Viking Link will need Volatile Spot Markets

Last year I expressed doubt about the profitability of the Viking Link between Denmark and England [1]. In Energinet's business case document from 2015, all essential information was covered, but now another version with more data has been released [2]. The large investment (13.4 billion DKK or 1.6 billion £) deserves a well-informed public debate, and the new document is a concession to this view.

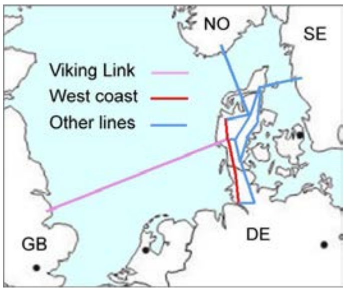


Fig. 1 - Viking Link and the new west coast lines form a whole

The Viking Link has been planned together with a reinforcement of the grids in the western parts of Jutland and Schleswig-Holstein (fig. 1).

Energinet: 89% Chance of Profit for the Danish Society

The business case document says that the Viking Link and the Westcoast lines will create 25 billion DKK trading profits for the countries involved directly or indirectly. The expected profit for the Danish society is 4.133 billion DKK (net present value or NPV). According to the risk analysis, there is 89% probability of a positive NPV corresponding to an 11% risk of loss to the Danish society.

These results are reassuring, but they are output from computer models and do not explain the origin of the profit in a convincing way. A report from EA Energy Analyses [3] gives some further details.

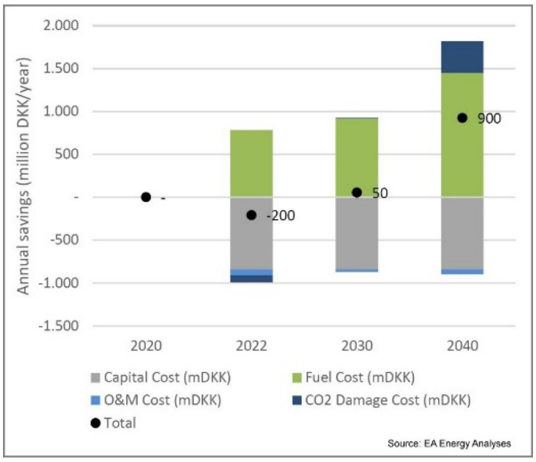


Fig. 2 - Viking Link - Annual savings [3]

The annual costs of the Viking Link will be about 1 billion DKK (fig. 2). The annual transfer of energy will be about 10 TWh[1]. *The necessary average contribution margin per MWh transferred will be about 100 DKK (or 13 €).*

According to fig. 2, the project will lose money in 2022 and it will balance about 2030. The decisive profit has not been found until the 2040 stage.

Market price differences indicate trade opportunities. At present, the wholesale prices are higher in Great Britain than on the continent, but the business case document assumes that the difference will be decreasing over the years to come. However, the link is supposed to generate increasing profits after 2030.

This note tries to understand this paradox and to establish an intuitive understanding of how a 1400 MW interconnection between Denmark and Great Britain can yield the assumed high contribution margins.

[1] The annual electricity consumption in Denmark is about 35 TWh.

Profitable Operation after 2030

Trade is driven by different market prices at the two sides of interconnectors. The European countries have quite different spot price levels. The differences call for stronger interconnectors.

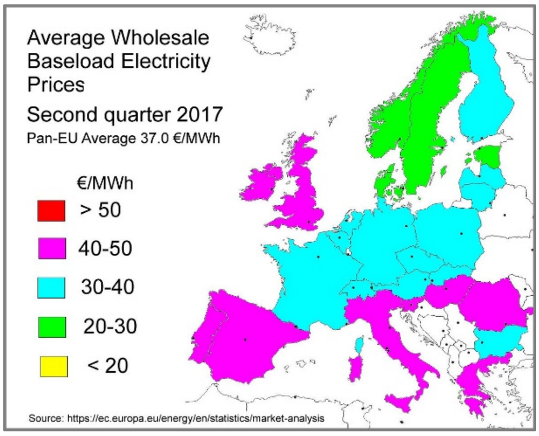


Fig. 3 - Price levels in Europe

Fig. 3 gives an impression of the European average price levels for the second quarter of 2017. There are high spot prices in the UK, Ireland and most Mediterranean countries, while the Scandinavian countries represent the low end. UK wholesale prices include the carbon floor, which is a tax on CO_2 emission.

