no conventional power station has been decommissioned after installation of wind turbines, confirming that they are required as stand by capacity.
e) The stand by capacity has to reactively ramp up and down to follow the reverse of the wind output variability, causing extra wear and fuel use in the power stations.
f) When open-cycle gas turbines have to be started to achieve this, the efficiency of fuel conversion falls from the 55% of a modern conventional power station to the 30% of an open-cycle turbine.
g) Where conventional power stations are required to move from steady operation to back up wind generators, the efficiency will fall, and if this falls from 55% to 50%, no emission reduction or fossil fuel saving has been achieved.

**E.2. The Impact of Wind Generated Electricity on Fossil Fuel Consumption.**
[http://www.clepair.net/windefficiency.html](http://www.clepair.net/windefficiency.html)

a) This study uses data provided by the Dutch Institute for Statistics on the efficiencies of the various fossil fuel generators used in Holland,
b) This data is used to estimate the point where the efficiency reduction of conventional power stations balance out the fuel savings of wind turbines, and where the carbon dioxide emission reduction turns negative.
c) A reliable estimate shows that when the fall in efficiency is greater than 2%, there is no carbon dioxide reduction as a result of wind generation.
d) It recommends that detailed studies should be carried out to measure and confirm this ineffectiveness, and hence the additional carbon burnt, in the fossil fuel generators which are required to cycle up and down to balance the wide variations in wind generator output.
e) Wind generators must operate at design capacity factor (30%) for at least 1.5 years before the energy required for their fabrication, construction and erection, is recovered. There are further costs and energy requirements to put in place the extensive infrastructure of transformers and power lines required to link the wind generators to the Grid.
f) Economical and practical methods of energy storage are essential for the large scale application of wind energy for electricity production, which avoids the need for the inefficient operation of fossil fuel generators to balance the variable wind load. These methods are many years from being practically available, and to maximise carbon savings, further growth of wind generation should await such developments.

**E.3. Wind Turbines as a Source of Electricity.**
[http://www.clepair.net/windstroom%20e.html](http://www.clepair.net/windstroom%20e.html)
This paper concentrates on the situation in Holland but the points raised are entirely relevant to the U.K. (apart perhaps from item a))

a) To install 8GW of installed onshore wind capacity in Holland (to provide 10% of the required electricity) would require 3 to 4,000 turbines and make 2,000 square Km. or 6% of the Dutch land surface unfit for habitation. As some Provinces are not allowing further wind developments, this is likely to make the concentration in other Provinces even higher.

b) Power producers must know ahead of time what the wind velocity will be in order to regulate the output of conventional power stations to compensate for wind over or under supply. Research indicates that wind speed in the next 24 hours can be predicted within 10% accuracy, but this leads to a 30% uncertainty in the forecast of energy production. The requirement for gas “spinning reserve” generators to cover this will require additional gas power stations and gas pipelines.

c) Spreading the wind generators over wide areas (such as the whole of Germany) does not eliminate wind variability. This is confirmed by experience of wind outputs in Germany over a long period – this demonstrates that weather systems are larger than Germany! There has been similar experience from western USA, and there is clear evidence that total UK wind output varies widely across the whole country in the short term.

e) It seems likely that it would be uneconomical for wind energy to contribute more than 5% of Dutch peak electricity demand due to the intermittency of wind and inefficient operation of back up generators. This is supported by studies based on actual carbon emissions from Colorado, Denmark and Ireland.

f) Studies of the lowest power output that must be kept available in the Dutch electricity supply system, (“must-run power level”) shows that during low demand levels this matches demand, and there is no room for wind energy. This is borne out by Danish experience, where about half the wind generated electricity is exported to Sweden, at a nominal price, and when wind cannot deliver, electricity is purchased from Norway at a premium price!

g) Power Duration Curves are used by electricity grid operators to balance supply and demand. Using these Curves and actual wind data as recorded by the Dutch Meteorological Institute, it can be seen that for about 40% of the time, the Dutch Grid will be unable to accommodate the 12GW target wind power in 2020, without severe throttling back of conventional power stations. These stations must remain ready and operational, but will be forced to work at minimal levels for half the year to accommodate wind power when it is available.

E.4. Electricity in the Netherlands.
http://www.clepair.net/windSchipol.html

a) This study looks further into the variations in the thermal efficiencies of conventional generators, by developing “heat rate curves” for each type of generator describing how its efficiency varies with required output.

b) It is made clear that the rapid variations in wind output rule out coal and nuclear as back up to wind in the longer term, as they cannot be ramped up and down sufficiently fast to follow the cycling of wind. This leaves CCGT (combined cycle gas turbines) and OCGT (open cycle gas turbines) but there are very significant reductions in carbon savings when running both these at less than design capacity.

c) OCGTs are more readily used when rapid power changes are required – as when augmenting wind. However, these are significantly less efficient running at design
power than CCGTs (32% compared to 60% for CCGT) and become even less efficient when running at less than design capacity.

d) Modelling for different wind contributions (100MW, 200MW and 300MW) in tandem with a 500MW modern gas fired plant, shows that carbon dioxide savings are likely to be negative. This allows for the necessary cycling of the gas unit to match wind variations.

e) Wind projects do not fulfil sustainable objectives. They cost more fuel than they save and do not reduce total carbon dioxide emissions.

**E.5. Wind Energy in the Irish Power System.**
http://www.clepair.net/IerlandUdo.htm

a) This study uses actual data from Eirgrid, the electricity transmission operator for Ireland, to study the influence of wind energy on a conventional generation system by using real time data taken every 15 minutes, on total electricity demand, wind energy and carbon dioxide emission from the conventional generators.

b) The amount of carbon dioxide produced (g/KWh) is calculated by using each generators output in MW, heat rate curves for each power station and the calorific value of the fuel used. Scatter diagrams are produced to show the correlation between carbon dioxide production and wind penetration as a percentage of electricity demand.

c) Analysis of the scatter diagrams shows that carbon dioxide emissions rise as wind penetration increases, so that when wind power was 30% of total demand, carbon dioxide emissions only fell by 3%, and at lower wind penetration are also significantly lower than claimed.

d) If allowance were to be made for the energy necessary to ramp the conventional power stations up and down, and the additional power losses in the extra transmission lines necessary, it is likely that wind turbines are causing an increase in carbon dioxide emissions.

e) The introduction of wind energy without buffer storage leads to increased fossil fuel use and carbon dioxide emissions.

