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Making Flexibility Pay: An Emerging Challenge in European Power Market Design

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Overview: "Flexibility" is crucial for ensuring efficiency in decarbonised power systems, so should be recognised as more than an "ancillary" service

European power systems are undergoing radical transformation, with substantial growth in low carbon generation driven by falling costs for new technologies such as solar photovoltaics, as well as government support motivated by climate change targets. The challenges of integrating these new technologies into power systems are the subject of increasing policy debate and much study by power systems engineers. However, they are also the concern of economists, as reform to existing electricity market trading arrangements may improve the efficiency of this transformation in the energy sector, moderating the impact on consumer bills.

Until recently, debates around power market design in Europe have focused on harnessing the benefits of competition to ensure the least-cost provision of *energy* and the provision of sufficient *capacity* to "keep the lights on". However, in addition to these aims, the focus of power market design will need to shift to ensuring electricity systems are also sufficiently "*flexible*" to integrate intermittent and/or inflexible low carbon generation technologies at least cost.

Power system flexibility refers to the ability of the system to adjust rapidly to changing conditions, such as shocks to demand or supply. In most European power systems, flexibility remains relatively abundant, as large fossil fuel power stations can adjust their production quickly when needed, and in practice, the need to do so is limited because both supply and demand are relatively predictable in systems dominated by fossil fuel generation technologies. As such, the remuneration of flexibility is tangential to the main markets for energy and capacity, and is provided, to a large extent, through (the aptly named) "ancillary services" arrangements.

However, flexibility will become less abundant as power systems become dominated by less flexible technologies such as wind, solar, and nuclear. The demand for flexibility may also rise to help integrate these technologies because the production from wind and solar is variable and intermittent, meaning the power system will be more prone to rapid changes in production that will need to be managed.

As we discuss in this paper, power market design will need to keep pace, making flexibility a core focus of power market arrangements and no longer ancillary to the markets for energy and capacity.

The technical and economic features of conventional power systems mean the provision of flexibility has received relatively little attention in power market design

Most electricity systems around the world were designed to transport electricity from centralised power stations, which produce electricity in bulk, in a relatively cheap, stable, and predictable way, to users whose patterns of consumption are similarly stable and predictable. Variations around these relatively stable and predictable patterns of production and consumption are typically addressed by a centralised system operator, which steps in to make small adjustments to equate supply and demand in real time. These technical characteristics of the power system have implications for the commercial arrangements governing the electricity sector.

Most power systems around the world were, at some stage in their recent history, dominated by monopolies, which were often vertically integrated and state-owned. However, many have restructured, attracting private investment to remove the inefficiency that comes with state ownership and control, and creating market institutions that foster competition in order to minimise costs and promote innovation and consumer choice.

Creating competitive markets for electricity requires a number of elements, including the definition of a "product" to be traded, the allocation of property rights between potential buyers and sellers of that product, and the creation of market institutions that allow for the efficient trade of the product amongst potential buyers and sellers. A wide literature on power market design addresses these design choices. However, the industry structure most widely adopted, in Europe at least, involves creating a wholesale market for the trade of a product defined as the energy produced or consumed during trading intervals (typically lasting up to an hour), possibly alongside markets for the provision of capacity.

Additionally, since supply and demand need to balance in real time within each trading interval, a system operator is required to adjust market participants' production or consumption in real time to help keep the system in balance, typically through a "balancing market". This system operator is also concerned with maintaining the capacity to respond to operational problems within the power system and so, normally procures "ancillary services". Ancillary services are effectively contracts giving system operators an option to ask market participants to perform certain functions or adjust their production or consumption at very short notice (e.g., within seconds of an instruction to do so), in order to maintain the stability of the system in real time. In practice, ancillary service providers may be called upon to deliver via the balancing market, blurring the dividing line between the two segments of the market.

However, the costs of these balancing and ancillary services have typically represented a relatively small proportion of the overall costs of the power system. National Grid, the system operator for Great Britain, recovers the cost of balancing from customers via the "BSUoS" charge. These charges accounted for about 1% of the average UK domestic customer's bill in 2011. Today, they account for roughly 1.5%.[1] In comparison, the cost of wholesale power supply currently makes up around 40% of an average domestic electricity bill.[2] As such, the design of efficient balancing and ancillary services markets has received less attention than the design of energy and capacity markets.

