Resource Adequacy, Regionalisation, and Demand Response

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Executive Summary

Regional day-ahead electricity markets are now well established in Europe, and progress in regionalising intra-day markets and establishing co-ordinated balancing areas is being made. However, supply reliability remains a national responsibility, with Member States required by Directive 2005/89/ EC to take all measures necessary to safeguard security and infrastructure investment.[1]

Given this national accountability to maintain supply reliability, Member States' response to a perceived lack of investment in new generation has been somewhat uncoordinated. Many different capacity remuneration mechanism (CRM) designs have been proposed or are being introduced that reflect national concerns and preferences, but lack any meaningful European dimension and take little or no account of potential support from neighbouring systems. The disparate nature of these CRM designs conflicts with progress toward the Internal Energy Market (IEM), potentially undermining the efficient operation of the regional day-ahead and intra-day markets and distorting cross-border trade. Furthermore, this uncoordinated approach risks unnecessary investment, while at the same time impeding the transition to a reliable, affordable low-carbon power system by locking in the current mix of inflexible high-carbon generation.

In addition, Member States currently take only limited account of demand-side participation when assessing resource adequacy. Demand response and end-use energy efficiency are essential to delivery of the least-cost portfolio of resources in the power system. A responsive demand side has the potential to reduce the investment in new generation capacity that would otherwise be necessary to balance supply and demand. Energy efficiency can lower the overall load on the system, including at peak times, further reducing the need for more costly investment in new generation and network infrastructure. There is a need to ensure that these contributions by demand response and end-use energy efficiency are fully taken into account in the resource adequacy process.

The following paragraphs examine these issues using information obtained from the European Network of Transmission System Operators' (ENTSO-e) 2015 Scenario Outlook and Adequacy Forecast (SO&AF) analysis.[2] Drawing on global experience and ENTSO-e's analysis, RAP concludes that, although generation capacity in some Member States is expected to fall below that required to maintain traditional levels of security (relying exclusively on domestic

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[1] European Commission. *Concerning measures to safeguard security of electricity supply and infrastructure investment*. Directive 2005/89/EC. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005L0089&from=EN

[2] ENTSO-e (2015). *Scenario Outlook & Adequacy Forecast (SO&AF)*. Retrieved from https://www.entsoe.eu/Documents/SDC%20documents/SOAF/150630_SOAF_2015_publication_wcover.pdf

plant), others will remain in surplus. Overall, Europe is likely to have a capacity surplus—albeit a declining surplus—over the period to 2025. This suggests that a regional or even European approach to supply security and resource adequacy could yield investment efficiencies and a reduction in the overall costs seen by consumers.

Similarly, the limited information available on demand response potential across Europe suggests that the capacity deficits forecast by some Member States could be overcome by releasing that potential, again reducing both consumer costs and the need for investment in conventional resources. Investing in the full, cost-effective energy efficiency potential, much of which is end-use electricity savings, can further deliver these benefits.

European Resource Adequacy Assessment

ENTSO-E's SO&AF Analysis

ENTSO-e produces its SO&AF analysis in accordance with Regulation EC 714/2009 and provides a pan-European view of resource adequacy out to 2025, based on standardised data submitted by individual Member States and connected countries. ENTSO-e uses a synchronised deterministic approach to assess resource adequacy on a regional and European basis, though the data allows an assessment of the situation within individual Member States at the time of national peak demand.

ENTSO-e requires Member States and connected countries to provide data using two scenarios, A and B. Scenario A includes only that fraction of new generation that is "certain" to commission, i.e. is in construction or whose construction cannot be cancelled. Scenario B, on the other hand, provides the best estimate of generation capacity out to the SO&AF 2025 horizon, including plant commissioning that is considered "reasonably credible."

The analysis in this paper utilizes ENTSO-e's 2015 Scenario B data, as Scenario A is overly pessimistic given the 10-year forecast horizon. However, though Scenario B forecasts are based on the best estimates of generation commissioning and decommissioning, they do include projects that have yet to achieve financial closure and therefore may not materialize. By the same token, the Scenario B forecasts do not include projects yet to be announced but that may materialize within the forecast time horizon in response to the forecasted need for new investment.

The deterministic approach to resource adequacy assessment adopted by the SO&AF involves comparing forecast generation availability with forecast peak demand, plus a security margin. The security margin varies from jurisdiction to jurisdiction, reflecting the particular resource adequacy standard in place. A recent exercise by the Council of European Energy Regulators (CEER) highlights the wide differences in resource adequacy standards across Europe and the methodologies underpinning these standards, which vary considerably in the level of sophistication applied.[3] CEER also highlights the varying extent to which each Member State's resource adequacy assessment methodology corresponds to ENTSO-e's methodology in compiling the SO&F. This raises the possibility that some Member States could come to different conclusions about the need for investment in new capacity than that suggested by ENTSO-e's analysis and as reported here.

[3] CEER (2014). *Assessment of Electricity Generation Adequacy in European Countries*. Retrieved from http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Electricity/Tab3/C13-ESS-32-03_Generation%20Adequacy%20Assessment%20Elec_10-Dec-2013.pdf

Demand

Peak demand and energy consumption have fallen across Europe in recent years due to the economic recession and improvements in end-use efficiency. However, in its 2015 SO&AF, ENTSO-e forecasts a gradual rise in both demand and consumption over the coming years as economic activity recovers, with only the UK and Germany seeing demand fall. The European Commission also predicts a slight rise in European electricity consumption over the period, while other predictions, such as those produced by Sandbag, suggest that consumption will fall in the immediate years ahead.[4]

If ENTSO-e's view proves optimistic and peak demand grows less than forecast, all other things being equal, resource adequacy should improve. In fact, there is some reason to believe that ENTSO-e tends to overestimate demand growth, as SO&AF forecasts of peak demand for the years ahead have generally been revised down year-on-year. This is illustrated in Figure 1, which compares the 2013, 2014, and 2015 SO&AF peak demand forecasts. For example, the forecast 2020 peak demand made in the 2013 SO&AF was 19 GW higher than the 2015 forecast, a fact acknowledged by ENTSO-e. Figure 2 compares the normalised consumption forecasts for the SO&AF period made by ENTSO-e, Sandbag, and the European Commission. Assuming that consumption and peak demand are linked, this comparison again suggests that ENTSO-e's forecast is high.

