

Wind energy in the Irish power system.



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Abstract.

This article describes the influence of wind energy on the CO₂ output of the fossil-fired generation of electricity in Ireland. Where most available publications on this subject are based on models, the present study makes use of real-time production data. It is shown, that in absence of hydro energy the CO₂ production of the conventional generators increases with wind energy penetration. The data shows that the reduction of CO₂ emissions is at most a few percent, if gas fired generation is used for balancing a 30% share of wind energy.

1. Introduction.

The claims, that large wind energy plants will be an important factor in the “green energy transition” have never been substantiated by studies based on facts about reduced CO₂ emission or fossil fuel consumption. There is enough reason for doubt, as wind energy is chaotic and its production is uncorrelated with the demand for electricity, which follows a regular day/night pattern.

Wind electricity has priority over the conventional sources of electricity in most grids, which means the other generators have to compensate for wind surges or ebbs, but 'No wind means no wind energy'.

As a consequence no fossil-fired plant has been closed after the recent large-scale build up of wind energy in Europe.

Wind energy has become a multi-billion dollar business financed by large amounts of public funds, despite the above-mentioned problems and uncertainties.

The interaction of wind energy with fossil-fired electricity generators could up till now only be discussed with the help of models^{1,2,3,4}. The reason is, that real-time operations data is kept away from the public.

On one occasion independent researchers got access to the real-time operations data. The result is the Bentek study⁵ about the introduction of wind energy in the Colorado and Texas systems. This study shows, that wind energy plays havoc in systems dominated by coal generation.

Model studies pleading the case of wind are among others from the Delft group⁶.

Semi-empirical studies were performed by Post⁷ and Sharman⁸. Both authors emphasise the disastrous financial consequences of large quantities of wind energy and show, that above about 10% contribution of wind energy one encounters a new phenomenon: curtailment. This occurs when demand is low and the production of wind energy is high. In that case wind turbines have to behave like any other supplier of electricity, namely to adjust the production to the demand. Clearly this phenomenon affects the already poor efficiency of wind turbines.

EirGrid, the Electricity Transmission Operator in Ireland, offers now the second occasion after the Colorado case to study the influence of wind energy on a conventional generator system on the basis of real data. The Irish grid operator provides real time data about the total demand for electricity, the wind energy and the CO₂ emission on a ¼ hour basis. The website www.eirgrid.com contains all this data from November 2010 to this day.

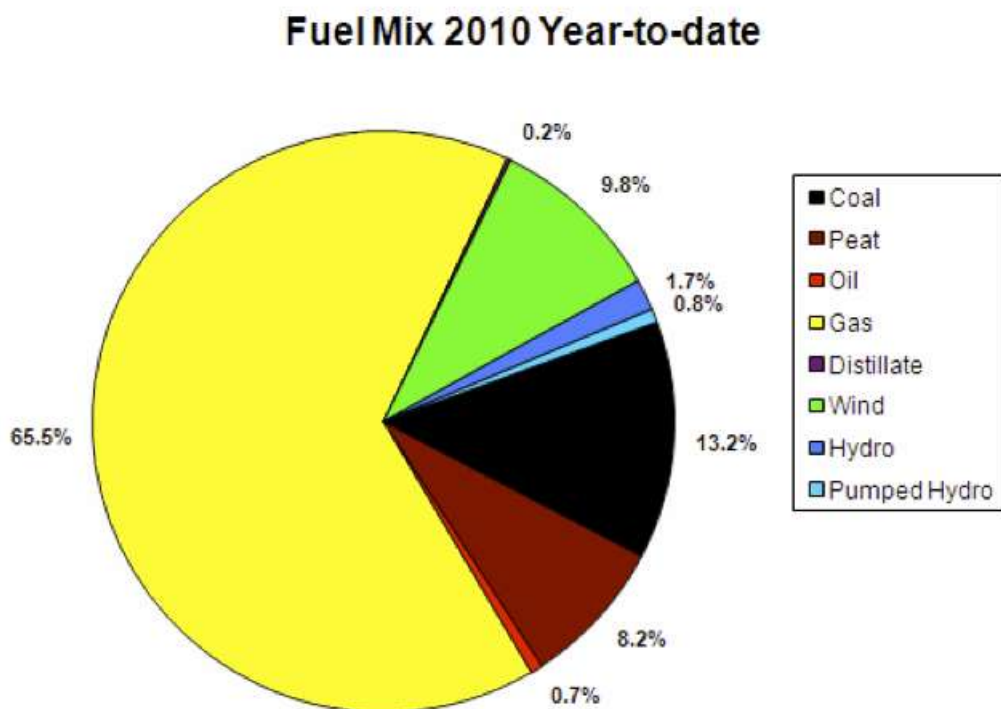
This study analyses the empirical data of Eirgrid to show the effects of wind energy on the CO₂ emission of a fossil-fired generator park, which is mainly based on gas. The website of EirGrid does not provide detailed data about the use of hydro energy, so hydro energy could not be incorporated in this analysis.

After the description of the Irish system and the data provided on the website, § 3 and § 4 analyse the data of April and June 2011 in detail. These periods are chosen, because of the near absence of hydro energy during those months.