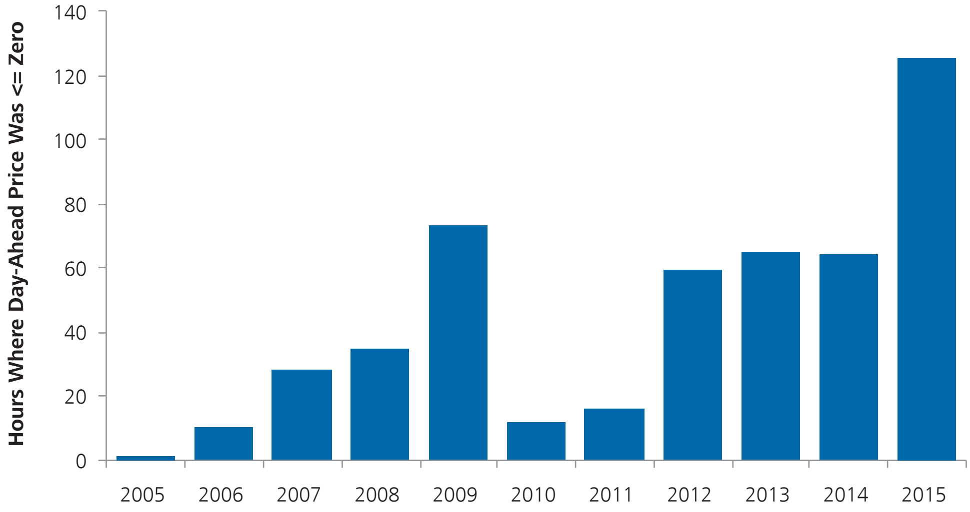
As European power systems decarbonise, generators will tend to see lower earnings from energy markets, while markets for flexibility will become increasingly important as a source of value and a mechanism for promoting efficiency

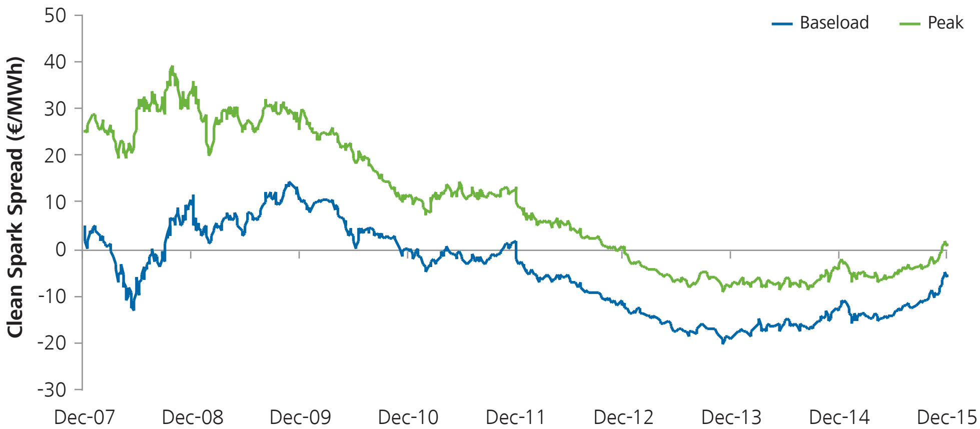
Low carbon and intermittent renewable generators will wish to produce power as long as their fuel, which may be wind or sunshine, is available and prevailing market prices are sufficient to cover their—often negligible—variable operating costs. Hence, in markets with high proportions of these technologies, energy market prices may be extremely low in off-peak periods when there is sufficient supply from low carbon technologies, such as on windy days, to meet all or most market demand for energy.[3]

This phenomenon is one cause of the recent reductions in baseload clean spark and dark spreads seen in European power markets and the periods of negative wholesale prices seen increasingly frequently in Germany, for example. As the share of low marginal cost technologies rises, these trends of low prices will tend to become more frequent, further eroding the value that generators earn from the sale of energy and increasing the importance of identifying alternative sources of value.[4] As the figure below illustrates for Germany, hours with zero or negative electricity prices have increased in recent years. Over the same period, clean spark spreads—a guide as to the level of profit that a gas generator can earn from selling electricity after paying for fuel and emissions costs—decreased materially.[5]

