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Power systems in the 2020s: What can Germany and the PJM region learn from each other?

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Introduction[1]

This briefing note intends to spur dialogue at the first Germany-PJM States Energy Trends Forum, which will take place in Chicago on October 31st and November 1st, 2018, hosted by the Organization of PJM States, Incorporated (OPSI) and by the German Federal Ministry for Economic Affairs and Energy on the occasion of the OPSI Annual Meeting. The note takes a look at how Germany and U.S. states in the PJM region are addressing several shared opportunities and challenges and offers some observations that emerge from the comparisons. We begin by summarizing trends and common themes in both regions, and the challenges both face in adapting to them. Next, we identify key institutional and economic differences between Germany and PJM. We finish by summarizing some of the lessons learned from experience in each region and how the other might make use of that learning.

Trends and common themes

Penetration of ultra-low-operational-cost resources

Recent years have seen growing investment in generation from resources with very low or zero variable production costs, like solar and wind. Germany, in particular, has seen significant investment, but the trend is emerging in PJM as well. This poses certain challenges, given that, in both regions, wholesale electricity markets are designed to set prices based on the marginal cost to

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serve the next increment of demand, and that energy prices thus established are intended to be the principal driver of investment needed to meet consumer demand for reliable, affordable electricity.

Alongside this trend is a trend in mischaracterizing the implications of these challenges. It is said, for example, that economic dispatch relies on marginal production costs and will therefore be undermined by very low production costs; however, economic dispatch relies on *differences* in marginal production costs. Dispatching resources in a merit order having large tranches of generation with very similar marginal production costs is a familiar challenge; such resources are dispatched based on numerous other factors, including their locations relative to grid constraints, their ability to provide needed non-energy services, and the price they offer to provide them. In a similar vein, it is sometimes claimed that because more resources will have (close to) zero variable operating costs, energy prices will be (close to) zero. In fact, even in such a system, marginal cost prices are likely to be more volatile but, on average, sufficient to incentivize investment in an adequate and cost-effective supply of system resources, provided they are set based on the actual marginal cost (including opportunity costs) to meet the combined demand for energy and balancing services.[2]

Growth in variable renewable sources

A related trend in both markets is the growth of variable electricity generation. Variable production from very-low-generation-cost resources confronts system operators with the challenge of optimizing the utilization of this low-cost—and clean—energy while at the same time ensuring that demand can be reliably balanced with supply, both in real time and forward over a period of hours. Addressing this challenge at the lowest reasonable cost calls for an increase in the ability of the system to adapt quickly and with sufficient resources to uncontrolled changes in the availability of primary energy (such as wind, solar radiation, water flow in rivers). Some stand-alone power systems (e.g., Hawaii, Texas, Ireland) are already reliably operating under higher shares of variable renewable generation than in either PJM or in the northwest European synchronous system, of which Germany is part.[3] The overarching lesson from this growing body of experience is that flexibility, not capacity, becomes the scarce resource. While the system overall becomes more capital-intensive, the principal source of value to the system shifts from the capacity to produce energy to the capability to provide a range of energy and non-energy services (in German: *Systemdiensleistungen*)—the broad spectrum of flexibility—including new categories of services (such as synthetic inertia provided by wind turbines emulating the rotating masses from thermal power plants).

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[2] See Hogan, Michael. (2017). Follow the Missing Money: How to Ensure Reliability at Least Cost to Consumers in the Transition to a Low-Carbon Power System. *The Electricity Journal*, *30*(1), pp.55-61. Retrieved from: https://www.sciencedirect.com/science/article/pii/S1040619016302512?via%3Dihub. See also, Hogan, W., and Pope, S. (2017). *Priorities for the Evolution of an Electricity-Only Market Design in ERCOT*. FTI Consulting. Retrieved from: https://sites.hks.harvard.edu/fs/whogan/Hogan_Pope_ERCOT_050917.pdf.

[3] Ireland and Texas are linked to neighboring systems only via DC links. Germany is part of the large continental European synchronous power system, ranging from Portugal to Poland and Turkey; Germany benefits from substantial AC connections with eight neighboring countries, as well as from DC connections to the Scandinavian system.

