

# Yellow River Wind Farm

## Assessment of Environmental Impact Statement

Imagine if one of the proposed turbines was put on O'Connell St. instead...



Now imagine 32 turbines...

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Connolly Scientific Research Group

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**Cover image:** Hypothetical representation of what O'Connell St. might look like with a wind turbine of the same size as those being proposed for the Yellow River Wind Farm project. Adapted from photographs taken from <http://commons.wikimedia.org/> under the Creative Commons Attribution-Share Alike 3.0 license. O'Connell Street photo by Jaqian. Wind turbine photo by Andol.

## Executive Summary

In this report, we provide an independent assessment of the proposed Yellow River Wind Farm project. This is a proposal by Green Wind Energy (Wexford) Limited to develop a 32 turbine wind farm on a multi-location site in the northeast part of Co. Offaly.

The developers claim that such a wind farm would be viable, because they believe that the average wind speeds at 100m in the region are fast enough, i.e., greater than 8 m/s.

However, in Section 2, we show that they came to this belief prematurely, by relying on a 2003 computer model which was known to have overestimated wind speeds for the Midlands region. The actual average wind speed at 100m is only 6 m/s. Because the energy content of the wind scales as the cube of the wind speed, this means that the average energy content of the wind would only be 42% of what they require.

The developers claim that their project will both significantly reduce Ireland's carbon footprint and increase Ireland's energy security. However, in Section 3, we show that their analysis neglects several serious problems with wind turbine-generated electricity. As a result, they substantially overestimated the amount of carbon dioxide emissions that would be averted.

Moreover, because wind turbines are a very diffuse and intermittent form of electricity generation, adding wind farms, such as the Yellow River one, to the grid would seriously reduce the efficiency, reliability and stability of the country's electricity network. We show that this leads to more frequent power outages, higher electricity prices, and ironically increases the carbon dioxide emissions of the other sources on the grid. We discuss several alternative approaches to

reducing our carbon footprint which would not have these problems.

In their Environmental Impact Statement, it is claimed that the proposed wind farm would not have any major negative environmental consequences for the local environment. Indeed, because of their claim that it would significantly reduce Ireland's carbon footprint, they claim that it would be good for the environment. This is simply not true.

Their Environmental Impact Statement was woefully inadequate, littered with basic errors, and overlooked many serious potential environmental impacts that the proposed project would have. In Section 4, we discuss these errors and oversights, and provide a more realistic assessment. We show that the wind farm would have a number of serious detrimental effects on the environment.

Finally, the developers claim that wind farms, such as their proposed one, provide a number of positive benefits and are, on balance, good for the country.

However, in Section 5, we show that they have overestimated the positive benefits of wind farms, and neglected several negative consequences that wind farms have for the country. On balance, wind farms such as this one are a bad investment for Ireland.

In summary,

1. The proposed site is not windy enough.
2. The claimed reduction of the national carbon footprint has been overestimated.
3. There are better ways to reduce our carbon footprint.
4. It would make the electricity network less reliable.
5. It would have detrimental consequences for the local environment.

"Facts do not cease to exist because they are ignored" – *Aldous Huxley (1927)*

## 1. Introduction

### 1.1. Project description

The proposed Yellow River Wind Farm project is a plan by Green Wind Energy (Wexford) Limited to develop a 32 turbine wind farm on a multi-location site in the northeast part of Co. Offaly.

The proposed site would start just north of Rhode, and would lie close to the borders of Co. Westmeath, Co. Meath and Co. Kildare. It would contain land in the townlands of Derryarkin, Derryiron, Coolcor, Coolville, Ballyburly, Greenhills, Bunsallagh, Derrygreenagh, Knockdrin, Wood, Killowen, Corbetstown, Carrick, Garr and Dunville.

Green Wind Energy accompanied their submission with a 585 page Environmental Impact Statement, and an additional 1186 pages of documentation (including figures; appendices; a visual impact study; a Natura impact study; and a 47 page Non Technical Summary). This documentation was compiled for them by the consulting engineering firm, Jennings O'Donovan & Partners.

### 1.2. Developer's justification for project

The developer makes the following claims to justify their proposed project:

1. A large scale wind farm in the Midlands can be economically viable
2. Such a wind farm will help reduce the country's carbon footprint, and moreover is the most sensible approach to reducing carbon dioxide emissions
3. The proposed development would only have minimal negative environmental impacts for the area
4. The project will have net positive benefits for the country through:
  - a. Increased employment

- b. Improved energy security
- c. Climate change mitigation

However, in this report we will demonstrate that none of these claims are valid. Since these four claims are the justification for the proposed project, we find that the project is **not** justified.

### 1.3. Relevance of this report for other proposed projects

In this report, we will be explicitly assessing the above proposed development, i.e., the Yellow River Wind Farm project. However, our analysis and conclusions are also of relevance for several other proposed projects that are currently being considered.

At least three other groups have announced that they are considering large-scale wind farm projects for the Midlands area, including some of the areas covered by the Yellow River Wind Farm project.

Mainstream Renewable Power are considering plans to install 450 wind turbines across seven counties in the Midlands. Element Power are also considering a similar project, called "Green Wire" to install 300 wind turbines (40 wind farms) across five midland counties<sup>1</sup>. Finally, Bord na Móna announced in October 2013<sup>2</sup> they are considering a similar plan for two midland counties (Offaly and Kildare).

It is unclear to what extent (if any) these three groups are planning on collaborating with each other in their proposals, but the stated purpose of all three plans is to provide electricity for export to Wales via a proposed

<sup>1</sup> Irish Independent, 28<sup>th</sup> November 2013.  
<http://www.independent.ie/irish-news/energy-firm-plans-100m-wind-farm-29790974.html>

<sup>2</sup> Irish Independent, 24<sup>th</sup> October 2013.  
<http://www.independent.ie/incoming/bord-na-mona-unveils-billion-euro-wind-energy-export-project-for-offaly-and-kildare-29697212.html>

underwater international connector. Apparently, they hope that they would then be able to take advantage of high feed-in-tariffs that the UK currently<sup>3</sup> provide in Great Britain for electricity produced by onshore wind turbines.

In contrast, the stated aim of Green Wind Energy's proposed Yellow River Wind Farm is to produce electricity for the domestic market, and the Yellow River Wind Farm only considers one region of Co. Offaly.

Nonetheless, most of the analysis in our report also applies to the entire Midlands region, and our conclusions hold regardless of whether the electricity production is planned for the domestic or foreign market. That is, most of the analysis and conclusions in this report will also apply to other proposed wind farm projects for the Midlands area.

Additionally, EirGrid are currently proposing to build 750 electricity pylons between Leinster and Munster in order to allow inter-county electricity distribution<sup>4</sup>. EirGrid's proposal has been very controversial and there has been a lot of public resistance to it, e.g., Irish Times, 16<sup>th</sup> January 2014<sup>5</sup> or 13<sup>th</sup> January 2014<sup>6</sup>. However, apparently, one of the main justifications for the proposal is so that the electricity system will be able to adequately distribute electricity from future wind farms.

As we will discuss in Section 3, wind farms are a very diffuse method for electricity production, and require a much larger and more widespread electricity distribution network than conventional electricity

generation. The electricity distribution network is probably still adequate for *conventional* electricity generation methods using power plants. However, *if* a large number of new wind farms were to be built across the country, the current network would be inadequate.

"Of course [*the EirGrid proposal*] has to do with [*the Midlands wind farm projects*]. I mean, the whole point is that we are trying to decarbonise the electricity system... We have to make better use of an indigenous resource that we don't have to pay for in this country – it is a resource that recurs and is renewable, namely we have some of the best wind in Europe, and by 2020, we will have 40% of our electricity generated from wind." – *Pat Rabbitte, Minister for Communications, Energy and National Resources, 14<sup>th</sup> January 2014 in a TV3 debate with a member of Comeragh's Against Pylons group*<sup>7</sup>

If accommodating multiple wind farm projects is indeed a primary justification for the EirGrid proposal<sup>8</sup>, then this report would also be of relevance, since our report discusses the viability (or lack thereof) of Midlands wind farm projects.

Finally, some of the analysis, discussion and conclusions in this report may be of relevance for other wind farm projects.

## 1.4. Format of this report

In this report, we will reassess all four of the purported justifications for the Yellow River Wind Farm. We find that each of these justifications are invalid, and arise from an incomplete consideration of the relevant issues, as well as several serious flaws and

<sup>3</sup> <http://www.energysavingtrust.org.uk/wales/Generating-energy/Getting-money-back/Feed-In-Tariffs-scheme-FITs>

<sup>4</sup> E.g. see RTE News, 7<sup>th</sup> January 2014.

<http://www.rte.ie/news/2014/0107/496309-eirgrid-pylon/>

<sup>5</sup> <http://www.irishtimes.com/news/politics/fine-gael-tds-press-kenny-on-pylon-plans-1.1656723>

<sup>6</sup> <http://www.irishtimes.com/news/environment/suspicion-of-eirgrid-pylon-plans-is-deep-and-pervasive-across-country-1.1652842>

<sup>7</sup> <http://www.tv3.ie/3player/show/184/74664/0/Ireland-AM>

<sup>8</sup> "Wind energy project can only proceed in compliance with a national policy framework". 3<sup>rd</sup> October 2013 keynote address by Minister Pat Rabbitte to the Irish Wind Energy Association. <http://www.dcenr.gov.ie/Corporate+Units/Press+Room/Speeches/2013/Wind+Energy+Speech+IWEA+Autumn+Conference.htm>

mistakes in the Environmental Impact Statement supplied by the developer.

We will assess each of the claimed justifications separately:

In Section 2, we will find that the Yellow River area is not windy enough for the proposed project. The developers based their belief that it would be windy enough on a faulty and inaccurate computer model estimate. The actual wind speeds are considerably less than the wind speeds the developers claim are required to make their project viable.

In Section 3, we will discuss how the proposed project would not provide the net reduction in carbon dioxide emissions that is claimed. We will also demonstrate that there are more sensible approaches to reducing carbon dioxide emissions.

In Section 4, we reassess what the environmental impacts of the project would be. We find that the original Environmental Impact Statement was highly inadequate, made numerous invalid assumptions, and neglected several serious negative impacts that the project would have for the local environment and community.

In Section 5, we assess the net impacts that the project would have for the country of Ireland. We find that installing large-scale wind farms in the Midlands, such as the proposed Yellow River Wind Farm, would have many negative consequences for the country, and that the alleged positive impacts have been seriously overestimated.

Finally, in Section 6, we will summarise the main findings of our report, and present our conclusions.



## 2. Assessment of wind resources in the Yellow River area

Being an island nation, bordered on the west coast by the Atlantic Ocean, Ireland is a relatively windy country. This makes the country a relatively good potential candidate for the location of wind farms. However, the Midlands are the calmest part of the country, and therefore generally **not** a suitable location for a wind farm.

The location for the proposed Yellow River Wind Farm project is in the Midlands. So, the first question that needs to be answered is whether or not the location is actually windy enough for a wind farm.

If the proposed location is not windy enough for a wind farm, then there is simply no justification for building a wind farm there.

With their submission for the proposed Yellow River Wind Farm project, Green Wind Energy included a long list of reports and documentation compiled for them by the consulting engineering firm, Jennings O'Donovan & Partners. The documentation comprised a 585 page Environmental Impact Statement ("**EIS**"); 94 pages of figures; 957 pages of appendices (639 of these pages came from one appendix - Appendix M); a 40 page Visual Impact study; a 48 page Natura Impact study; and a 47 page Non Technical Summary ("**NTS**"). In total, the documentation contained 1,771 pages.

However, remarkably, out of those 1,771 pages, their *only* references to the wind speeds in the proposed location were the following:

1. A paragraph on p7 of the NTS claiming that, according to the County Offaly Wind Strategy, the proposed location has "*sufficient wind speeds and access*

*to grid network*", and a similar reference on p53 of the EIS.

2. Figures 2.2 and 2.3 of the EIS which show that the proposed location is indeed in one of the zones considered "*suitable for wind energy development*" by the Country Offaly Wind Energy Strategy.
3. One sentence on p8 of the NTS and two sentences on p18 of the EIS stating that "*an average annual mean wind speed in excess of  $\approx 8$  m/s*" is generally considered necessary "*to operate a wind farm efficiently*".
4. A reference on p11 of the NTS and p56 of the EIS that the proposed site "*sustains winds in excess of 8.00m/s at an elevation of 100m above ground level*", according to the 2003 Irish Wind Atlas.
5. Figure 2.4 of the EIS which shows that according to the 2003 Irish Wind Atlas, the average wind speed at a 100m elevation in the proposed site is greater than 8 m/s.
6. 2 pages in Appendix M providing wind speed measurements for a 6 hour 40 minute period on 11<sup>th</sup> May 2013.

This is a woefully inadequate discussion of probably the most fundamental aspect of the entire project – is the area windy enough?

According to the NTS and EIS, windy enough means an average annual wind speed at 100m height of at least 8 m/s (*8 m/s is roughly 18 miles per hour*). If the average wind speed is less than 8 m/s, then the proposed wind farm would **not** be viable.

It seems that Green Wind Energy are relying on two sources for their claim that the proposed Yellow River Wind Farm site is windy enough:



1. The County Offaly Wind Energy Strategy
2. The 2003 Irish Wind Atlas

The County Offaly Wind Energy Strategy is itself based on the 2003 Irish Wind Atlas. So, essentially, the entire justification for their claim that the Yellow River site is a suitable location for a wind farm comes down to the fact that the 2003 Irish Wind Atlas gives an estimated average wind speed at 100m of more than 8 m/s for the areas in the proposed site.

### 2.1. Measured wind speeds in the area (10-12m height)

For the Midlands region, Met Éireann have operated four different weather stations: Mullingar, Co. Westmeath; Birr, Co. Offaly; Kilkenny, Co. Kilkenny; and Oak Park, Co. Carlow. The Birr station ceased operation in October 2009, and the Oak Park station was opened as a replacement. However, the Oak Park and Kilkenny stations are on the other side of the Slieve Bloom mountains from the Yellow River site. So, the two relevant stations are Mullingar and Birr.

A year's hourly wind speed measurements for these two stations were purchased from Met Éireann and provided to us by the Rhode Parish Wind Turbine Action Group. For Birr, data from the last 12 months of operation (October 2008-September 2009) was provided, and for Mullingar, data for 2013 was provided (i.e., January 2013-December 2013).

Figure 1 shows the average daily distribution of wind speeds at instrument height over the entire period. Both stations report low average wind speeds. Mullingar has an average wind speed of  $3.2 \pm 0.1$  m/s at 10m height (*roughly 7 miles per hour*), while Birr has an average wind speed of  $3.6 \pm 0.1$  m/s at 12m height (*roughly 8 miles per hour*).

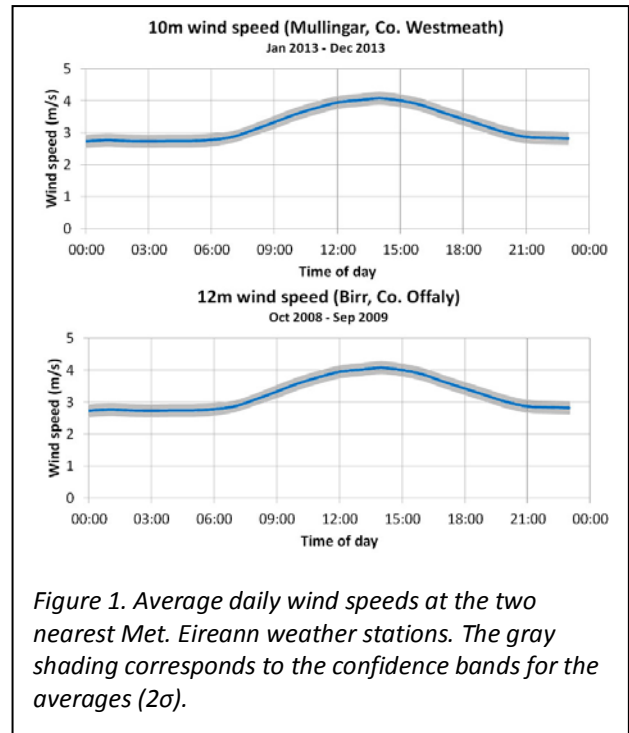


Figure 1. Average daily wind speeds at the two nearest Met. Éireann weather stations. The gray shading corresponds to the confidence bands for the averages ( $2\sigma$ ).