**E.6. The Wind Power Paradox.**
A Market Alert from the major U.S. Energy consultancy BENTEK Energy. (July 2011)

a) The independent study uses actual emissions data from the U.S. Environmental Protection Agency, from four regional power agencies across the U.S.A over a 3 year period, 2008-2010.

b) Detailed hourly data on wind generation from plants in the four regions is used to model the interaction between wind, coal and natural gas-fired generation and the resulting changes in emissions in response to wind generation.

c) The study consists of 300,000 data points including actual wind, coal and gas generation and emissions data from the E.P.A.

d) When power plants are cycled to accept wind energy, the plants run less efficiently leading to significant emissions and higher plant maintenance costs.

e) Equal or greater emissions reductions could be achieved at lower cost and greater reliability by replacing existing coal-fired power stations with natural-gas generation.

f) The study does not rely on the previous despatch models, which make numerous unit level assumptions on generation costs, demand and emission rates. Its conclusions reflect on what actually happened in each system.

g) The Report calls for a fundamental re-assessment of wind energy as an emission control strategy.
h) Recent reports from M.I.T., (Massachusetts Institute of Technology) express concern that costs of cycling conventional generators to accommodate wind turbine variability and the costs of transmission systems to feed wind electricity to consumers need greater evaluation.

Ian Murdoch.
January 2012.
Wind turbines at night: acoustical practice and sound research

Frits G.P. van den Berg

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Sound levels near a wind turbine park at night were much higher than expected. This is caused by strong winds at hub height especially when at ground level there is little wind, as is quite usual at night. This common and wellknown meteorological effect has not yet been recognized with respect to wind turbine noise. To determine turbine sound power levels we had to deviate from the recommended standard measurement procedure. Without park operator co-operation it was impossible to operate just one turbine or no turbine at all. Also a hard, reflective board as recommended was impractical or impossible to use. Impulsiveness is usually determined with a single turbine in operation. We conclude that sound pulses, not clearly audible in the wind park itself, are caused by the interaction of several turbines. The case described here shows that calculation models should regularly be checked for correctness, especially in new situations/applications and where a strong community reaction may indicate a model does not cover reality. We also recommend that it must always be possible to check calculated immission levels by immission measurements, with or without operator co-operation. This does not only apply to the case of wind turbines. Although standard procedures are necessary and useful, a negative effect is it makes citizens more dependent on experts. The cost of access to expertise is an important threshold to objective judgement.

1. INTRODUCTION

In 2001 the German wind park Rhede was put into operation just 400 m from the Dutch border. Local authorities as well as residents at the Dutch side had opposed the construction of the 17 wind turbines because of the effects on landscape and environment: with 98 m hub height the 1.8 MW turbines would dominate the skyline of the early 20th century village of Bellingwolde and introduce noise in the quiet area. With the turbines in operation residents at 500 m and more from the wind park found the noise (and flicker shadow, which will not be dealt with here) worse than they had expected. The wind park operator declined to take measures as acoustic reports showed that German as well as Dutch noise limits were not exceeded. When the residents brought the case to a German court, they failed on procedural grounds. For a Dutch court they had to produce arguments that could only be provided by experts.

Science Shops are specifically intended to help non-profit groups by doing research on their behalf. For the Science Shop for Physics in Groningen noise problems constitute the majority of problems that citizens, as a group or individually, come up with. Although the aim of sound research is the same as for acoustic consultants—-to quantify sound levels relevant for annoyance—the customers are different:
consultants mostly work for the party responsible for the sound production, whereas the Science Shop mostly works for the party that is affected by the sound. This may lead to different research questions. In the case of wind park Rhede a consultancy will check the sound production of the turbines and check compliance of the calculated sound immission level with relevant limits. The Science Shop however, taking the strong reaction from the residents as a starting point, wanted to check whether the real sound immission agrees with the calculated one and whether sound character could explain extra annoyance.

Earlier we showed in a Dutch magazine, on the basis of 30 acoustic reports, that acoustic consultants tended to rely too much on information from their customers, even when they had reason to be critical about it [8]. As consultant's customers are usually noise producers and authorities: the point of view of those that are affected by noise is not usually very prominent. The present paper shows that for wind turbines a similar case can be made.

2. RESULTS FROM THE WIND PARK RHEDE

The results of the investigation of the sound from the wind park Rhede are given in a Dutch report and an English paper presented to the JSV [1, 2] (there are efforts to produce a German translation of the report). Here the results will be dealt with briefly. The main cause for the high sound level perceived by residents is the fact that wind speeds at night can, at 100 m height, be substantially higher than expected. For acoustic purposes prediction of the wind speed at hub height is based on the wind speed vref at the reference height for wind speed measurements (href = 10 m), extrapolated to a wind speed vh at height h with the well known and widely used formula for the logarithmic wind profile: \( \text{vh} = \text{vref} \cdot \frac{\log(h/z)}{\log(href/z)} \). This profile may be used only implicitly when the relation between turbine sound power level and vref valid for daytime conditions is used for night time conditions. The logarithmic profile depends only on roughness length z, not on atmospheric conditions. It should be valid for a neutral, i.e. heavily overcast and/or very windy atmosphere, not for a stable atmosphere as is usual in night time. At night, given a specific wind speed at reference height, the wind speed at greater heights will be higher than expected from the logarithmic profile (or rather: given a specific high wind, the wind speed at lesser heights is lower). A well known observation is that at night the wind subsides. This is not caused by high, geostrophical winds (as these are not determined by diurnal influences but by the distribution of high and low pressure areas) but by atmospheric stability caused by radiative cooling. When at night cooling sets in the wind speed close to the ground is indeed reduced and the wind speed at hub height is higher than expected from the logarithmic wind profile. As a consequence a wind turbine produces more sound then expected from the wind speed at reference height. As measured immission levels near the wind park Rhede show, the discrepancy may be very large: sound levels are up to 15 dB (!) higher than expected at 400 m from the wind park. At a distance of 1500 m actual sound levels are 18 dB higher than expected, 15 dB of this because of the higher sound emission and 3 dB because sound attenuation is less than predicted by the sound propagation model. The important point is not so much that the maximum measured sound level is higher than the maximum expected sound level (it was, around +2 dB, but this was not an effect of the wind speed profile). The point is that this maximum does not only occur at high wind speeds as expected, accompanied by high wind
induced ambient sound levels, but already at relatively low wind speeds (4 m/s at 10 m height) when there is little wind at the surface and therefore little wind induced background sound. Thus, the discrepancy of 15 dB occurs at quiet nights, but yet with wind turbines at almost maximum power. This situation occurs quite frequently.

A second effect that adds to the sound annoyance is that the sound has an impulsive character. The primary factor for this is the well known swishing sound caused by the pressure fluctuation when a wing passes the turbine mast. For a single turbine these 1 – 2 dB broad band sound pressure fluctuations would not classify as impulsive. When several turbines operate nearly synchronously the pulses however may occur in phase: two equal pulses give a doubling in pulse height (+3 dB), three a tripling (+5 dB). Several low magnitude pulse trains thus cause sound with an unexpected, relatively strong impulsive character whenever they synchronise. The sound then resembles distant pile driving or, as a resident said: ‘an endless train’. Synchronisation here refers to the sounds that the wind turbines contribute at the immission point. In the wind park we never heard the impulsiveness.