These trends are also a major source of assertions by some industry commentators that "electricity markets do not work" in decarbonised power systems. However, as we argue below, such broad-brush assertions belie a lack of imagination as to the versatility of markets and their potential for promoting efficient outcomes. Abandonment of competitive electricity markets is neither inevitable nor desirable in the face of decarbonisation. Rather, the economics of designing effective, competitive power markets need to adapt to ensure that providers of flexibility services receive remuneration commensurate with the value they provide to the power system.

Figure 1. **The Number of Hours with Zero or Negative Day-Ahead Electricity Prices in Germany Has Increased (Top Panel) and Clean Spark Spreads Have Dropped (Bottom Panel)**





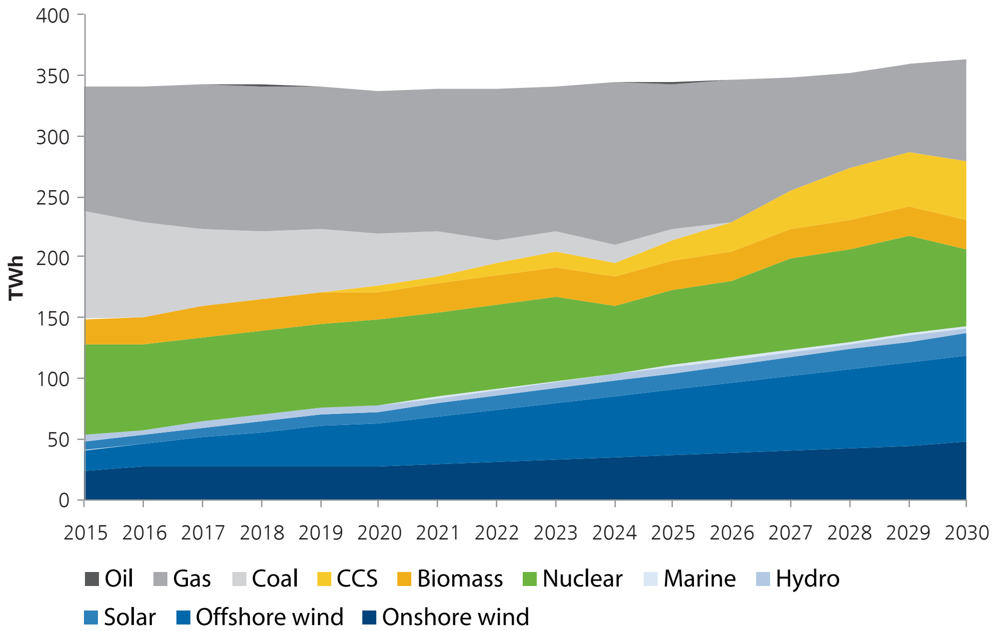
Source: (Top Panel) European Power Exchange via Platt's PowerVision. (Bottom Panel) OTC via Platt's PowerVision and NERA Analysis[6]

European systems will also see an increasing demand for flexibility services

Similar to many other European countries, the UK government has ambitious plans to decarbonise the electricity sector by deploying large amounts of intermittent and/or inflexible power generation. The generation mix under the fifth carbon budget, a roadmap for the UK's decarbonisation path suggested by the Committee on Climate Change (CCC), is shown below. The share of intermittent, non-dispatchable renewables, shown in blue in the figure below, rises from 16% in 2015 to 40% in 2030.

As a consequence, the costs of system balancing and ancillary services are likely to rise materially. In fact, there is some evidence that the costs of system balancing and ancillary services are already rising with the penetration of renewable and low carbon generation. These costs are recovered in the UK through the Balancing Services Use of System (BSUoS) charges, which have nearly doubled between 2010 and 2015.[7] Over the same period, while we recognise there may be other factors at play that have caused BSUoS to rise, wind generation has increased by 8.9 GW and solar by 9.1 GW.[8]

Figure 2. **The CCC's Predicted Generation Mix to 2030**



Source: CCC, Fifth Carbon Budget Dataset, Central Scenario

In the longer term, there is evidence that the supply of flexibility will become increasingly important to achieving the government's environmental targets efficiently. For instance, a recent study by NERA and Imperial College London demonstrated the value of flexibility in supporting the integration of low carbon power generation technologies.