The prevailing wind blows roughly in the direction from Birr to Mullingar, and the Yellow River site is located roughly three quarters of the way from Birr to Mullingar over mostly flat grass land. Therefore, the Yellow River wind speeds would be intermediate between these values. These wind speeds are far too low for a wind farm.

However, the proposed Yellow River Wind Farm would use very tall wind turbines, with a hub height of up to 110m. Generally speaking, wind speeds tend to increase with height from the ground up to a couple of hundred metres<sup>9</sup>.

Therefore, it is not the wind speeds at 10 or 12m which counts, but rather the wind speeds at hub height. Green Wind Energy claim that it is these wind speeds which are greater than 8 m/s, on average.

So, let us now consider the 2003 Irish Wind Atlas, which Green Wind Energy use to make this claim.

<sup>9</sup> The air in the region where the wind speed stops increasing with height is known as the "free atmosphere".

## 2.2. How the Irish Wind Atlas 100m height wind speeds were generated

The 2003 Irish Wind Atlas was developed for the Sustainable Energy Authority of Ireland (SEAI) by a U.S.-based sailing product company, Truewind Inc., and ESB International's engineering firm, ESBI. It can be viewed on the SEAI website<sup>10</sup>.

It is important to realise that the values in the Irish Wind Atlas are not measured wind speeds, but are instead *modelled* wind speeds.

The Irish Wind Atlas was generated by initially estimating a wind speed for the area using the NOABL wind model (short for "Numerical Objective Analysis of Boundary Layer").

The NOABL model is quite a crude model, which only gives approximate values for a general location. For this reason, its results have to be treated cautiously. In particular, it tends to overestimate wind speeds in low lying areas and underestimate wind speeds in mountainous or highland areas.

In order to compensate for this, after generating the initial map, the producers of the atlas compared the predicted wind speeds to the actual measured wind speeds in any locations where they had data from meteorological stations.

When they did this, they found that the initial map had quite a lot of errors. On average, the predicted wind speeds were out by about 0.3 m/s.

So, the producers applied adjustments to the model to an attempt to reduce the magnitudes of the errors. They then regenerated the map and repeated the process.

With the NOABL model they were not able to fine-tune the results so that each individual location matches the measurements, because each adjustment they make affects large regions of the model. Instead, they applied a series of general adjustments until the **average predicted** wind speed for all of Ireland, as a whole, was the same as the **average measured** wind speed.

The predicted wind speeds were still inaccurate at most of the locations where they had measurements to check. However, they found that, averaged over the whole of Ireland, the underestimated wind speeds were balanced by the overestimated wind speeds.

The experimental data they used for checking the NOABL model is provided in Table 1 of their Technical Project Report, which is available on the SEAI website<sup>11</sup>. For convenience, we have reproduced this table in Appendix 1.

If you check this table, it can be seen that they used data from 34 weather stations. They include 14 stations maintained by Met Éireann, 1 UK station (Orsay Lighthouse) and 19 privately owned stations.

The 19 privately owned stations were located mainly on hill tops of possible interest for wind energy projects and were monitored for only a year or two in the early 1990's before being dismantled. In contrast, the Met Éireann stations were located in lowlands and had more than 30 years of annual wind speed data, starting in 1972.

For this reason, the Met Éireann data is the most appropriate data for evaluating the Yellow River area wind speeds, in particular, the Birr and Mullingar stations that we

<sup>10</sup> [http://www.seai.ie/Renewables/Wind\\_Energy/Wind\\_Maps/](http://www.seai.ie/Renewables/Wind_Energy/Wind_Maps/)

<sup>11</sup> SEAI (2003). Report No. 4Y103A-1-R1. [http://www.seai.ie/Archive1/Files\\_Misc/IrelandWindAtlas2003.pdf](http://www.seai.ie/Archive1/Files_Misc/IrelandWindAtlas2003.pdf)

discussed above (although the Kilkenny station is also of some relevance).

When we studied the data for Birr and Mullingar, we found that the producers of the atlas had made significant errors for both of these stations.

They incorrectly reported the Birr station as being at 10m, when it was actually at 12m. They correctly identified the height of the Mullingar station as 12m (it was only moved to 10m in 2008). However, a more serious error is that they reported the average wind speed at Mullingar as 4.6 m/s. The actual average wind speed at 12m should have been about 3.6 m/s. We saw that the 10m wind speed in 2013 was 3.2 m/s.

It is possible that the reason for entering 4.6 m/s was just a clerical error. However, it meant that when they were comparing the NOABL modelled wind speeds to the meteorological wind speeds for Mullingar, they would not have realised just how badly the model prediction overestimated the Mullingar wind speeds. Ultimately, the propagation of this error helped contribute to the substantial overestimate of the 100m wind speeds in the Midlands.

### 2.3. Using wind shear to extrapolate 100m wind speeds

There are two main approaches to determining the average wind speed at a tall height, such as 100m:

1. Build a wind monitoring stand that is 100m tall, and record the measurements over a period of time
2. Theoretically extrapolate the 100m wind speeds from the wind speeds at a lower height, using a mathematical formula.

As we will illustrate in Section 4.1, a 100m tall structure is very tall, and so the second option is generally the one used.

There are a few theoretical methods for extrapolating the wind speeds at different heights. A common approach is to use a so-called “wind shear” value. The wind shear value tells you how the wind speed varies with height.

So, if you know the wind shear for a given region and you know the wind speed at one height, you can estimate the wind speed at a different height using a mathematical formula – we include this formula in Appendix 2.

Unfortunately, the wind shear value is not constant – it can vary from place to place and from hour to hour. It also changes with height, and so the accuracy of the formula decreases the greater the height distance you are considering is.

For this reason, to get accurate results, it is really best if you can measure the wind shear at the same time and place that you are measuring the wind speed at the lower height.

The handiest way to measure the wind shear is to record the wind speed at two different heights, and plug those values into your mathematical formula. This might seem a very complicated way to measure the wind speed at 100m, but the advantage is that your wind monitors can be at a much lower height.

For instance, you could place one wind monitor at 10m and the other at 50m. Using the wind speeds at both heights, you can then calculate the wind shear. Then, you can use the wind shear to extrapolate the 100m wind speed from either the 10m wind speed **or** the 50m wind speed. You can also extrapolate the wind speeds at any other height (as long as

you don't extrapolate more than about a hundred metres).

In Appendix 1, we include the wind shear values used by the producers of the 2003 Irish Wind Atlas for testing their modelled wind speeds.

For the Mullingar station, they used a wind shear value of 0.24, and for the Birr station, they used a wind shear value of 0.28. These are relatively high wind shear values. For instance, their wind shear value for Malin Head was only 0.10.

The higher the wind shear value is, the higher the extrapolated wind speed values at 100m will be. So, deciding on the most appropriate wind shear value is critical to estimating the actual 100m wind speeds.

As we discussed in Section 2.2, the producers of the 2003 Irish Wind Atlas made a couple of serious errors when they were testing their map for the Midlands stations. For Birr, they used an instrument height of 10m, instead of the actual height of 12m. The 12m wind speed is generally a little faster than the 10m wind speed, so this meant they would have slightly overestimated the Birr wind speeds. For Mullingar, they physically entered the wrong value (4.6 m/s instead of 3.6 m/s), i.e., they overestimated the 12m wind speed by 1.0 m/s. This overestimate would have been greater at higher heights.

Even with these errors, they still found that their final map wind speeds were too high for Birr (+0.9 m/s), Mullingar (+0.4 m/s), and also the other Midlands station, Kilkenny (+0.9 m/s).

In other words, the 2003 Irish Wind Atlas substantially overestimated the Midlands wind speeds. Since the basis for justifying the proposed Yellow River Wind Farm project is that the average 100m wind speeds in the

2003 Irish Wind Atlas are greater than their required 8 m/s, this already shows that the project is not viable.

Still, for completeness, it is worth calculating what the actual average 100m wind speeds are for the region.

## 2.4. The actual 100m wind speeds for the Yellow River area

As we discussed earlier, the average wind speeds for the Yellow River area should be intermediate between those for the Birr station and the Mullingar station. We know the average wind speeds at 10m and 12m respectively for those stations from Met Éireann's 2013 hourly measurements, i.e., Figure 1.

Therefore, if we know what wind shear value to use, we can extrapolate the average wind speeds at 100m from this data.

One option would be to use the values used for the 2003 Irish Wind Atlas, i.e., 0.24 for Mullingar and 0.28 for Birr. However, for the Environmental Impact Statement for the Yellow River Wind Farm project, the developers temporarily installed a meteorological station on the proposed site with wind monitors at 44.8m and 80.8m. Using the measurements from these monitors they were able to calculate the wind shear specifically for the Yellow River region.

Oddly, despite including more than 600 pages in their appendix describing this analysis (Appendix M), they just included one page of their actual wind measurements and a second page explaining some of their calculations. For convenience, we reproduce these values in Appendix 3.

The measurements that they did provide covered a 6 hour 40 minute period on 11<sup>th</sup> May 2013 (00:00 to 6:40), and consisted of their calculated wind shears along with their

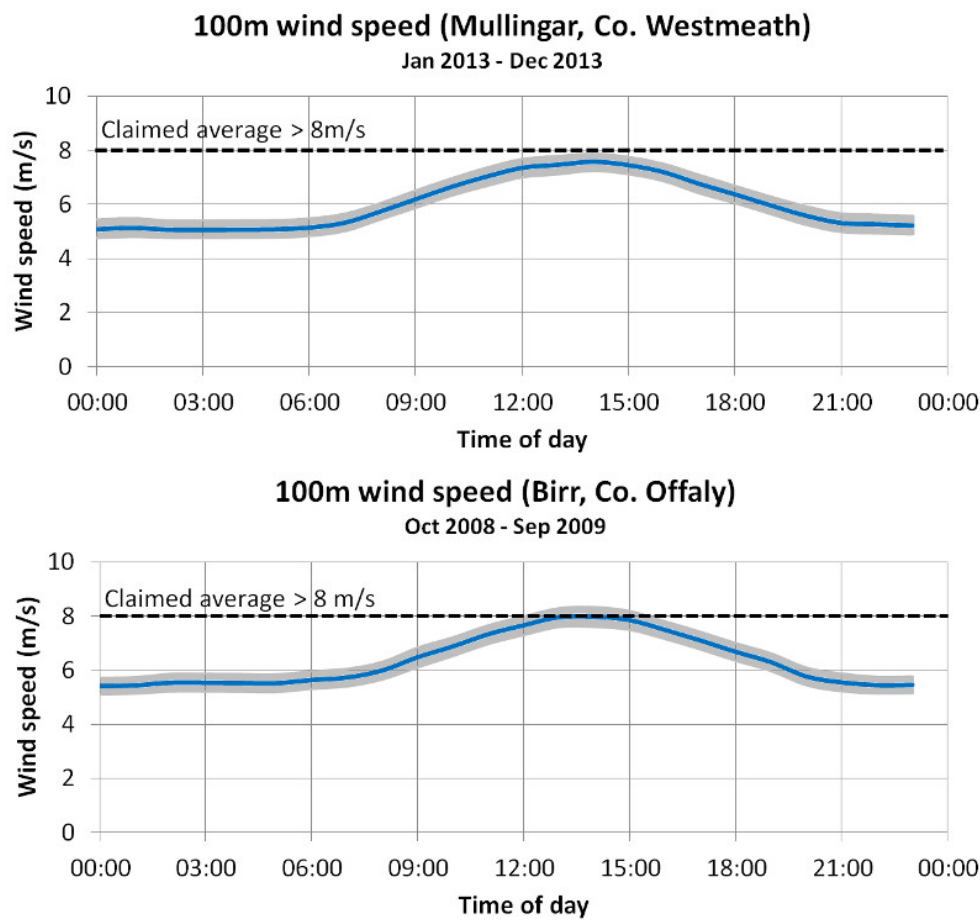


Figure 2. Average daily wind speeds at 100m height, for Mullingar and Birr, extrapolated using a wind shear value of 0.27. The gray shading corresponds to the confidence bands for the averages ( $2\sigma$ ).

extrapolated wind speeds at 113 m and 10m at 10 minute intervals<sup>12</sup>.

Presumably, since Jennings O'Donovan & Partners only decided to provide this 6 hour 40 minute period of their measurements, it was because they felt it was sufficiently representative of their entire measurement period. So, let us assume that this is true.

The mean wind shear over the period was 0.27 (with a standard error of 0.01) – see Appendix 3. This is intermediate between the Mullingar and Birr values used for the 2003 Irish Wind Atlas. So, it is a plausible value.

If we apply a wind shear value of 0.27 to the average wind speeds in Figure 1, and estimate the corresponding 100m wind speeds, we obtain the plots in Figure 2.

The average wind speed at Mullingar is only 6.0 m/s! The average for Birr is slightly higher, but still only 6.3 m/s. This is definitely less than the 8.0 m/s the developers assume to justify their proposed Yellow River Wind Farm.

If you look closely at Figure 2, you can see that for Mullingar, even the afternoon wind speeds (i.e., the daily maximum) are less than 8.0 m/s. For the Birr station, the average afternoon wind speed just about reaches 8.0 m/s for a short while (13:00-14:00), but the average for the whole day is only 6.3 m/s.

<sup>12</sup> It is unclear why they extrapolated to 113m. The turbines for the proposed Yellow River Wind Farm would only have a hub height of "up to 110m". It is possible that they confused the 113m rotor diameter of the Siemens SWT 3.0-113 with the hub height of 110m, as this is one of the turbine models considered.

Initially, you might think that a difference of 1.7-2.0 m/s is not much, and that if a wind farm is viable with an average wind speed of 8.0 m/s, it might be tolerable with an average wind speed of 6.0-6.3 m/s.

Unfortunately, as we demonstrate in Appendix 2, the actual energy content of the wind ("power density") increases as the cube of the wind speed. This means that wind with an average speed of 6.0 m/s only has 42% of the energy of a wind with an average speed of 8.0 m/s.

So, if we use the wind shear values provided with the developer's EIS, then the Yellow River Wind Farm is simply not viable.

However, it is plausible that the actual 100m wind speeds are even lower still.

Surprisingly, in their EIS, they used a different method for calculating the wind speed at 10m than the one they used for calculating the 113m wind speed. This second method does not use the wind shear value, but gives them larger values for the wind speeds at 10m, than if they had used the average wind shear value of 0.27.

If this second method is more accurate, then this means we can calculate a different wind shear for the area by comparing their calculated 113m and 10m wind speeds (labelled "V113" and "V10std" in their table).

In Appendix 3, we include the implied wind shear values from their data. The average of these values is only 0.16. If this value is accurate, then the average wind speed for the Yellow River region at 100m would be only 4.6 m/s.

As we will discuss in Section 4, they use this lower wind shear value when estimating the wind turbine noise levels, and as a result obtain a lower estimate for the noise levels.

An average wind speed of 4.6 m/s would only have 19% of the power density of an 8.0 m/s wind. So, if the lower wind shear value implied by their analysis for the wind turbine noise is correct, then the proposed Yellow River Wind Farm project is even less viable!

Of course, if the higher wind shear value of 0.27 is correct, then that means that their analysis of the wind turbine noise was completely wrong... **and** that the >600 pages of wind turbine noise calculations that they included in Appendix M of the EIS are completely worthless.

At any rate, the Yellow River region is simply not windy enough to justify the proposed Yellow River Wind Farm.

Certainly, there are relatively windy parts of Ireland, particularly near the western coast. For instance, according to Met Eireann's 1981-2010 climate averages<sup>13</sup>, Malin Head has an average wind speed of 8.0 m/s (21m) and Belmullet has an average wind speed of 6.6 m/s (12m). If we take the appropriate shear values used in the 2003 Irish Wind Atlas<sup>14</sup>, this gives an average 100m wind speed of 9.3 m/s for Belmullet and 9.4 m/s for Malin Head.

Either of these values would be higher than the 8 m/s minimum quoted by Green Wind Energy.

But, the proposed Yellow River site is **not** a windy region. The average 100m wind speeds of greater than 8 m/s which were implied by the 2003 Irish Wind Atlas were simply incorrect.