3. EARLY WARNINGS OF NOISY WIND TURBINES?

One may wonder why the strong effect of the nightly wind profile or the pulselike sound was not noticed before. In the 1998 publication IEC 16400 again only the neutral logarithmic wind profile is used [3]. And even in 2002 a Dutch report stated in a general way that wind turbine sound is not impulsive [7]. There have been some warnings. For example, in 1998 Rudolphi concluded from measurements that wind speed at 10 m height is not a good measure for the sound level: at night the (58 m hub height) turbine sound level was 5 dB higher than expected [4]. Since several years residential groups in the Netherlands, and probably abroad as well, complained about annoying turbine sound at distances where they are not even expected to be able to hear the sound. Recently Pedersen et al found that annoyance was relatively high at (calculated!) sound immission levels below 40 dB(A) [5] where one would not expect strong annoyance. As wind turbines become taller, the discrepancy between real and expected levels grows and as more tall wind turbines are constructed complaints may become more widespread. In the Netherlands residents near the German border were (apart from one single tall turbine elsewhere) the first Dutch to be acquainted with turbines of 100 m hub heights.

It may be that earlier discrepancies between real and projected sound immission were not sufficient to evoke strong community reactions and that only recently turbines have become so tall that the discrepancy now is intolerable. There are other reasons that early warnings perhaps did not make much impression. One is that sound emission measurements are usually done in daytime. It is hard to imagine the sound would be very different at night time, so (almost) no one did. Until some years ago, I myself could not imagine how people could hear wind turbines 2 km away when at 300 to 400 m distance the (calculated) immission level was, for a given wind speed, already equal to the ambient background sound level (L95). What is probably also a reason is the rather common attitude that ‘there are always people complaining’. Complaints are a normal feature, not a reason to re-investigate. Indeed Dutch noise policy is not to prevent any noise annoyance, but to limit it to acceptable
proportions. Added to this is a rather general conviction of Dutch authorities and consultants that routine noise assessment in compliance with legal standards must be correct. If measurements are performed it is to check actual emission levels – usually in normal working hours, so in daytime. It is quite unusual to compare the calculated sound immission from a wind turbine (park) with measured immission levels (so unusual that it is likely that we were the first to do so). A third reason may be partiality to the outcome of the results. Wind turbine operators are not keen on spending money that may show that sound levels do not comply with legal standards. And if, as expected, they do comply, the money is effectively wasted. Apart from this, we have the experience that at least some organisations that advocate wind energy are not interested in finding out why residents oppose wind parks.

4. THE USE OF STANDARD PROCEDURES

Although our objective was to measure immission sound levels, we also wanted to understand what was going on: if levels were higher than expected, was that because emission was higher or attenuation less? We therefore also measured sound emission as a function of rotational speed of the variable speed turbines. An interesting point that came up with the emission measurement was that compliance with the used standard [6] was impossible. As the park operator withdrew the cooperation that was previously promised, we had to measure emission levels with the full park in operation, as we obviously did not have the means to stop all turbines except the one to be measured, as the standard prescribes. To measure ambient background sound level, even the last turbine should be stopped. In compliance with the standard the emission should be measured within 20% of the distance to the turbine equal to hub height + wing span. However, to prevent interference from the sound from other turbines the measurement location had to be chosen closer to the turbine. The primary check on the correctness of the distance (i.e. not too close to other turbines) was by listening: the closest turbine should be the dominant source. If not, no measurement was done, and usually a measurement near another turbine was possible. Afterwards we were able to perform a second check by comparing the measured sound immission of the wind park at a distance of 400 m with the level calculated with a sound propagation model with the measured emission level of all (identical) turbines as input. The calculated difference between a single turbine sound power level and the immission level was 58.0 dB (assuming a constant spectrum this is irrespective of the power level itself). The measured average difference was 57.9 dB, with a maximum deviation of individual measurement points of 1.0 dB. In fact, from our measurements one may conclude that, to determine turbine sound power level, it is easier and cheaper to measure total sound emission at some distance from a wind park then measuring separate turbines. And in many nights the wind induced ambient sound, that easily spoils daytime measurements, is not an important disturbance!

Using a 1 m diameter round hard board, in compliance with the standard, was quite impractical and sometimes impossible. E.g. in one place potato plants would have to be cleared away, in another one would have to create a flat area in clumps of grass in a nature reserve, both unnecessarily. Instead of the large board we used the side (30x44 cm$^2$) of a plastic sound meter case. We convinced ourselves that this was
still a good procedure by comparing sound levels measured on the case on soft
ground with sound levels measured just above a smooth tarmac road surface a few
meters away, both at the same distance to the turbine as in the other measurements:
there was no difference.

Whether a turbine produces impulsive sound is determined by listening to and
measuring the sound near a single turbine (along with measurements to determine
sound power and spectral distribution). In the Netherlands impulsivity is judged
subjectively (by ear), not by a technical procedure as in Germany. Interestingly, in
Dutch practice only an acoustician’s ear seems reliable, though even their opinions
may disagree. Judgement can be supported with a sound registration showing the
pulses. From our measurements the impulsive character can be explained by the
interaction of the sound of several turbines. Even at a time the impulsive character
can be heard near residents’ dwellings, it cannot (never?) clearly be heard close to
the turbines in the wind park. So here also there was need to do measurements
where people are actually annoyed, and not to rely on source measurements only,
certainly not from one turbine.

When noise disputes are brought to court, it is clearly advantageous to have
objective procedures and standards to assure that the technical quality, which can
hardly be judged by non experts, is sufficient and therefore the results are reliable. In
the case made here a standard may however be non-applicable for valid reasons.
Already however the emission measurements are contested on procedural grounds
(viz. we have not complied to the standard). As a matter of fact the immission sound
levels were the primary research targets and we did not really need the sound
emission measurement results, so the opposition does not seem very relevant.

The tendency to put all noise assessment into technical standard procedures has the
disadvantage that it is hardly possible for non experts, such as residents, to bring
other arguments to court. They, the annoyed, will have to hire an expert to objectify
their annoyance. This is not something every citizen can afford.

5. MODELLING VERSUS MEASUREMENTS

Being able to calculate sound levels from physical models is certainly a huge
advantage over having to do measurements (if that, indeed, is possible) especially
as in practical situations conditions keep changing and other sounds disturb the
measurements. Because of its obvious advantages models have become far more
important for noise assessment than measurements. In the Netherlands usually
sound emission measurements are carried out close to a source to determine sound
power levels. Then, with the sound power level, the immission level is calculated,
usually on façades of residences close to the sound source. It is not common to
measure immission levels in the Netherlands; in some cases (e.g. railway, aircraft
noise) there is not even a measurement method (legally) available to check
calculated levels.