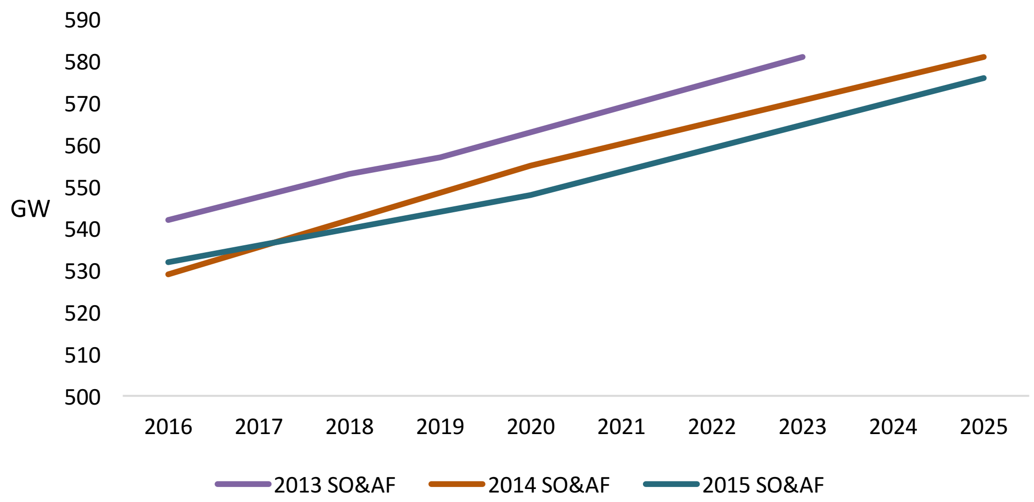


Figure 1. SO&AF Peak Demand Forecasts[5]

[4] Sandbag (2014). *Forecasting the EU ETS to 2020*. Retrieved from https://sandbag.org.uk/site_media/pdfs/reports/Briefing-2020surplusprojection.pdf

[5] ENTSO-e, 2015; ENTSO-e (2014). *Scenario Outlook & Adequacy Forecast (SO&AF)*. Retrieved from https://www.entsoe.eu/Documents/SDC%20documents/SOAF/141031_SOAF%202014-2030_.pdf; ENTSO-e (2013). *Scenario Outlook & Adequacy Forecast (SO&AF)*. Retrieved from https://www.entsoe.eu/publications/system-development-reports/adequacy-forecasts/soaf-2013-2030/Pages/default.aspx

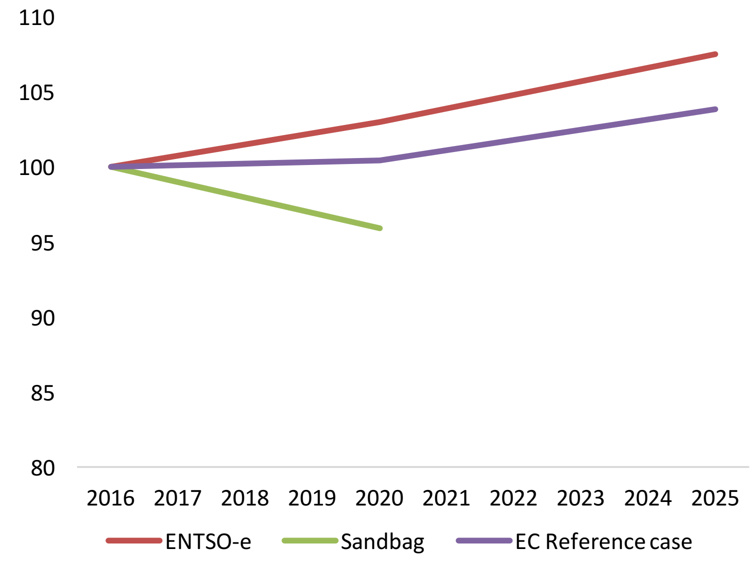


Figure 2. Normalised Demand Forecasts [6]

Generation Capacity

Over the period covered by ENTSO-e's analysis, the nature of Europe's generation mix will change significantly. As shown in Figure 3, ENTSO-e predicts that wind and solar capacity (RES in the figure) will increase markedly over the period to 2025, while conventional generation capacity will decline slightly. Because wind and solar capacity contribute little to meeting the winter peak demands that predominate in Europe, overall capacity available to meet peak demand is forecast to decline over time.

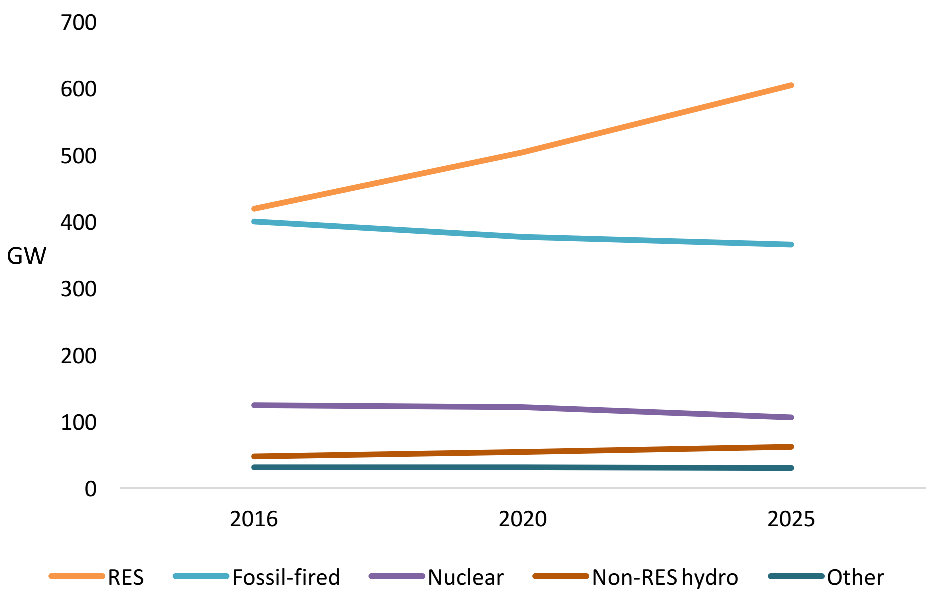


Figure 3. Forecast Generation Capacity, Scenario B [7]

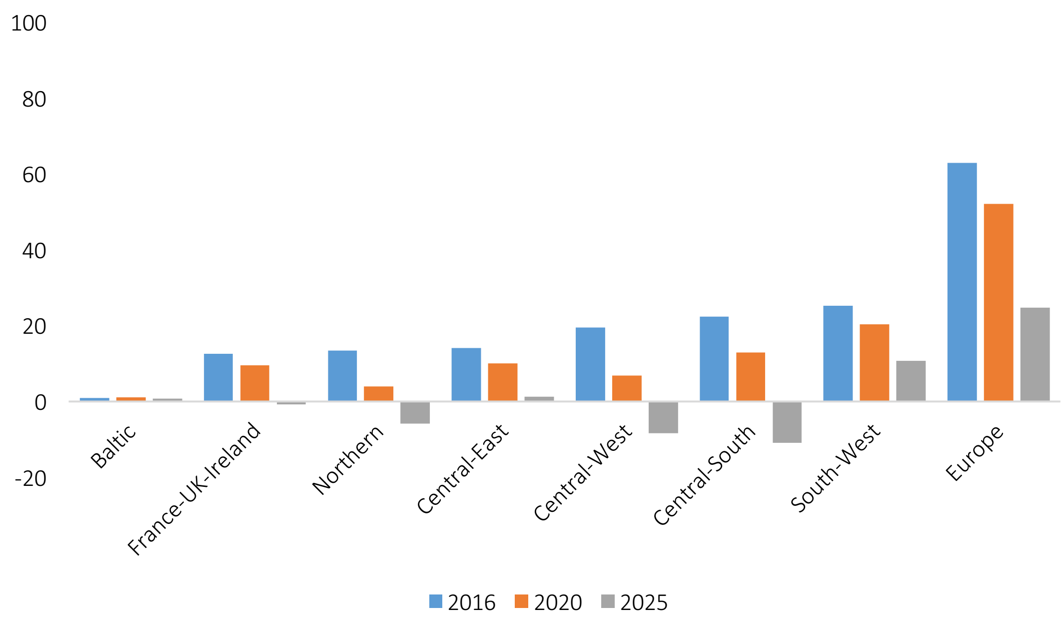
[6] ENTSO-e, 2015; Sandbag, 2014; and EU Commission (2014). *EU Energy, Transport and GHG Emissions Trends to 2050: Reference Scenario 2013*. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/trends_to_2050_update_2013.pdf