Since the County Offaly Wind Energy Strategy was relying on the 2003 Irish Wind Atlas to identify regions "*suitable for wind energy*"

<sup>13</sup> <http://www.met.ie/climate-ireland/30year-averages.asp>

<sup>14</sup> Belmullet wind shear = 0.16; Malin Head wind shear = 0.10. See Appendix 2.

*development*", the regions that they identified were invalid.

Green Wind Energy relied on both the County Offaly Wind Energy Strategy and the 2003 Irish Wind Atlas for claiming that the Yellow River site would be suitable for a wind farm. Therefore, their claim is invalid.

They should have realised that relying on modelled wind speeds from a study that is more than a decade old, and is known to have inaccuracies, is **not** a good enough basis for deciding to install 32 large wind turbines in a region that is well-known to be not very windy.

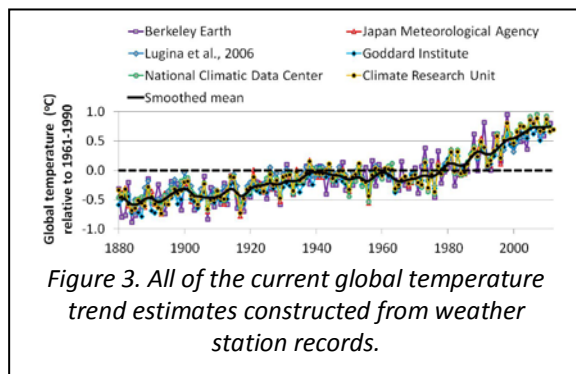
"If you put garbage in a computer, nothing comes out but garbage. But this garbage, having passed through a very expensive machine, is somehow ennobled and none dare criticise it." – *Rory Bremner (British comedian and satirist)*



### 3. Climate change policies

“It is immediately obvious that even if all the wind turbines the [U.K.] Government (and the Opposition) wants are built, they will make not even a tiny dent in the carbon concentration in the atmosphere.” – Prof. Dieter Helm, Professor of Energy Policy at the University of Oxford (UK), 16th July 2009<sup>15</sup>

#### 3.1. Basis for carbon footprint reduction policies



Several research groups have used thousands of weather station records from around the world to construct estimates of the global temperature trends since the late 19<sup>th</sup> century. All of these estimates suggest that there has been a long-term warming trend of about 0.8°C/century since the start of the estimates (Figure 3). This is the “*global warming*” which has created such concern in recent years.

Man-made global warming theory<sup>16</sup> predicts that increasing the concentration of carbon dioxide (CO<sub>2</sub>) and other “greenhouse gases”<sup>17</sup> in the atmosphere will lead to global warming. The use of fossil fuels releases water vapour and carbon dioxide as a side-product, and as a

result, the concentration of carbon dioxide in the air has been increasing. It has been estimated that since the Industrial Revolution, atmospheric carbon dioxide concentrations have increased from the pre-industrial concentrations of about 0.03% to about 0.04% today<sup>18</sup>.

The current climate models rely heavily on man-made global warming theory, and conclude that almost all of the “global warming” shown in Figure 3 is “man-made global warming” from increasing carbon dioxide concentrations. These models project that if fossil fuel usage continues “business-as-usual”, then by the end of the 21<sup>st</sup> century, global temperatures could be between 1.5°C and 6.0°C warmer than today.

Over the last few decades, the projections of these climate models have led many climate scientists to become very concerned about the world’s fossil fuel usage, and to recommend that international effort is made to drastically reduce our carbon dioxide emissions (or “*carbon footprint*”).

The latest Intergovernmental Panel on Climate Change (IPCC) reports have used these models to conclude that:

“It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20<sup>th</sup> century” – Section D.3 of the *Summary for Policymakers (IPCC Working Group I, 5<sup>th</sup> Assessment Report, 2013)*<sup>19</sup>

The IPCC is a United Nations scientific body charged with “*provid[ing] the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic*

<sup>15</sup> The Times, 16<sup>th</sup> July 2009

(<http://www.dieterhelm.co.uk/node/775>)

<sup>16</sup> Sometimes referred to as “*anthropogenic global warming*” (AGW) theory.

<sup>17</sup> Gases which absorb and emit infrared light. This excludes the main atmospheric gases, i.e., nitrogen (N<sub>2</sub>), oxygen (O<sub>2</sub>) and argon (Ar), but includes most of the trace atmospheric gases, e.g., water vapour (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>)

<sup>18</sup> Concentrations are reported here in percentage *by volume*. However, due to the low values, carbon dioxide concentrations are often reported in parts per million by volume (ppmv). Both representations are interchangeable, e.g., 300 ppmv = 0.03%.

<sup>19</sup> <http://www.climatechange2013.org/>

*impacts*”<sup>20</sup>. For this reason, their conclusions are assumed by many people, including governments, to be accurate.

As a result, the IPCC conclusions have prompted the E.U. and Ireland to introduce legislation, mandates and targets in an attempt to help prevent the alarming man-made global warming projected by the climate models from occurring.

If the climate models are accurate, then it is vitally important to urgently reduce the rate at which carbon dioxide concentrations are increasing, and ultimately stop them from rising at all.

In other words, we would have to urgently reduce, if not stop altogether, our current fossil fuel usage, and come up with some “alternative” sources for our energy supplies.

Understandably, people who believe in the climate models (or in the IPCC’s conclusions) feel very passionately that our increasing “carbon footprint” is leading to an environmental crisis of unprecedented proportions.

The climate models have been making essentially the same predictions for several decades now, yet carbon dioxide emissions have continued to increase. This seems to have led to a certain desperation amongst people who trust the models that **any** form of non-fossil fuel-based electricity generation is better than fossil fuel usage.

It is in this context, that wind farms are being promoted as being one of our only options for electricity generation. Supporters of wind turbine technology point to the fact that, *when the turbines are in operation*, the electricity they generate comes from wind energy, and does not release carbon dioxide.

They therefore argue that using wind turbines will reduce our carbon footprint. For this reason, they claim that wind electricity is “green”, “clean” and good for the environment.

In Section 4, we will show that wind turbines, and in particular the proposed Yellow River Wind Farm project, actually can seriously harm the environment. So, if we ignore the carbon dioxide issue, then wind turbines are **not** “green”, “clean” **or** good for the environment.

In this Section, we will show that the purported reduction in carbon dioxide emissions is substantially exaggerated by wind turbine promoters. This is especially so for wind farms built in areas that are not very windy – as we discussed in Section 2, the proposed Yellow River Wind Farm would be in a non-windy region.

We also will show how wind farms create major problems for the stability, efficiency and reliability of the electricity grid. As a result, introducing more wind farms like the proposed Yellow River Wind Farm into the network will have serious negative consequences for the country.

First, though, there might be room for an optimistic note...

### 3.2. The importance of the “climate sensitivity” debate

You might recall from our earlier discussion that the current climate models conclude that *almost all* the global warming in Figure 3 is “man-made global warming” from our carbon dioxide emissions. However, what if some (or all) of the global warming was just a natural phenomenon?

If the climate models have mistakenly attributed some “natural global warming” to being “man-made global warming”, then this

<sup>20</sup> Quoted from IPCC website: <http://www.ipcc.ch/>

would mean that they are also overestimating the amount of man-made global warming we should expect in the future. In climate science terms, the models would have too high a “climate sensitivity”<sup>21</sup>.

In other words, the alarming predictions of the current climate models are a bit less worrying. The greater the amount of global warming that is actually just “natural global warming”, the less worried we need to be about the climate models, and the less urgent it becomes for us to reduce our carbon dioxide emissions.

If *all* of the global warming was natural, then this would indicate that the climate models were completely wrong, and we do not need to bother reducing our carbon dioxide emissions at all.

If *most* of the global warming was natural, then we should probably still try to reduce our carbon dioxide emissions, but it is not a particularly urgent problem. It would be a problem we could gradually try to resolve over the next century or two. When we consider the technological advances that have been made since the 19<sup>th</sup> century, this seems quite manageable.

So, the urgency with which we should be trying to reduce our carbon dioxide emissions depends critically on just how reliable the current climate models are, and how high the true “climate sensitivity” is.

With this in mind, it is interesting to note that at the end of the 20<sup>th</sup> century, the climate models were predicting that global temperatures would have risen by quite a bit by now. This does not seem to have actually happened, and several calculations have

suggested that there has been very little (if any) global warming for the last 10-15 years.

This “global warming pause” or “hiatus” is leading quite a few climate scientists to conclude that the actual climate sensitivity is much lower than the climate models have been claiming.

Here is a recent quote from Prof. Hans von Storch, who is a professor at the Meteorological Institute of the University of Hamburg (Germany), Director of the Institute for Coastal Research, and an IPCC scientist:

“So far, no one has been able to provide a compelling answer to why climate change seems to be taking a break. We’re facing a puzzle. Recent CO<sub>2</sub> emissions have actually risen even more steeply than we feared. As a result, according to most climate models, we should have seen temperatures rise by around  $[0.25^{\circ}\text{C}]$  over the past 10 years. That hasn’t happened. In fact, the increase over the last 15 years was just  $[0.06^{\circ}\text{C}]$  - a value very close to zero...

If things continue as they have been, in five years, at the latest, we will need to acknowledge that something is fundamentally wrong with our climate models. A 20-year pause in global warming does not occur in a single modelled scenario. But even today, we are finding it very difficult to reconcile actual temperature trends with our expectations” – Prof. Hans von Storch in an interview with *Der Spiegel* in June 2013<sup>22</sup>

Similarly, Prof. Judith Curry, the chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology (USA) and a former IPCC scientist, has said:

“Since publication of the *[2007 reports]*, nature has thrown the IPCC a ‘curveball’ – there has been no significant increase in global average surface temperature for the past 15+ years... The IPCC has

<sup>21</sup> Climate sensitivity = the amount of global warming that would be expected for a doubling of atmospheric carbon dioxide.

<sup>22</sup> <http://www.spiegel.de/international/world/interview-hans-von-storch-on-problems-with-climate-change-models-a-906721.html>

failed to convincingly explain the pause in terms of external radiative forcing from greenhouse gases, aerosols, solar or volcanic forcing; this leaves natural internal variability as the predominant candidate to explain the pause. If the IPCC attributes the pause to natural internal variability, then this begs the question as to what extent the warming between 1975 and 2000 can also be explained by natural internal variability.” – *Prof. Judith Curry, 20<sup>th</sup> September 2013*<sup>23</sup>

We have recently completed a series of eight articles describing our own research into man-made global warming theory. The results of our new research have led us to conclude that the man-made global warming theory is invalid, and that carbon dioxide has no effect on global temperatures.

If our conclusions are correct, then the “climate sensitivity” is zero, i.e., doubling, trebling or quadrupling carbon dioxide concentrations will make no difference to the climate. In that case, there would be no reason for us to worry about our carbon dioxide emissions. This would remove one of the main justifications for the proposed Yellow River Wind Farm.

At the time of writing, we are in the process of submitting our research for peer review. We hope to shortly launch a website summarising our findings, and providing access to the non peer-reviewed drafts of our articles while the peer review process is underway. This website will be <http://globalwarmingsolved.com/>

Nonetheless, let us assume that we should be actively promoting developments which reduce Ireland’s net carbon footprint. Are wind farms a suitable development to achieve this?

### 3.3. The intermittency problem

For 2013, the average rate of electricity provided to the Irish grid by wind farms was 531 Megawatts (MW). This was 18.3% of the average electricity use. So, initially, you might think that wind power already accounts for 18.3% of the electricity generated. However, because of the intermittency problem, quoting an “average” value is misleading.

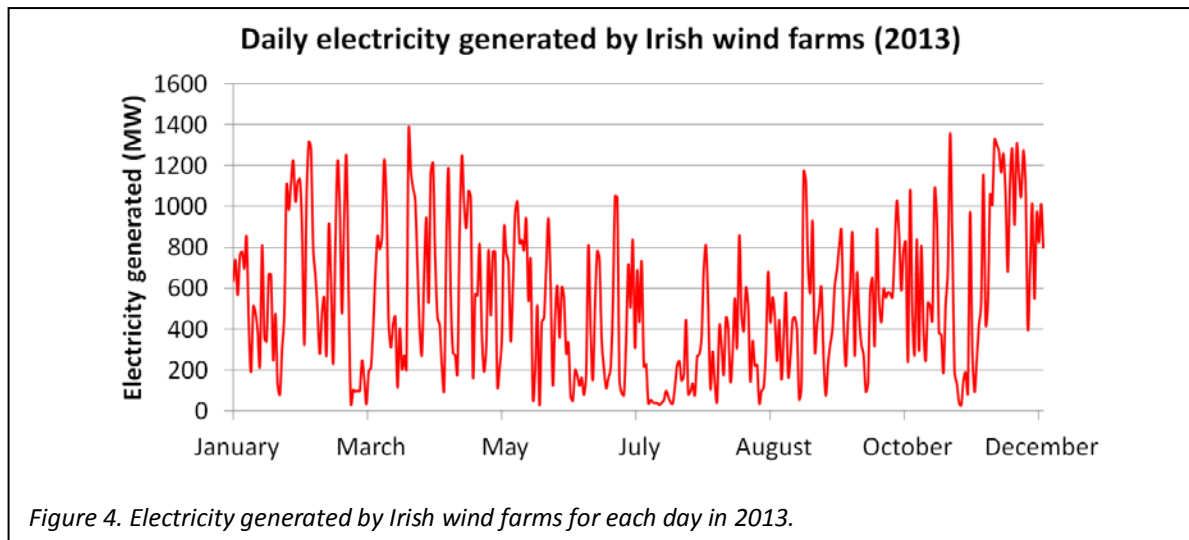
Unlike conventional electricity power plants which can operate almost continuously throughout the year, wind turbines only generate electricity when it’s windy enough (and not too windy!). Figure 4 (*on the next page*) shows the electricity contributed to EirGrid by all the wind farms in Ireland for each day in 2013<sup>24</sup>.

The amount generated varied wildly from day to day. On 14% of the days (51 out of 365), the wind farms were producing more than 1000 MW. However, on 10% of the days (36 out of 365), they were producing less than 100 MW!

The difference in generation from day to day can be very dramatic. On the 20<sup>th</sup> March 2013, the generation rate was 206 MW. The next day, the generation increased to 1369 MW (a rise of 1163 MW in production). On the other hand, on the 24<sup>th</sup> June 2013, wind farm generation dropped rapidly from 1043 MW to 150 MW (a drop of 893 MW in production).

<sup>23</sup> <http://judithcurry.com/2013/09/20/the-ipccs-inconvenient-truth/>

<sup>24</sup> Downloaded from <http://www.eirgrid.com/operations/systemperformancedata/windgeneration/>



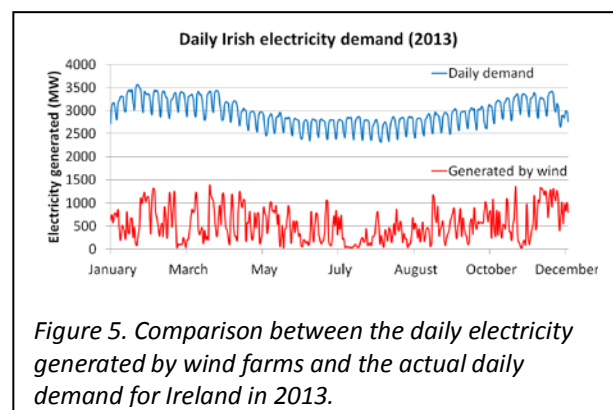
It is these rapid fluctuations which create havoc for the electricity network. If EirGrid is mandated to purchase all of the wind generated by the wind farms (“because it’s green”), then on the days when the wind farms are working, the conventional power plants have to immediately scale back generation. Then, when the wind farms stop working, the conventional power plants have to immediately scale back up.

From an engineering point of view this is very inefficient, and leads to problems. It also increases the carbon dioxide emissions per kWh for the conventional power plant. Conventional power plants are at their most efficient when they are in continuous operation. This is why electricity suppliers offer a half-price night-rate option. By encouraging consumers to spread their electricity usage more uniformly over the 24 hour period, the power plants can maintain a more constant operation. When they are starting up or shutting down, their efficiency decreases (a bit like how cars produce more smoke when they are being started).

