The Unbearable Lightness of Wind

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The omens for wind power are very good, and there is cause to believe that the EU's 2020 targets in this area will be exceeded. But as capacity grows, it may be wind's impact on electricity prices that presents the most immediate problem. Wind's intermittency cannot be wished away, even if it can be ameliorated, and the development of the infrastructure needed to deal with it is lagging the installation of wind power itself.

THERE ARE FEW RENEWABLE ENERGY policies that do not depend heavily on wind power and wind is certainly at the heart of the most ambitious, the EU's binding target of sourcing 20% of final energy consumption from renewable resources by 2020. As the EU's target for transport is half that for energy consumption as a whole, it follows that the power sector will be required to source a proportion of energy from renewables that is much higher than 20%. According to the European Wind Energy Association, the figure is 35%.

Within that, wind will be the largest contributor, accounting for just over one-third of "green" electricity, suggesting that between 11.6-14.3% of the EU's power will be supplied by wind by 2020, according to the EWEA. This would mean the installation of 180 GW of wind power by 2020, up from 56.535 GW installed in the EU-27 at end-2007, producing about 477 TWh of power. The transport element of the EU plan is also dependent on future scientific advances, for example, that second generation biofuels become commercially available. This uncertainty will put more pressure to achieve in areas that are already within technological reach.

But if these targets seem ambitious, it is also evident that wind capacity is being installed at much higher rates than previously forecast by bodies such as the International Energy Agency. According to Stefan Gsänger, secretary-general of the World Wind Energy Association, worldwide wind capacity had risen to about 120,000 GW by end-2008, an increase of 30% on 2007. According to Platts Power in Europe, wind additions in Europe for the first time in 2008 accounted for more new generation capacity than any other power source, including gas. A study carried out by the Deutsches Windenergie-Institut in 2008 estimated that the annual worldwide installation capacity of the industry would have risen above 100 GW by 2017.

Experience in Europe shows that with the right policy framework, wind capacity can rise fast. And while the "binding" nature of the EU's targets means little in practice, it is a serious statement of intent. Renewable energy also promises new jobs, making it an attractive sector for policy makers on a counter-recessionary spending spree. Wind would appear to tick all the right boxes in terms of energy, environmental and industrial policy, suggesting, as some non-governmental pressure groups do, that the EU's targets for wind are in fact not that ambitious and could well be exceeded.

The Desirability of Wind

But just because you can, doesn't mean you should. Wind power has its critics and they feel that their reservations have been overridden by policy makers whose imaginations have been captured by a green agenda that downplays wind's limitations. Wind's intermittency cannot be ignored just because it is the most readily available and domestically attractive technology to hand, they argue.

Any electricity system needs a mix of baseload generation power—which tends to be relatively inflexible in terms of switching on and off—and peaking plants, which are more flexible and, as their name suggests, designed to take advantage of high electricity prices at times of peak demand. Wind falls into neither of these categories because it is essentially unreliable.

Proponents of wind power dislike the negative connotations of the word "unreliable," pointing out that on average the amount of power supplied by a given capacity of wind turbines is reasonably predictable. But, according to the EWEA, wind turbines produce no electricity at all between 15% and 30% of the time. And, on average, the load factor for onshore turbines is about 30%. This means that over 24 hours, 1 MW of wind capacity would provide about 7.2 MWh of power, but there's no knowing exactly how much or when until the last minute.

As wind provides neither baseload nor peaking plant it has no impact on reserve capacity. There will always be the possibility that, at some point, no power will be produced at all. This threat falls as more wind capacity is added; some analyses suggest 26 GW of back-up is needed for 100 GW of wind, others that back-up needs range from 60-95%, depending on the make-up and size of the system. But wind's intermittency ultimately means that a system reserve must remain in place. The system must be set up to accommodate wind, but also to work as if it did not exist.

Wind Surges

But if wind turbines add little or no reserve capacity, they do produce power. And the impact they have depends on a range of factors, including when the power is produced, the ability of the system to add and withdraw non-wind capacity and how power is priced.

Imagine two scenarios; peak and trough demand. During lower demand periods, the system is at its least flexible, with power supplied by baseload plants. A surge of wind power may simply result in surplus power production, sending prices towards zero. In effect, it is as if the system has too much baseload generation plant that cannot be turned off quickly enough, either for technical or economic reasons.

The ability to export might provide a key safety valve, but would depend on; first, the physical infrastructure being in place; second, prices falling below the external system's baseload prices; and, third, the lack of a similar wind surge in the external market, either as a result of different weather patterns or of less wind capacity in that system.

At times of peak demand, the system is at its most flexible because the maximum

Figure 1. Cumulative wind power installed in Europe end-2007 (MW).

Source: EWEA

amount of the most flexible power generation capacity is in use. A wind surge would look as if the system had in effect much more flexible plant than it really does. Prices would be shaved, but underpinned by a greater ability to withdraw peaking capacity.