2. Description of the data.

In 2010 the Irish electric grid used the following fuel mix:

Figure 1



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

The “9.8% wind” is energy, not installed capacity.

During periods of low rainfall, hydro energy is minimal.

The Irish grid publishes the following system operating data:

- CO₂ emissions,
- total electricity demand and wind energy production every 15 minutes.

The energy production of the other sources, such as hydro, can only be estimated from the monthly totals posted on the site of EirGrid.

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

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

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

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

Note 1:

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

Note 2:

The total CO₂ emissions are presented in tons. The specific emissions of the fossil burning are called the CO₂ intensity. The CO₂ intensity is expressed in g/kWh.

Table 1 presents an overview of the data.

Month	Demand GWh	Wind+hydro GWh	Wind GWh	Cap fact wind % of 1,5 GW	Hydro GWh	Hydro % of total
Dec. 2010	2650	270	216	20	54	2,0
Jan. 2011	2550	354	248	23	106	4,2
Feb.	2220	443	369	34	74	3,3
March.	2330	256	183	17	73	3,1
April	2050	256	241	22	15	0,7
May	2050	551	510	47	41	2,3
June	1970	259	232	21	27	0,8
				Average:		
				26%		

It appears, that the drought in the first half of the year 2011 has adversely affected the use of hydropower in the months April to June 2011. This enables us to study the CO₂ emissions in absence of hydro power.

3. Analysis of the June 2011 period.

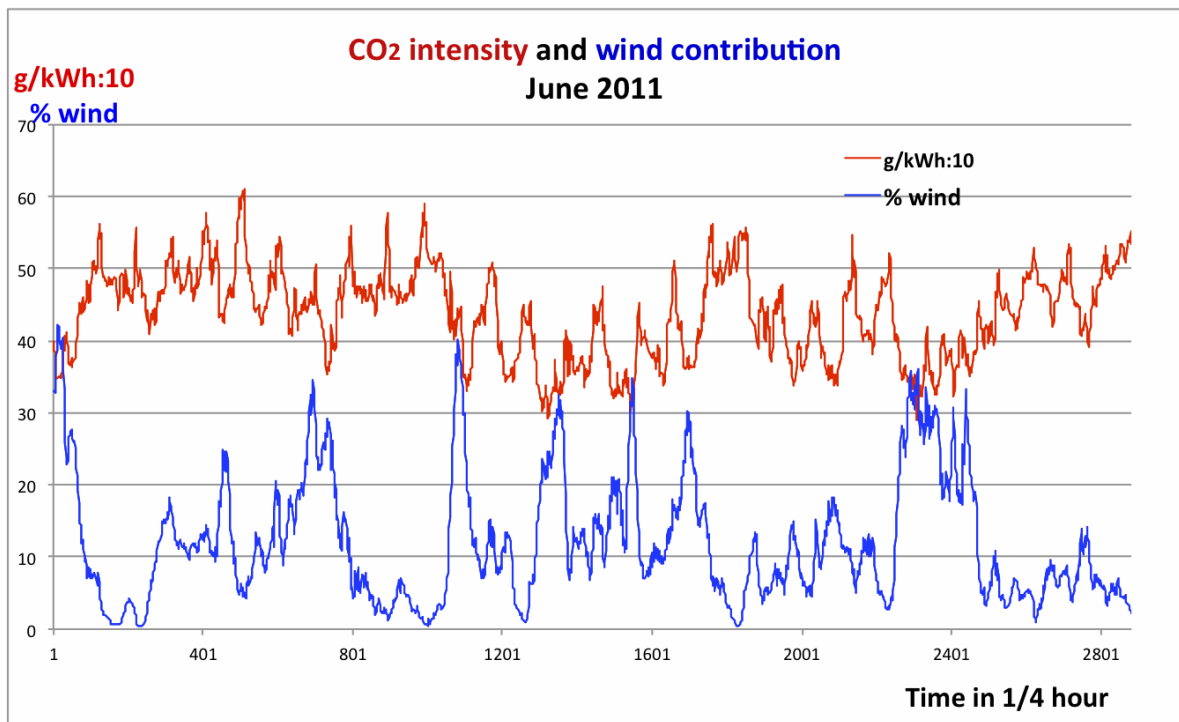
The total energy demand was 1970 GWh, on average 2,74 GW.

The wind production was 232 GWh, the sum of the 1/4-hour data.

The wind energy contribution was $232/1970 = 11.8\%$ in this month.

Figure 2 shows the time correlation between intensity as g/kWh and the wind energy penetration as % of the total demand. CO₂intensity is divided by 10 in order to fit the two lines on one scale.

