Wind Power Variations are exported

Can we make better use of Danish wind energy?
The installation of new wind turbines in Denmark has been seen as an essential step towards meeting the targets in climate and energy policy, but there has been little or no attention to the actual use of the wind energy. The production of wind power has a very different profile to the demand for electricity; sometimes demand is high and wind power low, and sometimes wind power is high and demand low. Therefore it is not obvious that wind power added to the Danish power systems will be useful to *Danish* consumers.

The process of adapting a power system to absorb a significant share of wind energy is called the integration of wind power. Denmark has developed sophisticated wind turbines and installed about 3,000 MW wind power, but so far comparatively little and certainly insufficient research has been focused on the integration of the wind power.

CEPOS recently opened up debate on this subject by publishing a report, *Wind Energy – The case of Denmark*[1]. The study is based on the observation that the profile of the net export of electricity from Denmark has a remarkably close relation to the wind power generation profile, particularly for the west Danish power system. This leads CEPOS to the assumption that the export is caused by the wind power.

One reaction to this work is the recent *Danish Wind Power – Export and Cost*[2], published by Aalborg University and partly financed by the CEESA (Coherent Energy and Environmental System Analysis) Research Project.

The CEESA report claims that, contrary to the CEPOS analysis, wind energy replaces energy from Danish thermal power stations, and depending on the market situation these thermal power plants in Denmark are either closed down or choose to produce for export.

Both viewpoints are defensible. Electricity cannot be traced; we cannot tag electrons as "wind" or "coal" generated. No definitive argument can be given in support of either, though evidence may be adduced in support of both. Of course, the viewpoints are very different, and would probably lead to different conclusions regarding the need for initiatives for the better integration of wind power. The purpose of a debate about the evidence should be to find a reasonable balance.

However, the CEESA report claims to present the "truth" and seems to hope that the scientific weight of the list of authors will close the debate before it ever started. The language is somewhat dogmatic and allows no alternative opinions.

It is surprising that the CEPOS study, which after all is simply empirical information on the export of wind energy and some related interpretation, should cause so much anger. It is furthermore very disappointing that a group of group of highly qualified Danish scientists should feel moved to employ dubious arguments that can only divert attention from the need for better integration of wind energy in Denmark. This is not in the public interest.

[1] http://www.cepos.dk/fileadmin/user_upload/Arkiv/PDF/Wind_energy_-_the_case_of_Denmark.pdf
[2] http://www.energyplanning.aau.dk/Publications/DanishWindPower.pdf

Paul-Frederik Bach

5 March 2010

While the amount of exported wind energy is a matter of interpretational definition, and is dependent on perspective, it is clearly evident from the data that the irregular variations of Danish wind power are reflected in the exchange of electricity with the neighboring countries. This much cannot be denied; the facts are clear.

Maintaining the myth of the successful Danish integration of wind power may be good public relations, but refusing to face realities is self-deception.

The purpose of this note is to question the statistical methods and conclusions presented in chapter 1 of the CEESA Report. Hopefully it will demonstrate that nobody has a monopoly on truth.

The main arguments in Chapter 1 of the CEESA report

The CEESA report claims that the charts in the CEPOS report do not support the following conclusion: "*…the coincidence of so much wind output with net outflows makes the case for claiming that there is a large component of wind energy in the outflow, indisputable.*"

The CEESA report uses linear regression analyses of hourly plots of electricity production and exchange of power to demonstrate that the correlation between wind power and net export of electricity is of the same nature as the correlation between thermal generation and net export and that the charts therefore cannot justify any conclusion related to wind power. However, linear regression is not a suitable tool for comparisons of time series, and consequently this method cannot support CEESA's conclusion.

Due to the merit order of suppliers in the international electricity market all thermal production (down to a minimum level determined by security reasons) are to be curtailed before wind power. Therefore, CEESA concludes, the exported surplus of power is supposed to be thermal power. This is a coherent view, but it is not necessarily the only coherent view.