This study examined the "system integration cost" associated with installing alternative low carbon power generation technologies[9] in a scenario where the power system is materially decarbonised through growth in a range of low carbon generation technologies.[10] It found that:

- Without the additional provision of flexibility, reductions in emissions to the levels currently targeted by the UK government (average emissions of around 50g/kWh) will be extremely difficult to achieve. Actual emissions will be nearly four times the targeted level.[11]
- The marginal cost to the system from adding one additional MWh of solar PV generation could be reduced by around two-thirds in a scenario where the supply of flexibility increases, compared to the levels seen today. The study found similar results for wind generation.[12]

Decarbonisation has prompted some changes in market arrangements, but additional reforms will be required to ensure flexibility services are provided efficiently through competitive market mechanisms

Recognising the challenges associated with the ongoing changes in the electricity industry and, in particular, the need to remunerate sufficient thermal generation to meet peak demand and back up intermittent renewable technologies, the UK government has recently introduced a market for capacity. This aims to "ensure adequate capacity within an electricity system that in future will rely increasingly on intermittent wind and inflexible nuclear generation".[13] Some reform of the balancing market has also taken place to ensure that prices more accurately reflect the underlying marginal cost of production at peak times,[14] which will help send efficient signals regarding the costs of system balancing and further support the remuneration of plants that supply the market in conditions of relative shortage.

However, these reforms have done little to isolate and explicitly recognise the increasing value of flexibility. In particular, they aim to ensure that the price of energy produced during 30-minute trading intervals reflects the marginal cost of production during that period, with no new market mechanisms to reflect the costs of adjusting supply and demand within that trading interval.

Further, there have also been no substantive reforms to enhance efficiency and/or competition in the procurement or provision of ancillary services:[15]

- Ancillary services tend to be procured through tenders for relatively long-term contracts between the system operator and generators or other providers. The minimum commitment period is generally about a month.[16] Given that the underlying need for ancillary services varies with conditions in the power system as a whole, such as variation in wind production or demand, it is likely that efficiency gains can be achieved by adjusting the volume of ancillary services that are procured over shorter time horizons.
- Also, transparent information on the marginal cost of procuring ancillary services (or the marginal benefit of providing them) can help market participants make an efficient allocation of their capacity amongst the various market segments (energy, capacity, and ancillary services of various types). However:
  - At present, the prices of ancillary service contracts are published retrospectively or, in some cases, not at all. What market data is published is generally geared toward calculating overall costs, not allowing ancillary service providers to make efficient allocation decisions at the margin.[17]
  - Ancillary service payments and penalties for non-delivery of contracted ancillary services are only loosely tied to conditions in the real-time market. Fees are set by tender or by bilateral negotiation prior to the initiation of the contract, and penalties for non-delivery generally involve forgoing all or a portion of these fees. Contracts may be cancelled entirely for multiple failures to deliver.[18] Hence, while fees/penalties may be reflective of marginal costs/benefit by coincidence or average across the contract period, they do not send any signal regarding the marginal cost of ancillary services in real time.

Therefore, the UK provides an example of a market where there are significant challenges associated with the increasing demand for flexibility and where the market reforms undertaken to date have not been sufficient to ensure that the increasing demand for flexibility can be met through competitive, market-based mechanisms, which ought, in theory, to promote economic efficiency.