So, if a conventional power plant is mandated to repeatedly scale down and scale up electricity generation, this reduces their efficiency, and therefore *increases* their average carbon dioxide emissions per kWh!

In other words, when wind farms (or another intermittent electricity source, e.g., solar photovoltaic cells) are given priority to the grid, the direct carbon dioxide emissions from the wind turbines might be low, but the carbon dioxide emissions from the other sources increase!

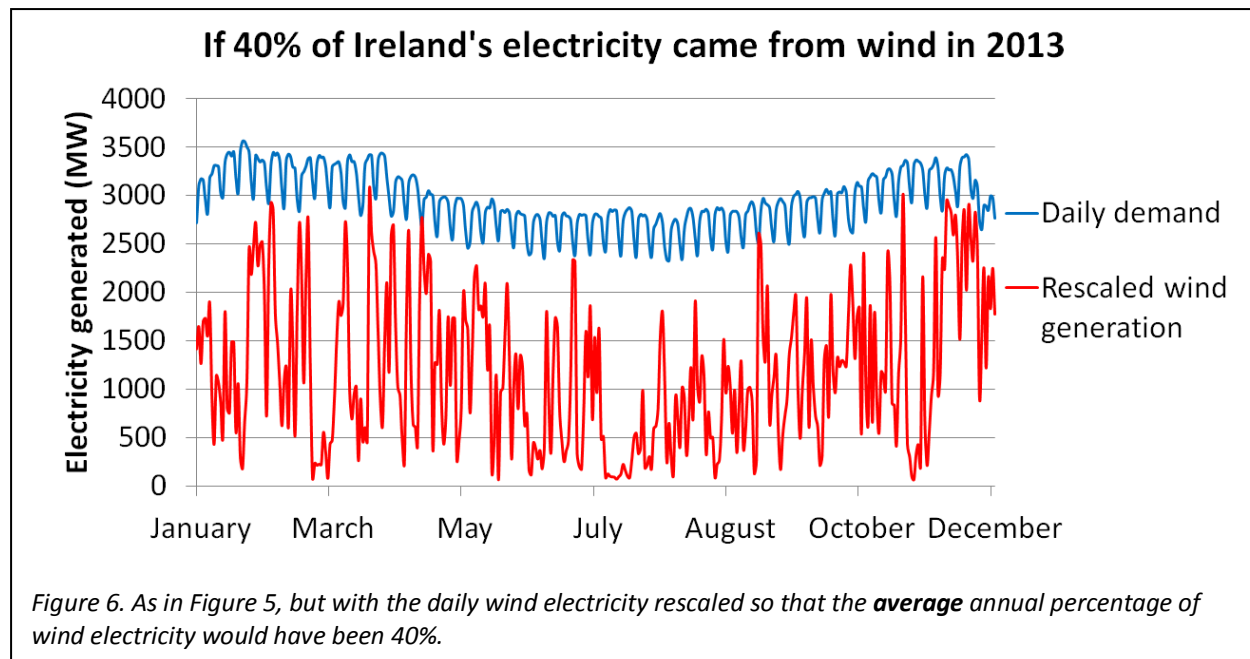
The intermittency also reduces the reliability and stability of the electricity network. Actual electricity usage (domestic or industrial) does **not** vary as widely as wind farm electricity generation – see Figure 5<sup>25</sup>.



When electricity generation decreases, this increases the frequency and duration of power outages. If the electricity generation is greater than the electricity usage, it is wasted.

<sup>25</sup> Electricity usage is slightly reduced on Saturday and Sunday. This is why the blue daily demand curve in Figure 5 shows a slight drop for two days every week.





These inefficiencies increase the cost of electricity and the average carbon dioxide emissions per kWh of electricity. It also reduces the stability and reliability of the network.

When the percentage of electricity generated by wind (or other intermittent renewables) is relatively low, these problems might be undesirable, yet tolerable. However, as the percentage is increased, e.g., by adding more wind farms to the network, then the magnitude of the problems steadily increases.

On our research farm, we have already detected a substantial increase in the frequencies of short-term power outages (1-2 minutes) over the last decade. The percentage of the country's electricity generated by wind farms has increased to about 19% over this period.

As we mentioned in Section 1.3, the current Minister for Communications, Energy & Natural Resources has said that the current government have set a target of having 40% of electricity production coming from wind farms by 2020.

Imagine if 40% of the country's electricity generation was subject to the same fluctuations we saw in Figure 4. Figure 6 illustrates what Ireland's wind electricity contribution would have been like in 2013, if 40% of our electricity had been wind-generated.

On days like 24<sup>th</sup> June 2013, there would be major blackouts across the country! Perhaps given enough warning, the electricity providers would be able to prioritise electricity for emergency services and industrial usage, but it could cause serious harm to the country's economy, as well as reduce the standard of living. Moreover, with frequent power shortages, users would be unable to rely on a constant supply of electricity, and so it is plausible that they would not use the excess electricity on those days when the wind farms are at peak.

### 3.4. Lack of suitable battery technology

In theory, one way to reduce the intermittency problem for wind farms (or other intermittent generators like solar photovoltaic cells) would be if the electricity produced during peak generation could be

temporarily stored on-site, and then transmitted when generation is at a minimum. That is, use large-scale batteries to even out the peaks and troughs in electricity generation. Unfortunately, suitable battery technology to do this has not been developed or invented yet.

Some electricity generation plants are located near a mountain reservoir, and can use this for large-scale “battery storage”, in that electricity can be used to pump water to the top of the mountain during peaks, and then during lows, the water can be released and used to generate extra electricity with a hydroelectric plant. However, this is only really viable for a few locations, and for high capacity power plants. Wind turbines only provide a relatively diffuse form of electricity generation. Moreover, the Yellow River area is a relatively flat land, and is not located close to a suitable hydroelectric power plant.

It is true that there is currently considerable research and development underway into using hydrogen fuel cells as a form of electricity storage<sup>26</sup>. Unfortunately, this technology is still not commercially viable for a wind farm. Also, it would require the on-site storage of hydrogen gas, which is highly flammable, and could be dangerous.

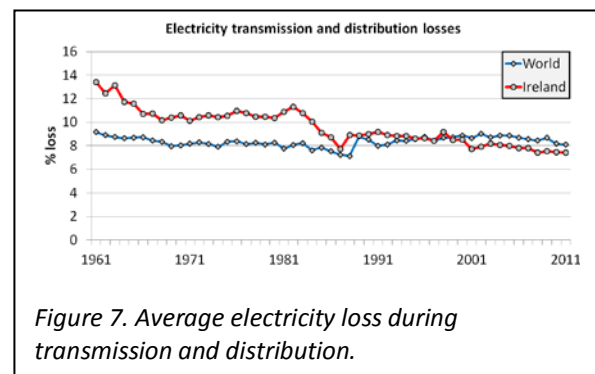
So, while it is plausible that over the next decade or so<sup>27</sup>, the technology for electricity storage may become viable, it is not currently an option. Instead, wind farms either have to shut down when they are producing excess electricity, or else rely on the electricity grid being able to cope with the farm’s highly intermittent electricity generation.

The proposed Yellow River Wind Farm project does not discuss methods for electricity storage, and instead assumes that all the generated electricity will be sold to the grid as soon as it is generated. In other words, they do not even attempt to deal with the intermittency problem!

### 3.5. Transmission losses and the “diffuse problem”

Another problem with wind farms is that wind turbines offer a very diffuse form of electricity generation. In a wind farm, each turbine only generates a relatively small amount of electricity, e.g., a turbine with an installed capacity of 3MW might produce an average of 1MW. This electricity then has to be transmitted to a distribution centre.

Electricity transmission and distribution is not a perfect process, and some electricity is lost along the way. Figure 7 shows the amount of electric power that is currently lost through transmission and distribution, as a percentage of output<sup>28</sup>.



Although Ireland had a relatively poor electric infrastructure in the 1960s and 1970s, for the last decade, our losses are less than the world average. Having said that, we still lose 7.4% (in 2011) of our electricity through transmission and distribution.

<sup>26</sup>

<http://www1.eere.energy.gov/hydrogenandfuelcells/accomplishments.html>

<sup>27</sup> BBC, 12<sup>th</sup> July 2013. <http://www.bbc.co.uk/news/science-environment-23259550>

<sup>28</sup> Power transmission/distribution loss data from <http://www.indexmundi.com/facts/ireland/electric-power-transmission-and-distribution-losses>



The longer the distances over which the electricity needs to travel, the greater the losses. These losses effectively increase our carbon footprint, because the amount of electricity being generated is greater than the amount of electricity actually used.

Also, wind farms tend to be located away from the urban areas which have the highest electricity usage. This would apply to the proposed Yellow River Wind Farm.

In contrast, a conventional power plant might produce several hundred MW of electricity. They can also be sited closer to the locations with the highest electricity usage.

Increasing the number of wind farms is likely to lead to greater transmission and distribution losses. Ironically, this could increase the country's total carbon footprint.

It appears that the proposal by EirGrid to build another 750 electricity pylons, which we mentioned in Section 1.3, is an attempt to improve the electricity network so that it could better cope with a large number of wind farms.

If extra wind farms such as the proposed Yellow River Wind Farm are **not** built, then the controversial proposal by EirGrid for more pylons would not be as essential.

### 3.6. The estimated lifespan of the wind turbines

It is worth stressing that it is still unknown exactly what the lifespan of the proposed wind turbines would be. Market promoters routinely quote figures claiming that their wind turbines have estimated lifespans of at least 15-20 years. However, modern wind turbines are still a relatively new technology, and so these estimated lifespans are often little more than guesses.

A major problem in estimating the average lifespan is that the technology has been undergoing rapid development over the last few decades. As a result, wind farm developers prefer to purchase the latest turbines. While this is understandable, and indeed sensible, it does mean that they are purchasing models which have not been in operation long enough to reliably estimate their average lifespan.

There have been unexpected problems with many of the older turbines, which **had originally** been given “*lifespan estimates of at least 20 years*”, when they were initially sold. For instance, according to one analysis in 2010<sup>29</sup>, “*wind turbine gearboxes have yet to achieve their original design life goals of 20 years. Most turbines require significant repairs and even complete overhauls in the 5-7 year range, well before that benchmark*”.

Some of the newer wind turbines, such as the Siemens SWT 3.0-113 turbine which Green Wind Energy propose as a possible choice, do not use gearboxes, but instead use “direct-drive generators”. In this way, they should bypass this specific “gearbox problem”, but it is possible that in a few years, other problems specific to the direct-drive generator turbines may be identified.

Green Wind Energy appears to be implicitly assuming that the wind turbines they are considering will have an average lifespan of at least 15 years. However, the models they are considering are still relatively new models, and so this might be overly optimistic.

If the wind turbines have a shorter lifespan than claimed, this means the environmental problems involved with the construction and installation of the turbines are even more

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<sup>29</sup> “The elephant in the wind turbine”. Tribology & Lubrication Technology. June 2010.  
[http://www.stle.org/assets/news/document/cover\\_story\\_06-10.pdf](http://www.stle.org/assets/news/document/cover_story_06-10.pdf)

serious. It also would substantially reduce the total carbon footprint savings over the turbine's lifespan.

The construction of wind turbines is quite a high energy process, particularly the manufacture of the steel, and therefore involves substantial carbon dioxide emissions. The installation of the turbine also involves the use of energy, and at the end of its lifespan, the turbine will need to be decommissioned.

All of this means that wind turbines have an implicit "carbon footprint debt" over their lifespan, that they will have to pay off, before we can claim that they are "reducing" the world's carbon dioxide emissions. If the turbine's lifespan is shorter than expected, then this reduces the total "carbon dioxide emissions savings" that the turbine offers.

Furthermore, many of the metals used to construct wind turbines are quite rare. Aside from the environmental degradation involved in mining these metals, their construction is leading to resource depletion.

It is sometimes argued that these rare metals can be recycled after the wind turbines are decommissioned, but that only applies if the world agrees to limit the total number of turbines in the world. By increasing global sales of wind turbines, projects such as the proposed Yellow River Wind Farm are encouraging the wind turbine manufacturers to continue making new turbines.

### 3.7. Are there better ways to reduce our carbon footprint?

#### Geothermal energy

The Yellow River site is at the base of Croghan Hill. Croghan Hill is the youngest volcanic structure in Ireland (3 million years old). This is because the Yellow River area is located on a geological fault line. The result is that this

area is the area with the most potential for geothermal electricity in the Republic of Ireland - see Figure 8 (*on next page*), which is adapted from the Goodman et al., 2004<sup>30</sup> report for Sustainable Energy Ireland.

The rate of improvements in geothermal electrical energy generation has been rapid in recent years, particularly with the introduction of "binary cycle power plants" that can accept fluid temperatures as low as 57°C.

Like wind electricity generation, geothermal electricity generation has low carbon dioxide emissions. However, unlike wind electricity, it is a continuous and concentrated form of electricity generation. It does not suffer from the intermittency problems of wind power.

Installation of wind turbines in the region could interfere with the future development of geothermal projects in the area.

#### Biomass

Already, a number of farmers in the Yellow River region have converted to timber production for use as a biofuel.

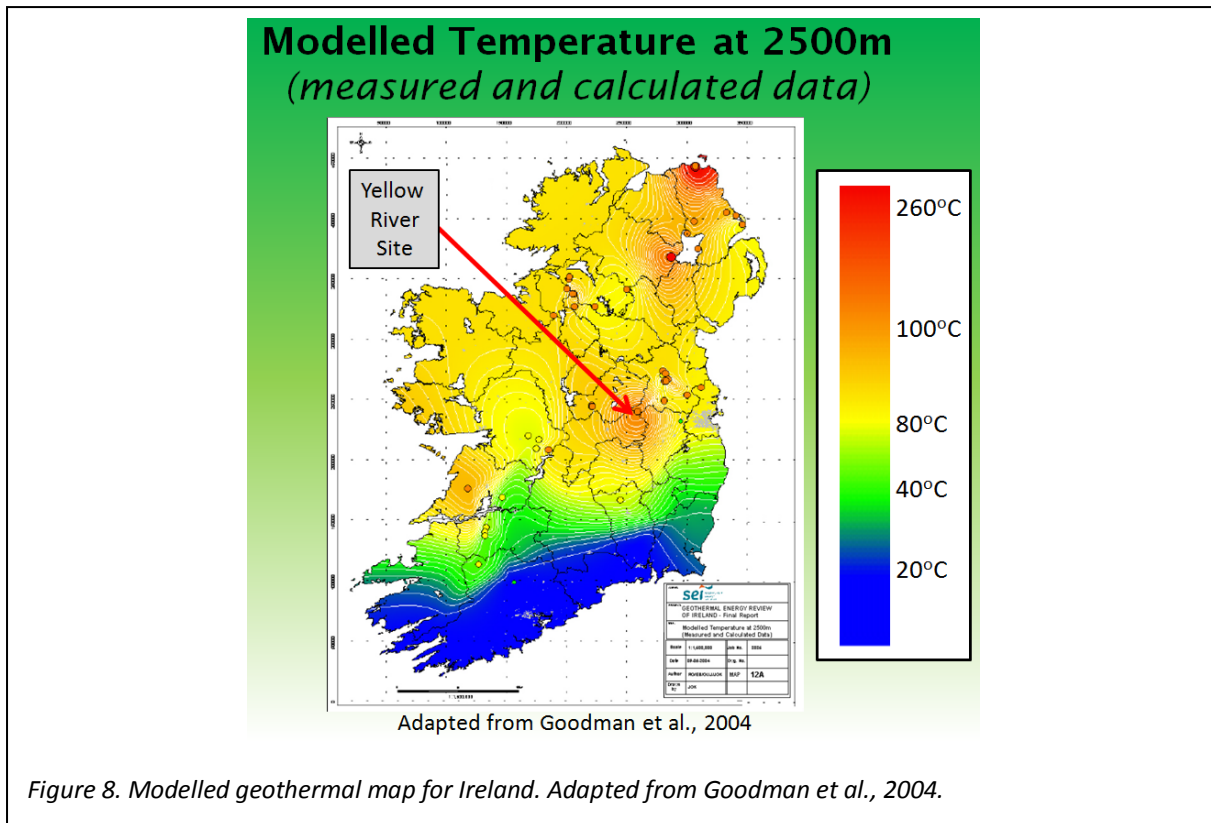
Production of energy from biofuels is often claimed to be a "carbon neutral" form of electricity generation.