A physical model however is never the same as reality. As was shown above, the
widely used model for sound production from wind turbines is implicitly based on a
specific wind profile. This profile is not correct at night, although the night is the
critical period for wind turbine noise assessment. Also attenuation with distance is overestimated for distances over 0.5 km. Even a perfect physical model will not reproduce reality if input values are not according to reality. An example is to apply sound power levels from new sources (cars, road surfaces, aeroplanes, mopeds, vacuum cleaners, etc.), maybe acquired in a specific test environment, to real life situations and conditions. In a wind park south of the wind park Rhede a turbine produced a clearly audible and measurable tonal sound, probably caused by a defect on a wing. It is very hard for residents to convince the operator and authorities of this annoying fact, partly because all experts say that modern wind turbines do not produce tonal sound. Incorrect models and incorrect input may well occur together and be difficult to separate. It should be important that calculation models are regularly checked for correctness. Situations where (strong) complaints arise may indicate just those cases where models do not cover reality.

6. CONCLUSION

In modelling wind turbine sound very relevant atmospheric behaviour has been ‘overlooked’. As a consequence, at low surface wind speeds such as often occur at night, wind turbine noise immission levels may be up to 15 or 18 dB higher than expected. The discrepancy between real and modelled noise levels is greater for tall wind turbines. International models used to assess wind turbine noise on dwellings should be revised for this atmospheric effect. A discrepancy between noise forecasts and real noise perception, as a result of limited or even defective models, cannot always be avoided, even not in principle. Its consequences can however be minimised if immission levels are measured at relevant times and places. This relevancy is also determined by observations of those affected. It should always be possible to check noise forecasts by measurement. For wind turbine noise (and other noise sources) standard measurement procedures require cooperation of the operator to be able to check emission sound levels. This introduces an element of partiality to the advantage of the noise producer. This is also generally a weak point in noise assessment: the source of information is usually the noise producer. There should always be a procedure to determine noise exposure independent of the noise producer.

Standard technical procedures have the benefit of providing quality assurance: when research has been conducted in compliance with a standard procedure lay persons should be able to rely on the results. It may however also have a distinct disadvantage for plain people opposing a noise source: when an assessment is not in agreement to a standard procedure is may not be accepted in court, regardless of the content of the claim. A negative side effect is the resulting dependency on legal as well as acoustical experts. If citizens are forced to use expert knowledge, one may argue that they should be given access to that knowledge. An important threshold is the cost of that access.

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Wind energy in the Irish power system.
Fred Udo.

Abstract.
This article describes the influence of wind energy on the CO\textsubscript{2} output of the fossil-fired generation of electricity in Ireland. Where most available publications on this subject are based on models, the present study makes use of real-time production data. It is shown, that in absence of hydro energy the CO\textsubscript{2} production of the classical generators increases with wind energy penetration. The data shows that the reduction of CO\textsubscript{2} emissions is at most a few percent, if gas fired generation is used for balancing a 30% share of wind energy.

1. Introduction.
The claims, that large wind energy plants will be an important factor in the "green energy transition" have never been substantiated by studies based on facts about reduced CO\textsubscript{2} emission or fossil fuel consumption. There is enough reason for doubt, as wind energy is chaotic and its production is uncorrelated with the demand for electricity, which follows a regular day/night pattern. Wind electricity has priority over the conventional sources of electricity in most grids, which means the other generators have to compensate for wind surges or ebbs, but: No wind means no wind energy. As a consequence no fossil-fired plant has been closed after the recent large-scale build up of wind energy in Europe.

Wind energy has become a multi-billion dollar business financed by large amounts of public funds, despite the above-mentioned problems and uncertainties. The interaction of wind energy with fossil-fired electricity generators could up till now only be discussed with the help of models.\textsuperscript{1,2} The reason is, that real-time operations data is kept away from the public. On one occasion independent researchers got access to the real-time operations data. The result is the Bentek study\textsuperscript{3} about the introduction of wind energy in the Colorado and Texas systems. The Bentek study shows, that wind energy plays havoc in systems dominated by coal generation. Model studies pleading the case of wind are among the Delft group\textsuperscript{4,5} and others.

Semi-empirical studies of wind energy were performed by Post\textsuperscript{6,7} and Sharman\textsuperscript{8,9}. Both authors emphasise the disastrous financial consequences of large quantities of wind energy and show, that above about 10% contribution of wind energy one encounters a new phenomenon: curtailment. This occurs when demand is low and the production of wind energy is high. In that case wind turbines have to behave like any other supplier of electricity, namely to adjust the production to the demand. Clearly this phenomenon affects the already poor efficiency of wind turbines.

EirGrid, the Electricity Transmission Operator in Ireland, offers now the second occasion after the Colorado case to study the influence of wind energy on a classical generator system on the basis of real data. The Irish grid operator provides real time data about the total demand for electricity, the wind energy and the CO\textsubscript{2} emission on a ¼ hour basis. The website www.eirgrid.com contains all this data from November 2010 to this day.

This study analyses the empirical data of Eirgrid to show the effects of wind energy on the CO\textsubscript{2} emission of a fossil-fired generator park, which is mainly based on gas. The website of EirGrid does not provide detailed data about the use of hydro energy, so hydro energy could not be incorporated in this analysis.

After the description of the Irish system and the data provided on the website, chapter 3 and 4 analyse the data of April and June 2011 in detail. These periods are chosen, because of the near absence of hydro energy during those months.
2. Description of the data
In 2010 the Irish electric grid used the following fuel mix:

![Fuel Mix 2010 Year-to-date](image)

The installed capacity mix is: 6,750 MW fossil, 1,500 MW wind, 250 MW hydro
The 7 GW of traditional capacity is only very partly used, as the average demand is normally between 3 and 4 GW.

Notes:
- The “9.8% wind” is energy, not installed capacity.
- During periods of low rainfall, hydro energy is minimal.

The Irish grid publishes the following system operating data: CO₂ emissions, total electricity demand and wind energy production every 15 minutes.
The energy production of the other sources, such as hydro, can only be estimated from the monthly totals posted on the site of EirGrid.

The following is a direct quote from the site of EirGrid:

“EirGrid, with the support of the Sustainable Energy Authority of Ireland, has developed together the following methodology for calculating CO₂ Emissions.

The rate of carbon emissions is calculated in real time by using the generators MW output, the individual heat rate curves for each power station and the calorific values for each type of fuel used. The heat rate curves are used to determine the efficiency at which a generator burns fuel at any given time.