Misleading statistical arguments

The CEESA report refers to the plot of wind power and export shown on page 15 and 16 in the CEPOS report, but ignores completely the time series shown on the previous pages.

In figure 1 the CEESA report shows a plot of hourly wind power and net export for west Denmark in 2008. The dispersed cloud of dots suggests that high wind power output may be connected with high net export.

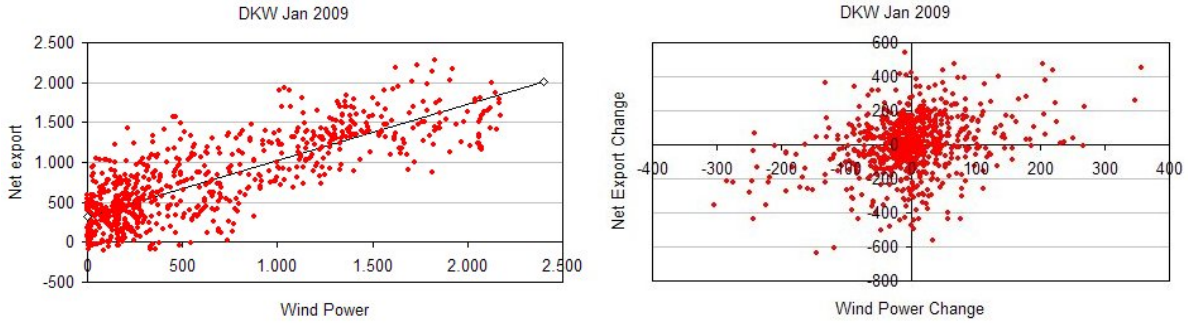
Figure 2 in the CEESA report shows a similar chart for the primary production of electricity (the large power plants). In this case the cloud suggests that high thermal production may be connected with high net export.

The CEESA report rightly concludes that the correlation is low in both cases and that the charts cannot justify conclusions on the causal relations.

However, instead of studying the time series the CEESA report looks for causal relations by plotting changes from hour to hour of production and export (Appendix 2). The results are clouds of dots without useful information. The purpose of this diversion seems to be to demonstrate the lack of relations between wind power and net export.

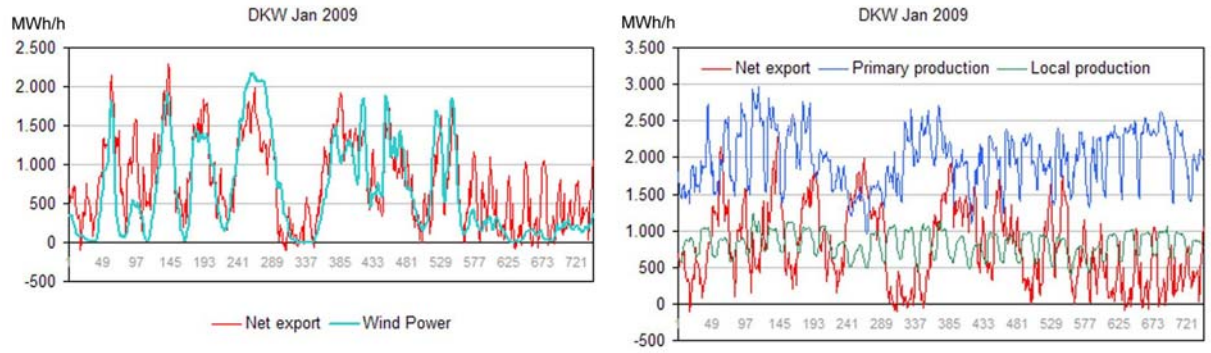
The correlation coefficients are then calculated by use of linear regression. These calculations are based on the assumption that there should be the same linear correlation between production and net export throughout the year. But this is not the case.

In this note January and July 2009 will be used for demonstration of the difference.



The left-hand chart suggests some connection between wind power and net export. The linear correlation coefficient is 0.81. As a contrast it is hard to see how useful information could be extracted from the right chart (corresponding to appendix 2 in the CEESA report).

