Can Denmark's remarkable renewables feat be duplicated—Perry Sioshansi's Letter from America

What would it take for other countries to achieve the same?

While renewable sceptics shake their heads in disbelief, Denmark's grid operator, Energinet Denmark, manages to routinely integrate double and triple digit percentages of wind in its daily operations. Wind accounted for 33% of demand in 2013, 42% for Jan-June 2014, 62% for Jan 2014 and an astonishing 105% on 19 Jan 2014, an unusually windy Sunday when demand on the network was low.

Lights, however, don't flicker in Denmark, nor has the grid's reliability been adversely affected thus far. If you ask Energinet Denmark's vice president Peter Jorgensen if the network can be safely managed, he will say, "Yes, you can do this, but not with our existing grids."

On closer inspection it becomes clear that Denmark's remarkable feat in managing huge swings in intermittent renewables, now exceeding 5GW, is possible due to the fact that its relatively small network is conveniently sandwiched between the giant German market to the south—which can easily absorb or export the excess or shortfalls in generation—and an equally large Nordic market to the north—which can store and retrieve large amounts of power in its vast hydro reservoirs. With strong transmission interconnections relative to the size of its domestic market, Denmark is unique, and blessed in ways that may not be easily duplicated elsewhere.

The fluctuations in wind and PV generation as a percentage of demand vary from low single digit figures to excess of 150%. The variability would not be a huge problem if these resources were a small part of the total generation. But as Denmark marches towards a nearly 100% renewables future by 2050, balancing load and generation will become more of a challenge.

Incidentally, Denmark's 100% renewables target does not merely apply to electricity generation, but all energy. The country wants to quit its fossil fuel habit altogether by transforming all energy to renewable resources including its transportation system. It will be a major feat if the country can pull it off successfully.

Data for early January 2014 indicates a more or less daily routine facing Energinet grid operators; namely the need to balance variations in customer demand with variable resources—notably wind and solar PVs—each with its own hourly, daily and seasonal variability. The situation is expected to get progressively more challenging over time.

Jorgensen points out the simple fact that "electricity generation and consumption do not go together", which means that the grid operator has to balance the imbalances in real time, while maintaining frequency and reliability. By 2035, electricity generation from wind is expected to dwarf total consumption on typical weeks, with considerable variability from week to week, day to day, and hour to hour.

Denmark is on a trajectory that will eventually get it off fossil fuels entirely by 2050. Not only is total consumption projected to decline—through energy efficiency measures—but what remains will be supplied from a mix of renewable resources. This means that the daily and weekly imbalances will get progressively more pronounced over time. On a typical week in Jan 2014, an especially windy period with relatively low demand, on some days wind generation exceeded demand while on other days, there was a net shortage. Energinet.dk manages these surpluses and shortages through exports and imports from neighbouring countries, Norway and Sweden to the north and Germany to the south.

The relative proximity and the diversity of resources within the Nordic electric system plus strong interconnections to Germany with its diversity of generation resources is what allows Denmark to get by—at least for now. Norway and Sweden, both blessed with vast hydro resources, can serve as massive batteries for any excess Danish generation.

Germany has a system much larger than Denmark, which can also serve as a shock absorber, taking up the excess or filling any shortages. Of course, as Germany's own renewable generation grows over time, it too will have to look beyond its borders for massive shock absorbers.

Not everyone can rely on its big and cooperating neighbours as Denmark currently does. For example, Spain and Portugal, both with their own large renewable portfolios, are currently poorly integrated with France. This limits how much trade can take place during periods of imbalance between generation and demand. The same is true of Texas, which has over 15GW of intermittent wind with virtually no interconnections to its neighbours. California, which is rapidly approaching its 33% new renewable target by 2020—plus existing hydro—would likewise have to find ways to manage its intermittent renewables, especially the uptake of solar PVs.

There are other explanations for what Denmark can do, namely a robust and functional wholesale trading system made possible through the interconnected Nordpool. Denmark not only manages its imbalances, it trades its excess generation and shortfalls through Nordpool market.

Speaking at a workshop on integration of high levels of variable renewable energy (VRE) on networks organized by The World Bank in Copenhagen in October 2014, Jorgensen was optimistic that given an unequivocal political commitment and stable regulatory regime such as those prevailing in Denmark, the future challenges can be met. He, however, pointed out the need for increased flexibility as countries like Denmark and Germany move towards high VRE penetration levels. His flexibility wish list includes the following:

- grid codes to ensure technical capabilities of all generation and demand to support the system;
- clear price signals reflecting system balance to incentivize dynamic response;
- state-of-art forecasting tools for VRE to enable efficient system balancing;
- specialized operational procedures and tools to ensure efficient system operation and security of supply; and
- a gradual shift from smart grids to what Jorgensen calls smart energy to optimize RES utilization across energy sectors and support price flexibility.

What may be the lessons for other places with high and rising VREs is clear:

- strengthen transmission interconnections with neighbouring regions;
- establish wholesale trade in energy imbalance markets that span large geographical areas with diversity of generation and load;
- invest in upgrading the transmission and distribution network;
- encourage a larger and more proactive role for demand and demand response; and
- consider a growing role for storage – in whatever form or medium it makes economic sense.

The growing significance of the so-called energy imbalance market is becoming obvious in all wholesale markets where a growing share of generation is coming from intermittent and non-dispatchable resources such as wind and solar. Naturally, a mechanism must be found to balance the variable generation with load while maintaining grid reliability and stability.

California, for example, will have to work on all of the above, some sooner than others. Aside from its mandatory 33% new renewables target by 2020, the state is likely to have at least 8GW of distributed solar PVs by the end of the decade. Traditionally a major net importer of electricity, it has to develop the means of becoming a net exporter, at least during the times and hours when its renewables generation exceeds its domestic demand. California has already introduced an energy imbalance market and has a mandatory storage target. It will need all of these and more to avoid an embarrassing blackout due to too much intermittent renewables.

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