So, in the low demand period, the impact on peaking plant is negligible—they are not producing power anyway. The impact on baseload plant is principally in terms of price rather than generation displacement and therefore would not necessarily result in carbon emissions being avoided. Prices react as the ability to withdraw capacity is low.

In the high demand period, baseload plants again suffer from lower prices when the wind blows. Peaking plants experience either lower prices or generate for shorter periods. This suggests that the principle result would be for wind to displace peaking plant, i.e. gas rather than more carbon-intensive coal or low-carbon nuclear.

The thorny issue of subsidies aside, adding an intermittent energy source would act to reduce prices overall as wind adds power but does not add reserve capacity. In so doing, it increases redundancy in peaking plant and reduces the profits of baseload generation; potentially good for consumers but bad for investment in non-intermittent sources of power, and presenting the risk of a decline in reserve capacity.

Back-up Not Required

The EWEA argues that "because of the way the electricity network is planned, there is no need to back up every megawatt of wind energy with a megawatt of fossil fuel or other power. All networks have enough spare capacity available to deal with disconnections, breakdowns and sudden surges in demand."

That argument is fine, but only because it assumes that sufficient reserve capacity and flexibility already exists from non-intermittent sources. However, if wind energy is built to meet growth in energy demand it implies a decline in reserve capacity. Wind can be added to a system if demand growth is static or if non-intermittent sources also grow with demand. The amount of "back-up" capacity is related to demand growth not to the amount of wind added to the system.

Take the argument to its extreme. In a system with no wind power, adequate reserve capacity and no demand growth, any proportion of wind can be introduced with no need for any additional fossil fuel powered generation. At 100% wind penetration, the non-wind plant would still be needed for low or zero wind days. However, peaking plant would be used much less and baseload plant would see sustained periods of potentially below cost prices—a particular nightmare for the nuclear industry.

As such, the proportion of wind that can be incorporated into a system is both an engineering challenge and an economic one. The conundrum that wind poses is not just technical i.e. organizing the electricity grid in such a way as to cope with increasingly large rises and falls in supply from multiple and decentralized sources, although this too is a significant challenge. It lies in the fact that wind does not directly displace fossil fuel generating capacity, but will make this capacity less profitable to maintain.

Mitigating Intermittency

There are a number of ways in which wind's intermittency might be mitigated. The organization of electricity systems is being rethought to incorporate decentralized, diffused and intermittent sources of energy. Demand response programs are aimed at shaving off peaks in demand, but also might be seen as tools in responding to sudden losses of wind power. Any innovation that increases flexibility within the system should enable the accommodation of higher proportions of intermittent power sources.

The problem of wind producing surplus power when it is not wanted may find a solution in the form of electric cars. The idea, being pioneered in Copenhagen, is that surplus wind power generated at night would be used to power electric plug-in cars for urban transport. Copenhagen is the perfect place to try this, given Denmark's 20% penetration of wind in the electricity system, the highest in the world, the inflexibility of its (highly efficient) baseload coal-fired CHP systems, and the fact that it is very flat.

It is also a move that could be very bankable in terms of meeting the EU's renewable energy targets. In the EU's renewable energy package, it says "the amount of renewable electricity used by electric road vehicles is to be considered to be 2.5 times the energy content of the renewable electricity input, in recognition of their greater efficiency." It is not clear what measure of efficiency is being used here (perhaps an accounting one).

However, the use of plug-in electric vehicles would create a relatively constant and inelastic demand load within a specific time period, to be satisfied by an intermittent supply. In practice, although it would clearly displace transport fuels, it would mean increased coal and gas burn at night when the wind wasn't blowing, or vehicle owners would find themselves with a flat battery in the morning.

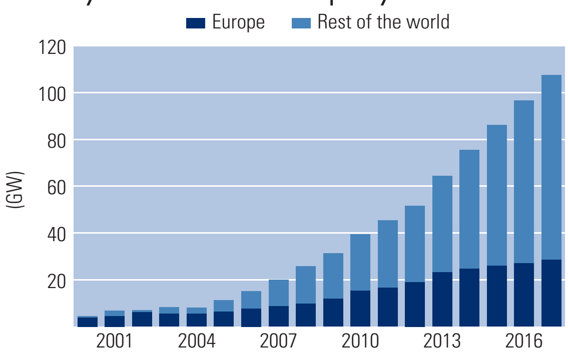
Proponents also argue that if the power wasn't used by the car, it could be returned to the grid at peak demand times. This suggests that plug-in electric vehicle manufacturers have found the holy grail of the electricity industry—the efficient storage and retrieval of power. It is more likely that they have not and that the renewable energy returnable to the grid after having been transmitted from wind turbine to car battery is not substantial. However, the displacement of transport fuel with electricity otherwise priced close to zero would be significant.

Efficient storage is a technological advance that could transform wind's contribution to an electricity system by ironing out the troughs and peaks of power production, effectively neutralizing its intermittency. It could turn wind from an intermittent power source into peaking power plant that makes a real contribution to reserve capacity. There are many experiments taking place in this field, some of which are promising, but (with the exception of pump storage hydro) commercially viable projects on a large-scale do not appear to be on the immediate horizon. But as wind capacity increases, the impetus to make this breakthrough will rise, and the future impact it would have, if it occurs, will be all the greater.