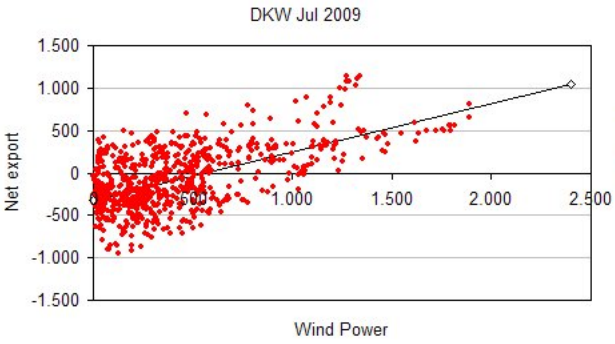
The time series tell different stories.

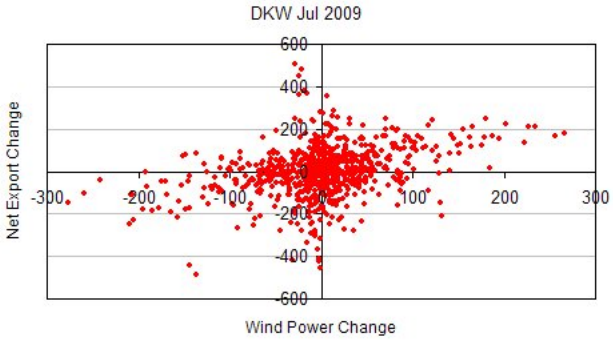


The left-hand chart suggests that there might be some sort of relation between wind power output and net export, but such relations are not obvious on the right hand chart which compares net export with primary thermal production.

<u>Therefore I cannot agree with the CEESA report that there is no real difference between the ways that wind power and thermal power relate to net export.</u> There clearly is a difference in the time series charts.

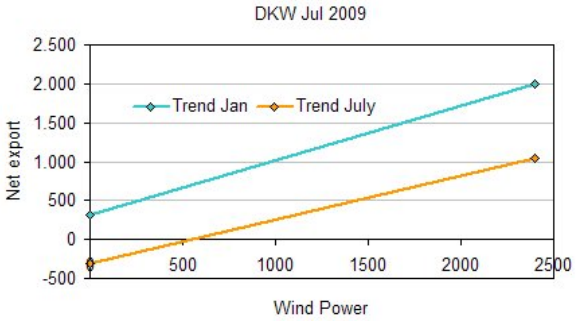
The left-hand chart also shows that a wave of wind energy is typically longer than one day. Therefore a plot of hourly changes cannot indicate if there are relations between power production and export or not, and it is difficult to see any merit in the calculations in appendix 2 in the CEESA report.





July is different from January. There is less wind power output. The average was 412 MW in July and 649 MW in January. The linear correlation with net export is less obvious. The correlation coefficient was 0.60 in July and 0.81 in January.

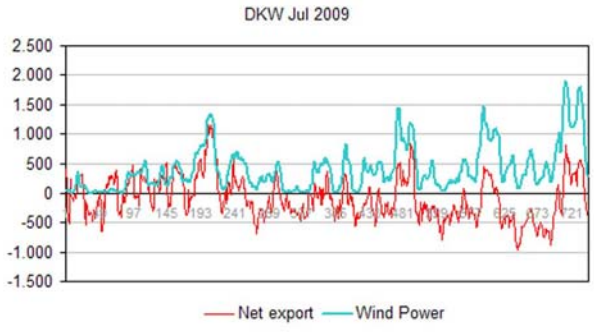
Of particular importance is the difference between the trend lines.