The fuel calorific values are then used to calculate the rate of carbon emissions for the fuel being burned by the generator. “

Note 1:
The heat rate degradation due to ramping down the fossil-fired plants with wind energy surges and ramping up with wind energy ebbings is not accounted for in the calculations of EirGrid.  
*This means the CO₂ emissions posted on the site are understated.*

Note 2:
The total CO₂ emissions are presented in tons. The specific emissions of fossil burning are called the CO₂ intensity. The CO₂ intensity is expressed in g/kWh.
Table 1 presents an overview of the data.

<table>
<thead>
<tr>
<th>Month</th>
<th>Demand</th>
<th>Wind+hydro</th>
<th>Wind</th>
<th>Wind %</th>
<th>Hydro</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GWh</td>
<td>GWh</td>
<td>GWh</td>
<td></td>
<td>GWh</td>
</tr>
<tr>
<td>nov-10</td>
<td>2324</td>
<td>400</td>
<td>298</td>
<td>13,3</td>
<td>102</td>
</tr>
<tr>
<td>dec_2010.</td>
<td>2555</td>
<td>270</td>
<td>216</td>
<td>8,5</td>
<td>54</td>
</tr>
<tr>
<td>jan_2011</td>
<td>2434</td>
<td>354</td>
<td>248</td>
<td>10,2</td>
<td>106</td>
</tr>
<tr>
<td>feb</td>
<td>2188</td>
<td>443</td>
<td>369</td>
<td>16,9</td>
<td>74</td>
</tr>
<tr>
<td>maart</td>
<td>2241</td>
<td>256</td>
<td>183</td>
<td>8,2</td>
<td>73</td>
</tr>
<tr>
<td>april</td>
<td>2027</td>
<td>256</td>
<td>241</td>
<td>11,9</td>
<td>15</td>
</tr>
<tr>
<td>mei</td>
<td>1913</td>
<td>551</td>
<td>510</td>
<td>26,7</td>
<td>41</td>
</tr>
<tr>
<td>juni</td>
<td>1953</td>
<td>259</td>
<td>232</td>
<td>11,9</td>
<td>27</td>
</tr>
<tr>
<td>juli</td>
<td>1913</td>
<td>200</td>
<td>173</td>
<td>9,2</td>
<td>27</td>
</tr>
<tr>
<td>aug.</td>
<td>1935</td>
<td>204</td>
<td>182</td>
<td>9,4</td>
<td>22</td>
</tr>
</tbody>
</table>

It appears, that the drought in the first half of the year 2011 has adversely affected the use of hydropower in the months April to June 2011. This enables us to study the CO$_2$ emissions in absence of hydropower.

The utilisation of the pumped hydropower station is during 2011 affected by a renovation of the installations.

3. Analysis of the June 2011 period.
The total energy demand was 1970 GWh, on average 2,74 GW.
The wind production was 232 GWh, the sum of the 1/4-hour data.
The wind energy contribution was 232/1970 = 11.8% in this month.
Figure 2 shows the time correlation between CO$_2$ intensity as g/kWh and the wind energy penetration as % of the total demand.
The CO$_2$ intensity is divided by 10 in order to fit the two lines on one scale.

![Figure 2](image)
The horizontal scale represents the 30 days in June subdivided into 1/4-hour periods.
The graph shows some correlation between wind energy and CO$_2$ emissions.
The CO$_2$ intensities shown above include wind and hydro energy.
The next step is to subtract the wind energy from the total demand and recalculate the CO$_2$ intensities (CO$_2$conv) due to the conventional generators. This also should be done for the hydro energy but the 1/4-hour data are not posted. However, the hydro energy influence may be ignored for this month, as it is only 0.8% of the total energy demand. See Table 1.
During a day the wind per cent contribution changes because of variation of the wind, but also because of the daily variation in demand. This implies, that wind penetration can be defined for every 1/4 hour as the wind energy divided by the total electricity demand. A scatter diagram is best suited to investigate the correlation between the CO₂ production and the wind penetration: figure 3

**Figure 3**

The data at low wind penetration shows, that the fuel mix has been switched from gas to coal/peat several times during this month. Subdivision of the data in smaller periods gives a better impression of the correlation.

**Figures 4 and 5** show the first 10 days of the month.
The trend of increasing CO2 with wind penetration becomes clear. The data behaves very different from period to period, so quantitative conclusions cannot be drawn from the June data.

4. Analysis of the April 2011 data
The April data are even better suited for investigating the influence of wind power on a conventional system without storage, because Table 1 shows, that the contribution of hydropower was only 0,7% that month.
The contribution of wind to the total electricity production is 12,4% in April.
This amount is a little higher than the year average of 9,8% wind energy.

The CO2 intensities for the 30 days of April 2011 are:
Including wind energy: 418 g/kWh  this is the average of the CO2 intensities posted by Eirgrid.
Without wind energy: 477 g/kWh  this is the average CO2 intensity divided by one minus the wind penetration or 418/(1 – 0,124) = 477 g/kWh.

Figure 6 gives the time diagram of the total demand and the total wind production.

Figure 7 shows the CO2 intensity of the fossil-fired plants as a function of the wind penetration for the whole month of April.
This diagram shows a clear correlation between CO₂ intensity and wind contribution. The CO₂ intensity varies between 300 and 600 g/kWh at low wind contributions. This variation in CO₂ intensity indicates, that during the month different configurations of the available generators have been used. The fit equation shows, that in the absence of wind the CO₂ intensity is 436 g/kWh. The CO₂ intensity averaged over April is 418 g/kWh. This number is directly extracted from the Eirgrid data.

The net effect of 12.4% wind is a decrease of the CO₂ intensity from 436 to 418 g/kWh in April. **Twelve per cent wind causes a reduction of the CO₂ emission by 4%**. The CO₂ reduction is one third of the reduction expected for this share of wind energy.

This conclusion can be refined by splitting the month into periods of one or two days, as the utilisation of the fossil fired generators will not drastically be altered within such a short timespan. The first week had a wind energy contribution of 28% and one had to use mainly gas as backup. This statement is based on the results of the subsequent analysis. Figure 8 shows the CO₂ intensity from the fossil-fired plants for the first two days in April.

The average CO₂ intensity from the data in figure 8 is 547 g/kWh. The contribution from wind is 28%, so the CO₂ intensity calculated over fossil plus wind is

\[ 547 \times (1 - 0.28) = 394 \text{ g/kWh} \]

The fit tells us, that without wind the production of CO₂ would be 398 g/kWh.
The effect of 28% wind power is a decrease of the emission from 398 to 394 g/kWh. (-1%)

The next two days show an even higher share of wind: 34%

The average CO₂ intensity calculated from the data points in figure 8 is 551 g/kWh. The wind contribution is 30%, so the CO₂ intensity calculated over fossil plus wind is: 
551x(1 – 0,30) = 386 g/kWh.
We obtain from the fit at x = 0: 398 g/kWh.