Climate change mitigation imperatives

The Paris Accord affirmed the heightened urgency of action on greenhouse gas emissions. In addition to the two trends identified above, the electricity industry is being impacted by a broader set of policies and influences, including carbon pricing programs like the EU Emissions Trading System (within which Germany operates) and the Regional Greenhouse Gas Initiative (which two PJM states have joined, soon to be joined by others). While there has been some backsliding by the current federal U.S. administration, actions at the state level continue and indeed have in some cases accelerated.

Liberalized markets like Germany and PJM have also seen a growth in action by corporate actors, local governments, and others to underwrite clean energy investments. Greenhouse gas mitigation in other sectors, such as transport and heat, will rely to a large extent on fuel-switching to more efficient and increasingly low-carbon electric options, which will present new challenges up and down the electricity value chain. The growing public recognition of the fact of accelerating climate disruption suggests these trends are only going to grow stronger.

Stagnating demand for electricity

In most developed economies, including Germany and PJM's territory, total electricity demand has stagnated or even declined in the past 15 years,[4] confounding forecasts of load growth, whether they be before, during, or after the economic crisis. There are a number of reasons for this, including a shift toward less energy-intensive economic activities and an increase in investments in energy efficiency measures.

While this trend is obviously beneficial in many respects, it has created some short- to medium-term challenges for both Germany and PJM, which we take up in the following sections. Both regions entered this period with comfortable generation margins. Although there have been significant capacity retirements in both regions, large-scale investments in new capacity (mainly gas in PJM and renewables in Germany) have added to the short-term oversupply and placed significant downward pressure on prices.

Shifting landscape of resource value

The value of specific power system resources has always depended on how their attributes and capabilities fit with the needs of the system and its consumers. The trends toward a more variable, less controllable mix of resources is driving a redistribution of value. Less flexible "baseload" resources are becoming less valuable, while more flexible mid-merit and peaking resources are increasing in value.

In every region, the system value of elastic demand is increasing as a low-cost, largely untapped source of flexibility that can lessen the need to invest large amounts of capital in "back-up"

[4] See, for example, International Energy Agency (IEA), Electricity Statistics: Compound annual demand growth in OECD countries of 0.67% from 2003 to 2016. Retrieved from: https://www.iea.org/statistics/electricity/.

generation and transmission.[5] Put differently, we are moving from a world where we forecasted load and scheduled production, to a world where we will increasingly forecast production and schedule load on the basis of price signals. New tools, like geographically granular wind and solar radiation forecasts and digital aggregation of flexible decentralized demand and generation capacities, are becoming highly valuable for power system management.

Digitalization and decentralization

The electricity industry has been slower than many other sectors to experience the effects of and adapt to the revolution in cost and performance of digital technologies, which means the steepest part of this curve is yet to come. This coming wave will affect supply in the form of lower costs and better performance of distributed generation (e.g., low-cost distributed solar photovoltaics with improved fault ride-through)—a phenomenon with which Germany has already had notable experience. It will also affect demand, with consumers rapidly adopting technologies for various reasons that at very low cost can, either as the primary application or as a collateral benefit, make consumption of electricity increasingly responsive to changing market conditions at both the transmission and distribution levels. This trend will be accelerated by the onset of new, large, and inherently controllable end-uses for electricity, including electric transport and heat pumps for space heating and hot water. PJM has been notable for its efforts to tap into more flexible demand. The increasing digitalization of demand and decentralization of resources will—or should—overturn basic assumptions that have historically driven electric industry business models and operating practices.

Cybersecurity

The growing, inevitable, and broadly beneficial penetration of digital technologies up and down the electricity value chain brings with it the equally inevitable challenge of cybersecurity. The electric industry is, of course, of special concern in this respect given the centrality of electricity to modern life and national security. System operators and regulators are challenged both to increase the digital security of critical infrastructure and, at the same time, strengthen their systems' resilience in the event of faults or attacks. Also, data protection and the privacy of final users are relevant issues.