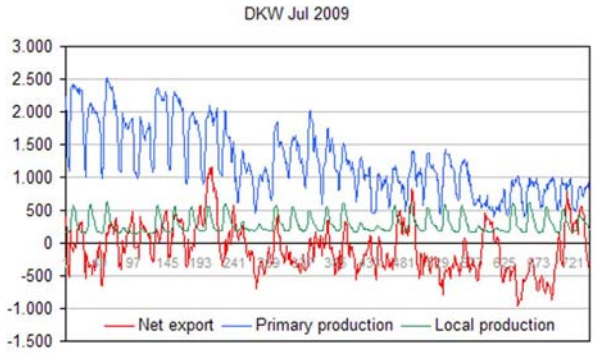


The practical reason for the difference is the high production of the combined heat and power plants during the cold season in order to meet the demand for heat in the district heating systems.

Due to this difference a linear regression analysis for the entire year is not useful. The correlation will inevitably be poor and the results cannot be interpreted in a meaningful way.

Again there is more information in the time series.





The wind power variations are reflected in the net export, even in July, while practically no co-variation between thermal generation and net export can be identified.

So on the one hand I agree with the CEESA report that the linear regression analyses do not support the identification of causal relations between wind power and export. On the other hand the time series indicate a relation between wind power and export which cannot be coincidental and which the CEESA report has ignored. See annex 1 to 3 for complete time series for 2009.

An exhaustive time series analysis might have shed more light on this interesting issue, but it is far beyond the scope of this note.

Misleading market arguments

The core of the market argument in the CEESA report seems to be the following: "*From a market perspective, it is generally the most expensive production in Denmark which is exported, as any cheaper production would already have replaced more expensive production operating to cover the Danish demand.*"

Already? The argument seems to be based on the understanding that the market is operated in two steps: In the first step domestic supply is determined and in the second step agreements on export are made.

This is not how the markets work.

The most important market prices for electricity in Denmark are the local area prices of the Nord Pool spot market.

In Denmark market participants must send their bids for the following day to Nord Pool every day before gate closure at 12:00. After gate closure Nord Pool aggregates all bids into two curves, a demand curve and a supply curve. The two curves determine a system price for each hour. In case of congested interconnections local area prices are calculated.

Owners of combined heat and power plants can offer their electricity output at quite low prices due to the high efficiency of the combined production. Therefore Danish power plants are very competitive during the cold seasons.

Even wind power is traded in the spot market. Normally wind energy is offered at very low prices, because the operators of wind turbines cannot control the time and level of their output. The resulting spot price is used for the settlement.

For each supplier the production is determined by the area price. Supplies for purchasers are determined accordingly. As a result of the process also exchanges across the borders are determined. There is no special reservation for domestic consumers. Therefore section 1.2 in the CEESA report is based on a misleading assumption.

The outcome of the spot market is a plan for the following day. Deviations from the plan are handled by other market arrangements, which will not be discussed in this note.

As noted above, electricity cannot be traced to its source. Therefore the destination of the wind energy can never be objectively determined. But the observations from the time series suggest some significant influence of wind power on net export. This is the background of the estimation of wind energy export in the CEPOS report.

The authors of the CEESA report are entitled to see the matter from a different perspective, but the arguments in their report are not valid, and they cannot justify their claim to know objectively what is right and wrong in this matter. The perspective of the CEPOS study is also coherent. When two or more perspectives are possible, we select them according to the understanding they yield and the assistance they give in solving problems. In what follows I

shall argue that the CEPOS perspective is helpful if we are to plan for high levels of wind power, while the CESSA view is less constructive.