Experience from other markets provide examples of ways to better recognise the value of flexibility in the energy and ancillary service markets

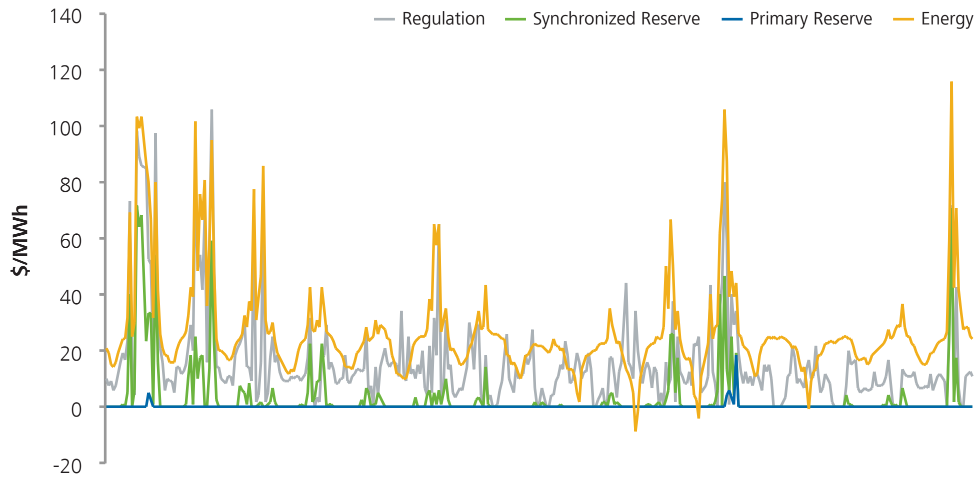
As noted above, recent reforms to the British energy market have done little to recognise the value of flexibility, due in part to the 30-minute length of trading intervals. A possible change to market design to help recognise the value of flexibility would, therefore, be to shorten the trading interval, for example, to five minutes. This change to trading arrangements would better value flexibility by rewarding those generators or consumers (or other market participants like storage owners) that can adjust their production or consumption quickly in response to changing market conditions. In effect, this reform would extend the role of the energy market for managing real-time variation in supply-demand conditions. This is similar to the approach adopted in some other markets, where trading intervals are shorter. In the PJM market, the trading interval for real-time pricing is five minutes.[19] In ERCOT, which covers most of Texas, it is 15 minutes.[20] Nord Pool similarly clears in 15-minute intervals.[21]

However, whatever the length of the trading interval, there remains some need to recognise the value that generators offer to the system by adjusting their output within trading intervals through ancillary service markets. Improving the efficiency of ancillary service markets can, therefore, also support the efficiency of price signals conveyed to market participants regarding the value of their assets in integrating low carbon generation efficiently.

A number of reforms may be helpful in achieving this objective. First, the underlying need for ancillary services is likely to vary with wind/solar output and demand. Hence, it may improve efficiency to adjust the volume of ancillary service contracts that are procured more frequently, such as in every trading interval. This would involve abandoning the current principle that providers of ancillary services are contracted to provide a given service at all times for relatively long contract periods (e.g., months or years). For example, National Grid's "Short Term Operating Reserve" (STOR) product is tendered three times a year, with a minimum commitment for about a month.[22] Similarly, "Fast Reserve" is tendered monthly, and commitments last at least a month.[23] These long contract periods limit providers' ability to continuously adjust the market segments they are serving (i.e., the energy market and different types of reserve) as market conditions vary, for reasons such as changes in wind speeds or demand.

By adjusting the supply of and demand for ancillary services on a more continuous basis, it would be possible to set prices for ancillary services in each trading interval. This follows from the approaches seen in a range of other markets, where the wholesale market and ancillary service markets are "co-optimised", allowing a price for energy and a price for a range of ancillary service products to emerge in each trading interval. For instance, three types of ancillary services are continuously traded in PJM alongside energy. The figure below shows the clearing prices for these four products, which vary in every trading interval, for the first half of June 2016. The contrast to the British market, where there is no continuously traded market for ancillary services, is stark.

Figure 3. **Three Types of Ancillary Services Are Traded Alongside Energy in the PJM Market**



Source: Energy prices are real-time LMPs for the RTO downloaded from SNL Energy; Ancillary Services prices are from PJM's website.[24]

The emergence of better pricing information for ancillary services will allow private investors to make more efficient decisions about the allocation of their generation and storage capacity between market segments, and decisions about how to provide demand response.

Better pricing information could also be used to calibrate the penalties that providers of ancillary services face for non-delivery, allowing them to be better aligned with the marginal value of the service to the system. This would improve on the current approach, in which penalties are unrelated to the marginal cost imposed on the system, as we discuss above.