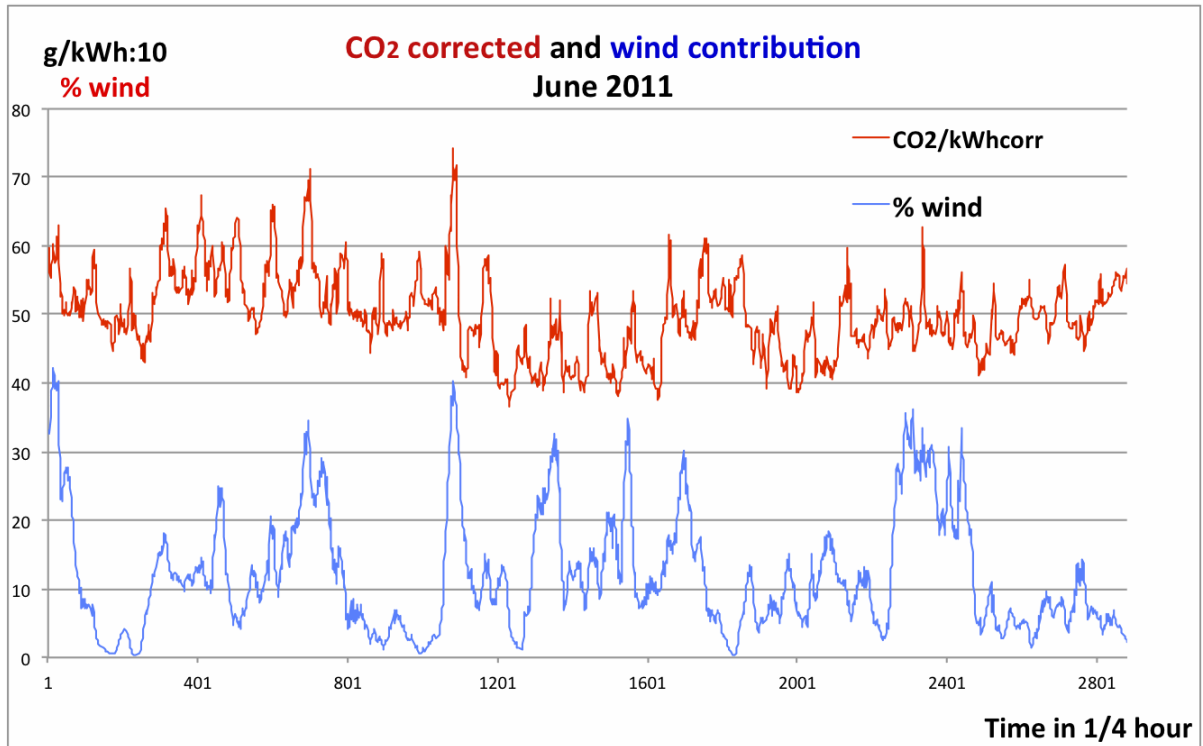
Figure 2



The horizontal scale is the 30 days in June subdivided into 1/4-hour periods. The graph shows some correlation between wind energy and CO₂ emissions. The above CO₂ intensities include wind and hydro energy.

The next step is to subtract the wind energy from the total energy and recalculate the CO₂ intensities based on the output of only the conventional generators. This also should be done for the hydro energy but the 1/4-hour data are not posted. However, the hydro energy influence may be ignored for this month, as it is only 0.8% of the total energy. See Table 1. The result of the cleaning is given in Figure 3.