The report from EA Energy Analyses [3] compares spot prices without Viking Link in West Denmark and England, hour by hour, and sorts the difference for the creation of a duration curve (fig. 4). The average price differences are falling to below the critical limit from 2020 to 2030 and increase again to over the critical limit in 2040.

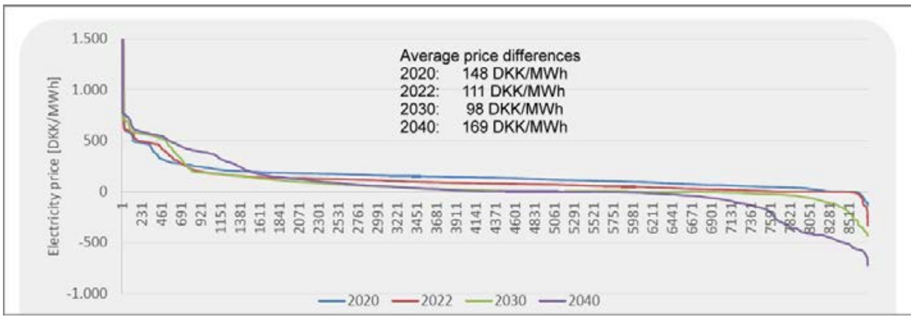


Fig. 4 - Hourly price differences (GB – DKW) arranged in duration curves [3]

The profitability of the Viking Link seems to depend on favourable market conditions 23 years from now. *What is supposed to happen between 2030 and 2040?*

Wind Power Variations and Spot Prices

Energinet’s business case refers to three advanced simulation models. Each of them include several European countries. I would like to look closer at the spot price variations in Great Britain and on the continent. I do not have access to advanced simulation models, but fortunately, much simpler tools can contribute to an understanding of the problem.

I can simulate Great Britain (GB) and Germany (DE) separately. West Denmark will be strongly interconnected with Germany, and the west Danish power system is just about 3% of the German power system. Therefore, I have assumed that spot prices in west Denmark and Germany will be similar. The purpose is to create possible spot price profiles and spot price differences for the years 2020, 2030 and 2040.

The simulations are not predictions, but possible cases. A vast number of choices must be made, and it is easy to manipulate the results.

	2030		2040	
	Wind	Solar	Wind	Solar
GB	24%	4%	38%	6%
DE	21%	10%	38%	12%

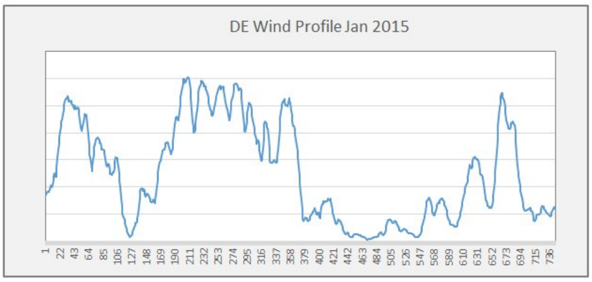
Fig. 5 - Shares of wind and solar energy

I have assumed increasing shares of wind and solar energy in both countries (fig. 5).

For Great Britain, the four scenarios in National Grid's FES 2017 [4] have served as an inspiration. However, none of the scenarios could be used without modifications. Only one scenario can meet the British climate targets, but it assumes a new generation of small nuclear units to be installed after 2030. This plan is too unrealistic. My choice was an ambitious plan for wind and solar power and a more conservative plan for nuclear and fossil-fired units. Obsolete units were closed down.

Many words have been written about the German Energiewende (the energy transition), but very few binding details are available. In my scenario the last German nuclear unit will be closed down before 2025 and the last lignite- and coal-fired units before 2040.

I had to add gas-fired backup units in order to keep the import within the capacity limits of the interconnectors, particularly for Germany. Sufficient dispatchable power units will still be decisive for a stable supply of electricity in 2040, unless other and so far unknown technologies can provide the necessary flexibility.