How wind power variations affect exchange of power

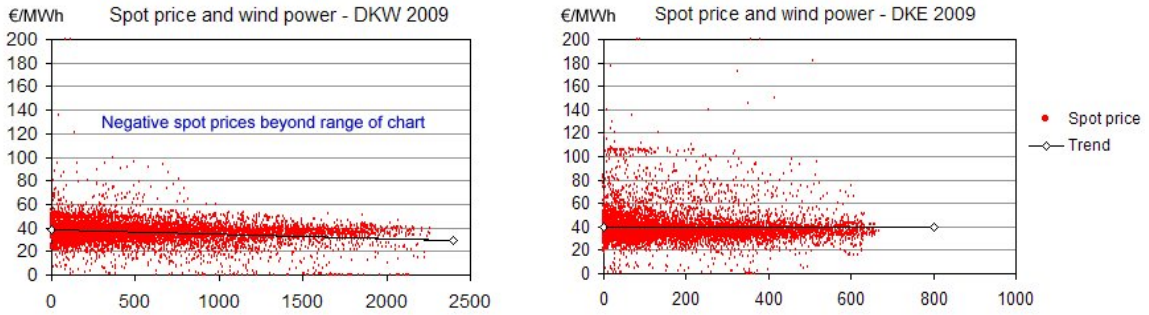
The variability of wind power does not fit with the profile of the electricity demand. Therefore a successful integration of wind power requires new types of electricity demands which can be satisfactorily served by the wind power.

Wind power was added to the Danish power systems without a corresponding adaptation of the electricity demand. As a result of that we see the wind power variations reflected in the net export of electricity (see annex 1 to 3).

From this we can conclude that wind energy has replaced more expensive energy somewhere, but not necessarily in Denmark.

The output from thermal power plants in Denmark depends mainly on the demand for heat for district heating and on the market prices. Thermal power plants are also used for system regulation and as operating reserves.

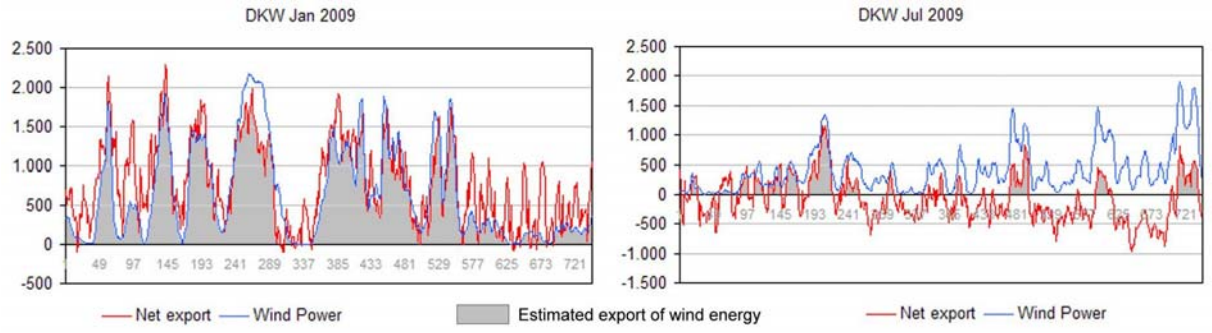
If high wind power output cause lower spot prices in Denmark the thermal production will be lower. However, Danish wind power has normally only little influence on the spot prices.



This is an indication that thermal power plants in Denmark with few exceptions are operated practically independently of the wind power output.

Therefore more wind results in more export and less wind results in less export. This is the simple causal relation and in good agreement with the observed exchanges of power, and this has been the background for the calculation of wind energy export.

The calculation is based on the simple rule that the smaller of either a) wind power output or b) net export of electricity for each hour, is considered as wind energy export.



The reader should note that this is not a scientific law. It is a rule grounded in engineering and logic which aims to describing the possible consequences of adding wind power to a power system without at the same time implementing proper integration measures.

Better integration of wind power is a common interest

The CEESA report claims that it is a theoretical possibility to operate the Danish power system without export of electricity. This would probably be very disturbing to the Danish combined heat and power production, which is also an essential part of Danish energy policy. Therefore this situation cannot be considered as a successful integration.

In 2009 the Renewable Energy Foundation in London published my study *Wind Power and Spot Prices: German and Danish Experience 2006-2008*[3]. The original purpose was to determine how wind power output affected the spot prices in Denmark. The surprising observation was that the correlation between wind power and spot prices is quite low. On the other hand close relations were observed between wind power output in Germany and Denmark and between the electricity markets in those two countries.

Based on these observations it could be said that Germany and Denmark together have solved the integration problems for about 7% wind energy, but only due to the common access to the regulation capabilities of the other Nordic countries, notably hydro power in Norway.