Bord na Mona have recently been granted planning permission for a biomass generator beside the proposed locations for Turbines 1-12 of the proposed wind farm, because of the potential for biofuel production in the area.

Unfortunately, forests are one of the most efficient ground covers for reducing wind speeds.

So, if the area of forest land in the region increases, as is currently happening, this will

<sup>30</sup> Geothermal energy resource map of Ireland, Final report, July 2004, prepared for Sustainable Energy Ireland. Downloaded from <http://www.iretherm.ie/publications.html>



reduce the wind power available for the proposed wind farm.

In other words, biofuel production using trees is not compatible with wind turbines. So, the biomass production which is been carried out in the area to help reduce carbon dioxide emissions would not be compatible with the proposed Yellow River Wind Farm.

### Increase the number of small regional power plants

In Section 3.5, we saw how the average losses of electricity in the transmission and distribution along the grid currently are about 7.4%. These losses indirectly increase our carbon dioxide emissions, since more electricity production is required to meet the demand of the consumers.

One way to reduce the transmission and distribution losses is to shorten the distance the electricity needs to be transported.

The average electricity usage is greatest in urban areas, since there are more people,

businesses, services, etc. Therefore, if a power plant can be located near to an urban area, this can dramatically reduce the total transmission and distribution losses for the country. In other words, it would reduce the national carbon footprint.

Moreover, in some cases, if the waste heat from the power plant can be harvested, it can be used to help heat the urban area, during the winter. This is called “district heating”<sup>31</sup>, and a number of “cogeneration” heat-and-power plants are already in use around the world<sup>32</sup>. This would reduce the heating bills, and therefore further reduce the total carbon footprint.

With this in mind, if extra power plants were built near to urban areas specifically to supply electricity to those areas, this could significantly reduce the national carbon

<sup>31</sup> See Wikipedia for a reasonable summary: [http://en.wikipedia.org/wiki/District\\_heating](http://en.wikipedia.org/wiki/District_heating)

<sup>32</sup> E.g., in Lünen, Germany - <http://www.cospp.com/articles/2013/12/new-chp-plant-supplies-district-heating-for-german-town.html>

footprint. It would also reduce the problem of intermittency which we discussed in Section 3.3.

The reduction in carbon dioxide emissions would be even greater if the power plants use fuels with lower carbon dioxide emissions than coal or peat, for instance gas.

### Switching from coal & peat to gas

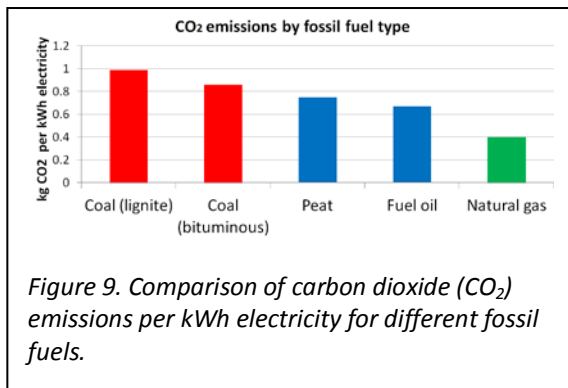


Figure 9 shows the average amount of carbon dioxide (CO<sub>2</sub>) emitted per kWh of electricity produced, depending on the type of fuel used<sup>33</sup>. While coal produces nearly 1kg of CO<sub>2</sub> for every kWh of electricity, natural gas (“gas”) only produces 0.4kg.

This means that every coal burning power plant that switches to, or is replaced by, a natural gas power plant more than halves CO<sub>2</sub> emissions.

In other words, if it is considered a national priority to reduce carbon dioxide emissions, then the government should be promoting the use of gas-powered electricity generation.

The old ESB peat-powered electricity plant was located near where Turbines 8-16 are proposed. This plant has already been replaced by a gas-powered electricity generator of 104 MW installed capacity, and has already reduced the carbon dioxide

emissions for electricity generation in the area.

This development proceeded with no objections from the residents, and expansion in the capacity of this plant is feasible.

In the last few years, a number of new sources of natural gas have become available.

In particular, a large number of shale gas extraction plants have been set up in the U.S., and U.S. gas production is beginning to give them energy independence<sup>34</sup>. As a result, global gas prices have reduced.

Although “fracking” has been controversial in Ireland, and Leitrim county councillors recently voted to ban fracking in Leitrim<sup>35</sup>, there appear to be substantial shale gas reserves in England<sup>36</sup>, and several shale gas projects are being considered in the U.K.<sup>37</sup>. So, it is likely that global gas prices, and in particular local gas prices, will continue to remain relatively low for the proposed lifespan of the Yellow River Wind Farm project, i.e., 15 years or more.

In addition, when the Corrib gas project<sup>38</sup> eventually manages to bring gas ashore, this would provide a large Irish source for gas.

A promising future source for gas lies with the so-called “methane hydrate” reserves. These are large pockets of frozen gas which are located underwater at various places around the world – see Figure 10.

<sup>34</sup>

[http://thebreakthrough.org/archive/shale\\_gas\\_fracking\\_history\\_and](http://thebreakthrough.org/archive/shale_gas_fracking_history_and)

<sup>35</sup> The Journal.ie. 14<sup>th</sup> January 2014.

<http://www.thejournal.ie/leitrim-county-councillor-1263205-Jan2014/>

<sup>36</sup>

<http://www.bgs.ac.uk/research/energy/shaleGas/howMuch.html>

<sup>37</sup> BBC. 13<sup>th</sup> January 2014. <http://www.bbc.co.uk/news/uk-25695813>

<sup>38</sup> Mayo News. 31<sup>st</sup> December 2013.

[http://www.mayonews.ie/index.php?option=com\\_content&view=article&id=19139:corrib-will-cost-34-billion-when-completed&catid=23:news&Itemid=46](http://www.mayonews.ie/index.php?option=com_content&view=article&id=19139:corrib-will-cost-34-billion-when-completed&catid=23:news&Itemid=46)

<sup>33</sup> Data taken from International Energy Agency, 2012. “CO<sub>2</sub> Emissions from Fuel Combustion – Highlights”. <http://www.iea.org/publications/freepublications/publication/name,32870,en.html>

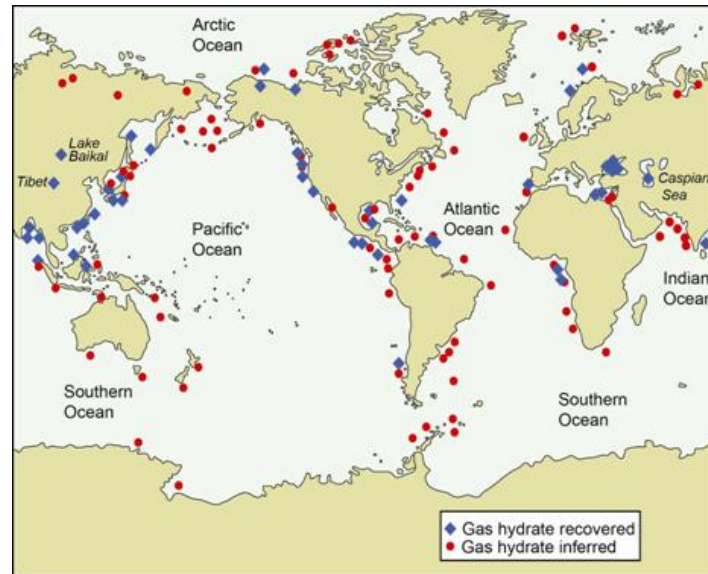


Figure 10. Known and inferred locations of methane hydrate ("gas hydrate") reserves. Map compiled by the U.S. Geological Survey. Downloaded from <http://woodshole.er.usgs.gov/project-pages/hydrates/primer.html>

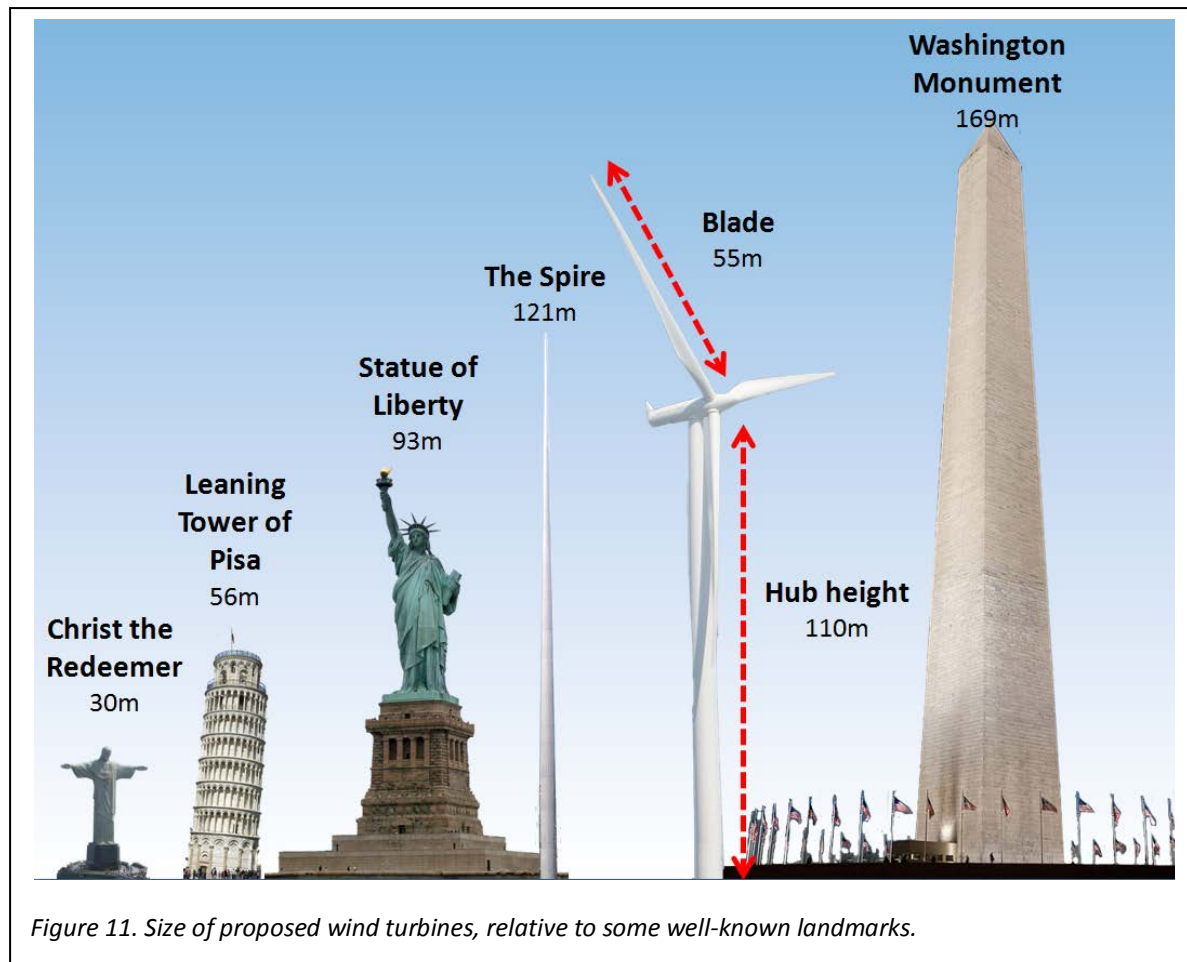
Globally, methane hydrate reserves appear to be quite abundant<sup>39</sup>. At present, the technology for extracting gas from these reserves is not fully developed. However, the Japanese have made good progress in this field, and have already started extracting methane hydrates from the sea floor<sup>40</sup>.

Moreover, it is thought likely that a methane hydrate reserve exists in Irish waters, off the west coast of Ireland (see Figure 10). This might provide considerable energy independence for Ireland in the future.

<sup>39</sup> Charles Mann, The Atlantic, May 2013. <http://www.theatlantic.com/magazine/archive/2013/05/what-if-we-never-run-out-of-oil/309294/>

<sup>40</sup> Financial Times. 17<sup>th</sup> January 2014. "Methane hydrates could be the energy of the future". Sylvia Pfeifer. <http://www.ft.com/intl/cms/s/0/8925cbb4-7157-11e3-8f92-00144feabdc0.html#axzz2rFrIVx4r>





## 4. Environmental Impacts of proposed development

### 4.1. Landscape and visual

Although Green Wind Energy consider several different wind turbine models, we saw in Section 2 that they require that their proposed turbines have a hub height of at least 100m. They propose that the exact hub height could be up to 110m. So the turbines would have a hub height somewhere in the range 100-110m.

One of the main options they consider is the Siemens SWT 3.0-113 model<sup>41</sup>, which has a blade length of 55m and can have a hub height of 110m. This means that the maximum ground-to-blade-tip height is 165m.

<sup>41</sup> <http://www.energy.siemens.com/hq/en/renewable-energy/wind-power/platforms/d3-platform/wind-turbine-swt-3-0-113.htm>

The other options they consider suitable are of a similar size.

Figure 11 compares a wind turbine of this size to some well-known landmarks<sup>42</sup>. It can be seen that the height of the proposed turbines would be very tall. For instance, the Great Pyramid of Giza in Egypt is only 134m tall.

The width of the area that would be swept by the blades is also very large. The total rotor diameter (including the nacelle at the hub) of the SWT 3.0-113 is 113m (the 3.0 in the model name refers to the installed capacity in MW, and the “-113” part refers to the rotor

<sup>42</sup> Photographs of all structures were downloaded from <http://commons.wikimedia.org/> under Creative Commons Attribution-Share Alike 3.0 license (<http://creativecommons.org/licenses/by-sa/3.0/>). The authors of each photograph are as follows: Christ The Redeemer - Jcsalmon; Leaning Tower - Saffron Blaze; Statue of Liberty - Elcobbola; The Spire - Vmenkov; Washington Monument - Túrelío; Wind turbine – Billy Hathorn.

diameter). In comparison, the width of the pitch in Croke Park is only 88m.

The location for twelve of the proposed wind turbines (T1-12) is on relatively flat bog land at the base of Croghan Hill.

Croghan Hill is a prominent and well-known hill in the proposed Yellow River Wind Farm area. The hill (an extinct volcano) is only 216m above sea level. However, because the Bog of Allen is a relatively flat, low-lying land, Croghan Hill commands extensive views of the surrounding counties, and similarly is visible from much of the surrounding countryside.

The Bog of Allen is itself 70-80m above sea level. The maximum ground-to-blade tip height of the proposed wind turbines is 165m. As a result, the tips of the blades of many of the proposed wind turbines would reach 235-245m above sea level, i.e., 20-30m higher than Croghan Hill.

The aesthetics of wind turbines are somewhat subjective – some people love the look of them, while others hate them. However, due to the flat, low-lying nature of the region and the large size of the proposed wind turbines, this would significantly alter the landscape of a large section of the Midlands.

As a crude measure of the scale of this visual impact, residents or commuters who can currently see the northern side of Croghan Hill would probably be able to see several of the proposed turbines, if the project was installed. This includes much of the northern Midlands, i.e., the visual impact is not just confined to the local residents of the area.

## 4.2. Climate change caused by wind turbines

Wind turbines are often promoted as being a “green” form of electricity production, which

could help “*stop climate change*”. The basis for this claim is almost entirely due to fact that, while they are in operation, the electricity they generate does not directly involve the production of carbon dioxide. As we discussed in Section 3.1, the current climate models assume that carbon dioxide emissions lead to unusual global warming, which is of course, a form of climate change. However, ironically, while one of the primary motivations for large scale wind farms is to help reduce climate change, wind turbines can lead to substantial *local* climate change.

There are three major aspects of the climate which wind turbines alter:

1. Regional wind patterns
2. Regional precipitation
3. Local ground and air temperatures (night and day)

The idea of a wind turbine is to extract energy from the wind passing through the swept area of the blades. The more effective the turbine is, the greater the energy extraction is.



Figure 12. Demonstration of wake effect turbulence shown with smoke generated at a single blade's tip. Taken from Ragheb, 2013. Original source: Risö National Laboratory,

This means that the energy content of the wind leaving the turbine is much less than the wind entering the turbine. This is known as the “wake effect”.