A Regional Approach to Resource Adequacy

ENTSO-e's SO&AF analysis shows that most European countries currently have a surplus of generation capacity over peak demand plus capacity margin. Some countries, such as Belgium, Denmark, and Finland, do not and are therefore dependent on imports from neighbouring systems at times of peak demand. However, Europe as a whole retains a surplus of generation capacity through 2025, even though the surplus declines over time with the reduction in conventional capacity and the increasing number of countries forecasting a capacity deficit.

Most countries projected to develop a capacity deficit during this period have sufficient usable interconnector capacity to ensure that imports necessary to maintain supply reliability can be accommodated. However, some Member States do not, and, if they are to be able to take advantage of a regional approach to resource adequacy, then additional interconnection capacity will be required. At least theoretically, Europe as a whole has sufficient generation capacity to ensure security of supply for the foreseeable future.

Some indication of how a regional approach to resource adequacy may work can be obtained by considering the seven Electricity Regional Initiative (ERI) regions. These were established in 2006 by the European Regulators Group for Electricity and Gas (ERGEG), the predecessor to the Agency for the Cooperation of the Energy Regulators (ACER), to advance progress to an integrated IEM. Figure 4 shows that all ERI regions are in surplus in 2016 and 2020, indicating that there is no shortage of investment in generating capacity in the near future. Longer term, however, the Central-West, Central-South, and Northern regions are forecast to fall into deficit by 2025 assuming no investment response. This is somewhat misleading because Germany and France, which are both forecast to have a relatively large deficit in 2025, are included in four of the seven ERI regions. Again, it is important to note that Europe as a whole has a capacity surplus in all years out to 2025.



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[7] ENTSO-e, 2015.

Figure 4. Forecast Resource Surplus and Deficit (GW)[8]

Baltic	F-UK-I	Northern	Central-East	Central - West	Central-South	South-West
Estonia	France	Denmark	Austria	Belgium	Austria	France
Latvia	Great Britain	France	Czech Republic	France	France	Portugal
Lithuania	Northern Ireland	Germany	Germany	Germany	Germany	Spain
	Ireland	Norway	Hungary	Luxembourg	Greece	
		Poland	Slovak Republic	Netherlands	Italy	
		Sweden	Slovenia		Slovenia	

Table 1. ERGEG/ACER Electricity Regional Initiative Country Groupings[9]

Italy is projected to have a significant capacity deficit, and combined with Germany, contributes to the Central-South ERI deficit in 2025. However, both Germany and Italy have sufficient interconnection capacity to accommodate the imports necessary to overcome their individual deficits. Furthermore, the usable interconnection connecting the Central-South ERI to neighbouring regions appears to be sufficient to accommodate any regional deficit that may arise.

Norway and Spain have the largest resource surpluses. These surpluses, together with the smaller surpluses seen elsewhere across Europe will need to be accessible by other Member States or connected countries that are in deficit. In this context, it should be noted that neither Norway nor Spain is forecast to have sufficient usable interconnection capacity to fully export surplus energy, despite planned increases in interconnection capacity. This suggests that further interconnection between both countries and their neighbours is necessary to support a fully regional approach to resource adequacy.

In conclusion, the ENTSO-e 2015 SO&AF analysis suggests that, while some Member States and connected countries may develop resource capacity deficits within the next ten years, Europe as a whole is forecast to have more than sufficient generation capacity to meets its needs. In turn, this suggests that a regional or European approach to supply reliability and resource adequacy could avoid the inefficient investment implied by a continuation of the current approach, where Member States or connected countries invest to meet their individual needs taking little or no account of support available from their neighbours. However, for a regional or European approach to be fully effective, some selective increase in usable interconnector capacity will be required to accommodate the anticipated energy flows.

[8] ENTSO-e, 2015.
[9] CEER (2015). Electricity Regional Initiative (ERI). Retreived from http://www.ceer.eu/portal/page/portal/EER_HOME/EER_ACTIVITIES/EER_INITIATIVES/ERI

What Role can Demand Response Play?

Current Situation and Demand Response Potential in Europe

European countries appear to take relatively little account of demand response when assessing resource adequacy. According to the SO&AF data illustrated in Figure 5, many countries take no account of demand response, and those that do assume no more than 4 percent of peak demand by 2020 and no more than 6 percent by 2025.

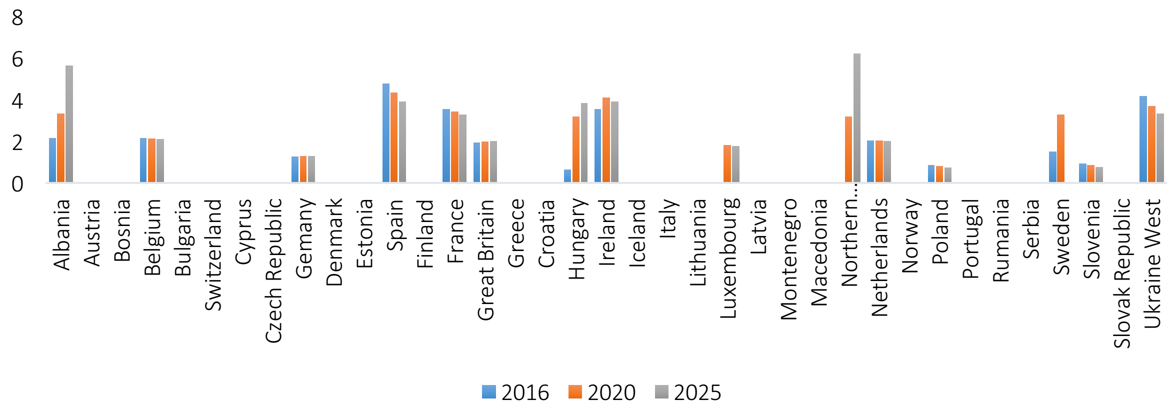

Figure 5. Percent of Peak Demand Forecast to Be Met by Demand Response in Resource Adequacy Assessments[10]

A recent study by Sia Partners (see Figure 6) suggests that demand response in many Member States could amount to 6 to 14 percent of peak demand and total 52 GW for the European Union.[11] Other studies propose even higher figures (68 to 72 GW), suggesting that Sia Partners' conclusions are realistic and achievable.[12]

A comparison with the United States also supports Sia Partners' view of what could be achieved in Europe. Currently, it is estimated that demand response could economically displace approximately 9.2 percent of forecast U.S. national peak demand, i.e. around 72 GW.[13] Furthermore, in 2009 the Federal Energy Regulatory Commission (FERC) estimated that by 2020 the U.S. could achieve 138 GW of demand response.[14] Attachment 1 provides a more detailed description of the role of demand response in the U.S.