Both Germany and Denmark have ambitious targets for the development of wind power, and it is important that the general public as well as politicians and engineers realize the magnitude of the necessary integration effort in order to go from 7% to 50% wind energy.

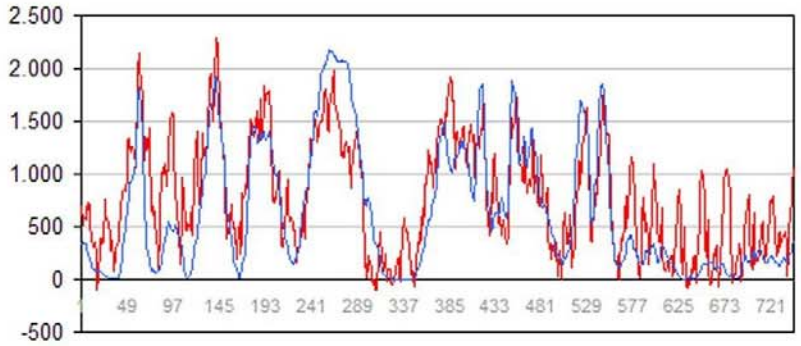
I consider the Danish integration of 20% wind energy as incomplete. Therefore I do agree with the CEESA report about the need for the measures described in section 1.3.

If we attempt to achieve a level of wind energy in Denmark corresponding to 50% of the demand for electricity there is an urgent need to intensify the development of measures to facilitate the use of wind power, that is to say to integrate it. Hopefully a more constructive debate focusing on these essential integration measures will develop. But this will not happen if legitimate and constructive debate is closed down, as the CEESA report seems to intend.

[3] http://www.ref.org.uk/Publications

Annex 1

DKW Jan 2009



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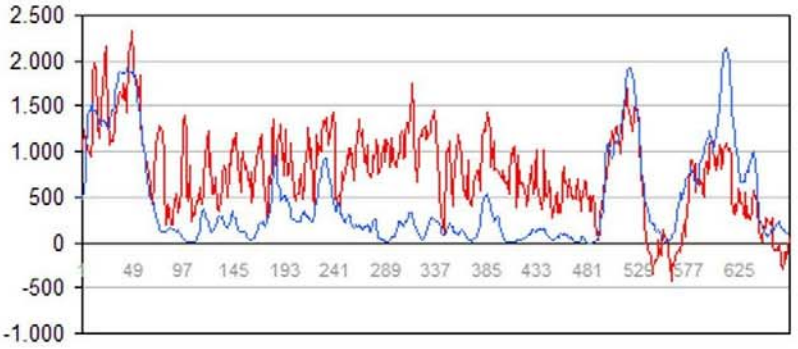

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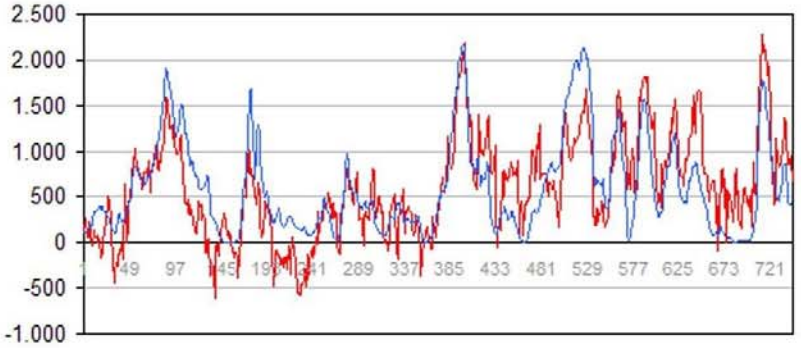