That said, it will be important to prioritize attention and resources wisely, focusing on those system components and functions that are most vulnerable and consequential. It will be important to understand how and where generating facilities may be a point of vulnerability, but the principal risks for widespread system failure appear to lie overwhelmingly in the transmission and distribution infrastructure for both electricity and fuel supply. There is little evidence, for instance, for the claims by some that certain types of resources, such as large central station "baseload" plants, are uniquely or even especially important for resilience, indeed perhaps quite the contrary. Each type of resource comes with its own weaknesses and can make its own contribution to

[5] See "Tapping the potential of flexible demand" below.

resilience. System components will also need to be protected against "backdoor" exposure via digital devices proliferating in homes, businesses, and industry—the "internet of things."[6]

Electrification of transport and heating

Deep electrification of the transport and the heating sectors (in Germany often referred to as *Sektorkopplung*) is an increasingly likely scenario, given its potential for decarbonization and greater efficiency in services and industries currently supplied principally by fossil fuels. Electrification will advance and be shaped by the trends discussed above but, on its own, it represents both a challenge and an opportunity for the electricity industry. Electrification is not an end in itself; it should deliver new and better services, at reasonable cost, and lead to sustained net declines in harmful emissions. The greater efficiency of leading-edge technologies such as electric vehicles and heat pumps, compared to the fossil fuel options they can replace, will reduce the growth in overall energy consumption as well as greenhouse gas and other emissions but it will reverse the recent trend in flat-to-declining electricity demand. Whether that leads to a disproportionate increase in peak demand remains an open question. Given the nature of many of these technologies, they can also contribute significantly to, or complicate, the task of integrating variable generation reliably and at the lowest reasonable cost. To a great extent, markets and innovation will determine the outcomes, but policy, regulation, and wholesale and retail system operations can also play a critical role in determining whether electrification, if and when it goes mainstream, is "beneficial electrification."[7]

Some main differences between PJM and Germany

Institutional setting and physical context

PJM is an independent system operator (ISO) serving a region of 13 politically heterogenous states and the District of Columbia. Each has extensive energy policy competencies, including, for example, the power to establish support schemes for renewables (such as renewable portfolio standards) and nuclear energy (as in Illinois and New Jersey). Because PJM manages interstate wholesale electricity transactions, it is regulated by the Federal Energy Regulatory Commission (FERC) and, with respect to reliability, by the North American Electric Reliability Corporation (NERC, which is itself overseen by FERC). PJM is part of the Eastern Interconnection, an AC system covering the Eastern part of the U.S. and most of Eastern Canada, and shares borders with surrounding ISOs (New York ISO, Mid-Continent ISO, IESO in Ontario) as well as with federal power authorities and integrated utility reliability regions on its southern border (Tennessee Valley Authority, SERC Reliability Corporation).

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[6] See, for example, Register, C. (2015, February 3). Former FERC Chief Jon Wellinghoff Speaks Out on Grid Security and Distributed Generation." *Forbes.com*. Retrieved from: https://www.forbes.com/sites/chipregister1/2015/02/03/former-ferc-chief-jon-wellinghoff-speaks-out-on-grid-security-and-distributed-generation/#51197e1df7ec.

[7] Farnsworth, D., Shipley, J., Lazar, J., and Seidman, N. (2018). *Beneficial Electrification: Ensuring Electrification in the Public Interest*. Montpelier, Vermont: The Regulatory Assistance Project. Retrieved from: https://www.raponline.org/wp-content/uploads/2018/06/6-19-2018-RAP-BE-Principles2.pdf.

Germany is embedded in the EU internal electricity market, which is defined by a regulatory and policy framework enshrined in EU law. In some ways, EU law gives Brussels more authority than Washington in the electricity sector (e.g., with respect to the basic rules defining competitive wholesale and retail markets) while, in others, Brussels has less authority (e.g., regarding security of supply). Provided that renewable energy and emission reduction targets established at EU level are met, the Member States can freely determine their own generation mixes, and Germany has not hesitated to do so, notably by adopting the nuclear phase-out plan and the program to massively deploy renewable energy sources. This same issue is currently the subject of debate in the U.S. but, for the moment, PJM has regulatory authorization to attempt to offset the effects of state resource preferences in its markets.

