Staring at the sun: an analysis of solar generation in Great Britain

Humbeat uses key GB electricity market operational data to analyse the characteristic impacts of solar generation on GB transmission demand, and discusses why many market participants will have different interests in how its impacts are mitigated.

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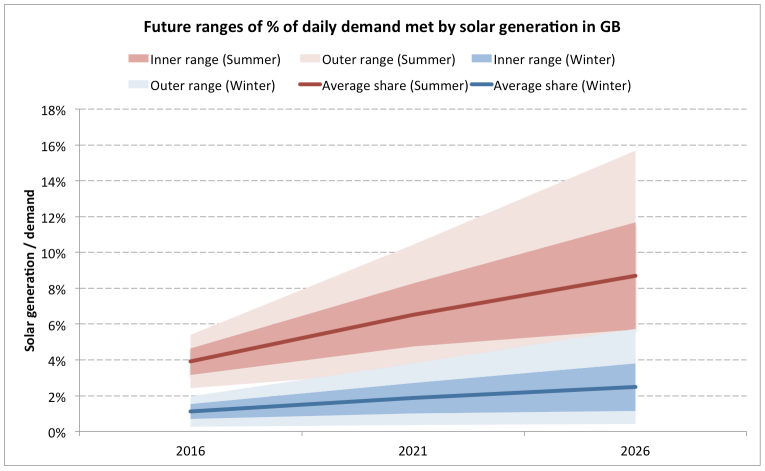
A new sunrise

When the sun comes up in the morning, solar panels on consumers' roofs, farmers' fields and other open areas start generating power. Their output reduces customer consumption, displacing supply from traditional transmission-connected power stations. When the sun goes down in the evening, solar's contribution ceases and supply is again required from traditional plant.

Solar energy is growing in GB, and by 2026 could contribute up to 5% of national demand (Chart 1). But solar generation is concentrated in the middle of the day, and is weighted to the summer when demand is lower. During winters, solar may struggle consistently to provide 2% of national demand, and on many days may generate around a tenth of that number. Conversely, during a string of bright, cloudless summer days, up to 15% of demand may be met by solar, temporarily displacing other generators from the market. Solar uncertainty drives operating schedule uncertainty for generators, therefore understanding solar generation patterns is important for many market participants.

Chart 1:



In November, Humbeat shared an analysis of variability and uncertainty in GB RES supply which showed that:

- Day-to-day solar variability is already significant ($P_{50} \approx 700$ *MW)* but near-term (half-hour) uncertainty is not as disruptive ($P_{50} \approx 200$ *MW)*;
- Solar takes up a significant share of national demand at foreseeable periods of the day/week/year, which are most susceptible to system operability issues and risk of oversupply; and
- Residual demand (i.e. that which is to be met by traditional transmission-connected generators) is changing shape over days/weeks/years.

As solar capacity grows, the energy it generates remains locked into the same daily profile, punctuating the daily rhythms of the power market in a new way. Without careful intervention, further solar capacity growth will cause seasonal residual demand shapes which are complex to manage. Shifting *when* generation is released to consumers (through physical storage and subsequent dispatch, or commercial shape-shifting services) is the front-runner solution to this problem,

and could unlock solar generation's potential within multi-technology energy systems.

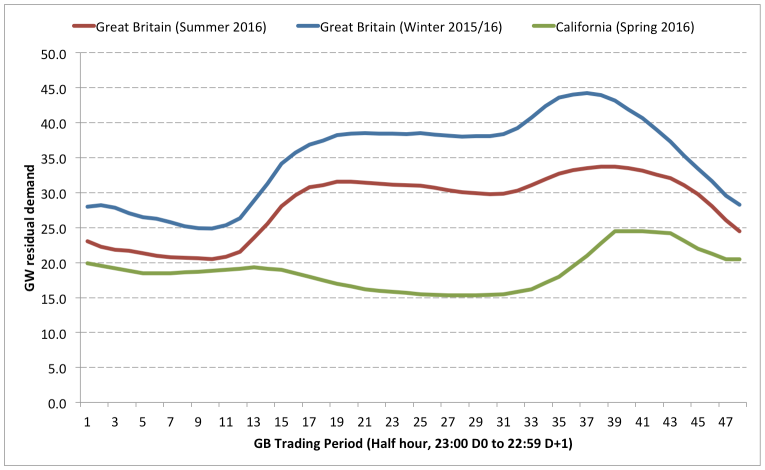
Residual demand shape will have a direct influence on the design of new services and technologies which will both support system operation, and exploit market opportunities. Importantly, it is not only solar generators who may be interested in storage technologies to improve the returns of their assets. Independent investors in search of bankable projects will also be interested in this area.

Perhaps most importantly though, residual demand shape has a direct influence on the operating plans, performance, costs and profitability of conventional generators. Owners of such existing assets will also be motivated by what storage technology can bring to their plant, in terms of protecting the running routines of their valuable and important assets and insulating them from the disruptions of a solar-driven, new, daily routine.

Introducing: a duck

Chart 2 shows average demand profiles for GB during Summer 2016 (red); Winter 2015/16 (blue) and for California (green) in Spring 2016. California, which is advanced in its solar generation deployment, uses the term "duck curve" to describe the power shape required from traditional assets through the day. Notably, during 2015, the Californian evening ramp (periods 32 through 38) was greater than 1,800 MW per hour almost two-thirds of the time, contrasting with 6% of the time during 2011.