Some jurisdictions have chosen to better recognise the value of flexibility through reforms to capacity markets. Two US electricity markets, ISO New England and PJM, which together cover most of the power-intensive New England and mid-Atlantic states,[25] have recently reformed their capacity markets to introduce new, more expansive definitions of capacity and higher penalties for non-performance:

- PJM has chosen to procure "Capacity Performance" resources that can be called upon at any point in the year, instead of just the summer peak period, and to have higher penalties for non-performance. Capacity Performance will be the only product in the supply mix as of June 2020, after a few years of transition.[26]

- Under ISO New England's "Pay for Performance Mechanism", which will start in 2018, resources that perform better during system stress will be compensated by resources that do not perform as well.[27]

Enhanced performance is undeniably a good thing when needed. However, recognising the value of flexibility through reform of capacity markets may blur the line between markets for capacity and flexibility, which it may be better to recognise as two distinct services to the power system.

Conclusion: The consequences of failing to create markets that value flexibility will be the erosion of competition and higher costs for consumers

As power systems decarbonise with high levels of low marginal cost and intermittent generation, energy will be plentiful at certain times and prices will be low, eroding the value of the energy market as a source of revenue to generators. While energy will be plentiful, flexibility will be limited and valuable to the system. In essence, to ensure the system's needs for flexibility are met efficiently and to ensure generators (and other market participants such as storage) are adequately remunerated for the services they provide, market arrangements will need to ensure that it pays to be flexible.

This paper discusses how electricity market arrangements in the UK could improve to better value flexibility services through the energy and ancillary service markets and promote competition in provision. While significantly more work would be needed to develop improved arrangements for remunerating flexibility, other markets around the world provide inspiration on how this can be achieved in practice. For instance, many markets have continuously traded markets for ancillary services, with prices for each trading interval.

Absent new market arrangements to place more value on flexibility, system operators will need to continue to procure balancing and ancillary services through relatively opaque, long-term contracts. Such arrangements will undermine the ability of competition to promote the efficient transformation and ongoing operation of the power system. Ultimately, such a failure to foster competition and efficient pricing in the ancillary service markets would impose unnecessary cost on consumers.

Notes

1 We estimated this using average BSUoS charges per year from "Balancing Services Use of System", National Grid, available at: http://www2.nationalgrid.com/bsuos; and the average annual domestic standard electricity bill for UK customers from "Average annual domestic standard electricity bills by home and non-home supplier", DECC, 31 March 2016, available at: https://www.gov.uk/government/statistical-data-sets/annual-domestic-energy-price-statistics. We assumed a flat consumption profile for the sake of illustration.

2 "Understanding energy bills", Ofgem, May 2016, available at: https://www.ofgem.gov.uk/information-consumers/domestic-consumers/understanding-energy-bills.

3 Prices may even be negative if generators' subsidy arrangements provide revenues outside of the wholesale market linked to supported generators' production.

4 In a competitive market, theory suggests that the price should be approximately equal to the "system marginal cost" of production. So, when the marginal generator is solar or wind, the price ought to drop close to zero (or below zero if subsidized), since these generators have no cost of fuel.

5 The fact that both baseload and peak clean spark spreads are negative suggests that gas-fired generation can only generate profitably in a very small number of hours per year.

6 Baseload spark spreads from PowerVision based on year-ahead contracts. Peak spark spreads calculated by adding the difference between peak and baseload contracts of the same tenor.

7 "Balancing Services Use of System", National Grid, available at: http://www2.nationalgrid.com/bsuos.

8 "Renewable electricity capacity and generation (ET 6.1)", Gov.uk National Statistics Energy Trends: Renewables, 14 July 2016, available at: https://www.gov.uk/government/statistics/energy-trends-section-6-renewables.

9 System integration costs exist because when a change in the generation mix occurs, optimal generation dispatch to meet energy demand changes; the generation investment required to maintain a given security standard changes; network infrastructure requirements change; and the requirements for ancillary services change. Hence, the Levelised Cost of Energy (LCOE) of competing technologies is not the only consideration that government weighs when estimating the costs of alternative generation mixes. Imperial's modelling estimates these system integration costs and finds, amongst other things, that they are significantly higher for intermittent renewables than for other forms of low carbon generation, such as nuclear or carbon capture and storage (CCS). They are also higher in scenarios where the supply of flexibility technologies, such as flexible power generation, demand side response, storage, and so on, is relatively low.