Gas versus coal prices

The large-scale extraction of shale gas in the U.S. resulted in falling gas prices. This had the opposite impact on the merit order dispatch in the power markets of PJM and Germany. In the PJM region, the newfound abundance of natural gas at very competitive prices led to a switch from coal- to gas-fired generation. Part of the redundant coal was then exported, causing a decline of hard coal prices on the global market, including Europe. At the same time, domestic gas production in the EU is in decline, shale gas has not been a factor, and Europe remains reliant on pipeline imports under long-term contracts. As a result of these factors, gas prices in Europe remain high relative to coal prices, and PJM and Germany are experiencing very different market drivers in the competition between gas-fired and coal-fired generation.

Learning from each other's experience

Both PJM and the EU's integrated electricity market are examples of competitive wholesale electric markets. As such, both approach the task of delivering reliable electricity to consumers at a reasonable cost from a broadly shared perspective. That said, the details of each and the contexts within which they operate are in many respects quite different and offer a diverse range of experiences and lessons.

Wholesale energy price formation—part 1: Locational pricing

Germany and PJM differ, *inter alia*, in at least two important respects: scarcity pricing and locational pricing. Here, we will address locational pricing: PJM, like most organized markets outside of Europe, establishes locational marginal prices at each node on its system, relying on alignment of prices with marginal costs to resolve grid congestion via the market. Germany, like most of the EU countries, employs a single-price market that sets a uniform energy price across all locations in the country,[8] relying on continuous intraday trading and system operator re-dispatch to resolve congestion. While PJM switched early on from zonal pricing to a nodal market, others have

[8] Germany and Austria were combined in a single price market that was split at the Austrian-German border on 1 October 2018. Some European countries (Italy, Sweden, Norway) have divided their territories into several price zones, according to frequent grid congestion points; however, this does not address the costs of congestion that occurs across the many nodes within those zones.

switched more recently,[9] driven by, among other things, the benefits a nodal market offers in facilitating the integration of variable production. Investment in needed transmission and generation has proceeded apace in PJM, with robust liquidity and with concerns about market power abuse largely under control.

The EU is debating a switch to smaller bidding zones—rather than to the more common nodal approach—but the German government and regulator have made clear their desire to maintain Germany's single-price market. In this context, commonly used arguments made in favor of maintaining zonal pricing include lower risk of market power, the avoidance of transaction costs, and lower regulatory costs.[10] Germany and its neighbors face ongoing challenges with uncontrolled flows, escalating congestion-related costs, and comparatively low utilization of transmission. It remains to be seen how those issues will finally be resolved in the absence of more granular, market-based resolution of locational constraints.

Wholesale energy price formation—part 2: Supporting investment in resource adequacy

"Resource adequacy" is the provision of a quantity and a mix of supply resources sufficient to ensure a level of reliability that reflects a reasonable trade-off between cost and the value consumers place (or are assumed to place) on having uninterrupted supply. PJM operates under an explicit standard (a version of the "one-day-in-ten-years" loss-of-load standard observed in different forms in all North American markets), which is translated into a target reserve margin (currently 16.1 percent[11]); PJM is currently well above this target, at about 32.5 percent.[12]

Germany has no stated standard or target reserve margin, but the latest EU analysis puts Germany's loss-of-load expectation at zero hours per year into the early 2020s, which would be consistent with an assumed infinite value of uninterrupted supply.[13] Thus, both systems are currently quite oversupplied with generation capacity, such that one should not expect current energy prices to support new investment. Nonetheless, ensuring the market does support investment when it is needed remains a relevant question and each system takes a different approach.