Chart 2:



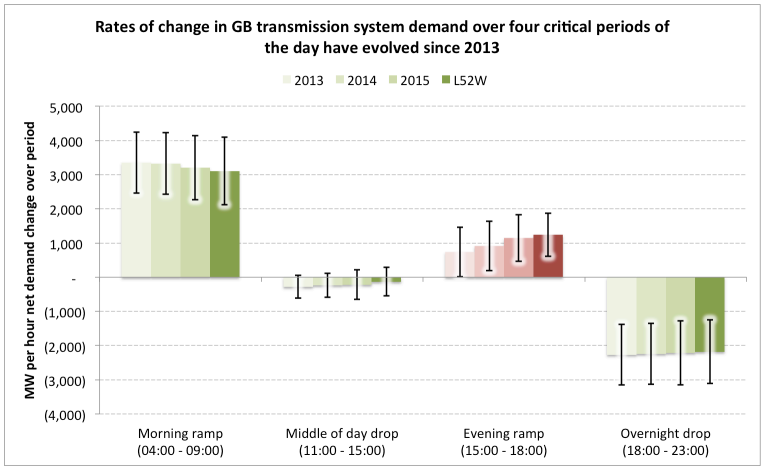
As solar capacity grows in GB, should we expect the Californian duck to migrate to our shores? Well, the beginnings of a duck curve can be seen in the red line in Chart 2 around period 30. And as solar capacity is added, the duck grows. So: yes, we should, and two trends will likely emerge.

Firstly, daily residual demand minima will continue to go lower. Transmission system management at these times will become more complicated. The potential for short periods of over-supply will also increase, introducing risk to the running profiles of traditional assets.

Secondly, the rate of change of residual demand (ramping) will increase. Dispatchable assets will be required to undertake larger and/or longer compensatory power changes as a result.

Chart 3 shows that, over the last 4 years, solar generation and national demand evolution have, on balance, helped reduce power ramp requirements over much of the day. However during the late afternoon, ramping requirements have increased significantly.

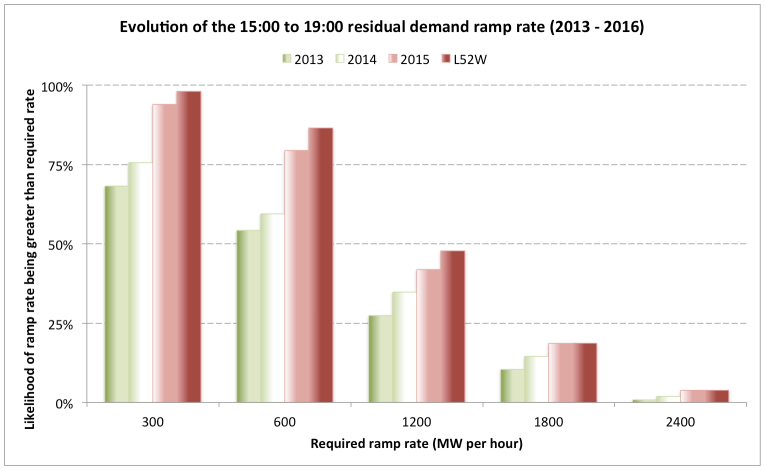
Chart 3:



The black error bars in Chart 3 show the range (to 1 s.d.) of ramp rates in each year. The distribution is generally widening. Chart 4 shows the distribution of ramp rates across different days, and how this distribution has changed. As solar capacity has increased, large ramp requirements have become more commonplace, and also larger.

To put this result into context, a ramp rate of 1,200 MW per hour between 15:00 and 19:00, which in GB in 2013 was a 1-in-4 event, has today become an every-other-day occurrence. A ramp rate of over 2,400 MW per hour, virtually unheard of in 2013, occurred on average once every three weeks during 2015/2016! GB is not as far down the duck curve as California therefore, but … the quacking does seem to be getting louder!

Chart 4:



Who should be interested in storage?

So we have presented further characteristics of an electricity system with high solar generation and low storage capability. We have seen the duck curve emerging in GB, and have presented data on historical national system ramp rates, which have resulted largely from the effects of solar energy. We have also touched upon the opportunity for storage (physical or commercial) to help integrate solar assets, and protect existing assets from the disruption of raw solar generation profiles.

For market players to invest in storage which is operated to reduce ramp-rates on the transmission system, the commercial frameworks which support this form of operation must be sufficiently robust and attractive, against all other options. Operating strategies will be guided by where revenues are available, be that through price arbitrage opportunities or contracts for system services (such as frequency response). So unless regulation ensures that shape-shifting assets operate always with the interests of transmission system operation at front-and-centre, there remains a risk that shape-shifting assets will not bring the market and system stability benefits which are expected of them, because they may be able to return more value in other ways.

For example, arbitrage opportunities arise against market price, and arbitrage revenues increased with churn (number of cycles) and the volume of each cycle. A strategy of pure arbitrage is therefore likely to result in short-term, full-range charge/discharge operations for a shape-shifting asset, thus reducing its system service offering. Further, market signals may not always be aligned to support ramp-dampening.

Conversely, a strategy for system service operation may limit the potential for storage assets to capture arbitrage revenues, or support ramp dampening. System service operation may require new contracts, with new securities placed on assets to ensure they are fully capable of performing their roles when needed. These may limit the availability of an asset to perform other roles requiring charge or discharge of power.

As with all things, a blended approach is likely to be most successful, but the question remains of how best to encourage the market to invest in and operate the assets to meet both the system and the asset owner's needs. Not all operating strategies will deliver ramp dampening, and a real difference to national system ramp profiles would be made only through the co-ordinated operation of large capacities of (independently operated) storage assets.

By considering both the opportunities for storage to make an independent return on its investment, and the costs which storage can help avoid at existing plants, it is clear that all market participants should have some interest in storage. It remains to be seen whether the participants who do invest, are those who would have the most to gain, or the most to lose, from solar power's rapid growth in capacity.