Figure 3

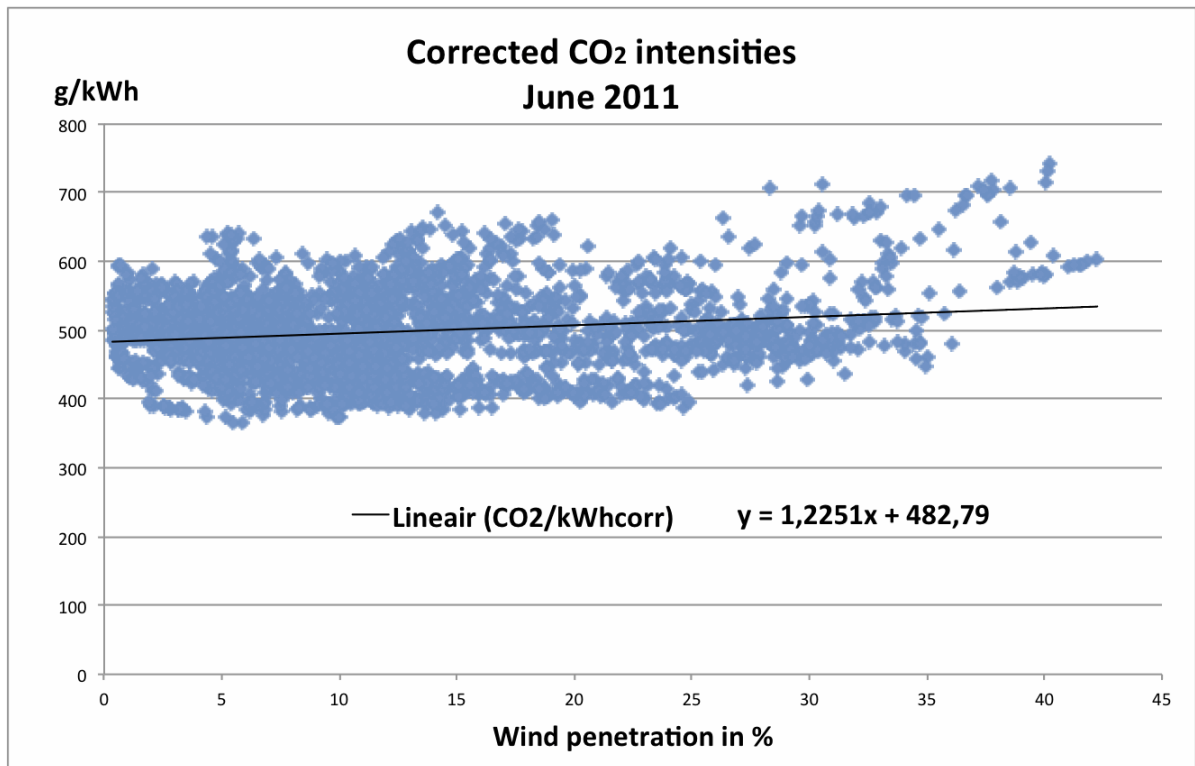


The vertical scales in figure 1 and 2 are the same.

Figure 3 shows that emissions per kWh of the fossil fuel plants are to some extent correlated with the wind energy production, but the degree of correlation varies considerably during the month. The behaviour around point 1100 is remarkable as the CO₂ output rises from 500 g/kWh to 700 g/kWh during a surge of wind. The wind per cent contribution changes because of variation of the wind, but also because of the daily variation in demand. This implies, that wind penetration can be defined for every 1/4 hour as the wind energy divided by the total electricity demand.

A scatter diagram is best suited to investigate the correlation between the CO₂ production and the wind penetration: figure 4.

Figure 4



The data at low wind penetration shows, that the fuel mix has been switched from gas to coal/peat several times during this month. Subdivision of the data in smaller periods gives a better impression of the correlation. Figures 5 and 6 show the first 10 days of the month.

Figure 5

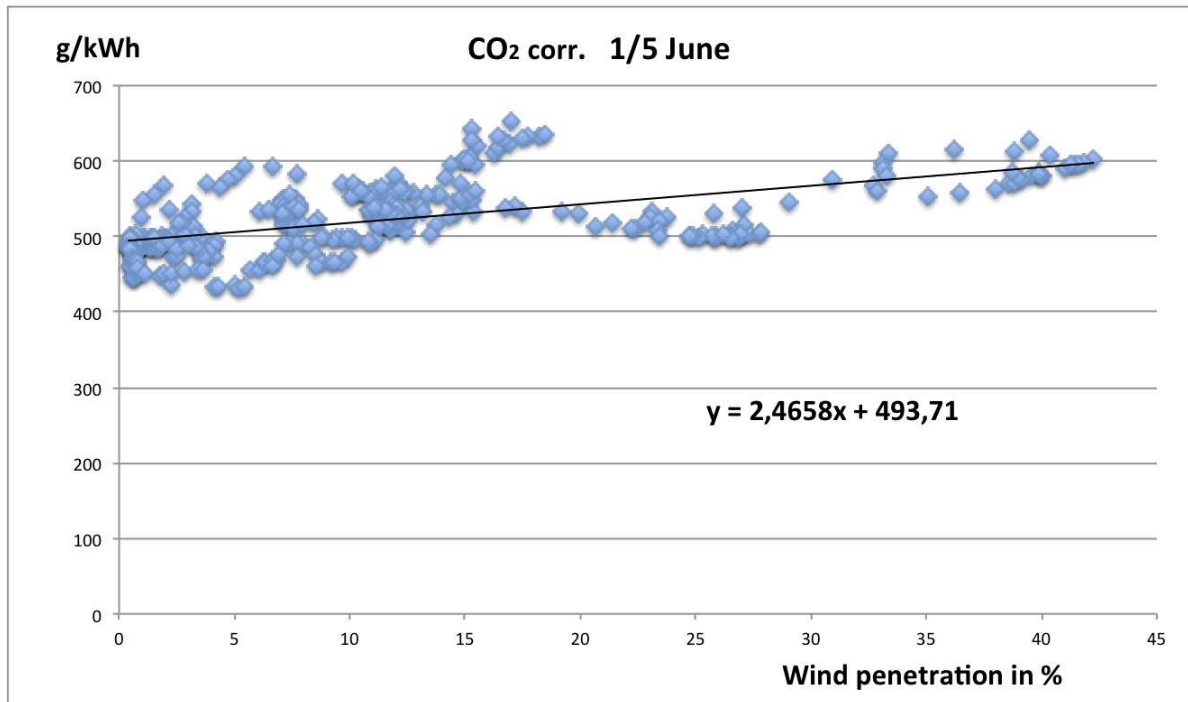
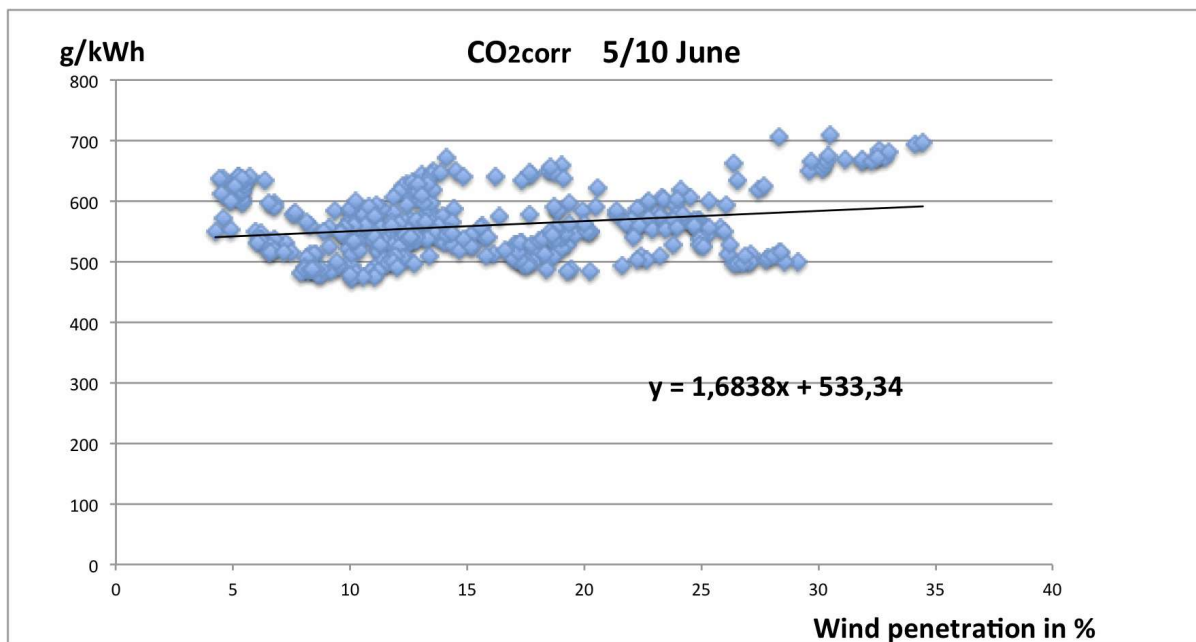