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[9] Of the 24 organized wholesale electric markets around the world, 17 have either always employed nodal pricing or have switched to nodal pricing over the past 20 years. Figures are based on RAP analysis combining a variety of key sources, which include: The King Abdullah Petroleum Studies and Research Centre (KAPSARC) [wholesale markets], (2017); Brattle Group, (2017) [Ontario, Canada]; Frontier Economics. (2009) [international transmission pricing]; Veselov, F., (2014) [Russia]; Potomac Economics, (2018) [Midcontinent ISO]; Southwest Power Pool, (2017) [Southwest Power Pool market]; California ISO, (2016) [EIM]; NERA Economic Consulting, (2017) [Mexico]; Pérez-Arriaga, I.J., and Olmos, L. Rivier, M., (2013) [Chile]; ADB Consulting, (2016) [Philippines]; Cramton, P., (2017) [Columbia and Brazil]; Freudenthaler, G., (2016) [Alberta, Canada]; Hohki, K., (2006) [Japan]. A list of the full citations is available upon request.

[10] Maurer, C., Zimmer, C., Hirth, L. (2018). *Nodale und zonale Strompreissysteme im Vergleich* [A comparison of nodal and zonal price systems]. Retrieved from: https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/nodale-und-zonale-strompreissysteme-im-vergleich.pdf

[11] "Reserve margin" in the U.S. is the margin above the system peak, whereas, in Europe, it is the margin above [system peak + a number of reserves and provisions]; as such, reserve margins can appear to be very different.

[12] North American Electric Reliability Corporation. 2018. *2018 Summer Reliability Assessment*, p. 24. Retrieved from: https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_05252018_Final.pdf.

[13] See ENTSO-E Mid-Term Adequacy Forecast 2017, available at https://www.entsoe.eu/outlooks/midterm/.

The second important difference in energy price formation is in the approaches to scarcity pricing. Germany's "Energy-Only Market 2.0" removed price caps, in theory permitting uncapped scarcity pricing until the market fails to clear. Beyond that, there is no mechanism for reflecting the combined demand for energy and balancing services in energy price formation, nor any mechanism for reflecting the cost of reserve shortages in energy prices.

PJM imposes a cap on generator offers of $1,000 per MWh, but it does co-optimize energy and ancillary (or balancing) services and employs a number of other mechanisms, including a reserve shortage pricing mechanism, that can drive effective scarcity energy prices to well above the published cap. The decentralized forward market structure in Europe makes it more challenging to adopt such practices, but it is possible, as shown by the success of the U.K.'s cash-out price reform.[14] Both Germany and PJM appear to be acting, albeit in different ways, on the realization that improved energy pricing is important.[15]

Nonetheless, both regions have adopted measures outside of the energy market to address concerns that energy prices will not, or cannot, always be counted on to support needed investment (the so-called "missing money" problem), especially during the ongoing energy transition. PJM employs an auction-based capacity market with a mandatory reserve margin, whereas Germany has adopted a strategic reserve as its backstop mechanism. This reserve consists of power plants that are not allowed to bid in the energy market and are activated only in case the market does not clear at any price.[16]

PJM's capacity market has undergone periodic revision and been mired in occasional controversy, currently over how to accommodate state preferences concerning the generation mix. Germany is currently discussing with the European Commission and other EU Member States whether its strategic reserve will be treated as a capacity mechanism under proposed legislation that could impose CO_2 emissions limits on resources participating in capacity mechanisms. In both cases, the decision to pursue out-of-market procurement of capacity would seem to be causing difficulties. A different approach is suggested by the success so far of the Electric Reliability Council of Texas' (ERCOT) market, with nearly 20 percent of its energy from variable renewables.[17] There, reliability has been maintained at a lower cost by focusing on its reserve shortage pricing mechanism and allowing energy prices (virtually uncapped, as a practical matter) to drive needed investment.

Retirement of surplus fossil generation capacity

As already noted, the combination of low to no growth in electricity demand, starting positions of adequate to more-than-adequate resources, and continuing support for investment in low-carbon

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14 For more information, see *Ofgem's Electricity Balancing Significant Code Review*. Retrieved from: https://www.ofgem.gov.uk/electricity/wholesale-market/market-efficiency-review-and-reform/electricity-balancing-significant-code-review.