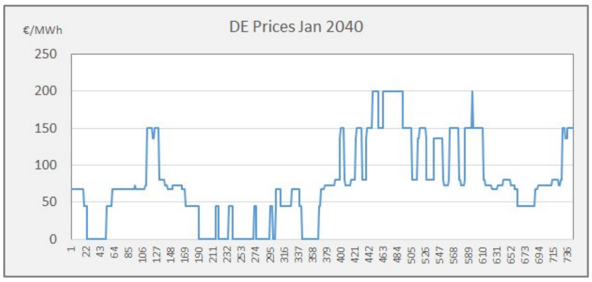
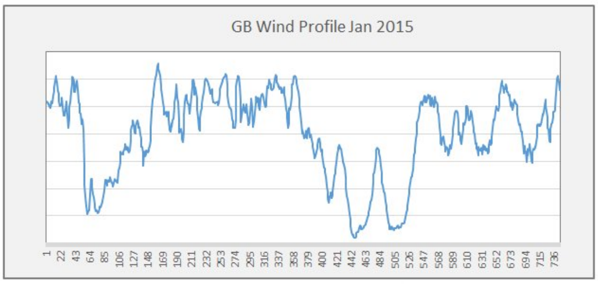


Fig. 6 - Germany: Wind power profile and marginal prices in January 2040

Fig. 6 shows the spot price response to a German wind power profile in 2040 with 38% annual share of wind energy. It is obvious that strong wind is followed by low prices and vice versa, but the shapes are very different. The marginal prices seem to gather in levels. This is partly due to limitations of my model. Three levels occur. In case of energy overflow, the model sets the price to zero. Any other value could be defined. Negative prices occur already in the present market. In case of shortage, two levels have been defined. One level (about 150 €/MWh) represents an estimated import capacity. Price of support, exceeding the import capacity is set to 200 €/MWh. Prices between about 40 and 100 €/MWh are set by dispatchable electricity production.



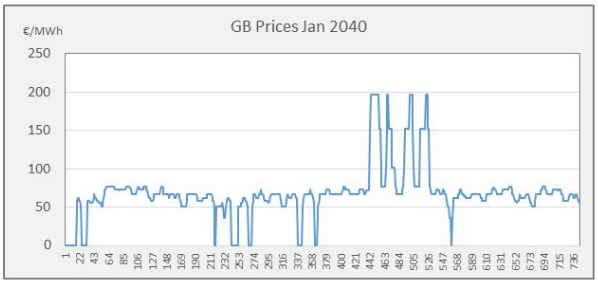


Fig. 7 - Great Britain: Wind power profile and marginal prices in January 2040

A comparison between fig. 6 and 7 shows similarities between the wind power variations, but Great Britain seems to have more favourable wind power conditions than Germany and therefore not quite the same need for backup capacity. The British spot prices have the same main levels as the German prices, but the price curves are different, and there are interesting price differences.

Three price levels have been defined for the comparison: 1) overflow (< 10 €/MWh), 2) shortage (> 100 €/MWh) and 3) normal price setting between 10 and 100 €/MWh. Three levels for each area make *nine combinations* (fig. 8).

The differences between the two hourly time series for marginal prices in 2040 have been arranged as a duration curve.

Fig. 8 shows that both areas have normal price setting in 6666 hours. The average price difference for these hours is 7.82 €/MWh, which is less than needed for profitability.

The “shoulders” (sections B and D) are the interesting combinations with price differences between 50 and 100 €/MWh. These hours are decisive for the profitability of the project.
Fig. 9 combines duration curves for 2020, 2030 and 2040.

Price	levels		Av. price	difference	Section
		Hours		€/MWh	
GB high	DE low	2		102,06	A
GB high	DE normal	158		53,19	B
DE low	GB normal	775		61,32	B
Both high		121		29,89	C
Both normal		6666		7,82	C
Both low		221		0,00	C
GB low	DE normal	491		61,16	D
DE high	GB normal	317		81,43	D
DE high	GB low	9		148,52	E
			All year:	19,30	