Figure 13. Illustration of wake effect. Taken from Ragheb, 2013. Original source: Vattenfall.

The wake effect reduces the wind speed, but increases the turbulence of the air on the lee side of the turbine. This can be seen from Figure 12, which is taken from Ragheb, 2013<sup>43</sup>

The reduction in the lee side wind speed can be quite significant. Indeed, Adams & Keith, 2013<sup>44</sup> have suggested that large-scale wind farm installations can substantially alter the regional wind patterns, and that as a result the various analyses of the total global wind resource have been significantly overestimated.

By extracting energy from the wind, the turbines can also trigger the condensation and precipitation of the water vapour in the air. This can be visually illustrated by the offshore wind farm in Figure 13, where we can see

clouds forming in the wake of all of the turbines.

This means that wind turbines can dramatically alter the hydrology of the region, i.e., it can lead to a greater average rainfall in the area. If more rain falls in the region near the wind farm, then the water content of the air is reduced, and this would reduce the average rainfall in regions further downwind.

This can constitute a substantial climate change, which may have significantly alter the local ecology of the landscape. In particular, it could substantially alter the hydrology of the many peat bogs which occur in and around the Yellow River site.

The increase in air turbulence caused by the wind turbines also creates a greater mixing of the air, leading to significant air and ground temperature changes.

If the air at ground level is relatively cold, the wake effect can increase the ground

<sup>43</sup> "Orography and wind turbine siting", Dr. Magdi. Ragheb (18<sup>th</sup> April 2013).

<http://mragheb.com/NPRE%20475%20Wind%20Power%20Systems/Orography%20and%20Wind%20Turbine%20Siting.pdf>

<sup>44</sup> Environ. Res. Lett., 8 (2013) 015021.

<http://dx.doi.org/10.1088/1748-9326/8/1/015021>

temperature, while if the ground air is relatively warm, the wake effect can cool the ground temperature (Baidya Roy & Traiteur, 2010<sup>45</sup>).

A series of MIT studies (Wang & Prinn, 2010<sup>46</sup>; Wang & Prinn, 2011<sup>47</sup>) has calculated that if 10% of the world's electricity were to come from wind farms, this could cause an annual average of more than 1°C warming of the land around the wind farms (although offshore wind farms have the opposite effect, i.e., sea surface cooling).

Zhou et al., 2012<sup>48</sup> have used satellite measurements over wind farms in west-central Texas (USA) to confirm that wind turbines significantly increase the ground temperature, particularly during the summer night-time. They estimate that the widespread installation of wind farms in the area has led to a warming of up to 0.72°C/decade in the area. Although this warming is localised to the land near wind farms, this is a substantial climate change. To put it in context, the reported global warming since the Industrial Revolution which we discussed in Section 3 was only 0.08°C/decade.

### 4.3. Wind turbine noise

The Environmental Impact Statement for the proposed Yellow River Wind Farm provides an assessment of the potential impacts of the noise and vibration the wind turbines would cause. They concluded that the noise would only be minor, and within tolerable levels for the area.

However, their assessment was majorly flawed and made several critical errors. As a result, they seriously underestimated the substantial noise pollution that the turbines would cause for the area.

First, they used the wrong values in the computer program that they used for their analysis.

As we discussed in Section 2.4, the developers temporarily installed a meteorological station on the proposed site with two wind monitors – one at 44.8m and the other at 80.8m. The purpose of this was to determine the wind shear for the area, so that they could plug it into their noise analysis computer program.

However, while their measurements gave a range of wind shear values with an average of 0.27, the values that they plugged into their computer implied an almost constant value of 0.157 (see Appendix 3)<sup>49</sup>.

It can be seen from Appendix 1 that the average wind shear value varies from 0.10 to 0.30 across Ireland. In other words, their measured wind shear values (0.27) were relatively high, but the value they used for their noise analysis (0.157) was relatively low.

The reason this is a problem, is that the computer program uses wind shear to calculate the noise level, and how it drops off with distance. This is why wind farm applications are mandated to experimentally determine the wind shear value in the first place.

The lower the wind shear value, the lower the noise levels are, and the quicker the noise drops off with distance. So, by plugging in values that were much lower than they had actually measured, their computer program

<sup>45</sup> Proc. Natl. Acad. Sci. 107 (2010), 17899-17904.

<http://dx.doi.org/10.1073/pnas.1000493107>

<sup>46</sup> Atmos. Chem. Phys. 10 (2010), 2053-2061.

<http://dx.doi.org/10.5194/acp-10-2053-2010>

<sup>47</sup> Environ. Res. Lett., 6 (2011) 025101.

<http://dx.doi.org/10.1088/1748-9326/6/2/025101>

<sup>48</sup> Nature Clim. Change. 2 (2012), 539-543.

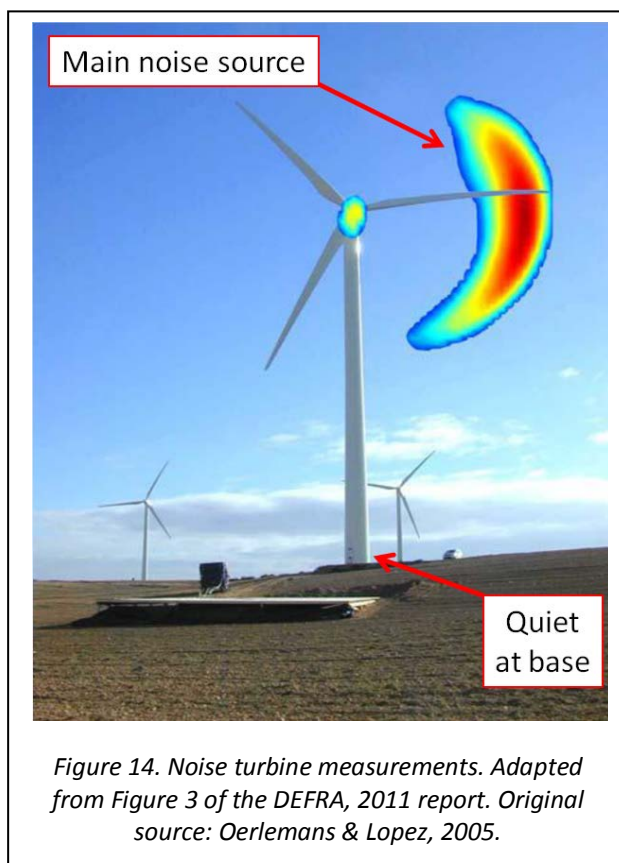
<http://dx.doi.org/10.1038/nclimate1505>

<sup>49</sup> For those interested, they obtained this lower wind shear value because, when they were extrapolating their 10m wind speeds from the 113m wind speeds, they incorrectly used an inappropriate "surface roughness" constant of 0.05.

would have substantially underestimated the noise levels.

Second, no analysis was done on the so-called “swish-and-thump noise”, and how the grid effect of having multiple turbines can cause large amplification of the noise at certain locations, due to constructive interference. Instead, their noise analysis was more appropriate for old turbines, where most of the noise was “hub noise”, e.g., caused by gear mechanisms.

In modern turbines, most of the noise is caused by the tip of the downward moving blade. This can be seen from Figure 14, adapted from a June 2011 report for the UK’s Department for Environment, Food & Rural Affairs (DEFRA) on wind farm noise<sup>50</sup>.



For this reason, most planning authorities restrict the tip speed to 68 m/s when dwellings or work places are in the vicinity. Unfortunately, restricting the tip speed reduces the output of the turbine, particularly for large turbines like the ones proposed for the Yellow River project.

For instance, the Siemens SWT 3.0-113 turbine (one of the models they propose) only works efficiently when the rotor speed can vary from 6.0 to 15.5 r.p.m., which gives a tip speed of between 35 and 90 m/s. In other words, curtailing the tip speed to 68 m/s would seriously reduce the annual output of the turbine.

Third, in order to determine how noise drops off with distance, it is first necessary to determine the geometry of the noise source. In practice, it is common to use one of three approximate source geometries:

1. A point source
2. A linear source
3. A disc source

The point source is used when the observation distance is very large, relative to the area of the source. The linear source is used when the noise source is linear, for example roads or railways. The disc source is used when the area of the source is of a similar order of magnitude to the observation distance.

For a point source, the noise drops off as the square of the distance. For a linear source, the noise drops off in proportion to the distance. For a disc source, the drop off with distance is smaller still.

The consultants state in their preamble that they treated the turbine noise as a point source. This is a mistake.

<sup>50</sup> “Wind Farm Noise Statutory Nuisance Complaint Methodology” Ref. PB13584 for DEFRA.  
<https://www.gov.uk/government/publications/dealing-with-wind-farm-noise-complaints>

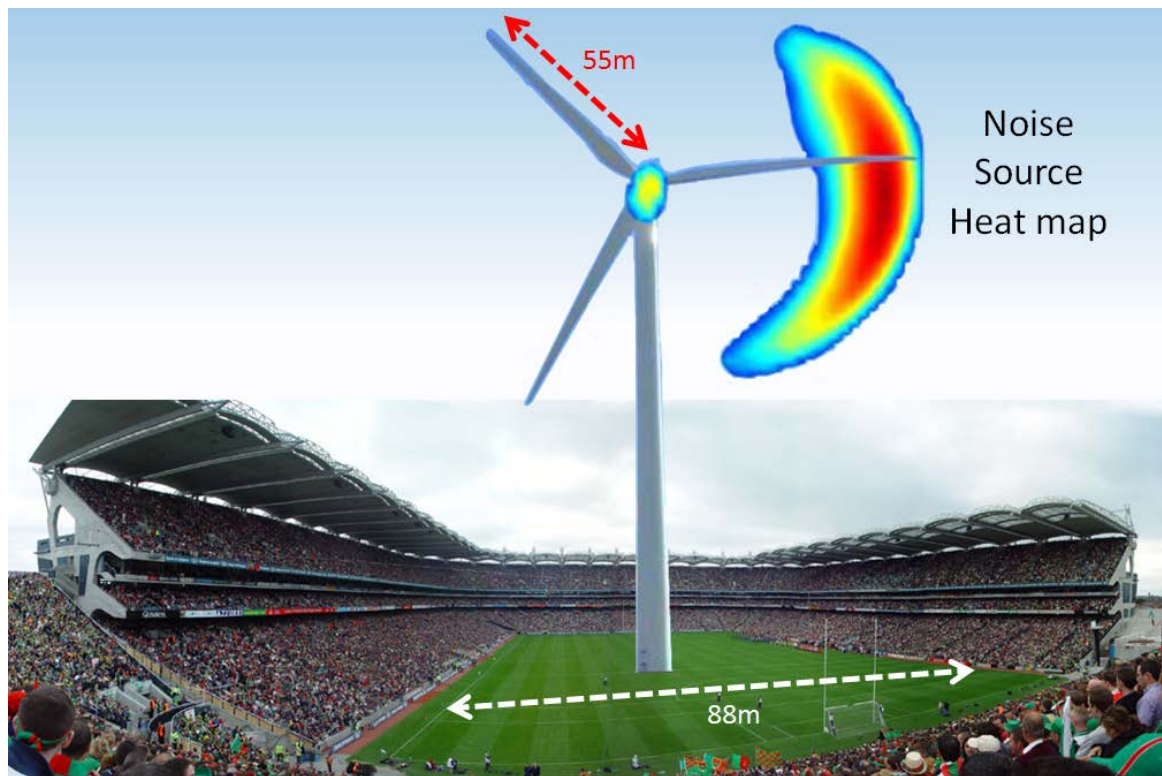


Figure 15. The area swept by the proposed turbines would be greater than the width of Croke Park, and therefore should **not** be treated as a “point source” for noise. Turbine and noise source heat map adapted from DEFRA, 2011. Photo of Croke Park by John H. Nolan is taken from the public domain:

[http://commons.wikimedia.org/wiki/File:Croke\\_Park\\_from\\_the\\_hill.jpg](http://commons.wikimedia.org/wiki/File:Croke_Park_from_the_hill.jpg)

As can be seen from Figure 15, the noise source from the proposed wind turbines would be larger than Croke Park, and should therefore have been treated as a disc source. This means that their model underestimated the carrying distance of the noise.

Fourth, when considering noise, it is necessary to consider how the sound is propagated. If you talk into a pipe, the sound can be carried to the other end, with very little loss in intensity.

Similarly, sound is carried downwind over greater distances than upwind. This is why, on windy days, the sound of people talking can be carried downwind much further than on calm days.

Also, as any angler could tell you, on days with a temperature inversion over a lake, the sound from the shore on one side of the lake

can be carried to the other side. This is because the sound is reflected back to ground, due to the density difference caused by the inversion layer.

All three of these factors coincide in the wake of a wind turbine. As can be seen from the wakes of the wind turbines in Figure 16, the wake forms a long “tube” of air downwind from the blades. Because the wind turbines



Figure 16. Wind turbine noise can travel in “tubes”. Adapted from Figures 13 and 14.



extract energy from the air, the density of the air in the wake will be different from the air outside the wake. Finally, the wind is blowing in the direction of the wake.

As a result, the noise from a wind turbine can be funnelled in a particular direction, and keep its volume for quite a large distance.

All this leads to the bizarre fact that you can stand at the foot of a large wind turbine, in what is a relatively quiet zone (see Figure 13), while downwind, in the wake, the noise can be deafening - especially at the locations where the wake reaches the ground.

This phenomenon was not considered in the noise model used in the Environmental Impact Statement, and so they seriously underestimated the high intensity noise that is localised in the wake.

Finally, their analysis was only carried out for properly working machines. If, for example, there is no load to the rotor (perhaps because a wire has been broken in an electrical circuit, or the grid is down), the rotor will over-speed, and the noise can become alarming. Although Siemens claim in their sales brochure that they have expert crews on-hand to repair defects quickly, there may be call-out delays in getting these out to the wind farms.

#### 4.4. Flicker

In their Environmental Impact Statement, the Jennings O'Donovan & Partners did an analysis of the potential effects of flicker from the proposed turbines. However, their analysis was severely limited, and as a result inadequate.

They only studied shadow flicker. They did not study the flicker from reflected sunlight.

Their study of shadow flicker was only carried out for dwellings, and the out-of-date aerial photographs they used did not show all

dwellings or buildings. For example, Riverside House, at Garr Bridge is not shown.

They did not consider the effects of flicker (either shadow or reflected) on commuter traffic. The main road from Rochfortbridge to Rhode (R400) passes within 500m of some of the proposed turbines, and the road to Castlejordan passes within the flicker range of the other proposed turbines.

They did not consider the strobe effect of sunlight reflecting off the blades. Although the frequency of the blades for one turbine is only of the order of 1 Hz, in some locations on the road, the frequency of reflections from multiple turbines could exceed 2.5 Hz, which has been known to induce seizures in some people.

The effect that the distractions caused by the wind turbines would have on driver safety was not considered.

#### 4.5. Ecology

Jennings O'Donovan & Partners also provided a discussion of the potential impacts on the local ecology of the region (i.e., the flora and fauna).

This discussion was totally inadequate, and seriously underestimated the potential impacts that the turbines would have on the flora and fauna.

##### Reptiles and amphibians

In their discussion of reptiles and amphibians, the surveyors found some frogs, and said that it was probable that there were lizards in the area, but they could not find any.

In less than one hour, by knowing where and how to look, we found 44 frogs, 17 newts and 1 lizard. They did not even consider newts.

With no evidence, they concluded that there would be no effect from the wind turbines on lizards or reptiles. For example, they did not



Figure 17. Pine marten  
 Scientific name: *Martes martes*  
 Irish name: Cat crainn  
 Legal status: EU Habitats Directive [92/43/EEC] Annex V. Wildlife Act (1976), Wildlife Amendment Act (2000).  
 Photo: Daniel Ahqvist  
 Source: Wikimedia Commons.  
 License: Creative Commons Attribution-Share Alike 3.0 Unported

investigate the effect that the increased turbulence in the lee of the turbines would have on insect behaviour, i.e., the main food source for these animals. Neither did they investigate the effect of temperature changes brought about by the wind turbines.

### Mammals (excluding bats)

In their mammal study, they mention that they found evidence for foxes, badgers, hares, otters, shrews and field mice. They did not find, look for, or mention: pine martens, stoats, mink, or feral cats – all of which are abundant in the area.