15 For more information, see PJM. (2018 May 11). *Response to the 2017 State of the Market Report*, pp. 7-9. Retrieved from: https://www.pjm.com/-/media/library/reports-notices/state-of-the-market/20180511-pjms-response-to-the-2017-state-of-the-market-report.ashx?la=en.

16 Germany also employs other reserves that do participate in the market, the effect of which is to limit the possibility of high market prices.

17 Fares, R. (2018, January 29). Texas Got 18 Percent of its Electricity from Wind and Solar Last Year. *Scientific American*. Retrieved from: https://blogs.scientificamerican.com/plugged-in/texas-got-18-percent-of-its-energy-from-wind-and-solar-last-year/.

resources has left both Germany and PJM in positions of considerable oversupply. PJM has seen a number of retirements of uncompetitive coal and nuclear generators for economic reasons, while Germany has retired for political reasons most of its nuclear fleet and will retire the remainder by 2022.

Nonetheless, both markets will continue for the foreseeable future to have higher reserve margins than would be indicated by applying a reasonable "value of lost load" standard. This depresses energy prices, worsening the missing money problem, and it forestalls market demand for new low-carbon investment. Both markets would be healthier and less reliant on out-of-market mechanisms if most or all of the surplus could be gotten off the system. PJM is benefitting from the fact that U.S. natural gas prices favor lower-carbon, more efficient gas generation over older, less efficient coal, but retirements have not brought the market into a reasonable balance and there are efforts to protect some of the existing inflexible coal and nuclear generation. In Germany, it is the newer, more efficient gas generators that are being pushed to the margin. In response, Germany has convened a commission to establish an administered coal phase-out plan, which will be required for Germany to achieve its 2030 climate targets since it is becoming apparent that Germany will most likely fail to reach the similarly ambitious 2020 targets.

Both regions face a "replacement challenge"—transitioning to a decarbonized power system in the necessary time frame cannot be accomplished merely by attrition; it requires that much of the existing generation be replaced. That implies a program of ongoing retirement of inflexible high-carbon resources at a much higher rate than has been achieved thus far.

Deployment of investment in low-carbon resources

The two regions present quite different pictures when it comes to supporting investment in low-carbon resources. Germany has famously pursued an aggressive federal policy framework for renewables, beginning with a principal focus on feed-in tariffs that digressed over time and has now transitioned to auctions for feed-in premiums.[18] Renewable generators also currently benefit from EU legislation giving them priority dispatch rights over other generators except where it would threaten security of supply. The result has been rapid growth in investment in renewables, principally wind and solar, driving a steep decline in the cost of new renewables. Variable renewables (i.e., wind and solar) delivered 22.4 percent of German electricity generation in 2017, despite relatively poor domestic solar and onshore wind resources.[19] At the same time, Germany is forcing retirement of its nuclear generation.

It is important to note that PJM is not a government agency and has no remit over resource policy, as this is dealt with by other institutions. Federal support for renewables that would affect PJM has been limited principally to tax credits granted to wind and solar generators, so most of the support

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[18] Very small-scale PV is still supported by a feed-in tariff.

[19] German Federal Ministry for Economic Affairs and Energy. (2018). Informationsportal Erneuerbare Energien, Retrieved from: https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html. The total share of renewables, including dispatchable options like biomass and reservoir hydro, grew to 36 percent of gross consumption in 2017. For visuals on the German energy transition, see also: Clean Energy Wire. (2018 April 3). *Factsheet: Germany's energy consumption and power mix in charts.* Retrieved from: https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts.

for investment in low-carbon resources in PJM has come from PJM states. This has principally been in the form of "portfolio standards," quotas imposed on load-serving entities to procure a certain percentage of their requirements from designated resource categories. As a result, development of new renewables in PJM has been uneven and limited even by U.S. standards (variable renewables provided 2.8 percent of PJM energy in 2017), reflecting in part also the fact that the highest-quality onshore wind and solar resources tend to be found in other regions.[20] Renewables have been able to participate in PJM's capacity market for a portion of their capacity, but, as noted earlier, treatment of resources that are the subject of state resource preferences is now under intense debate.