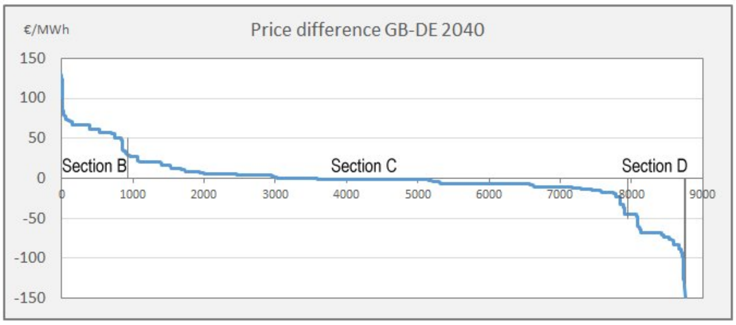


Fig. 8 - Nine combinations and the price difference duration curve

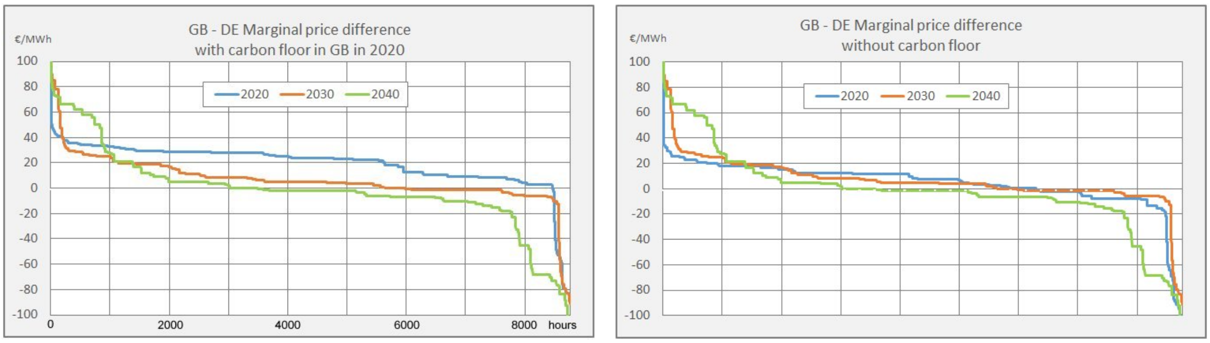


Fig. 9 - Duration curves for price differences 2020-2040 ***with*** *and* ***without*** *carbon floor in GB in 2020*

The duration curves in fig. 9 are similar to the curves in fig. 4 and the average price differences (fig. 10) have the same magnitudes as in fig. 4 (13 €/MWh required for profitability).

	€/MWh	Carbon floor
2020	23.16	Yes
2020	13.03	No
2030	11.59	No
2040	19.30	No

Fig. 10 - Average price differences

The calculations in [2] assume that the British carbon floor will be phased out before 2030. The carbon floor is a tax on CO_2 emission. Profits, which are due to the carbon floor are paid by British tax payers and may give a misleading impression of the profitability of the project. After the removal of the carbon floor in fig. 9, the “shoulders” are the main difference between 2040 and the other years.

Why is 2040 different?

In 2040, there will be a large number of hours with marginal prices set by import or local shortage measures.

Shortage can be limited by adding traditional power plants as backup. Economic considerations will determine the reasonable extent of this option in comparison with other measures.

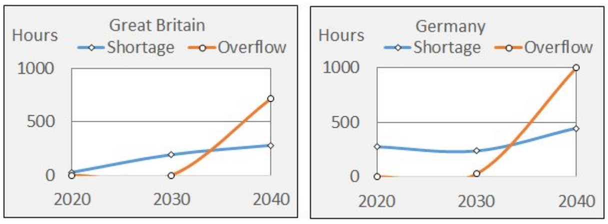


Fig. 11 - Hours with shortage and overflow

Overflow will reduce the marginal benefit of added wind power, also in terms of emission of greenhouse gasses. Additional backup capacity will not reduce the overflow. Therefore, overflow must be limited by other measures, including stronger interconnections.

Fig 11 illustrates the reason for the increased average spot price difference from 2030 to 2040. The increasing number of hours with overflow will create the “shoulders” in fig. 9. The Viking Link will begin generating profit after 2030 if the data assumptions are realistic. This conclusion confirms and explains the results in [3].

Ignored Risks

The risk analysis in [2] considers 15 possible deviations from the main assumptions with corresponding probabilities. The results of this note could point to a few other deviations.