10 In this scenario, the system was assumed to be decarbonised to a point where the average emissions of carbon dioxide from the power sector reach 50 g/kWh.

11 The Imperial team attempted to model a scenario in which the generation mix had been designed with high levels of low carbon generation to achieve an emissions intensity of 50g/kWh. Imperial found that without the provision of additional flexibility, the actual emissions were nearly four times higher because a much larger amount of thermal plant had to be part loaded to provide flexibility than had been assumed when this generation mix had previously been analysed.

12 "System Integration Costs for Alternative Low Carbon Generation Technologies – Policy Implications", Prepared for the Committee on Climate Change, NERA Economic Consulting and Imperial College London, 19 October 2015. Results cited here are presented in Figure 2.5 of the NERA/Imperial report.

13 "Keeping the Lights on", National Grid, available at: http://www.nationalgridconnecting.com/keeping-the-lights-on.

14 For example, Ofgem's "Electricity Balancing Significant Code Review", the details of which are here: https://www.ofgem.gov.uk/electricity/wholesale-market/market-efficiency-review-and-reform/electricity-balancing-significant-code-review. This review resulted in multiple reforms to the UK's balancing mechanism, a residual market for ensuring electricity produced matches demand over each trading interval.

15 There have been a few reforms related to ancillary services and balancing, but they largely keep the status quo of ad hoc, non-market reflective services. For instance, National Grid added an "Enhanced Frequency Response" product aimed at response in one second or less, which many feel is geared principally toward batteries. Its first tender will be in 2016. Earlier, National Grid also added a "Demand Side Balancing Reserve" and a "Supplemental Balancing Reserve" to shore up any shortfall in generating capacity. Some plants that were not successful in the UK capacity market and that threatened to close have been supported and kept on the system through the award of "Supplemental Balancing Reserve" contracts.

16 "Assessing the impact of CLASS on the GB Electricity Market", Baringa, 31 May 2016, available at: http://www.enwl.co.uk/docs/default-source/class-documents/assessing-the-impact-of-class-on-the-gb-electricity-market.pdf?sfvrsn=4, Appendix A.

17 "Services Reports", National Grid, available at: http://www2.nationalgrid.com/UK/Industry-information/Electricity-transmission-operational-data/Report-explorer/Services-Reports/.

18 "Firm Frequency Response Frequently Asked Questions", available at: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=40837; "STOR Frequently Asked Questions", National Grid, available at: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=28065; and "Assessing the impact of CLASS on the GB Electricity Market", Baringa, 31 May 2016, available at: http://www.enwl.co.uk/docs/default-source/class-documents/assessing-the-impact-of-class-on-the-gb-electricity-market.pdf?sfvrsn=4, Appendix A.

19 Data Directory, PJM, available at: http://www.pjm.com/markets-and-operations/data-dictionary.aspx.

20 Real-Time Market, ERCOT, available at: http://www.ercot.com/mktinfo/rtm.

21 Nord Pool Intraday, Nord Pool, available at: http://www.nordpoolspot.com/TAS/nord-pool-spot-intraday.

22 "Short Term Operating Reserve", National Grid, available at: http://www2.nationalgrid.com/uk/services/balancing-services/reserve-services/short-term-operating-reserve.

23 "Fast Reserve", National Grid, available at: http://www2.nationalgrid.com/UK/services/Balancing-services/Reserve-services/Fast-reserve.

24 http://www.pjm.com/markets-and-operations/ancillary-services.aspx.

25 PJM covers all or parts of all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia.

26 "Capacity Performance Training", PJM, 8 July 2015, available at: http://www.pjm.com/~/media/markets-ops/rpm/20150708-capacity-performance-webex-training.ashx.

27 "2016 Regional Electricity Outlook", ISO NE, available at: http://www.iso-ne.com/static-assets/documents/2016/03/2016_reo.pdf.

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