The heightened intensity of that debate is in part due to the fact that, in contrast to Germany, some PJM states have adopted or are considering adopting support schemes for existing nuclear capacity that would otherwise be retired for economic reasons. This is driven in part by a desire to keep these plants running until they can be replaced by comparably low-carbon generation, combined with the absence of federal carbon pricing that could otherwise make them more competitive in the market. PJM's charter leaves it very much in the middle, obligated to operate its markets so as to provide non-discriminatory access and to deliver reliable wholesale energy at just and reasonable rates.

Tapping the potential of flexible demand

PJM has had notable success in tapping flexible demand as a system resource. This has been accomplished most famously through its capacity market which provided *early-stage* support for the emergence of a demand response industry by providing ready access to a market. As a result, demand response has delivered 5 to 10 percent of system capacity.[21] That said, the rules affecting demand participation in the capacity market—both directly and indirectly—have been subject to frequent revision, in most cases making participation more challenging. Demand response commitment rates plateaued and have declined somewhat in the last two auctions. By contrast, flexible demand has played an increasingly significant role in PJM's ancillary services markets, particularly for frequency regulation services. PJM's recent introduction of a Price-Responsive Demand product in its capacity market could be seen as indicating that dispatchable demand response as a capacity product—that is, the PJM demand response that has historically received so much attention—has reached its limited potential, while the demand response that will be of greatest value now is that which effectively shifts the demand curve simply in response to improved wholesale energy prices (that is, demand response driven by prices rather than acquired through administrative means). There will also continue to be value in demand response that can provide more of the non-energy services PJM and others will need as variable production gains a greater share of the market.

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[20] Bowring, J. (2018 March). 2017 State of the Market Report for PJM. [presentation, slide 13]. Retrieved from: http://www.monitoringanalytics.com/reports/Presentations/2018/IMM_MC_Special_Session_SOM_20180322.pdf.

[21] PJM Interconnection. (2017, June 28). *Demand Response Strategy*. Retrieved from: https://www.pjm.com/-/media/library/reports-notices/demand-response/20170628-pjm-demand-response-strategy.ashx?la=en. See also: Hurley, D., Peterson, P., and Whited, M. (2016). *Demand Response as a Power System Resource*. Montpelier, Vermont: The Regulatory Assistance Project. Retrieved from: https://www.raponline.org/wp-content/uploads/2016/05/synapse-hurley-demandresponseasapowersystemresource-2013-may-31.pdf.

The picture for demand response in Germany is more muddled. Demand response in Europe is affected by the decentralized self-dispatch model for the forward market, necessitating the designation of "balancing responsible parties" responsible for ensuring that commitments to supply are balanced by commitments to produce and vice versa (this role is played by PJM in its market). As a result, there are wide differences in, and great disagreement about, the rules affecting demand aggregators, especially those who do not wish to become retail suppliers/balancing responsible parties. A major element of the debate is over whether, and how, demand aggregators should compensate suppliers who have purchased energy in advance to meet forecasted demand that does not materialize due to the actions of the aggregator. Suppliers themselves have been very uneven in their level of interest in developing demand response. This is compounded in Germany by the fact there are over 1,000 suppliers, most of which are very small or local and, in many cases, still bundled with generation-owning municipal utilities.

Germany also has no capacity market, and capacity oversupply means there will be little or no natural demand for demand response as a capacity resource. In contrast, the forward capacity market in PJM provided the infant demand response industry access to market. Finally, congestion is resolved in Germany through re-dispatch and continuous intraday trading, both processes that create significant barriers to participation for demand response aggregators. As a result of all of these factors and others, demand response does not today play a significant visible role in Germany. With high and growing variable production, it is conceivable that Germany will see more activity than PJM in the higher-value price-responsive demand, especially as there is no supplier compensation problem with price-responsive demand.

Such a trend is increasingly evident, for instance in the ERCOT market, with its large variable renewable production. But the ERCOT market's reliance on energy prices to determine the economic level of reserves has led to a better balance between supply and demand.[22] As a result, energy prices periodically reach levels that can mobilize the latent flexibility of many end uses as an alternative to the traditional practice of maintaining reserves of more costly "backup" generation.[23] The large oversupply of generation in Germany makes that unlikely for the foreseeable future.