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[10] ENTSO-e, 2015.
[11] Sia Partners (2014). *Demand Response: a Study of its Potential in Europe*. Retrieved from http://energy.sia-partners.com/wpfiles/2015/02/20141218_Article_DR-potential-in-Europe-1.pdf
[12] For example, Gils, H.C. (2014). Assessment of the Theoretical Demand Response Potential in Europe. *Energy*, 67, 1-18, calculates potential demand response in Europe to be 68 GW. Capgemini (2008). *Demand Response: a Decisive Breakthrough for Europe*, suggests that demand response potential in the EU-15 countries could be as high as 72 GW. See https://www.capgemini.com/resource-file-access/resource/pdf/Demand_Response__a_decisive_breakthrough_for_Europe.pdf
[13] FERC (2014). *Assessment of Demand Response & Advanced Metering*. Retreived from https://www.ferc.gov/legal/staff-reports/2014/demand-response.pdf
[14] FERC (2009). *National Assessment of Demand Response Potential*. Retrieved from http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf

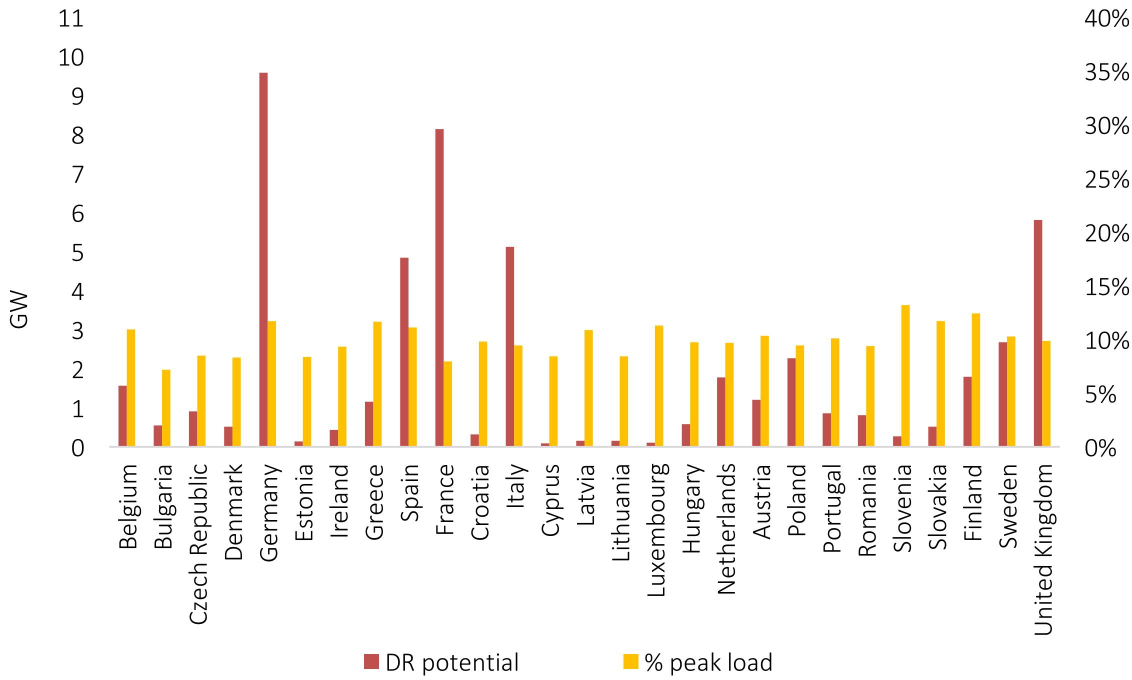

Figure 6. Demand Response Potential in European Member States[15]

The 8.6 GW of demand response (representing 1.6 percent of total peak demand) assumed by connected Energy Union countries for 2015, rising to 9.4 GW by 2025, appears to represent only a small fraction of what is economically feasible. This suggests that demand response could play a much greater role in maintaining supply reliability and reducing the need for investment in conventional generation and interconnector capacity.

Impact of Demand Response on Resource Adequacy

If Member States and connected countries were to realise the demand response potential identified by Sia Partners for 2020 and 2025, the resource adequacy situation in Europe would improve dramatically. Assuming that this improvement does not result in the cancellation of generation projects or increased decommissioning, fewer countries would have a forecast capacity deficit in those years and any deficits that remain would be much reduced. For example, Germany, which is currently forecast to have a capacity deficit of 8.2 GW in 2025, would expect a small surplus of 0.8 GW. Italy, which is currently forecast to have a capacity deficit of 7.7 GW in 2025, would see that deficit reduced to 2.1 GW.

Viewed from a regional perspective, the improvement is equally dramatic. Figure 7 illustrates that the seven RI groupings would forecast surpluses in all years and that the surplus capacity seen at a European level would rise to around 70 GW. Comparing Figures 4 and 7 gives a good indication of how effective demand response could be in avoiding regional capacity deficits.

[15] Sia Partners, 2014.

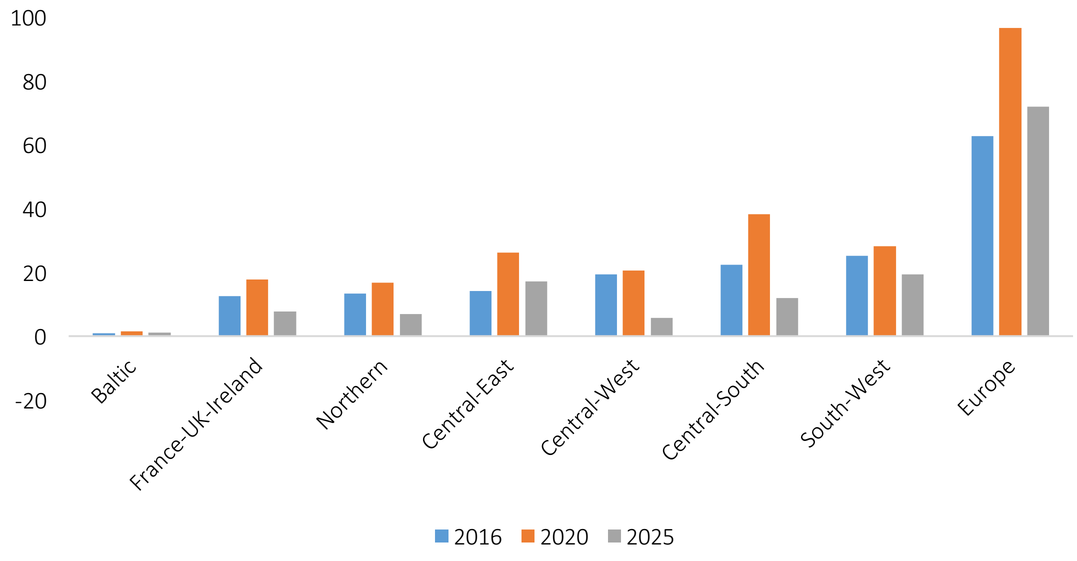

Figure 7. Forecast Capacity Surplus and Deficit, Accounting for Demand Response Potential (GW)[16]