Figure 6



The trend of increasing CO₂ with windpenetration becomes clear. The data behaves very different from period to period, so quantitative conclusions cannot be drawn from the June data.

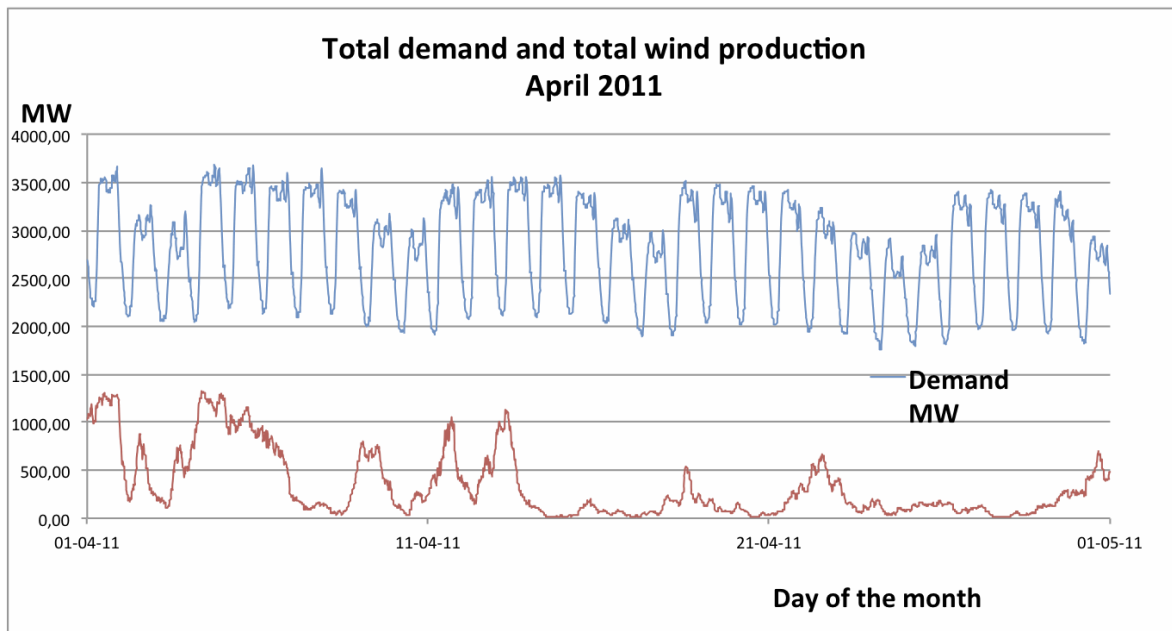
4. Analysis of the April 2011 data.

The April data are best suited for investigating the influence of wind power on a conventional system without storage, because Table 1 shows, that the contribution of hydropower was only 0,7% that month. The contribution of wind to the total electricity production is 12,4% in April. This amount is a little higher than the year average of 9,8% wind energy. The CO₂ intensities for the 30 days of April 2011 are:

Including wind energy: 418 g/kWh. This is the average of the intensities posted by Eirgrid.
Without wind energy: 477g/kWh this is the average CO₂intensity divided by one minus the wind penetration or $418/(1 - 0,124) = 477$ g/kWh.

