Energy briefing

Whole in one?

WHAT WHOLE SYSTEM COSTS MEAN FOR ENERGY POLICY

SWITCHING CLUBS

The sources of power generation and system flexibility are changing and, with them, the costs of operating the entire power system. Historically, the vast majority of electricity generation has come from thermal power plants. However, in recent years, the power system has become more diverse. Exhibit 1 below traces the growing importance of solar and wind in European generation since 1990, from relative insignificance at the start of the century, to having taken a visible bite out of the historical dominant fossil-fuel driven fleet in recent years.

These comparatively new technologies have brought big changes to both emissions intensity and the variable costs of generation, but are also having far-reaching impacts on system operation and design. For example, differences in the volatility and predictability of a generator's output or its location within the network affect the costs of balancing the system and of reinforcing the transmission network. In short, the differences between these technologies are affecting the costs of the power system as a whole to a greater extent than when capacity was largely thermal.

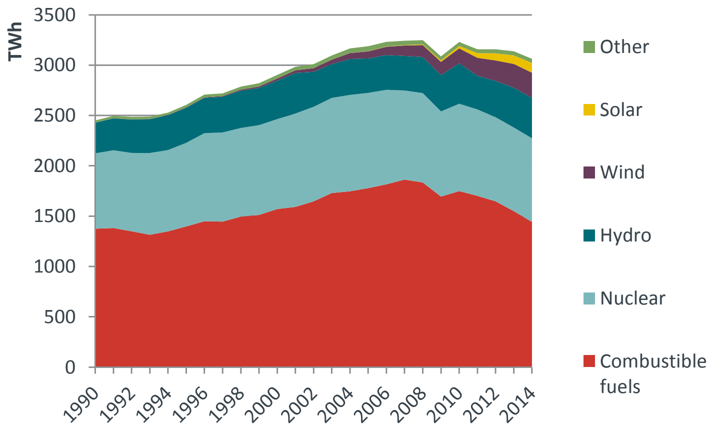
Key messages:

- In this briefing we show that developers will rarely, if ever, face the full impact of their cost impacts on the whole electricity system.
- We also highlight that generic adjustments to existing support mechanisms are not an appropriate policy response.
- Finally, we suggest that the solution lies in the use of well-designed charging frameworks and energy market regimes applied universally to generation, storage and demand.

At the same time, experience of past support schemes, as well as the desire to improve cost-effectiveness and encourage competition, is putting pressure on governments to ensure that future support schemes for low-carbon generation are both market-based and technology-neutral. Only recently, auctions for renewable support in Denmark, the Netherlands and Great Britain, among others, have all had success in bringing down support costs through the use of competition either within or among technology groups.

The problem for policy makers is that many of the system costs affected by build decisions are not currently passed on to developers. This results in a market failure. These wider system impacts, though relevant to the total costs of electricity supply, will not be reflected in

Exhibit 1. Net electricity generation by technology in the EU28



Source: Eurostat (online data code: nrg_105a) developers' bids into a technology-neutral auction for a low-carbon subsidy. Consequently, low bids might not necessarily imply low costs overall; there is a real risk that plants winning support through such auctions come with a range of hidden costs for the wider power system.

What's the solution? In this briefing, we set out how we think about the whole system impacts of adding generation or storage capacity to the system, and give some thought to what policy makers seeking to minimise whole system costs might do.

SURVEYING THE COURSE

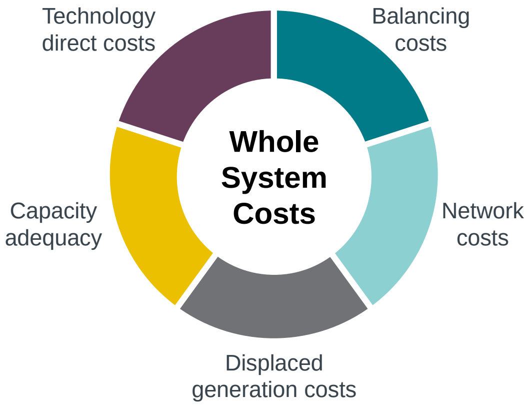
One of the many challenges of accounting for the whole system impacts of different technologies is bringing together the myriad system effects attributable to the relevant capacity in a way that is both easily understood and fully comprehensive.

To try and solve this problem, we split system impacts into five mutually exclusive groups, and then consider how each group of costs would be affected by the marginal addition of generation or storage capacity to the system.

Our five groups are:

- **Technology direct costs** – These are the direct capital, operation and maintenance costs of the additional capacity.
- **Displaced generation costs** – Output from the new capacity can displace generation from existing sources, potentially reducing fuel use and emissions. The associated system cost savings would be lower if the capacity had to be curtailed, or if its output profile induced inefficient cycling in the rest of the fleet.
- **Capacity adequacy** – Adding new capacity might allow existing capacity to retire, or to have refurbishment delayed, if, for example, the new unit contributes to meeting the system's peak demand requirements.