The pine martens are easily located in the hedges and trees, along the river banks, and ditches at dawn and dusk, using infrared cameras. Pine martens are protected under three different pieces of legislation. Stoats are

found at ground level in the fields and hedgerows, at similar times.

The mink, particularly the black variety, are easily spotted during the middle of the day along the banks and on the roads, and do not seem to fear humans.

There is also a herd of 17 deer which hide in the woodlands on the south side of the Yellow River, during the day, but roam over the entire site at night.

### Bats

They did find evidence for most species of bats in the area. They mentioned that the bats follow tree-lines, but they failed to mention why.

On windy nights, the bats forage mainly on the lee side of tree-lines. When they are foraging on the windward side, they tend to forage close to the tree-line. This is because, the air at these locations has less turbulence, and this makes it easier for them to locate prey.

The developers propose that planting low hedges at distances from the wind turbines would encourage the bats to stay away from the turbines. However, they seem to be unaware that the increased turbulence caused by the wake effect from the turbines would not be counteracted by these hedges.

The wake effect of turbines is still large at distances of at least 20 rotor diameters.

### Birds

There are many bird species in the area, however their discussion of the possible effects that the wind turbines would have on these species was very limited.

In particular, for the Yellowhammer (a red-listed protected species), they mentioned the possibility that the Yellowhammer might nest



in the locality, but that they had found no evidence for this.

In a short 10 minute walk, from Garr Bridge to the turn-off for Knockdrin, at approximately 7pm in May 2013, we counted six singing males in the hedges along the road, indicating at least six nesting pairs on the lee side of Turbines 13-19. This would be well within the wake effect of the turbines. Although the Yellowhammers are mainly seed-eaters, during the breeding season, they feed their young on an insect diet.

No study was carried out of what the consequences of the wake effect from these turbines would be on this nesting population.

### Insects

They did do some studies on the micro-invertebrate population in the Yellow River, and did detect slight pollution on the lower side of the river at Garr Bridge, below the discharge point for the wastewater from the Rhode treatment plant. However, no study was done on the general insect population for the area. Insects are the primary food source for swifts, bats, fish, etc. No attempt was made to assess the consequences of the wake effect for the insect population.

Their only wake effect study was to determine the effect of the turbine wakes on the energy extraction of the neighbouring turbines. Bizarrely, no consideration whatsoever was given to the effect of the turbine wakes on the climate and ecology of the region.

For example, the honeybee mates in midair, and a female virgin queen bee will only mate once in its lifetime. During the mating process, the queen flies out looking for mates. Male bees ("drones") then swarm about her as she flies, competing for attention. A queen will typically mate with a dozen or so of these



*Figure 18. Yellowhammer*  
*Scientific name: Emberiza citrinella*  
*Irish name: Buióg*  
*Legal status: Red-listed on Irish list of Birds of Conservation Concern.*  
*Photo: Alan Vernon*  
*Source: Wikimedia Commons.*  
*License: Creative Commons Attribution 2.0 Generic*

drones (each drone dying during the mating process)<sup>51</sup>.

Other winged insects have similar mid-air once-off mating patterns, e.g., the mayfly<sup>52</sup>. It is unclear what effects the artificial alteration of the turbulence of the air near a turbine has on the life cycles of these insects. In many cases, it might have no effect. However, in some cases it could increase or decrease the survival abilities of those species. This could in turn affect terrestrial (or aquatic) animals which feed on insects.

We do not know what the net ecological effects of the artificial turbulence alterations of the wind turbines would be for the Yellow River Wind Farm project. However, we were surprised to find that Green Wind Energy's Environmental Impact Statement did not even **mention**, let alone attempt to quantify, the potential effects on the insect population!

<sup>51</sup> <http://insects.about.com/od/antsbeeswasps/qt/Honey-Bee-Mating.htm>

<sup>52</sup> Peckarsky et al., 2002. Behav. Ecol. Sociobiol. 51, 530-537.  
<http://dx.doi.org/10.1007/s00265-002-0471-5>

## 5. National impacts of proposed development

The Irish government *currently* appears to believe that the general large-scale installation of wind farms across the country would be good for Ireland:

"Irish renewable energy policy imposes no significant cost on consumers as we have abundant wind resources that generate power at an economic rate. When one puts the reduction in spending on imports of gas, oil and coal into the balance, our renewable energy policy is a no-brainer" - *Pat Rabbitte, Minister for Communications, Energy and National Resources, 17<sup>th</sup> January 2014*<sup>53</sup>

From this perspective, the proposed Yellow River Wind Farm might initially seem to be of net benefit for the country. However, when we look in more detail, we find that it is not!

In this section, we will consider the potential national impacts of a) the proposed Yellow River Wind Farm; and more generally, b) government policies to encourage the installation of wind farms.

Both factors are of relevance for this report, since the proposed Yellow River Wind Farm project appears to be the type of project that Pat Rabbitte was referring to in the above quote.

Some of the negative impacts which the proposed wind farm, and others like it, could have on the country have already been discussed in this report:

- In Section 3, we showed that the **net** effect of wind farms on carbon footprint reduction has been seriously overestimated.

- Moreover, the **local** climate changes that wind turbines cause (Section 4.2) would be much greater *for the country* than the modelled reduction in global warming that the wind farms are planned to cause.
- In Section 3, we showed how increasing the relative fraction of our electricity which comes from wind farms (or other diffuse and intermittent electricity production forms) substantially reduces the reliability and stability of the electricity network.
- We mentioned in Section 3.2 how the intermittent nature of wind electricity also decreases the efficiency of the conventional power plant electricity generation. This further increases the average cost of electricity generation, as well as increasing the carbon dioxide emissions per kWh.
- In Section 4.4, we showed that the potential impacts of the proposed wind turbines on the local ecology could be very substantial, and have been seriously underestimated.

Wind farms also have many other negative national impacts. In this section, we will briefly outline some of the main ones.

### 5.1. Property values

In Section 4.1 & 4.3, we showed how the large visual intrusion on the landscape of wind turbines with a tip-to-ground height of 165m, and the noise pollution they would produce has been seriously underestimated.

Both problems could substantially reduce local property values. It would also tarnish the image of Ireland as the land of "*forty shades of green*", which could be harmful for the tourism industry.

<sup>53</sup> Irish Times.

<http://www.irishtimes.com/news/environment/eu-renewable-energy-targets-to-be-significantly-scaled-back-1.1658122>

The construction of wind farms also has implications for future development in the area. At the moment, there is legislation stating that wind turbines cannot be built within 500m of a residence, without the approval of the residents.

This legislation seems to have been a major factor in the developers deciding on how many wind turbines to include, and where to locate them in their proposed Yellow River Wind Farm project. They seem to have tried to maximise the number of turbines on the proposed site, by positioning them in their identified regions at least 500m from the **current** houses in the area<sup>54</sup>.

For the many reasons we outline in this report, we do not believe wind farms are appropriate for this region, and that 500m is too short a minimum distance for the large turbines that are being proposed, i.e., that the current legislation is inadequate.

Nonetheless, it is important to consider the corollary of the legislation. In the same way that turbines cannot be built within 500m of houses or buildings, houses or buildings cannot be built within 500m of the turbines.

If the proposed wind farm were to be built, many of the turbines would be located at distances not much further than 500m from houses. In other words, the 500m radius from the proposed turbines incorporates much of the undeveloped land in the area.

From a planning point of view, the wind farm would seriously restrict any future development in the area. In effect, the presence of the turbines would “sterilise” the area, until such time as the turbines could be removed.

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<sup>54</sup> They say that they have received permission from those residents who are living less than 500m from one of their proposed turbines.

## 5.2. Energy costs and security

We discussed in Section 3 how, because wind farms are a very diffuse and intermittent form of electricity generation, they reduce the reliability and stability of the electricity grid.

Even with the latest wind turbine technology, the **net** cost of electricity generation via wind farms is still more expensive than conventional electricity generation from gas, coal or oil power plants.

Currently, there are three main approaches that governments have adopted to encourage wind farms (or other renewable energy sources):

1. Offering grant aid for particular technologies.
2. Offering Feed-In Tariffs for electricity from a particular type of electricity generation. This means that electricity suppliers are obliged to buy whatever electricity they are offered, at a fixed (high) price, whether they need it or not, if the producer of that technology (e.g., wind turbines) offers to sell it to them.
3. Mandating that electricity suppliers maintain a particular “Renewable Portfolio Standard”. This means that they are obliged to ensure that a certain percentage of their electricity is sourced from a renewable energy source, e.g., wind electricity.

The first approach does not *directly* affect energy costs or the electricity consumer, since it generally is taken from the exchequer, but it does affect the taxpayer, since the grants are paid for either at the expense of other projects or by increasing taxes.

The other two approaches both generally lead to higher electricity bills, since the electricity suppliers are being mandated to produce a

certain percentage of their electricity using less competitive means.

There is a lot of controversy over the total costs of electricity generation for different renewable energy technologies. Many supporters of renewable energies, such as wind electricity, like to *imply* (and sometimes even claim) that their favoured technology is “as cheap as” or “even cheaper than” conventional electricity production.

Due to the vitriolic nature of the debate over different electricity technologies, it can often be hard to distinguish between “market spin”, “market counter-spin” and the actual facts. However, amongst all of the claims and counter-claims, there is at least one fact that is indisputable:

If electricity suppliers have to be *mandated* (by whatever means) in order to get them to use a particular form of electricity generation, then that form is probably less competitive.

In other words, it will lead to higher electricity costs. In order for the suppliers to remain in business, these higher costs are often passed onto the consumers through higher electricity bills.

The government are currently encouraging wind farms through such a scheme (i.e., a renewable portfolio standard). Therefore, we can conclude that the current wind farms lead to higher electricity costs/energy costs.

### Consequences of higher energy costs

Higher energy costs have at least three significant negative consequences:

1. Increases in “fuel poverty”<sup>55</sup>. In other words, the number of people spending a substantial fraction of their income (e.g., >10%) on heating costs increases.

<sup>55</sup> <http://www.iea.org/topics/energypoverty/>

2. Reduction in competitiveness. Businesses and industries have to spend more money for their energy requirements.
3. Discourages foreign investment, particularly for energy intensive businesses and industries.

Germany has been adopting a major, heavily-subsidised, expansion of wind and solar power through their “Energiewende” project. As a result of this, German electricity bills have been increasing so much that many commentators are seriously worried that electricity will soon become a “*luxury good*” for German consumers, e.g., see Der Spiegel, 4<sup>th</sup> September 2013 <sup>56</sup>.

Similarly, the British Secretary for Business, Innovation and Skills, Vince Cable, has recently expressed his concern that spiralling energy costs arising from similar renewable energy policies in the UK are becoming a “*big problem*” for British industry, and that they are “*pricing in a disadvantage to UK producers*” (International Business Times, 16<sup>th</sup> January 2014<sup>57</sup>).

### Consequences of less reliable electricity supply

We mentioned in Section 3.2 how the intermittent nature of wind electricity leads to a more unreliable electricity supply, i.e., more power outages.

This also has serious negative consequences:

1. Reduction in standard of living. The average household will not be able to rely on a constant, secure electricity supply.
2. Increased damage to electronic appliances. The power surges which

<sup>56</sup> <http://www.spiegel.de/international/germany/high-costs-and-errors-of-german-transition-to-renewable-energy-a-920288.html>

<sup>57</sup> <http://www.ibtimes.co.uk/vince-cable-soaring-energy-costs-big-problem-uk-manufacturing-1432625>

occur at the start and end of a power cut can often damage electronic appliances which were turned on at the time of the cut, e.g., computers, satellite boxes, internet routers.

“Surge protection” devices can help mitigate the problem<sup>58</sup>, but they can be expensive and are generally designed for infrequent power cuts.

3. Emergency services, such as hospitals and care units, often have standby generators for critical items. However, they also rely on mains electricity, and so emergency services for the country might suffer.
4. Power cuts can interfere with basic services (schools, administration, etc.), shops, businesses and offices, as well as industries and factories. If power cuts become more frequent, this could have serious negative effects on local and national economies.
5. Foreign companies and businesses would be discouraged from locating themselves in a country with an unreliable electricity supply.

### 5.3. Employment

It is often promised by supporters of the renewables industry that wind farms (and other renewable energy developments) will lead to more “green jobs”. This promise has a great emotional appeal, particularly, as Ireland currently has a quite high unemployment rate (12.4% in December 2013<sup>59</sup>). However, while we all would like the country to have a lower unemployment rate, the *promise of jobs* is not the same thing as actual jobs.

<sup>58</sup> <http://electronics.howstuffworks.com/everyday-tech/surge-protector.htm>

<sup>59</sup> Irish Times. 8<sup>th</sup> January 2014.

<http://www.irishtimes.com/business/economy/ireland/unemployment-falls-again-in-december-1.1648219>

The debate over whether wind farms and other renewables create more jobs than they destroy, or vice versa, has been complex and very contentious, and for brevity, we will not review it here.

Having said that, we will note that while some groups claim that the renewables industry creates new jobs, e.g., Lantz & Tegan, 2009<sup>60</sup>, other groups claim that for every green job produced, several are lost, e.g., Álvarez et al., 2009<sup>61</sup>.

We will also note that, before the 2007/2008 financial crisis, Spain invested heavily in the solar and wind industries, partially on the basis of the “green jobs” promise, yet it currently has one of the highest unemployment rates in the EU (26% for final quarter 2013<sup>62</sup>). The problem of high unemployment is especially severe amongst the young Spanish population, e.g., youth unemployment was 56.1% in August 2013<sup>63</sup>.

If the promised green jobs were as plentiful as is implied by advocates for renewables investment, then Spain’s unemployment rate should be much lower.

We suspect that much of the popularity of this “green jobs” claim is due to the so-called “*broken window fallacy*”<sup>64</sup>, which was identified by French economist, Frédéric Bastiat in 1850. Bastiat noticed that when a valuable commodity, such as a shop window was destroyed, observers would often offer

<sup>60</sup> “Response to the report ‘Study of the effects on employment of public aid to renewable energy sources’” (2009).

<http://dx.doi.org/10.2172/963557>

<sup>61</sup> “Study of the effects on employment of public aid to renewable energy sources” (2009).

<http://www.juandemariana.org/pdf/090327-employment-public-aid-renewable.pdf>

<sup>62</sup> Bloomberg. 20<sup>th</sup> January 2014.

<http://www.bloomberg.com/news/2014-01-20/spain-s-worst-year-for-work-leaves-rajoy-counting-cost-of-slump.html>

<sup>63</sup> The Guardian. 30<sup>th</sup> August, 2013.

<http://www.theguardian.com/business/2013/aug/30/spain-youth-unemployment-record-high>

<sup>64</sup> See this Wikipedia article for a summary:

[http://en.wikipedia.org/wiki/Parable\\_of\\_the\\_broken\\_window](http://en.wikipedia.org/wiki/Parable_of_the_broken_window)



the consolation: *“It is an ill wind that blows nobody good. Everybody must live, and what would become of the glaziers if panes of glass were never broken?”* In other words, because the incident created more work for the glazier, the loss to the shopkeeper was balanced, and it might even offer some benefit to the economy, by encouraging people to spend money.

Similarly, advocates for the renewables industry claim that by forcing electricity suppliers to use less competitive electricity sources like wind farms, the government will create “new jobs”.

Bastiat pointed out that this was nonsense – if it was true, then the government would have paid people to go around the town breaking all the windows! The fallacy is that, because the shopkeeper had to spend money on the replacement window, they had less money to spend on other products, e.g., new shoes or a book, and the economy as a whole suffers.

In the same way, while it is true that forcing the electricity suppliers to use electricity from wind farms, creates some employment for the wind farms (“the glaziers”), this reduces the competitiveness of the electricity suppliers (“the shopkeeper”), and the net effect on the economy is actually negative.

Before we celebrate the creation of new “green jobs” by a particular industry, it is important to check how many old jobs are being displaced by that industry.

#### 5.4. Infrastructural costs

Finally, it is worth recalling that, because wind farms are a very diffuse form of electricity generation, they require a much larger and widely distributed electricity network than conventional electricity generation methods.

One single power plant can create as much electricity as several hundred wind turbines.