The beneficial impact of energy efficiency measures on resource adequacy should not be neglected. Energy efficiency functions much as a "baseload" resource, reducing overall load on the system. Proper implementation of Article 7 of the Energy Efficiency Directive[17] by Member States, and compliance with requirements within the Ecodesign and Energy Performance of Buildings Directives will significantly drive down peak demand as well as total energy consumption, and therefore contribute directly and cost-effectively to any emerging or projected capacity deficits. Furthermore, existing policies fall short of delivering the estimated cost-effective energy efficiency potential in Europe, indicating that greater investment would yield additional benefits.[18]

Demand Response as a Means of Managing Intermittency

As Europe transitions to a low-carbon electricity system, the generation portfolio is changing. Large amounts of intermittent generation such as wind and solar will be commissioned over the next ten years, adding to the capacity already in place, while older fossil-fired generation will retire and be replaced by cleaner more efficient gas fired plant. Figure 3 suggests that, by 2025, renewable generation capacity will increase by 50 percent

[16] ENTSO-e, 2015 and Sia Partners, 2014.

[17] European Parliament and Council. (2012, October 25). Directive 2012/27/EU on energy efficiency. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN

[18] Braungardt, S., et al. (2014). *Study evaluating the current energy efficiency policy framework in the EU and providing orientation on policy options for realising the cost-effective energyefficiency/saving potential until 2020 and beyond.* Report for DG ENER: Fraunhofer Institute for Systems and Innovation Research ISI, Vienna University of Technology, and PricewaterhouseCoopers. Retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/2014_report_2020-2030_eu_policy_framework.pdf

to 608 GW, while conventional fossil-fired capacity will decrease by around 6 percent to 367 GW over the same period.

This changing plant mix presents new challenges in balancing supply and demand. As more intermittent generation capacity is connected to the grid, the "residual" demand (i.e., actual demand minus intermittent renewable output and "must run" conventional generation) to be met by conventional resources will become increasingly variable. Figure 8 illustrates generically how wind and solar output, together with the conventional generation that is required to operate for technical or commercial reasons, will combine to reduce the energy space available to accommodate other conventional plant.

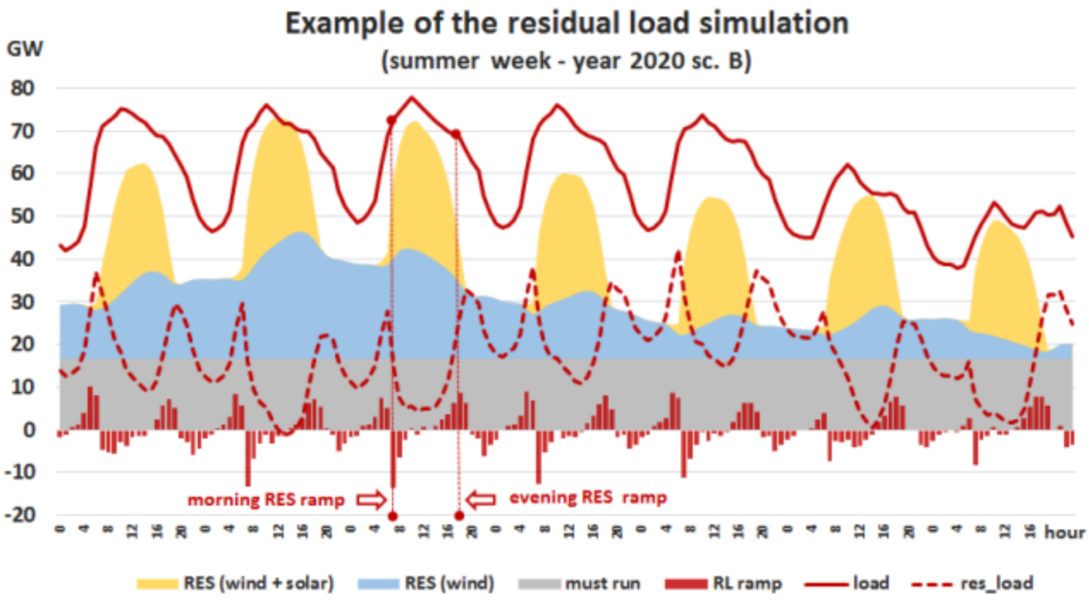

Figure 8. Residual Demand Simulation, Summer 2020[19]

Figure 8 also illustrates the increasing potential for residual demand to go negative on occasion, requiring excess energy to be exported or the output of wind or solar energy to be expensively curtailed. The rapidly changing and irregular nature of residual demand can also be seen. In fact, analysis by ENTSO-e suggests that residual demand ramping rates of up to 12 GW per hour could be experienced within the time horizon of the 2015 SO&AF analysis, a rate significantly higher than historic demand variability.

The stochastic approach ENTSO-e adopted in the 2015 SO&AF illustrates how these issues of negative residual demand, curtailment, and ramping are likely to develop over the next ten years with the continuing deployment of intermittent generation. While the situation will remain manageable in many Member States, some, notably Denmark, Germany, Great Britain, Ireland, and Northern Ireland, are predicted to see a significant increase in curtailment as shown in Figure 9. If not addressed, this increase in curtailment could undermine the economic viability of technologies such as wind and solar, while the low or even negative energy prices that accompany curtailment will also reduce the revenues available to conventional generation.

[19] ENTSO-e, 2015.

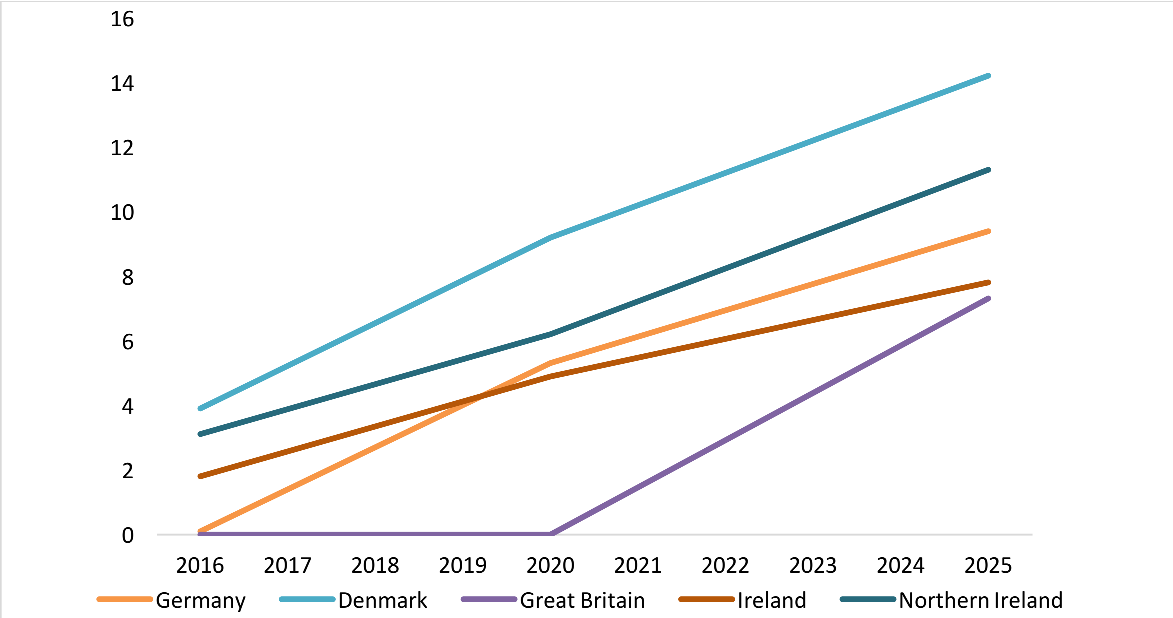

Figure 9. Percent Increase in Curtailment Risk[20]

The issues around residual demand can be at least partially addressed by increasing the flexibility of conventional plant. Increases in the rate at which generation can ramp up output, together with reductions in minimum stable operating load, minimum generator running and shutdown times, will help to improve system flexibility and free up energy space for other flexible generation.