Exhibit 2. Components of Whole System Cost



Source: Frontier

- **Balancing costs** –For generation, if the new capacity's output is uncertain, incorporating it into the system may require the System Operator to incur greater costs when buying reserve or balancing the system. These costs will be particularly pronounced for large potential variations in output, or if the unexpected deviations in output are correlated with similar deviations in the rest of the system. Storage, on the other hand, may actually help to reduce the costs of balancing.
- **Network costs** – Depending on the new capacity's location, it may trigger network reinforcements or extensions, increase losses, or increase the costs of congestion due to insufficient network capacity. Conversely, it could allow network reinforcements to be deferred, or reduce losses and congestion costs.

While all developers face their technology direct costs, the extent to which they internalise the system effects under the remaining four categories varies:

- Under most European Feed in Tariff (rather than Feed in Premium) support regimes, generator payments are flat irrespective of whether their output displaces generation at peak or in the middle of the night. This is despite the difference in the cost of the generation that is displaced and the implied savings to the system as a whole.[1]

[1] Time-invariant pricing is sometimes justified on the grounds that it reduces developer risk and, potentially, financing costs. However, it's important to note that the price risk is just transferred to the taxpayer or consumer, rather than removed outright. Even where this does lower developer costs, it may not be welfare maximising overall, especially if generators no longer face appropriate signals on when to generate.

- In many countries, there will be no differentiation among renewable sources of energy to reflect differences in their contribution to capacity adequacy. Ironically, this may be especially true of jurisdictions where there are explicit capacity remuneration mechanisms.
- Few countries have imbalance pricing mechanisms that account for the full costs of balancing (i.e. including the costs of reserve capacity procured by the System Operator). Recently, Great Britain changed its imbalance pricing rules to try and better reflect the costs of reserve.
- And, since numerous countries in Europe have zero network charges on generation, many developers face limited incentives to limit network costs, with incremental network costs instead passed on fully to final consumers.

Overall therefore, developers will rarely, if ever, face the full impact of their cost impacts on the whole system.

This wouldn't matter if these impacts were negligible, but, as can be seen below, this needn't be the case. Exhibit 3 shows a very simple illustration focused just on the capacity adequacy part of our framework, which compares the value of UK-based wind and solar capacity as an example of the types of hidden impacts that are currently ignored. We have used the capital costs of building an OCGT plant to set the notional value of a 1kW contribution to capacity adequacy. By combining this with the capacity credits of these three different generation technologies (effectively their expected contributions to serving peak demand in the UK), we can value the equivalent capacity adequacy contributions for both wind and solar.

Exhibit 3. Illustration of differences in capacity value

Technology	Capacity credit	Implied capacity value	
		per kW	per 100MW
OCGT	*95%*	*£300*	£30.0m
Wind	*20%*	£63	£6.3m
Solar	*0%*	£0	£0

Source: *Frontier calculations. Capacity credits for OCGT and wind are consistent with those used in the design of the GB capacity market. Capacity credit for solar is based on 'Grid Integration Cost of PhotoVoltaic Power Generation' (Imperial College, 2013). OCGT construction cost is taken from the UK Government's 'Electricity Generation Costs' publication.*

Note: *Assumed values in italics. Wind and solar capacity values are derived from the OCGT numbers.*

This example highlights both that wind has a far lower capacity credit than a dispatchable thermal generator, but also shows that wind's capacity credit is significantly higher than that of solar alone, which, in the absence of associated storage capacity, will rarely contribute to dark winter evening peaks in the UK. To some degree, adding wind capacity in the UK means that less capacity is needed elsewhere on the system to ensure security of supply. Unless complemented by storage capacity, the same isn't true of solar. Using the cost of building OCGT capacity as a guide, the value of investment that could be avoided due to the addition of wind, i.e. wind's contribution to capacity adequacy, would be on the order of £6.3m for a 100MW wind farm. To put that in context, this amounts to just over 4% of the wind capacity's construction costs.[2]

The conclusion to draw from this is not that wind is inherently better than solar. In fact, in countries like Greece, where solar output is more strongly correlated with peak demand, solar may actually make a greater contribution to capacity adequacy than wind. Rather, it is that opting to ignore wider system impacts brings with it a material risk of building the wrong type of capacity.

To take another example, consider how much locational network charges vary within Great Britain, where charges are based on modelling to estimate the incremental network investment cost implications of a generator's location. Comparing the charges for a 100MW conventional generator in Lochalsh, in Western Scotland, with those of the same generator in West Devon, in South West England, implies an annualised difference in investment costs of £4.7m. In countries that ignore

[2] Assuming construction costs of £1500/kW as per 'Electricity Generation Costs' (DECC, December 2013).

these differences, there is again a real risk of building plants that make the system as a whole more expensive than it needs to be.