For instance, the Moneypoint power plant in Co. Clare currently has a 915MW capacity<sup>65</sup>, while each of the proposed turbines for the Yellow River Wind Farm would only have an **installed** capacity of 3MW (the actual capacity for a wind turbine is very low relative to the installed capacity, e.g., 15-30%).

So, while the current electricity network is probably reasonably acceptable for conventional electricity generation, if a large number of wind farms are to be installed, this would require a major upgrade of the electricity network.

This appears to be the motivation for the controversial proposal by EirGrid to construct several hundred new pylons, which we discussed in Section 1.3.

If the proposed wind farms are not built, then the current network would probably be adequate, and the new pylons non-essential.

*“[Environmentalists are] cheating themselves if they keep believing this fiction that ‘all we need’ is renewable energy such as wind and solar” – Dr. James Hansen, director of NASA Goddard Institute of Space Studies from 1981 to 2013, 3<sup>rd</sup> November 2013<sup>66</sup>*

<sup>65</sup> <http://www.esb.ie/main/about-esb/history.jsp>

<sup>66</sup> The Guardian, 3<sup>rd</sup> November 2013.

<http://www.theguardian.com/environment/2013/nov/03/climate-scientists-support-nuclear-power>



## 6. Conclusions

In this report, we reassessed the proposed Yellow River Wind Farm project. We found that it is a seriously flawed project, which aside from being non-viable, would have serious detrimental environmental effects, and would in general be bad for Ireland.

First, the claim that the average 100m wind speeds on the site would be greater than 8 m/s is simply incorrect. They had obtained this value from a 2003 computer model which was known to have overestimated the wind speeds for the Midlands. The actual value is only 6 m/s. As a result, the average energy content of the wind would be only 42% of the minimum Green Wind Energy require to make their project viable.

The Midlands are simply not as windy as their computer model had assumed. Unless they are expecting their wind turbines to spin from wishes and hopes, their proposed project will simply not work. They would have more luck making a silk purse out of a sow's ear.

Second, because wind turbines do not produce carbon dioxide when they are generating electricity, it is claimed that wind farms such as the proposed project are "clean", "green", and good for the environment. This is not true.

Because of the highly intermittent and diffuse nature of wind electricity generation, wind farms actually increase the carbon dioxide emissions of the other electricity sources on the grid. In other words, the *net* carbon footprint reduction for the country of wind farms is considerably less than claimed.

Moreover, the detrimental effects that wind turbines have on the local (and regional) ecology and environment are quite substantial. We show that the developer's

Environmental Impact Statement was error-ridden, incomplete and wholly inadequate.

Thirdly, it is **claimed** that, since wind electricity is a local and renewable source, wind farms will increase the country's energy security, and improve the reliability and stability of the electricity network.

Nothing could be further from the truth. We showed that the diffuse and intermittent nature of wind electricity means that wind farms lead to more power outages, more power surges, higher electricity prices and a generally less reliable electricity supply.

Finally, we think it is worth mentioning that once a wind farm is installed, it is very expensive and difficult to "uninstall".

While there is **currently** a popular belief that wind farms are good for the country and the environment, this belief seems to be just an emotional, gut feeling. In this report, we showed that, in reality, more wind farms would have serious negative consequences for both the country and the environment.

"I am an environmentalist and founder member of the Greens but I bow my head in shame at the thought that our original good intentions should have been so misunderstood and misapplied. We never intended a fundamentalist Green movement that rejected all energy sources other than renewable, nor did we expect the Greens to cast aside our priceless ecological heritage because of their failure to understand that the needs of the Earth are not separable from human needs. We need take care that the spinning windmills do not become like the statues on Easter Island, monuments of a failed civilisation." – Dr. James Lovelock, environmentalist and a founder of the international Green movement, 27<sup>th</sup> January 2013<sup>67</sup>

<sup>67</sup> <http://www.windturbinesyndrome.com/2013/james-lovelock-on-wind-energy-as-vandalism-uk/>

## About Connolly Scientific Research Group

We are a family-run independent scientific research group based in Ireland.



**Dr. Michael Connolly**

*B.Sc., M.Sc., H.D.E., D.E.E., Ph.D.*

### Research Interests

In 1989, together with Imelda, we built, operated and owned the National Aquarium in Bray, Co. Wicklow which at the time was the top privately-own tourist attraction in Ireland.

Since 1996, we have been carrying out fundamental research in the fields of physics, chemistry and biology, both in Ireland and in USA. We have been granted patents in aquaculture, wastewater treatment and heat exchangers. We have also been designing new eco-friendly buildings and materials.



**Dr. Ronan Connolly**

*B.Sc., Ph. D.*

### Research Interests

Since my Ph.D., I have been working with the research group on a number of topics. We have been researching and developing:

- New technologies and techniques for fish-farming, aquaponics and waste-water treatment
- Low cost heat-exchangers
- New energy efficient building materials and techniques

We have investigated the life cycles and spawning conditions for hundreds of species of fish, invertebrates and algae.

We have also been actively researching climate change since 2009.



**Dr. Imelda Connolly**

*A.M.I. Mont. Dip & Sp. Ed. Dip, A. Mus. VCM,  
Adv. Dip. Ed., M.A., Ph. D.*

### **Research Interests**

Apart from being involved in research projects with the research group, my current research interests are in Computer Mediated Communication and the social impact of new technologies.

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### **Potential conflicts of interest**

We can see two potential conflicts of interest, however we do not believe either of them affects the analysis in this report.

Firstly, one of our research farms borders the Yellow River. For this reason, it might be argued that our analysis is biased because the proposed wind farm would directly affect us. However, this gives us unique insights into the local ecology and environment.

Also, we were asked to give an independent EIA on the Lagan Cement plant EIS when planning permission for the plant was been sought. Even though we did not like the idea of a cement plant in our area, our report was not used by the residents because its findings did not benefit their position. In other words, our assessments are based on the data, and not on our own personal preferences.

When the EPA released their EIA for the Lagan Cement project in June 2013, its assessment was broadly in agreement with ours, especially with respect to our wind analysis.

Secondly, we have recently finished eight scientific articles which we believe show the man-made global warming theory to be invalid (see our <http://globalwarmingsolved.com/> website for a detailed discussion of these results).

Therefore, we personally do not believe that it is necessary for Ireland (or the world) to reduce its carbon footprint. This might introduce a bias to our analysis, since one of the primary motivations for the Yellow River Wind Farm project appears to be the suggestion that it could reduce carbon dioxide emissions. However, as we discuss in Section 3, **for the analysis in this report**, we explicitly assume that carbon footprint reduction is considered a national priority, even though we personally believe this is a misguided priority.

## Appendix 1. Data used for generating the SEAI 2003 Wind Atlas

Below is the data from Table 1 of SEAI's 2003 Wind Atlas Project Report<sup>68</sup>:

Station Name	Anem. Height (m)	Obs. Speed (m/s)	Shear Exp.	Obs. Speed at 50m (m/s)	Est. Error Margin (m/s)	Prelim. Map (m/s)	Prelim. Map Bias (m/s)	Final Map (m/s)	Final Map Bias (m/s)
Orsay Lighthouse	10	8	0.1	9.4	0.3	9.3	-0.1	9.4	0
Malin Head	21	8.3	0.1	9.1	0.2	8.9	-0.1	8.8	-0.3
Proprietary	34.5	9.5	0.1	9.8	0.3	10.5	0.6	10.5	0.7
Proprietary	30	7.1	0.3	8.2	0.3	8.7	0.4	8.5	0.3
Proprietary	25	9.2	0.13	10.1	0.5	9.5	-0.6	9.4	-0.7
Proprietary	41	9.5	0.23	10	0.3	9.7	-0.3	9.6	-0.4
Proprietary	41	8.4	0.18	8.7	0.3	8.6	-0.1	8.7	-0.1
Bellmullet	12	6.9	0.16	8.7	0.3	8.7	0	8.8	0.1
Clones/	10	4.1	0.28	6.4	0.5	6.8	0.4	6.3	-0.1
Proprietary	30	9	0.15	9.7	0.3	9.6	-0.1	9.8	0
Proprietary	30	7.5	0.17	8.2	0.3	9.2	1	8.8	0.6
Proprietary	50	8	0.25	8	0.2	8.3	0.3	7.6	-0.4
Mullingar	12	4.6	0.24	6.5	0.4	7.3	0.8	6.9	0.4
Dublin	12	5.2	0.22	7.1	0.4	7.5	0.4	7	-0.2
Casement	10	5.9	0.22	8.4	0.5	8.2	-0.2	7.7	-0.7
Birr	10	3.6	0.28	5.6	0.4	7.1	1.4	6.6	0.9
Proprietary	30	7.8	0.15	8.4	0.3	8.6	0.2	8.4	0
Shannon Apt.	12	5	0.22	6.8	0.4	7.1	0.2	6.8	-0.1
Kilkenny	12	3.5	0.28	5.2	0.3	6.5	1.3	6.1	0.9
Proprietary	40	9	0.18	9.4	0.4	9.1	-0.3	9	-0.4
Rosslare	10	5.8	0.21	8.1	0.5	8.2	0.1	8.1	0
Proprietary	40	8.9	0.18	9.3	0.3	9	-0.3	8.8	-0.4
Proprietary	30	8.1	0.21	9	0.3	8.9	-0.1	8.8	-0.2
Proprietary	30	7.7	0.19	8.5	0.3	8.9	0.4	8.9	0.4
Proprietary	40	7.6	0.17	7.9	0.5	8.2	0.3	7.7	-0.2
Valentia Obs	12	5.7	0.23	7.9	0.4	8.2	0.3	7.8	-0.1
Cork Airport	12	5.8	0.2	7.8	0.4	8.2	0.4	7.7	-0.1
Proprietary	40	8.5	0.13	8.8	0.3	9.5	0.7	9.4	0.6
Proprietary	40	7.9	0.1	8.1	0.3	8.6	0.5	8.6	0.5
Proprietary	10	6.9	0.17	9.1	0.5	9.3	0.2	8.9	-0.2
Roches Point	12	6.3	0.15	7.8	0.3	8.3	0.5	7.7	-0.1
Claremorris	12	4.6	0.28	6.9	0.4	7.7	0.9	7.3	0.4
Proprietary	30	8.3	0.17	9	0.3	9.3	0.2	9.2	0.2
Proprietary	30	8	0.18	8.8	0.3	9.1	0.4	8.8	0.1
Average (m/s)				8.3	0.3	8.5	0.3	8.3	0
RMS Discrepancy (m/s)							0.5		0.4
Model-Only Error (m/s)							0.4		0.2

<sup>68</sup> SEAI (2003). Report No. 4Y103A-1-R1. [http://www.seai.ie/Archive1/Files\\_Misc/IrelandWindAtlas2003.pdf](http://www.seai.ie/Archive1/Files_Misc/IrelandWindAtlas2003.pdf)

## Appendix 2. Mathematical formulae used in report

### Equation for extrapolating wind speeds at different heights

The wind speed,  $v_2$  at height  $h_2$ , is *approximately* related to the wind speed  $v_1$  at the lower height  $h_1$ , with a wind shear value  $\alpha$ , by the following equation,

$$v_2 = v_1 \left( \frac{h_2}{h_1} \right)^\alpha$$

For instance, if the average wind speed at 10m is 3.2 m/s, and the wind shear,  $\alpha=0.27$ , then the average wind speed at 100m should be,

$$v_2 = 3.2 \left( \frac{100}{10} \right)^{0.27} = 6.0 \text{ m/s}$$

By rearranging this equation, we can also calculate the wind shear value from the wind speeds at two heights,

$$\alpha = \frac{\log \left( \frac{v_2}{v_1} \right)}{\log \left( \frac{h_2}{h_1} \right)}$$

### Equation for the power density of wind

The power density per square metre,  $P$ , contained in the wind is related to the wind speed,  $v$ , and the density of the air,  $\rho$ , as follows:

$$P = \frac{1}{2} \rho v^3$$

The density of air is relatively constant near the ground, at typical outdoor temperatures, i.e., approximately 1.232 kg/m<sup>3</sup>. Therefore the power density of the wind increases as the **cube** of the wind speed.

For example, if  $v=6.0$  m/s, the power density is,

$$P = \frac{1}{2} (1.232)(6.0)^3 = 133 \text{ W/m}^2$$

While, if  $v=8.0$  m/s, the power density is,

$$P = \frac{1}{2} (1.232)(8.0)^3 = 315 \text{ W/m}^2$$

That is, an increase of just 2.0 m/s more than doubles the power density of the wind ( $315/133 = 2.4$ ).

Or, alternatively, the power density of the 6.0 m/s wind is only 42.2% of that for the 8.0 m/s wind, i.e.,  $133/315 \times 100\% = 42.2\%$

### Appendix 3. Wind speed measurements provided by Jennings O'Donovan & Partners

In Appendix M of the Jennings O'Donovan & Partners report, they include one page of wind speed measurements as “an example of values derived from the Yellow River wind farm site”. For reference, these values are reproduced below. They cover a period of nearly 7 hours starting at midnight on 11<sup>th</sup> May 2013.

Using the equation in Appendix 2, we have also calculated the wind shear values implied by their V113 (calculated velocity at 113m) and V10std (calculated velocity at 10m). These implied wind shear values are included in the 5<sup>th</sup> column. Also, we have calculated the mean values and standard errors for this 6 hour 40 minute period, and included them at the bottom of the table.

Date/time	Wind shear	V113 (m/s)	V10std (m/s)	Implied wind shear
11/05/2013 00:00	0.27	8.0	5.5	0.155
11/05/2013 00:10	0.36	8.9	6.1	0.156
11/05/2013 00:20	0.30	8.5	5.8	0.158
11/05/2013 00:30	0.31	8.6	5.9	0.155
11/05/2013 00:40	0.34	8.5	5.8	0.158
11/05/2013 00:50	0.33	8.6	5.9	0.155
11/05/2013 01:00	0.29	7.7	5.3	0.154
11/05/2013 01:10	0.28	7.5	5.1	0.159
11/05/2013 01:20	0.33	8.2	5.6	0.157
11/05/2013 01:30	0.38	9.2	6.3	0.156
11/05/2013 01:40	0.28	8.9	6.1	0.156
11/05/2013 01:50	0.27	8.7	6.0	0.153
11/05/2013 02:00	0.30	8.8	6.0	0.158
11/05/2013 02:10	0.23	9.1	6.2	0.158
11/05/2013 02:20	0.25	9.6	6.6	0.155
11/05/2013 02:30	0.30	10.2	7.0	0.155
11/05/2013 02:40	0.25	10.0	6.9	0.153
11/05/2013 02:50	0.32	10.2	7.0	0.155
11/05/2013 03:00	0.34	10.6	7.2	0.16
11/05/2013 03:10	0.21	9.8	6.7	0.157
11/05/2013 03:20	0.22	9.5	6.5	0.157
11/05/2013 03:30	0.24	9.7	6.6	0.159
11/05/2013 03:40	0.29	9.5	6.5	0.157
11/05/2013 03:50	0.29	10.5	7.2	0.156
11/05/2013 04:00	0.31	10.3	7.0	0.159
11/05/2013 04:10	0.26	10.1	6.9	0.157
11/05/2013 04:20	0.34	11.0	7.5	0.158
11/05/2013 04:30	0.31	10.0	6.8	0.159
11/05/2013 04:40	0.33	10.7	7.3	0.158
11/05/2013 04:50	0.22	10.9	7.5	0.154
11/05/2013 05:00	0.26	10.8	7.4	0.156
11/05/2013 05:10	0.24	10.2	7.0	0.155



11/05/2013 05:20	0.18	13.9	9.5	0.157
11/05/2013 05:30	0.16	11.0	7.5	0.158
11/05/2013 05:40	0.26	10.8	7.4	0.156
11/05/2013 05:50	0.28	9.6	6.5	0.161
11/05/2013 06:00	0.25	10.6	7.2	0.16
11/05/2013 06:10	0.29	12.8	8.7	0.159
11/05/2013 06:20	0.27	11.9	8.1	0.159
11/05/2013 06:30	0.09	10.7	7.3	0.158
11/05/2013 06:40	0.23	10.7	7.3	0.158
Mean	0.27	9.9	6.7	0.157
Standard Error	0.01	0.2	0.1	0.0003