While all this is all possible and indeed necessary, improving the flexibility of conventional generation is not a cost-free option. Designing generation to operate at very low loads and change output rapidly increases the thermal and mechanical stresses that need to be accommodated, and therefore incurs additional capital cost. Furthermore, operating generation at part-load, ready to rapidly increase output, reduces thermal efficiency and wastes fuel.

Given these difficulties, increasing the responsiveness of demand is an increasingly important and attractive option, with the potential to cost-effectively reduce the flexibility burden placed on conventional generation.[21] Demand response can be near instantaneous and able to provide rapid response beyond the capability of any generator. The responsiveness of demand can be augmented by readily available and quite inexpensive energy storage options. As an example, Danish combined heat and power (CHP) plants are adding large thermal storage tanks so that they can accommodate the demand for heat during times when renewable electricity production is high and demand for CHP electricity production is low. Residential hot water and storage heating systems offer similar low-cost opportunities.

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[20] ENTSO-e, 2015.
[21] See Lazar (2014). *Teaching the Duck to Fly*. Montpelier, VT: Regulatory Assistance Project. Retieived from http://www.raponline.org/document/download/id/6977; and Hogan, M. and Paulos, B. (2014, January). Dealing with the Duck. *Public Utilities Fortnightly*, 22-25. Retrieved from http://www.raponline.org/document/download/id/6980

While industrial and commercial consumers will incur costs in developing the ability to flex their demand in response to price or other signals, the cost/MW is likely to compare favourably with that of increasing generator flexibility. Data on the comparative costs is difficult to come by. However, an insight is given by the outcome of a recent tender for Supplementary Balancing Reserve (SBR) and Demand Side Balancing Reserve (DBSR) for Winter 2015-16 held in Great Britain. SBR and DSBR are "strategic reserve" balancing services based on generation and demand response, respectively. It is notable that the tender for DSBR, which can be instructed at short notice and ramps up very rapidly, cleared at around £11.6/kW, while the auction for SBR, which has to be instructed hours in advance and ramps up relatively slowly, cleared at around £13/kW.[22] DSBR and SBR are designed to address the same issue and are, to all intents and purposes, interchangeable. While there may be some operational limit to the extent to which demand response can replace generation in the provision of flexibility and other ancillary services, this example demonstrates that demand response is likely to provide a convenient and cost-effective alternative to generation-based services prior to any operational limit being reached.

Currently, in Europe, only industrial and larger commercial demands can realistically participate directly in the energy market or provide flexibility services to system operators. However, the rollout of smart metering, smart appliances, introduction of time of use and dynamic tariffs, and growth in third parties that can aggregate customer demand response into volumes that are useful to utilities, should all serve to extend the range of potential providers.[23] Furthermore, as issues of volatile residual demand, ramping, and curtailment become more significant with the growth in renewables, the value of flexibility services will increase and the economic case for engaging smaller consumers should steadily improve.

Conclusion

Based on ENTSO-e 2015 SO&AF Scenario B "best estimates" data, it appears that Europe as a whole is forecast to have sufficient generation capacity to meet peak demand in the years out to 2025. However, the surplus in capacity is expect to decline markedly over the period as conventional generation is replaced with intermittent capacity, which contributes little to meeting peak demand. Furthermore, a number of Member States and connected countries have or are forecast to have insufficient capacity to meet national peak demand over the period and will therefore be dependent on support from their neighbours. This combination of an overall surplus in generation capacity and some national deficits strongly suggests the need for three policy responses.

Firstly, a more coordinated regional or European approach to resource adequacy could result in investment efficiencies, lowering the cost of national reliability mechanisms and supporting the orderly retirement of aging, higher-emitting, generation. Implementing a more regional approach would require high levels of data exchange and cooperation between neighbouring transmission system operators, together with the development of a

[22] Bingham, P. (2015). *SBR & DSBR Market Update Winter 2015/16: Results of Tender Round 2*. National Grid. Retrieved from http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=41248

[23] See Hurley, D., Peterson, P., and Whited, M. (2013). *Demand Response as a Power System Resource Program Designs, Performance, and Lessons Learned in the United States*. Brussels, Belguim: Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/6597

standardized stochastic assessment methodology. ENTSO-e is ideally placed to develop such a mechanism and foster the necessary cooperation and data exchange.

Secondly, greater physical interconnection capability would improve reserve margins across regional markets and enhance many Member States' security of supply. Europe is already well down the road to developing a fully integrated day-ahead market, while progress in integrating intra-day and balancing markets is being made. Providing sufficient usable interconnection capacity exists, it would be a natural extension of this integrated approach to move to regional resource adequacy assessments in order to achieve the investment efficiencies referred to above.

Thirdly, across Europe, there is a growing need to recognise and capture the reliability and economic potential of more active demand-side resources. Member States make quite different assumptions about the potential of demand response and end-use energy efficiency to contribute to resource adequacy and, generally, these assumptions appear to understate what is economically justified and realisable. Estimates of demand response within European vary and a systematic country by country survey of potential would be valuable. However, currently available evidence plus comparisons with the situation in the United States, strongly suggests that demand response could play a significant role in enhancing resource adequacy both at a European level and national level. Moreover, analysis indicates that there is significant untapped potential for end-use energy efficiency in Europe, indicating the added value of further investing in energy efficiency as a cost-effective resource.

Demand response will also have an increasing role to play in mitigating "residual demand" issues as intermittent renewable capacity increases. Those countries with large amounts of connected wind or solar capacity will experience increasingly rapid changes in residual demand, challenging the ability of conventional generation to respond in a cost-effective manner. This, together with the emergence of transmission constraints, will result in an increasing need to curtail the output of renewable generation thereby undermining the economic viability of these technologies and increasing support costs. The availability of a flexible demand base, able to respond to price or other signals, has the potential to mitigate these residual demand and curtailment issues, easing the flexibility burden otherwise to be borne by the conventional generation fleet and allowing Europe's decarbonisation goals to be achieved in a more cost-effective fashion.

Attachment 1: Demand Response in the United States

The use of demand management in the United States originated in the 1970s, in part due to the spread of air conditioning and the emergence of spiky demand peaks on hot summer days.[24] In some U.S. regions, such as the Pacific Northwest, a similar problem of high peak loads occurs in winter due to the use of electric heat. The high cost of meeting these peaks with conventional generation drew attention to the need for cost-effective alternatives and, since that time, demand response has become well established in U.S. electricity markets, performing an active role in peak demand reduction, as an energy source, and in providing ancillary services.