The presence of 30% wind power has decreased the CO₂ emission from 398 to 386 g/kWh. (-3.0%)
5. The period from November 2010 to August 2011

The analysis as described above has been applied to all the data available on eirgrid.com. The results are presented in table 2.

Table 2.

<table>
<thead>
<tr>
<th>Month</th>
<th>Wind (%)</th>
<th>CO2 avg. g/kWh</th>
<th>zero wind g/kWh</th>
<th>CO2 conv g/kWh</th>
<th>Saving (%)</th>
<th>Wind eff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>nov-10</td>
<td>13,3</td>
<td>475</td>
<td>528</td>
<td>549</td>
<td>10</td>
<td>75</td>
</tr>
<tr>
<td>dec_2010</td>
<td>8,5</td>
<td>481</td>
<td>525</td>
<td>529</td>
<td>8</td>
<td>95</td>
</tr>
<tr>
<td>jan_2011</td>
<td>10,2</td>
<td>433</td>
<td>478</td>
<td>486</td>
<td>9</td>
<td>88</td>
</tr>
<tr>
<td>feb</td>
<td>17</td>
<td>426</td>
<td>495</td>
<td>510</td>
<td>14</td>
<td>83</td>
</tr>
<tr>
<td>maart</td>
<td>8,2</td>
<td>513</td>
<td>536</td>
<td>562</td>
<td>4,6</td>
<td>56</td>
</tr>
<tr>
<td>april</td>
<td>11,9</td>
<td>418</td>
<td>450</td>
<td>480</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td>mei</td>
<td>26,7</td>
<td>381</td>
<td>445</td>
<td>517</td>
<td>14</td>
<td>53</td>
</tr>
<tr>
<td>juni</td>
<td>11,9</td>
<td>436</td>
<td>484</td>
<td>498</td>
<td>10</td>
<td>84</td>
</tr>
<tr>
<td>juli</td>
<td>9,2</td>
<td>488</td>
<td>537</td>
<td>537</td>
<td>9</td>
<td>98</td>
</tr>
<tr>
<td>aug.</td>
<td>9,4</td>
<td>462</td>
<td>486</td>
<td>516</td>
<td>4,9</td>
<td>52</td>
</tr>
<tr>
<td>Average</td>
<td>12,7</td>
<td>451,3</td>
<td>496,4</td>
<td>518,4</td>
<td>8,7</td>
<td>72</td>
</tr>
</tbody>
</table>

The three columns are all three CO$_2$ intensities. CO$_2$ avg is the emission as given by the EirGrid tables. "Zero wind" means CO$_2$ emissions extrapolated from the correlation diagrams to zero wind contribution. The wind efficiency is defined as the saving of CO$_2$ in % divided by the amount of wind in %.

The time sequence of this number looks as follows:

![Efficiency of wind energy](image)

Figure 11 The time sequence of the wind efficiency

There are 4 months with a particularly low wind efficiency: March, April, May and August.
Three out of four have a low contribution of hydro energy and fall in the dry period of the year.
The average CO$_2$ emissions of the Irish power system for 2009 was 533g/kWh.
This is considerably higher than the number derived from the tabular data: 451g/kWh is the average emission calculated directly from the tables of Eirgrid.

6. Conclusions and remarks.
The availability of very detailed data series in Ireland on wind contribution, electricity demand and the CO$_2$ emission figures (calculated as a function of static heat rates of the power stations) has finally enabled a facts based analysis of the maximal emission and fuel saving effected by wind generated electricity.
Unfortunately the role of hydro energy could not be isolated from the data. Currently the combination of wind energy with gas turbines is seen as the ideal configuration to deal with the problem of the fluctuations of wind energy. 

*The April data of the Irish electricity system shows clearly, that the combination of wind energy with gas turbines does not achieve the goal of CO$_2$ emission reduction, if no storage of energy is present. In general it is shown that the CO$_2$ saving decreases with increasing wind contribution to the electricity supply.*

The consequence is that an investment of billions of Euros in wind turbines produces not more than a few per cent reduction in CO$_2$ output.

This analysis does not take into account the energy necessary to ramp the conventional generators up and down nor the energy to build wind turbines nor the extra transmission lines with their additional losses. It is highly probable, that taking all these effects into account will show, that the few per cent gain in CO$_2$ will revert to a loss (i.e. an increase in CO$_2$).

*The Irish system performs slightly better in other months probably due to the greater contribution of hydropower, but it never comes near to the promises made by wind energy advocates. This study shows, that building wind turbines without constructing adequate storage of energy is futile. It only leads to high extra costs and hardly any fuel or emission saving. Therefore, the introduction of wind energy without buffer storage leads to increased fossil fuel use and CO$_2$ emissions and is a non-sustainable practice.*

**Acknowledgements.**

Thanks are due to Hugh Sharman who suggested the use of correlation diagrams to analyse the data and Willem Post who kindly did the editing of the text.

Monnickendam, August 29 2011.

Revised September 21 2011.

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Low Wind Power Output in 2010: An Information Note

Background
In today’s *Times* (02.02.11) it is reported that Scottish and Southern Energy (SSE) has published data confirming that its wind turbine fleet has reported a 20% reduction in energy generation in the last year. SSE is said to have released this data in response to requests from concerned shareholders.¹

This is consistent with data examined by Renewable Energy Foundation at the request of the *Sunday Telegraph*, which resulted in a report by Andrew Gilligan to the effect that the UK wind fleet load factor in the year October 2009 to September 2010 was very low in comparison to previous years.²

REF is receiving requests for further detailed information on this matter, and is therefore releasing the following information note.

**UK Wind Power Output in 2010**

In response to Mr Gilligan’s query, REF considered all wind farms, both onshore and offshore, with an installed capacity of 1 MW or greater, taking all Ofgem data (see [www.renewablesandchp.ofgem.gov.uk](http://www.renewablesandchp.ofgem.gov.uk)) since April 2002 in monthly tranches, and calculated each month’s load factor in the standard way (actual output/theoretical maximum output), given the installed capacity of wind generators for that month. From this we calculated the average annual load factors.

For the purposes of Mr Gilligan’s research we calculated actual load factors for October 2009 to September 2010, since stable empirical data for the last three months of 2010 was not yet available in the public domain from Ofgem. However, by using other industry standard empirical sources it is possible to estimate the output and load factor for those months with a high degree of confidence.