Valuing climate externalities

Germany's push for renewables has been complemented by the EU-wide Emissions Trading System (ETS), a cap-and-trade scheme for greenhouse gas emissions that covers the generation, industrial, and aviation sectors. As a result, Germany has benefited from an explicit program for pricing the externalities of greenhouse gas emissions. Unfortunately, the ETS has historically been plagued by an oversupply of allowances, which have therefore traded at prices around 5 euros/tCO_2, i.e., well below what EU authorities and many market actors expected. The scheme has recently been reformed to create a market reserve designed to remove allowances from the market for some

[22] One difference between Germany and ERCOT's markets is the longer duration of the ERCOT market structures, but the biggest difference is that ERCOT allows energy prices to drive the economic level of capacity reserves. Germany, in contrast, maintains multiple layers of reserves through different mechanisms that have the practical effect of capping energy prices. This difference is exacerbated by the absence in Germany of virtually all of the price formation refinements used in ERCOT to ensure that energy pricing reflects the full cost of actual scarcity, if and when scarcity ever appears in the market.

[23] See Hogan and Pope, (2017) for a fuller description of the ERCOT market.

period of time; this has so far had some success, with ETS allowance prices trending upward in the range of 20 euros/tCO_2 and expectations they might rise to the range of 55 euros by 2030.[24] Some Member States, not wanting to rely on this, have considered adopting carbon price floors as a way to boost support for investment in low-carbon resources (the U.K. has done so, in the process raising additional tax revenues and reducing the costs of direct renewables support policies). This also improves the finances of nuclear generators. Germany has so far shown little interest in adopting a carbon price floor.

As with renewables support, PJM's mandate does not allow it to adopt carbon pricing unilaterally in its market, and there has been no progress on federal carbon pricing policy. Several PJM states are or will soon be members of the Regional Greenhouse Gas Initiative (RGGI), which currently covers only the generation sector in the participating (mostly northeastern) states. This has put fossil generators in those states at a slight disadvantage to their counterparts in other PJM states, leading to some "carbon leakage" concerns that RGGI seeks to neutralize in various ways. But, in the end, the RGGI prices have been quite modest and have not been a major competitive concern. (RGGI has focused at least as much on the reinvestment of allowance auction revenues in greenhouse-gas-reducing actions, such as energy efficiency, as it has on boosting allowance prices. The resulting reduction in emissions at modest allowance prices convinced the RGGI states in 2017 to agree with little fanfare to a permanent 30 percent reduction in the emissions cap). PJM and some of its stakeholders have recently explored the possibility of introducing shadow carbon pricing into PJM's energy market,[25] in effect setting merit order dispatch as if a price for carbon were being charged, but there is considerable opposition in some PJM states to anything that would disadvantage their coal-fired generation or raise market prices. As a result, the design of a scheme that could garner the necessary stakeholder approval would be extremely challenging, and the initiative appears to have stalled for the time being.

Conclusion

PJM and Germany have developed different approaches in different contexts in attempting to address the trends and challenges outlined above, yet both do so in a competitive electricity market environment. This broad commonality may offer grounds on which to explore some mutually beneficial ideas. Each has gained experience from which the other can profit, though drawing lessons that provide the basis for tangible action on those learnings is something that, in most cases, will require a robust discussion. In crafting this note, we had no expectation of providing all the answers—or really many answers at all—nor would that have been appropriate. But it is certainly our hope that this note will be of good value to the parties in spurring just the sort of robust dialogue that will lead to new progress in both regions in tackling these incredibly important and exciting challenges.

[24] Carbon Tracker. (2018 April 26) EU carbon prices could double by 2121 and quadruple by 2030. [press release]. Retrieved from: https://www.carbontracker.org/eu-carbon-prices-could-double-by-2021-and-quadruple-by-2030/.

[25] For more information, see PJM. (2017 August 24). PJM offers ideas on carbon pricing. Retrieved from: http://insidelines.pjm.com/pjm-offers-ideas-on-carbon-pricing/.

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