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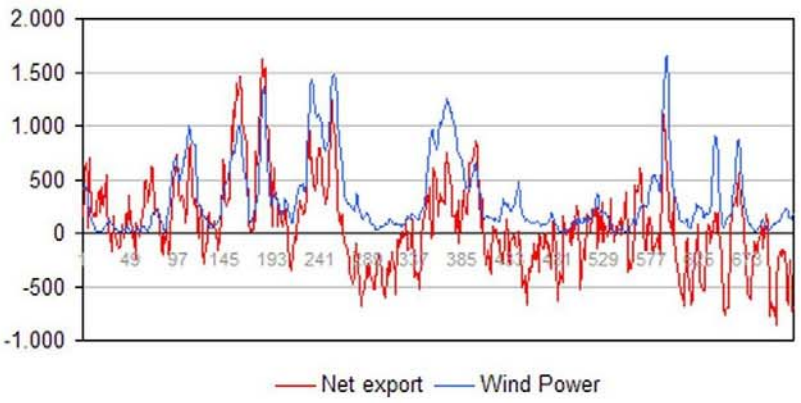

Annex 2

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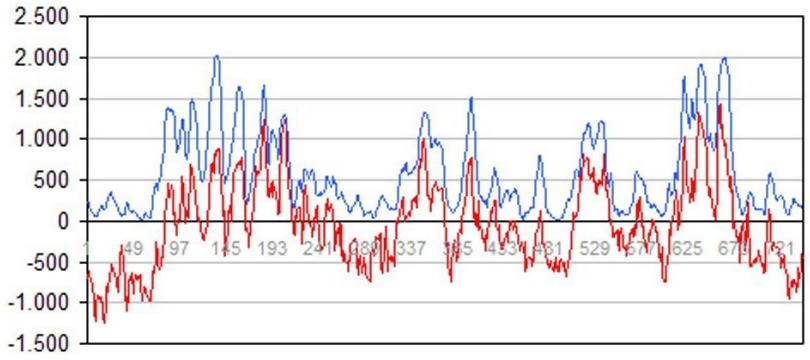

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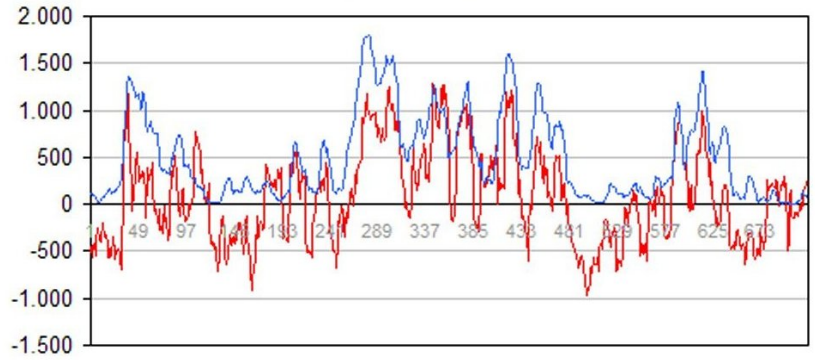

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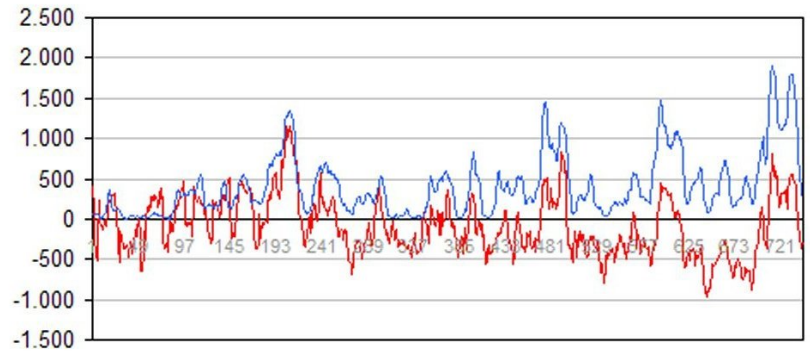