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¹ [http://www.thetimes.co.uk/tto/business/industries/utilities/article2896287.ece](http://www.thetimes.co.uk/tto/business/industries/utilities/article2896287.ece)

² [http://www.telegraph.co.uk/earth/energy/windpower/8261827/Britain-is-becoming-less-windy-raising-doubts-over-Governments-wind-farm-strategy.html](http://www.telegraph.co.uk/earth/energy/windpower/8261827/Britain-is-becoming-less-windy-raising-doubts-over-Governments-wind-farm-strategy.html)
The following chart shows UK windfarm fleet load factors for the years 2003 to 2010. The dark blue bar gives the Load Factor for the year labeled on the axis below, for example 2003. For 2003 to 2009 this figure is empirical. The light blue bar calculates the Load Factor for the period from October in the previous year to September in the year on the axis. For example, the light blue bar over 2003 gives the load factor for the period October 2002 to September 2003; and the light blue bar over 2010 gives the load factor the period October 2009 to September 2010. These figures are empirical.

![UK Windfarm Fleet Load Factors by Year](chart.png)

**Figure 1: UK Windfarm Fleet Load Factors by Year.**

Source: Renewable Energy Foundation.

The load factor shown in the dark blue bar for 2010 contains empirical data for January to September, and estimates based on other industry sources for October to December. This gives a slightly higher load factor than has been measured empirically for the year October 2009 to September 2010, but is still relatively low.

Overall, it is clear that the load factor for 2010 was low in comparison with preceding years, indicating that winds in this year, and particularly in the winter 2009-2010, were themselves relatively low.

This finding is consistent with data from Ireland and Northern Ireland. The following chart is taken from information published by Eirgrid at the Irish Renewable Energy Summit on the 20th of January this year.
According to Eirgrid load factor in 2010 was approximately 23.5%, as compared to 31% in the previous year, and the average figure of 32.3% for the years 2002 to 2009.

**Comment**

Wind power output is significantly variable and difficult to predict over several timescales, minutes, hours, days, weeks, months, and years. Variability over short time scales has been much discussed, and it is now well known that low wind conditions can prevail at times of peak load over very large areas. For example, at 17.30 on the 7th of December 2010, when the 4th highest United Kingdom load of 60,050 MW was recorded, the UK wind fleet of approximately 5,200 MW was producing about 300 MW (i.e. it had a Load Factor of 5.8%). One of the largest wind farms in the United Kingdom, the 322 MW Whitelee Wind Farm was producing approximately 5 MW (i.e. Load Factor 1.6%).

Load factor in other European countries at exactly this time was also low. The Irish wind fleet was recording a load factor of approximately 18% (261 MW/1,425 MW), Germany 3% (830MW/25,777 MW), and Denmark 4% (142 MW / 3,500 MW).

Such figures confirm theoretical arguments that regardless of the size of the wind fleet the United Kingdom will never be able to reduce its conventional generation fleet below peak load plus a margin of approximately 10%.

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4 Data drawn from public sources in all those countries.

They also suggest that while widespread interconnection via the widely discussed European Supergrid, may assist in managing variability, its contribution will not on its own be sufficient to solve the problems, since wind output is approximately synchronised across very large geographical areas.

Conventional generators acting in the support role and guaranteeing that load is met will be faced with operating in a market that is physically and economically volatile.

The now emerging fact that wind power can be highly variable year on year adds further layers of complication to this problem. Conventional generators will not only have uncertain income over shorter timescales, but will face significant year on year variations.

The all but inevitable result of such uncertainties is higher prices to consumer.

Dr John Constable
Dr Lee Moroney

02.02.11
Critiques of:

DECC0076. 15/12/2011  

2 Planning our Electric Future: Technical Update. December 2011  

Preamble

The two documents are full of repetitive and incomprehensible jargon – only someone versed in civil service speak could fully understand these reports. There is some quantitative analysis, but there is much that is qualitative and I get the strong impression that there are a lot of assumptions made when the answers from the analysis are unpalatable. Charles Hendry has signed the first document (Impact Assessment) to say that he has read it and is satisfied that “it represents a reasonable view of the likely costs, benefit and impact of the leading options”. I don’t believe he has read and understood it.

Neither document specifically states why extra capacity is required. The need to back-up intermittent wind power is barely mentioned (“back-up” is only mentioned once). The impacts of the effect of operating back-up plant in an inefficient mode and the resulting increased emissions are not mentioned.

Discussion

Document 1 addresses the problem arising in the future as the electricity generation moves from flexible fossil fuel to intermittent and less flexible generation and there is a risk of shortage of security of supply because there is no incentive to build flexible (dispatchable) capacity that will be used only as back-up. Unless actions are taken, as despatchable generators are retired with the introduction of intermittent and less flexible generation, multiple brownouts are likely, with possible blackouts by 2024 “there is a strong rationale for a capacity mechanism to reduce the risk of blackouts/brownouts occurring in a GB market with a much greater proportion of intermittent generation” (para 3.28). The document compares a Capacity Market solution with a Strategic Reserve solution. The Capacity Market solution is chosen to ensure “there is sufficient reliable and diverse capacity to meet demand, for example during winter anti-cyclonic conditions where demand is high and wind generation is low for a number of days” (para 1.4).

“Capacity Market (market wide volume-setting mechanism): The total volume of capacity is set, and the required amount is procured from market participants, who participate in both the energy market and capacity market. Penalties are in place for providers of capacity who fail to deliver when required” (para 4.1).
The base-case assumption (business as usual) is that “the power sector decarbonises so that the average plant emits at most 100g CO\textsubscript{2}/kWh in 2030” (para 4.6). This figure is twice that recommended by the Committee on Climate Change for 2030 (footnote 11). Looking at Fig 5 (see below), it appears that this is predominantly the result of closing coal-fired power stations (“closure of around 12 GW of coal and oil-fired fleet by 2016 at the latest” with “further closures by 2023” (para 4.7)) and a reduction in fossil-fuel-derived electricity generation capacity from ~64 GW (2010) to ~43GW. Nuclear has increased from ~11GW to ~16GW and so has little impact. Wind has gone from ~5GW to ~30GW. Total capacity has gone from ~87GW to ~104GW. Thus the total capacity of despatchable generation has been reduced by ~8GW and this gap presumably is the reason for a Capacity Market.

The figure of 100g CO\textsubscript{2}/kWh in 2030 from the average plant mix implies a figure of 200g CO\textsubscript{2}/kWh in 2030 from fossil plant because fossil plant will produce about 50% of the electricity generated (assuming a mean capacity factor of 30% for all wind). This is a significant reduction from the current figure of 430g CO\textsubscript{2}/kWh in the so-called benefit of wind power due to displaced fossil fuel. Fig 5 suggests that the average figure over the 20year period from fossil plant would be <300g CO\textsubscript{2}/kWh because the majority of the reduction in fossil-fuel capacity (and in coal-fired generation) has occurred by 2020 – it is not a linear reduction from the currently accepted figure of 430g CO\textsubscript{2}/kWh to 200g CO\textsubscript{2}/kWh in 2030; it is front-end loaded. Thus wind farms currently in planning, with a proposed life of 20years or more should at best use a CO\textsubscript{2} emissions saving figure of no more than 300g CO\textsubscript{2}/kWh (300kg CO\textsubscript{2}/MWh).