Figure 8 shows the estimated enrolled U.S. demand response capacity in 2012, divided into incentive (where consumers are paid to provide a service) and pricing (where customers respond to tariff pricing signals) programs. Overall, the United States can be considered as to some extent ahead of Europe in terms of integrating demand response into the electricity markets.[25]

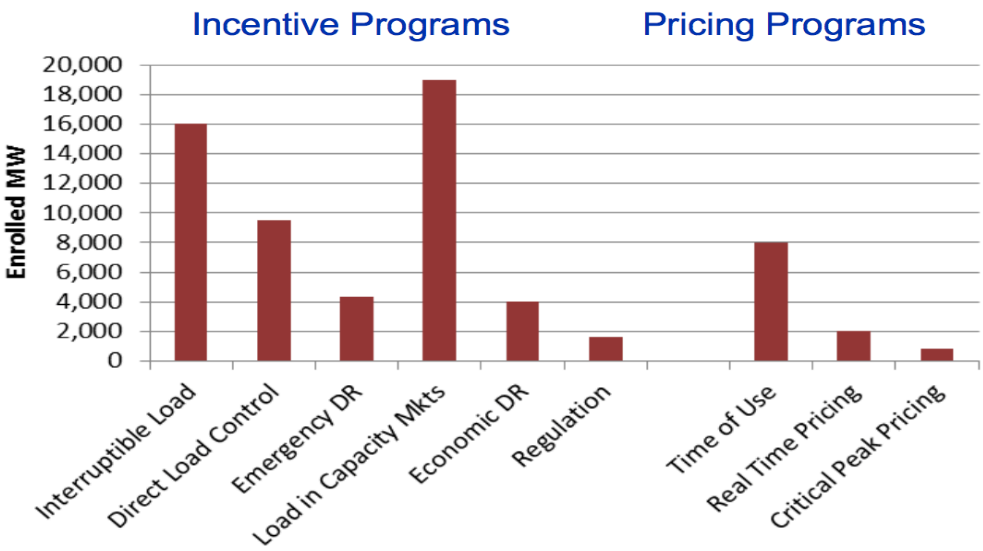

Figure 8. Enrolled Demand Response Load by Program Type (2012)[26]

[24] Hurley, et. al., 2013.

[25] As noted, in the United States, the chief motivation to tap demand response resources historically was the need to meet peaks driven by growing heating and cooling loads. In Europe, looking ahead, the need is driven more by the low-carbon transition, away from higher-emitting fossil units and towards lower-emitting but more variable renewable resources. In this sense, Europe is "ahead of" the United States in exposing the need for active demand response to integrate a growing fraction of renewable energy supplies. Regional power markets in both the United States and Europe will need to mobilize demand-side resources in depth to reliably manage growing shares of renewables.

[26] Godin, C. (2013). *Energy Efficiency and Demand Response Programs in the United States*. Retrieved from http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/files/documents/events/8_dnv_kema_15102013.pdf

Demand Response as a Reliability Resource

Several U.S. regional power markets have developed forward capacity mechanisms as a primary means of ensuring appropriate levels of supply reliability and, increasingly, European Member States are thinking of following suit. While demand response grows in scale and value, it is important to understand that the U.S. experience with demand response in regional markets is evolving rapidly. In the early stages, demand response was only called upon as an “emergency” resource in extraordinary circumstances. Later, as regional forward capacity markets were created, in an important breakthrough, demand response was able to compete alongside generation in capacity auctions.

By 2013, it was estimated that the potential peak demand reduction from regional transmission operators’ (RTO) and independent system operators’ (ISO) demand response programs was around 29 GW, or approximately 7 percent of peak demand in those markets. Importantly, the contribution from residential customers amounted to almost 9 GW.[27] The impact of demand response in reducing the cost of capacity mechanisms can be significant. For example, the 2012/13 PJM capacity market (Reliability Pricing Model or RPM) auction cleared at $16.5/MW-day with the participation of around 7 GW of demand response. Astonishingly, it was reliably estimated by the independent PJM Market Monitor that, without the participation of demand side resources, the 2012/13 RPM auction would have cleared at $179/MW-day,[28] and that the inclusion of demand response in the market solicitation saved PJM consumers ***$12 billion*** in that auction period alone.[29]

Certainly, if a forward capacity mechanism is to be used, it is extremely beneficial to design it so that demand-side resources are mobilized whenever they are less costly than conventional supply. However, it is far from settled that traditional forward capacity markets—even with demand-side participation—are the best or most efficient means of ensuring security of supply in markets that must integrate increasing fractions of variable renewables. In such markets, reliability challenges are less predictable and more frequent than those that are mainly oriented to cutting demand at a few peak periods. The good news is that in low-carbon power systems, demand response resources can be tapped to work in both directions—to absorb excess generation when renewable supplies are ample, and to reduce load when supply, including renewables, is temporarily insufficient.

There are numerous ways in which this bidirectional demand response can be realized, including “smart charging” of vehicles, thermal storage, lighting and refrigeration controls, advanced district heating, and co-generation systems. One lesson from the U.S. experience is that customer enrolment is key. For this reason, it is essential to create a value proposition in the energy, capacity, and services markets for creative competitors to enter the demand response market and offer new services. Market and regulatory barriers to customer aggregation and market entry must also be removed.

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[27] FERC, 2014.

[28] Gottstein, M. and Schwartz, L. (2010). *The Role of Forward Capacity Markets in Increasing Demand-side and Other low-carbon Resources: Experience and Prospects*. Montpelier, VT: Regulatory Assistance Project. Retrieved from http://www.raponline.org/docs/RAP_Gottstein_Schwartz_RoleofFCM_ExperienceandProspects2_2010_05_04.pdf.

[29] Monitoring Analytics (2010). *Analysis of the 2013/2014 RPM Base Residual Auction Revised and Updated*. p.52. Retrieved from http://www.monitoringanalytics.com/reports/Reports/2010/Analysis_of_2013_2014_RPM_Base_Residual_Auction_20090920.pdf.

It is important to realize that the foundation for "demand response for reliability" lies first in the way energy and balancing services are priced. Price-responsive load can, and does, emerge from pricing rules that allow various dimensions of system cost and customer value to interact in the market. A variety of mechanisms are available, including energy-only pricing as used by the Electric Reliability Council of Texas (ERCOT), locational pricing, used in a number of U.S. systems, and making sure that balancing costs in real time are priced appropriately and are reflected in the price of consumption. With respect to linking energy and balancing prices, some U.S. markets have already taken action. The PJM, New York Independent System Operator (NYISO), and ERCOT markets have all adopted measures that will allow energy market clearing prices to be set by an expanded set of balancing actions including deployment of demand-side resources.[30] All of these policies help the system to be more efficient at signalling the need for investment, and in particular the need for investment in the right locations, and with greater resource flexibility.