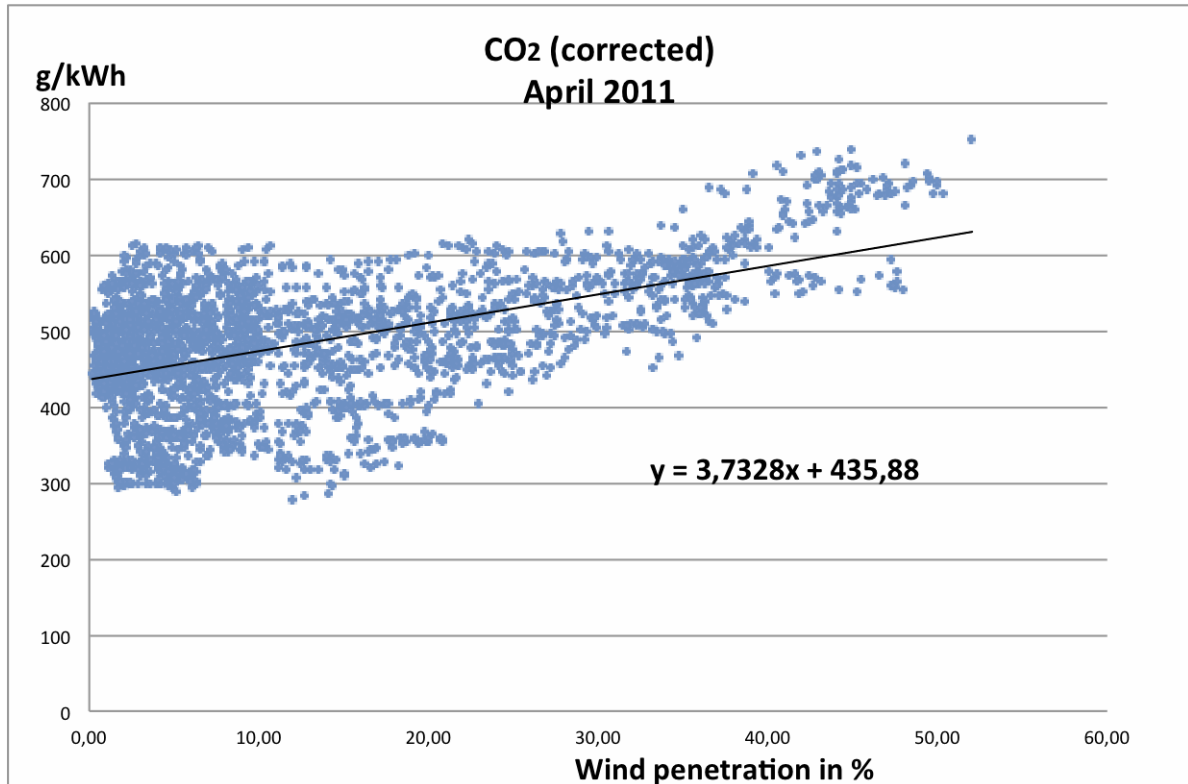
Figure 7 gives the time diagram of the total demand and the total wind production.

Figure 7



Wind penetration is defined as the windproduction (the red line) divided by the total demand (the blue line in the same graph). This quantity is calculated for every quarter of an hour. Figure 8 shows the intensity of the fossil-fired plants as a function of the wind penetration for the whole month of April.

Figure 8



This diagram shows a clear correlation between CO₂ intensity and wind contribution. The CO₂ intensity varies between 300 and 600 g/kWh at low wind contributions. This variation in CO₂ intensity indicates, that during the month different configurations of the available generators have been used.

The fit equation shows, that in the absence of wind the CO₂ intensity is 436 g/kWh.

The average of CO₂ intensity data in April as posted on the EirGrid site was 418 g/kWh.

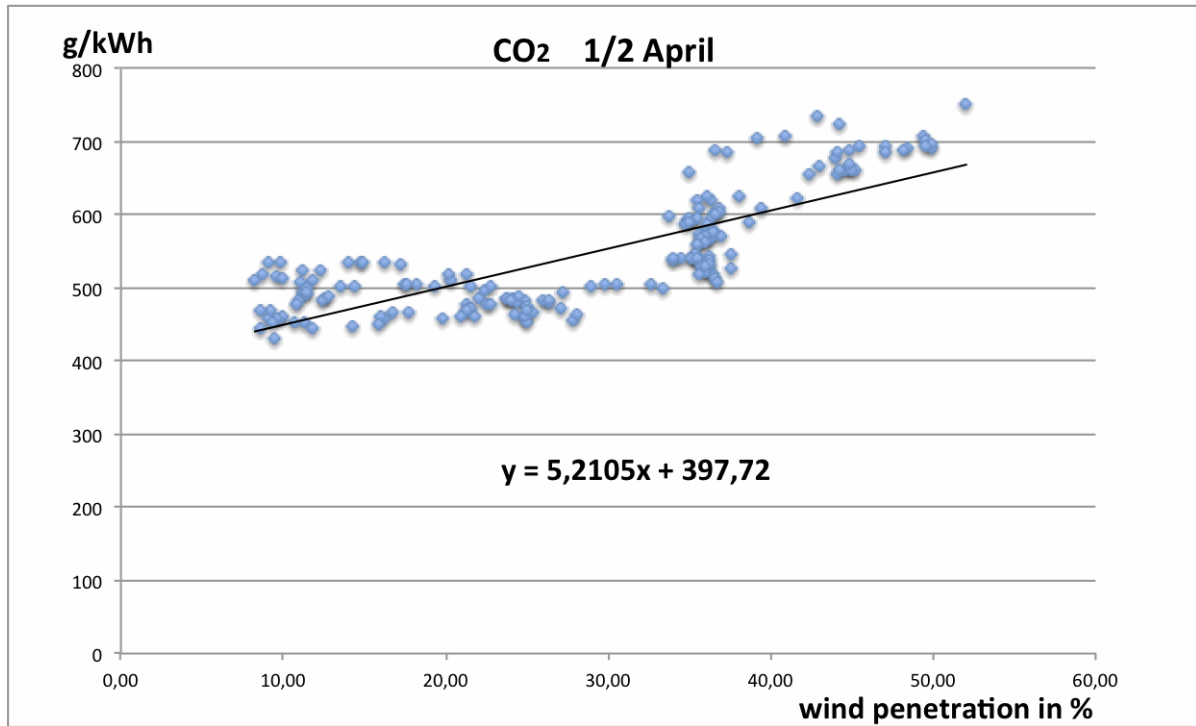
The net effect of 12,4% wind is a decrease of the CO₂ intensity from 436 to 418 g/kWh in