With overall system design ultimately led by decentralised investor decisions, especially when using technology-neutral auctions for support, this matters. When investment decisions are based on an incomplete picture of the system impacts, the result could be a system in which costs that aren't recognised aren't minimised, and one with higher costs to society overall.

GETTING OUT OF THE ROUGH

Given the importance of these wider system effects, policy makers are starting to try and rework existing support mechanisms in an attempt to account for these costs. However, this isn't easy. It's tempting to believe that these issues might be solved by a quick and dirty adjustment to existing technology-specific levels of subsidy. However, doing so implies the need to calculate some generic adjustment that is appropriate to the technology as a whole. In practice, the number of factors that influence whole system costs, and the variation of these impacts even within a single technology group, makes identifying a single magic number to account for all of these wider impacts difficult, if not impossible.

In the end, generic adjustments like this will inevitably be a poor reflection of the actual system impacts and therefore cannot make developer decisions genuinely efficient. Consider how ineffective altering technology support levels would be as a means to account for network costs in the example above, in which the same generator implied radically different network costs based on its specific location. Similarly, no single number is going to appropriately capture the balancing implications of adding wind or solar capacity to the system when the relevant impact varies so markedly with the amount of existing variable capacity on, and the flexibility of, the rest of the system.

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Given these challenges, governments should avoid the urge to go down this route. Instead, the focus should be on developing market and charging frameworks that apply holistically across all developers and that expose them to the system cost differences identified above. Doing so will enable decentralised energy market decisions, like those of developers, to effectively contribute to the creation of an efficient power system.

To start, policy makers should aspire to market designs with the following features:

- Low-carbon support mechanisms that value the profile of a generator's output in line with the market price – the challenges associated with storing electricity mean that a kWh of electricity generated during peak demand is not worth the same as a kWh of electricity generated in the middle of the night. The market understands this; fixed feed-in tariffs don't. Consequently neither encourage patterns of generation that actually match demand, nor recognise the true value of storage.
- Capacity Remuneration Mechanisms that recognise contributions to capacity adequacy from all sources, including variable renewable generators and demand response – remunerating only some contributions to achieving capacity adequacy means that these may be pursued regardless of whether or not they are least-cost. Furthermore, excluding variable renewable generators from CRMs means that important differences between these technologies, as shown by the wind and solar example above, aren't recognised.[3]
- Imbalance charges that reflect the *total* cost of balancing – failing to include the complete cost of balancing in imbalance charges means that flexible generation and storage technologies are

[3] Getting variable or intermittent generators to participate alongside dispatchable generators has important implications for the penalty regime with the CRM, as certain approaches may impose unreasonable exposures on non-dispatchable generators.

undervalued and that variable technologies put too little effort into improving predictability. Even countries with 'market-based' imbalance prices often fail to account for the complete system costs of balancing actions, such as the need to pay for reserve capacity as well as balancing energy.

- Locational network charging – As implied by the GB example, network costs aren't invariant to where developers add capacity. Failing to account for these differences encourages generation to cluster in areas where development costs are low or renewable resources are rich, regardless of whether the power generated there can be transported at reasonable cost to where it's ultimately needed. It is also important to think about both transmission and distribution networks as a whole, as it is no longer the case that the majority of generation new build is transmission-connected.

Looking across Europe, it's clear that no market has resolved all of these issues. However the diversity of approaches employed does provide significant scope for policy makers to learn from the experiences of other countries when seeking to better account for wider system impacts at home.

FOLLOWING THROUGH

In conclusion, as power system technologies have become increasingly diverse, so too have developers' impacts on the wider costs of system operation. If policy makers are going to succeed in decarbonising their power systems at least cost, they need to redouble their efforts to ensure that these wider system cost differences are appropriately internalised in developer decision making. Otherwise, the current push for technology-neutral, market-based support mechanisms is simply going to funnel consumers' money into projects where the overall costs are well-hidden, rather than low.

Unfortunately, these wider system costs tend to be both complicated and context-specific. While it's tempting to believe that these forgotten costs can be incorporated into existing support schemes through the judicious use of simple technology uplifts or penalties, this isn't the best approach, not least because the necessary adjustments will prove very difficult (and controversial) to calculate. Efficient decentralised decision making, which will be needed to minimise the complex and context-specific costs of the power system, is best achieved by exposing developers, generators and consumers directly to their cost impacts.

Rather than trying to solve these problems through low-carbon support mechanisms, policy makers should focus on revising their market and charging frameworks to make all actors – conventional and low-carbon alike – better accountable for their whole system impacts.

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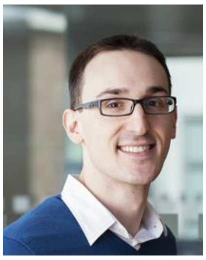

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