It is obvious that high spot price volatilities in both connected areas are necessary conditions for the profitability of Viking Link. Therefore, deviations with an impact on the spot price variations are of particular interest. This is confirmed by some of the results in the risk analysis. For instance, a lower growth of wind power will cause a loss.

Increasing overflow of electricity will reduce the marginal benefit of new wind power, discourage investments in new wind power and postpone the profitable stage of Viking Link.

Additional interconnectors are also considered in the risk analysis. Another 2.8 GW from Norway and Germany will result in a total British interconnector capacity at 13.3 GW. The probability of each of these two links is set to 50%. They can reduce the profit by 773 million DKK.

In [4], National Grid considers even more interconnector capacity than 13.3 GW. The interconnector capacities in the four scenarios in [4] by 2035 are 10 GW, 15 GW, 17 GW and 20 GW. An updated risk analysis should therefore cover the whole range from 10 to 20 GW.

A different policy on backup power is not among the 15 deviations. Great Britain is developing a capacity market. It is difficult to forecast, how the capacity market will be operated when the risk of power shortage becomes obvious. Similarly, a shortage of power in Germany may cause an unpredictable political intervention, regardless of the wind energy policy.

Price differences and variations are main drivers in a market. Price differences cause exchange of power in the wholesale markets. Price variations are supposed to encourage the development of price sensitive electricity consumption. Flexible electricity demand has been developed for decades, but the results have been modest so far. “Power to heat” and electric vehicles are still expected to be able to absorb electricity overflow from wind and solar energy.

The risk analysis in [2] does not consider any influence from flexible electricity demand on the spot price profiles. The poor results so far may justify this choice, but it excludes the development of new flexible electricity demand due to high volatility in the end-user market.

Conclusion

This note confirms and explains how high wind energy shares on either side of Viking Link can generate sufficient price differences for a profitable operation after 2030. The price differences are not average levels, but random positive and negative hourly peaks for a limited number of hours per year.

The note explains why return on investment for Viking Link is modest until after 2030. An argument for an early investment is that Viking Link and the west coast line in Germany and Denmark are elements in a joint long-term grid plan and may be difficult to implement at a later stage.

The expected net present value (NPV) of the Viking Link project after 40 year’s operation is 4133 million DKK [2] (about 550 million €). The calculated risk of a negative NPV is 11%.

A high volatility in both interconnected markets is a necessary condition for the profitability of Viking Link. The growth of wind energy from about 25% to about 38% of the electricity demand can create sufficient price volatility in the hourly wholesale markets for the Viking link, but the electricity overflow must be utilized by new types of electricity demand, which in turn may reduce the price variations and the profitability of the link.

A balanced development of grid reinforcements and new types of electricity demand for the absorption of wind power peaks will be required for an optimal utilization of wind shares exceeding about 25%. Viking Link is among the most expensive interconnection projects and its profitability will be sensitive in comparison with other measures. The profitability depends on expected conditions after 2030.

Some risks have been disregarded or underestimated in the risk analysis:

- The possible amount of new competing interconnectors to Great Britain has been set low in comparison with the four scenarios in [4].
- Risk of power shortage might lead to decisions on additional backup capacity, which in turn will reduce the spot price fluctuations (and the project profitability).
- Increasing overflow of electricity will reduce the marginal benefit of new wind power, both economically and in terms of saved emission of greenhouse gasses. Reduced investments in wind power will reduce the spot price fluctuations.
- The possible impact of flexible electricity demand such ad power to heat and electric vehicles has been disregarded. If flexible demand can absorb overflow of electricity, the price volatility will be reduced correspondingly.

These risks can reduce the price spot price volatilities and the profitability of Viking Link. Therefore, the 89% chance of a positive profitability in the risk analysis seems to be rather optimistic.

The combined wind power output in Europe will still have a high variability. A new interconnection will be a marginal measure in wind power integration, and other measures will be required. Until large-scale storage solutions have been found, dispatchable power plants will remain necessary for security of supply in any power system. This note indicates that for wind power penetration in large power systems approaching 38%, special solutions for absorbing overflow must be implemented. Further studies might help finding a balanced combination of measures for the implementation of even higher penetrations of wind power.

A large European study, e-Highway2050, was published in November 2015 [5]. The analyses includes five very different scenarios from "Fossil and Nuclear" to "100% RES". I made a comment on the study in January 2016 [6].

References:

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