April. Twelve per cent wind causes a reduction of the CO₂ emission by 4%. The CO₂ reduction is one third of the reduction expected for this share of wind energy. This conclusion can be refined by splitting the month into periods of one or two days, as the utilisation of the fossil fired generators will not drastically be altered within such a short timespan.

The first week had a wind energy contribution of 28% and one had to use mainly gas as

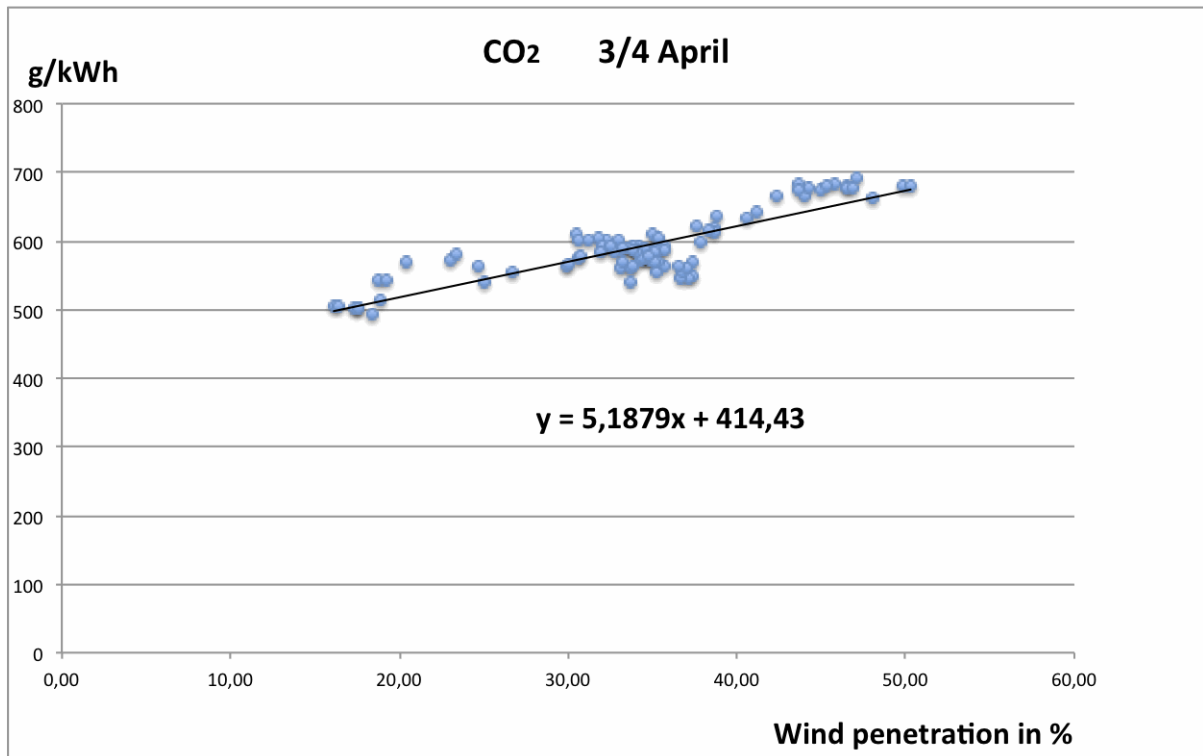
backup. This statement is based on the results of the subsequent analysis. Figure 9 shows the CO₂ intensity from the fossil-fired plants for the first two days in April.

Figure 9



The average CO₂ intensity from the data in figure 9 is 547 g/kWh. The contribution from wind is 28%, so the CO₂ intensity calculated over fossil plus wind is $547 \times (1 - 0,28) = 394$ g/kWh. The fit tells us, that without wind the production of CO₂ would be 398 g/kWh. The effect of 28% wind power is a decrease of the emission from 398 to 394 g/kWh. (-1%)
The next two days show an even higher share of wind: 34%.