Interconnections

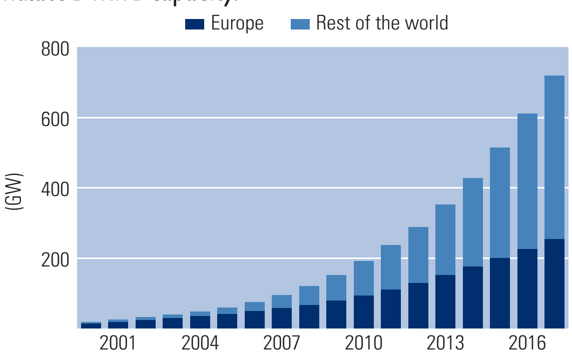
As mentioned, exports could prove a major safety value for intermittent power sources, enabling them to find new sources of demand when there is a surplus of power and acting as additional reserve capacity when the wind fails. Denmark's capacity to import and export power as a proportion of total system capacity is just as impressive as the world-beating penetration of wind power within its system. But even so, it has its limitations in that excess power occurs when demand is low in external markets, markets that as yet do not have the same level of wind penetration as Denmark.

Figure 2. Wind industry annual installation capacity.



Source: Wind Energy Study 2008 Deutsches Windenergie-Institut

Figure 3. Accumulated wind capacity.



Source: Wind Energy Study 2008 Deutsches Windenergie-Institut

In the 2nd Strategic Review of the EU's Energy Security and Solidarity Action Plan, great emphasis was placed on major infrastructural plans that would benefit wind integration. These include the Baltic interconnection plan, completion of a Mediterranean energy ring, the development of North-South electricity interconnections within Central and South-East Europe, and most significantly the development of a blueprint for a North Sea offshore grid, interconnecting national electricity grids and plugging in planned offshore wind projects.

All of these are major projects, requiring a high degree of international cooperation, planning and capital. And international interconnectors can be notoriously difficult to get built; it may well be to the North Sea offshore grid's advantage that it is indeed offshore. But assuming (optimistically) that they get built within the required timeframe, they should promote competition and improve security of supply, as any available capacity on one national system can be put at the disposal of another, subject to the restrictions of the interconnection.

But the North Sea offshore grid goes a step further than an international interconnection because it implies multiple connections with an added common power source through linked offshore wind farms, potentially serving the UK, French, Dutch, Belgian, German, Danish and Nordic markets. The grid would be more likely to produce some power all of the time. According to the UK Meteorological Office all areas of the North Sea are usually affected by the same weather systems, typically Atlantic depressions from the west, but it is fairly rare for calm to descend across the whole of the North Sea at any one time.

That suggests that offshore wind capacity tied into a North Sea grid would start to provide power that could be depended upon, albeit never quite with 100% certainty. However, that "dependable" power would only be a fraction of the capacity of the total offshore system, and would be split between all the markets the grid would serve. Moreover, raising each national market's exposure to wind might negate the advantages of the export/import facility. The most common experience could well be that they all experience similar patterns of rises and falls in wind power.

Hydro Option

A tried and tested form of storage might prove more reliable. According to Swiss parliamentarian and economist Dr. Rudolph Rechsteiner, Swiss hydro reservoirs are already being adapted to create a system that provides storage capacity.

Swiss hydro has historically been developed on the basis of huge storage volumes released in one season to meet peak seasonal demand. Investment is now taking place to install pump storage so transfers can take place once a week rather than once a year.

Swiss hydro resources could provide sufficient storage to manage all of Switzerland and Germany's power, and there are at least two dozen possible pump storage sites in the Swiss Alps and 12 in Germany. At the moment, pump storage in Switzerland is absorbing excess baseload nuclear power and releasing the power at peak times into the German market.

Retaining Reserve Capacity

The potential problems of a high penetration of wind power are being downplayed by European policy makers grateful for a domestically produced renewable technology. Although the target 2020 proportion for wind as a percentage of total electricity generation is not that large, 12%, this average is likely to see large differences between EU states. And while wind's intermittency is likely to be ameliorated over time, the impact on prices of a growing proportion of wind in the EU energy system may prove more immediately challenging than the technical difficulties that a higher penetration of wind poses.

The issue for the producers of power from fossil fuels (and nuclear) and for policy makers is that as the penetration of wind rises, they are likely to see a material effect on prices, while wind turbine income is protected by feed-in tariffs and the like. This is a commercial problem for power generators, but also for the wider system, as in all likelihood fossil fuel plant will still be needed for reserve capacity. It appears that the installation of wind capacity is racing ahead of investment in the infrastructure required to manage that capacity reliably. Taken to its logical long-term conclusion, in this scenario, the only companies eventually able to manage such infrequently used reserve assets commercially, will be the wind producers (or aggregators) themselves. ■