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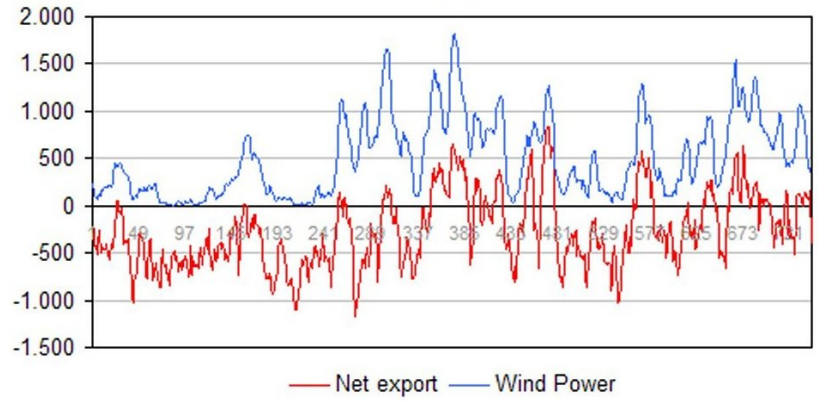

Annex 3

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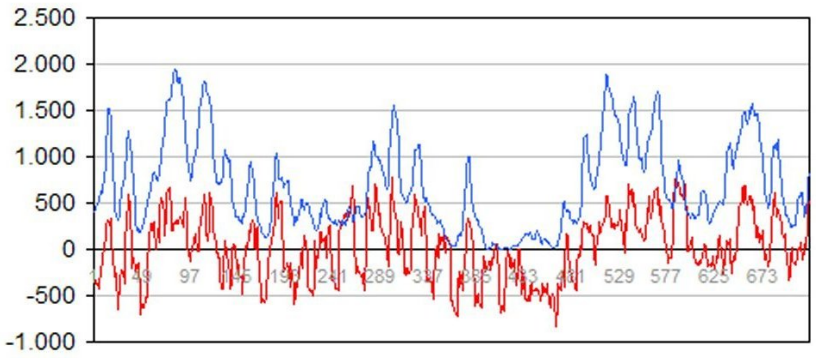

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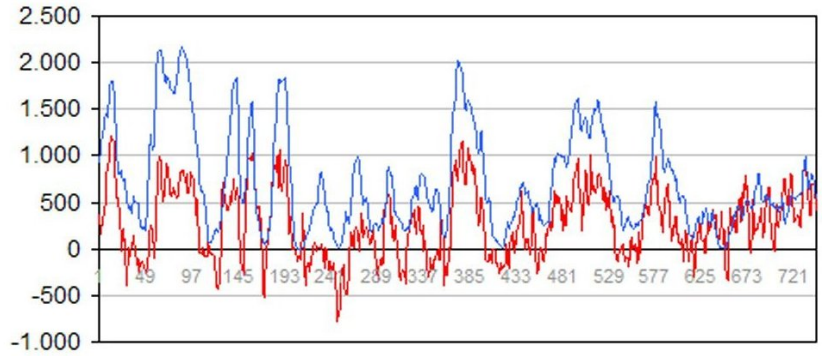

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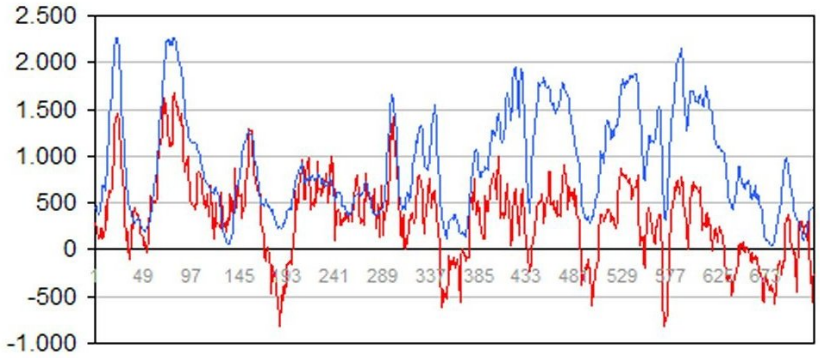

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