“Increased intermittency on the system (we expect up to a quarter of generating capacity to be wind by 2020) leading to greater fluctuations in the electricity wholesale price because wind is not despatchable” (para 3.10)
It is acknowledged that there is a problem looming, though the term “medium-term” is not defined. “The key points to take away from looking at the range of modelling we have undertaken is that there is a credible risk of a capacity problem in the medium-term” (para 3.24).

“The costs of capacity will be shared among suppliers, so capacity contracts will ultimately be paid for by consumers” (para 4.12). However, we learn that the Capacity Market can reduce consumers’ bills because “the rents that generators receive in the new Capacity Market are not as large as the rents they no longer receive” (para 5.10). It seems that the producers can build and operate these extra gas-fired power stations and we will all get lower bills (para 5.11)! They will be paid for the new capacity under the Capacity Market, but they will be paid less in the wholesale market for the electricity produced by the existing generators because of the increased capacity holding down prices (para 5.17). Of course overall the producers make lower profits (para 5.15) and so will be keen to build this extra capacity! Note that because the new capacity is used for back-up to wind power, it operates at low load factor, although the load factor for new plant is not given (para 5.19 and Fig 13 below). The load factors for the less and more efficient existing CCGTs are assumed to be 11% and 23% respectively, without any explanation given for these assumptions. There is no obvious reason why a less efficient plant should operate at a lower load factor than a more efficient plant. If it is assumed that the revenue/kW is proportional to the load factor (i.e. all three plants are of the same size), then it can be inferred that the new CCGT has an assumed load factor of ~30%. The new CCGT has a revenue in the wholesale market of ~£250/kW = £250,000/MW. Thus a 600MW new CCGT at a load factor of 30% gets a revenue of ~£150m for producing 1.6GWh (i.e. ~£96/MWh plus a Capacity Market payment of ~£28/kW = £18m. Total revenue is ~£170m/annum. For all three plants, the assumption being made is that the revenue for electricity produced is of the order of £100/MWh (10p/unit). The total revenues for the less efficient and more efficient existing 600MW CCGTs are ~£80m/annum and ~£135m/annum respectively.

Document 2 is the Government response to the consultation on implementing a Capacity Market. The need for this is “The Capacity Market is designed to ensure sufficient reliable capacity is available to ensure security of electricity supply in times
of system stress, for example during a cold, windless period” (para 30). In other words, the whole process is to build and operate capacity to cope with the intermittent nature of wind power, resulting from the stochastic nature of wind.

It is claimed that consumer electricity prices will be lower than under current policies by 15% by 2030 (para 38) despite 250,000 more people (an estimate, with no justification given) being employed in the industry (para 39). If the employment cost of each of those people is say only £50k, that comes to a total of £12.5bn/a. If the employment cost of each of those people is say more realistically £100k, that comes to a total of £25bn/a. No more electricity is being produced in 2030 than is being produced today. It should be possible to operate 100GW of plant with no more than 50,000 people. The claim makes no sense!!! A more efficient and lower cost electricity supply system in 2030 should employ fewer people, not several times more.

The purpose is to “ensure adequate levels of reliable capacity” (page 21) (i.e. despatchable) via the Capacity Market as a result of wind power “periods of low wind and high demand” (para 89). “Increased levels of intermittent and less flexible capacity on the system leads to greater fluctuations in the electricity wholesale price and limits the times when flexible generation can profit from operating, but makes it important that it is ready to run when required” (para 93). Providers of capacity will be paid primarily for capacity, rather than for delivering electricity and of course the consumer will pay! “providers of capacity will receive revenue (‘availability payments’) for providing reliable capacity”. “This creates an investment challenge, in particular for flexible capacity which will increasingly serve as backup plant so will be increasingly reliant on volatile, unpredictable prices to secure the revenues needed to justify investment” (para 94). “The costs of capacity will be shared among suppliers, so capacity contracts will ultimately be paid for by consumers” (page 23). But electricity bills may be lower “Electricity users will pay the costs of the capacity contracts awarded in the auction process via their electricity bills, but will also benefit from less volatile (and potentially lower) electricity prices, and from a higher level of reliability, than would otherwise have been the case” (page 24). Of course, this ignores the fact that if it weren’t for the presence of wind power, there would be no need for the Capacity Market to provide the back-up capacity. “The increased proportion of intermittency on the system will tend to exacerbate these market failures and increase the risk to security of electricity supply” (para 96).

It is recognised that under some assumptions, (not the central forecast) “a potential capacity problem arises in the second half of this decade”, (para 100) although the modelling to get to that situation is not given and the timing is uncertain. The new mechanism does not appear to be available until 2013 “We therefore propose to fully develop the parameters of the Capacity Market in the detailed design phase in 2012-13, and ensure the System Operator is fully prepared to run the auction process” (para 121).

There is talk of “storage”, but no details. Difficulties with the existing balancing services and the Capacity Market are mentioned but will be resolved (para 141). The document also mentions “low-carbon mechanisms”, with no mention of the current collapse of the carbon market and the rapid unwinding of the “climate change” agenda. Interconnectivity capacity conflict with the Capacity Market is also mentioned but is another problem to be resolved (para 147). It appears that new
capacity under the Capacity Market will not be in place until mid-2019 (fig 10). So will there be a capacity gap in the meantime?

**Some thoughts**

Will this revised figure of average emissions displaced over the next 20 years of 300g \( \text{CO}_2/\text{kWh} \) appear at the BWEA (RenewableUK) site or that of developers? It is a figure that opponents of wind farms can use.

Will RenewableUK and developers now admit that wind generation can be low for a number of days across the whole of the UK?

Will RenewableUK and developers now admit that back-up is needed due to the intermittency of wind generation?

**Conclusions**

By producing these documents the Government does at least appear to have realised a number of key points:

- That wind energy is intermittent and needs back-up from conventional generators when the wind drops.
- That new conventional generation capacity must be built to back up the increasing numbers of wind turbines that are projected.
- That the vast majority of this new generation capacity will be gas fired.
- That commercial generation companies will not be enthusiastic about building new plant which will be used on standby for most of the time.
- That some sort of mechanism will need to be established to encourage these generation companies to build and operate back-up capacity.

Only time will tell if the Government’s proposals set out in these documents work. If they do not work, then the UK will be facing major electricity supply problems in the near future.

In common with other Government documents concerning energy provision, the costs appear to have been considerably underestimated whilst the benefits have been overestimated.

A figure of 300g \( \text{CO}_2/\text{kWh} \) (300kg/MWh) is now justified as the average emissions displaced by wind turbines over the next 20 years. This figure is on the conservatively high side.