As U.S. system operators have gained more experience with capacity mechanisms, they have reformed them to reward resources that are available during scarcity events, and not just pure capacity or "iron in the ground." ISO-New England, for example, moved to raise energy prices during shortage hours, and launched a "pay for performance" rule that gives a bonus to those resources that are available during shortage events, with the bonus being paid by owners of resources that turn out not to be available when needed.[31] The key concept in these reforms is that the "missing money" that a capacity market is designed to provide should be paid in relation to an asset's availability to balance demand and supply during shortage periods. This principle can be applied both to supply-side and demand-side resources.

Demand Response as an Energy Resource

While there are numerous examples of programs that allow demand response to participate directly in U.S. energy markets, demand response that is purely price-driven is still a developing market segment. As can be seen from Figure 8, participation volume in price-driven demand response was relatively low in 2012 compared with participation in incentive-based programmes such as peak demand reduction and capacity markets. This is not a surprise, since price-driven demand response programs require time-of-use pricing and smart metering and communications systems that are not in place in many jurisdictions.

But progress is being made as experience is gained with various combinations of price transparency, smart metering and controls technology, and market rules. As part of the 2009 American Recovery and Reinvestment Act (ARRA) following the economic recession, the U.S. Department of Energy (DOE) launched a large number of Smart Grid Investment Grants, testing numerous pricing, technology, and marketing combinations. Counting both the DOE grants and the utility and private co-investments made, more than $9 billion has

[30] In Europe, the United Kingdom's Ofgem has recently adopted similar measures as part of their Electricity Balancing Significant Code Review. More detail on these points can be found in Hogan, M., Weston, F., and Gottstein, M. (2015). *Power Market Operations and System Reliability in the Transition to a Low-Carbon Power System: A Contribution to the Market Design Debate.* Brussels, Belgium: The Regulatory Assistance Project. Retrieved from http://www.raponline.org/document/download/id/7600

[31] Katsigiannakis, G., et. Al. (2014). *How ISO-NE's Pay-for-Performance Initiative Will Shake Up New England.* ICF International. Retrieved from http://www.ourenergypolicy.org/wp-content/uploads/2014/11/ISO_NE_Pay_for_Performance_Initiative.pdf

been invested to accelerate demand response learning and adoption under this program, and there are now more than 100 ARRA-funded case examples of demand response capabilities across the United States. Many of these projects have demonstrated the significant potential that demand response initiatives can bring to power systems and energy markets.[32]

In Texas, the ERCOT market has revealed the substantial potential that price-driven demand response resources can deliver in energy markets. Demand participation in short-term energy markets has only recently been initiated in Texas and already represents 3.4 percent of ERCOT's forecast load.

As with the PJM capacity market example above, the impact of even small reductions in demand can achieve large decreases in market clearing prices when capacity is scarce and the supply curve is steep. The contribution of demand response during the severe "polar vortex" conditions of winter 2014 is also worthy of note. Large areas of the United States were subject to prolonged periods of cold temperatures and snow that, in addition to prompting record demands for energy, immobilised a large amount of generation capacity due to frozen coal stocks, etc. During these extreme conditions, demand response generally responded very well, often exceeding capacity expectations.

Demand Response as a Provider of Ancillary Services

As in Europe, ancillary services have traditionally been provided by generation and this continues to be the case. However, demand response in increasingly seen as a potentially cost-effective alternative source of many ancillary service products such as frequency regulation, regulating reserves, and load-following services. The need for these services will increase with the continued deployment of intermittent renewable generation, and there are numerous examples of programs where demand response is eligible to participate.

As system operators and utility managers become more knowledgeable about the technical capabilities of demand response assets in providing ancillary services, support for them has grown. In some cases, advanced metering and communications capabilities are not even required to tap end use equipment for ancillary services, such as frequency regulation. Figure 9 below shows the results of a pilot program in which PJM sent out a frequency regulation signal (red line) and the responses, both up and down (blue line), were measured. This pilot and many others have shown the capabilities of demand response resources to provide multiple benefits to power systems and markets.

[32] See, e.g., the long list of projects and analyses shown at the National Town Meeting on Demand Response and Smart Grid (May 2015) found at http://www.demandresponsetownmeeting.com/presentations/.

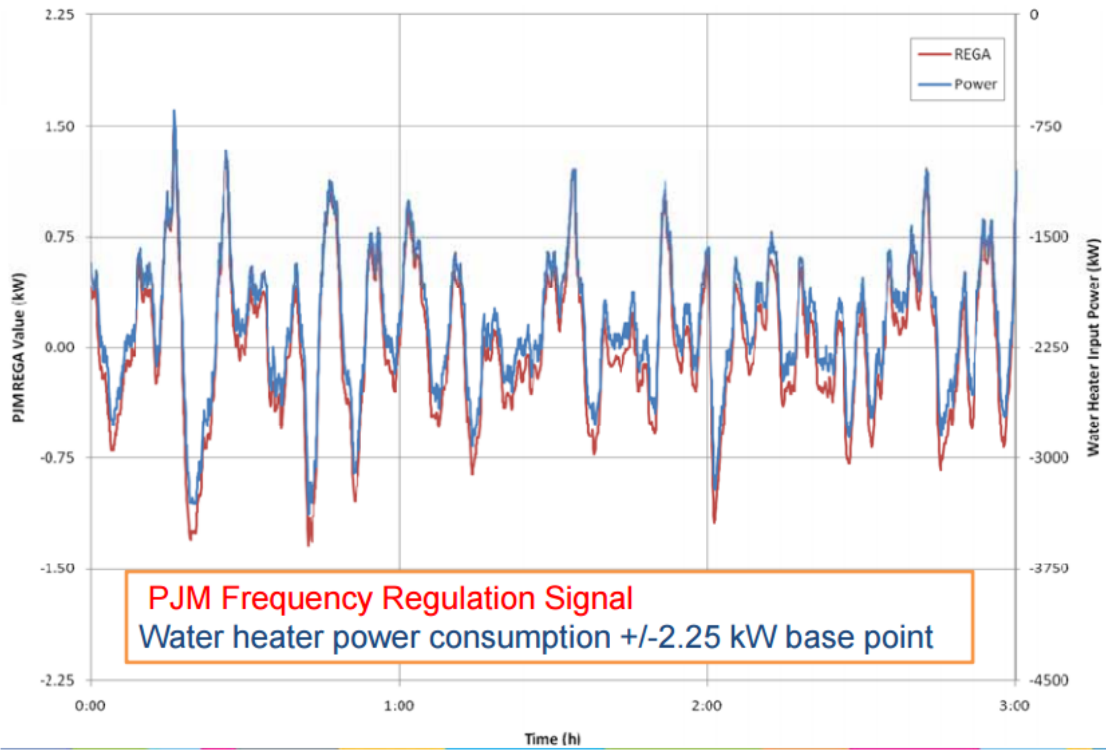

Figure 9: PJM Pilot Shows Water Heaters Can Provide Rapid Response Frequency Regulation[33]

[33] Callis, J. (2011). *Advanced Technology Pilot Projects: Fast-Response Regulation.* PJM. Retrieved from http://www.pjm.com/~/media/committees-groups/task-forces/rpstf/20110527/20110527-item-05-rptf-ed-regulation-pilots-app-aol.ashx