Figure 10



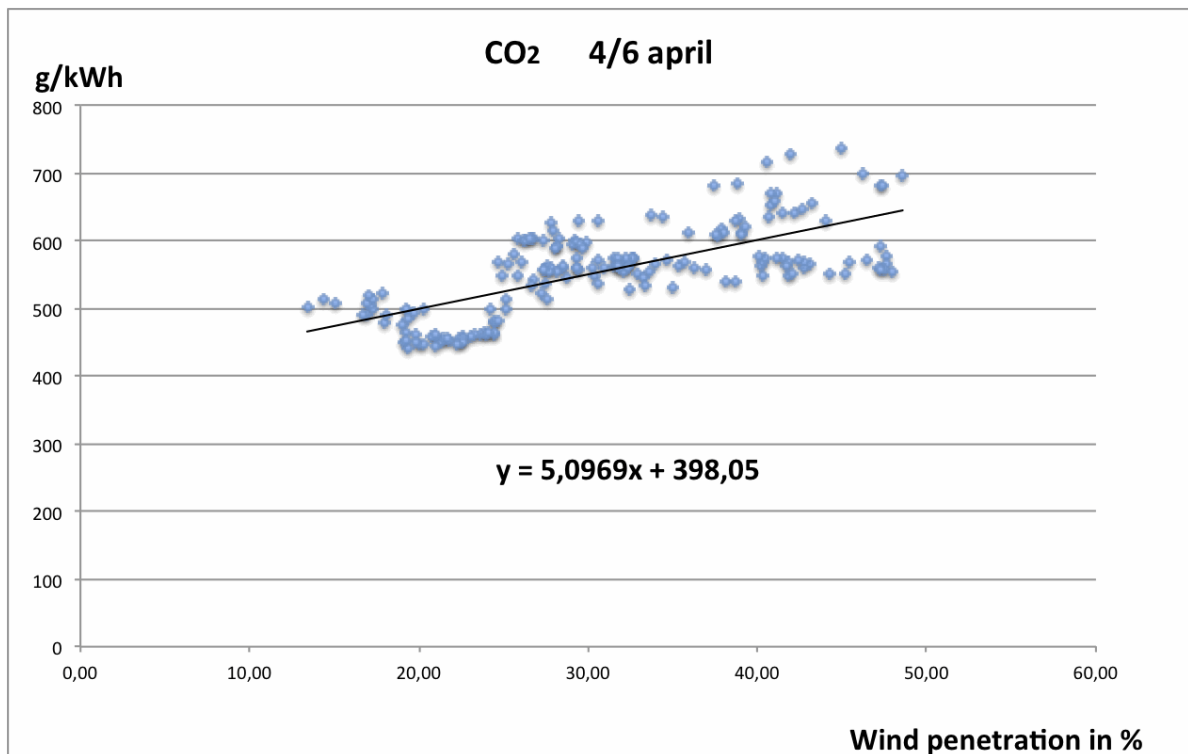
The average CO₂ intensity calculated from the data in figure 7 is 591 g/kWh.

The wind contribution is 34%, so the CO₂ intensity calculated over fossil plus wind is: $591 \times (1 - 0,34) = 390$ g/kWh.

The fit equation shows, that the CO₂ intensity without wind turbines is 414 g/kWh.

The presence of 34% wind power has decreased the CO₂ emission from 414 to 390 g/kWh. (-6%)

Figure 11



The average CO₂ intensity calculated from the data points in figure 8 is 551 g/kWh. The wind contribution is 30%, so the CO₂ intensity calculated over fossil plus wind is: $551 \times (1 - 0,30) = 386$ g/kWh. We obtain from the fit at $x = 0$: 398 g/kWh. The presence of 30% wind power has decreased the CO₂ emission from 398 to 386 g/kWh. (-3,0%)

It has to be stressed, that these minuscule decreases in CO₂ emission or fuel usage are calculated for the entire system of Eirgrid in April 2011. During the first days of the month large variations in wind energy occurred and the operators counteracted this by using mainly gas as a backup. This can be inferred from the fits, which point to about 400 g/kWh for zero wind. This is a normal figure for generators based on gas turbines.

5. Conclusions.

Currently the combination of wind energy with gas turbines is seen as the ideal configuration to deal with the problem of the fluctuations of wind energy. The April data of the Irish electricity system shows clearly, that the combination of wind energy with gas turbines does not work, if no storage of energy is present. An investment of billions in wind turbines produces not more than a few per cent reduction in CO₂ output. This analysis does not take into account the energy necessary to ramp the conventional generators up and down nor the energy to build wind turbines nor the extra transmission lines

with their additional losses.

Furthermore the role of hydro energy could not be isolated from the data. It is highly probable, that taking all these effects into account will show, that the few per cent gain in CO₂ will revert to a loss (i.e. an increase in CO₂).

The Irish system performs slightly better in other months probably due to the greater contribution of hydropower, but it never comes near to the promises made by wind energy advocates.

Acknowledgements

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

Monnickendam, August 29 2011.

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