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R STREET POLICY STUDY NO. 123
December 2017

ENHANCING MARKET SIGNALS FOR ELECTRIC RESOURCE ADEQUACY

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CONTENTS

EXECUTIVE SUMMARY

Reliable electric service has major benefits for society. But there are also costs, as reliability depends upon having sufficient aggregate supply to meet demand, or generation "resource adequacy," as well as transmission and distribution reliability. Regulators have a long history of employing standards for electric reliability but with little consideration for the economic costs and benefits. However, mounting evidence shows that incentives are far better tools to lower costs, benefit consumers and drive innovation. On top of this, new technologies are rapidly altering the economic characteristics of resource adequacy, with major policy implications.

Historically, resource adequacy was non-excludable, which meant that suppliers could not limit receipt of their product to those parties that pay for it. This creates an incentive for market participants to "free ride" on this "common good," which results in under-provision of the service by private actors. This formed the policy basis for treating resource adequacy as a pooled resource, where participants share equally in resource adequacy benefits[1] and costs, by enacting compulsory resource adequacy mechanisms to ensure sufficient resource procurement.

However, resource adequacy policy differs markedly between states that retain monopoly regulation and those that adopted competitive electricity markets. Regulated states require monopoly utilities to procure resources on behalf of customers, typically through a cost-minimizing process known as integrated resource planning (IRP). This feeds into the process for regulators to decide whether to approve utility investment in new resources for which they earn a guaranteed rate of return. In deregulated or "restructured" states, load-serving entities (LSEs) buy power on the wholesale transmission market and resell it to end-use consumers, who have the option to choose their power supplier. Competitive "merchant" resource owners decide to retire existing resources or build new ones based on expected returns from net revenues in the wholesale market.

All competitive wholesale markets operated by regional transmission organizations or independent system operators (RTO/ISOs) employ energy and ancillary service markets. These short-term markets reflect the marginal cost of system operations at granular locational levels and short time intervals. They provide incentives for long-term resource investment (retirement or new entry) by providing a basis for forward price expectations. To ensure resource adequacy, RTO/ISOs employ shortage or scarcity pricing that administratively sets prices above marginal cost when resource reserves

1. Like, for example, the avoidance of indiscriminate rolling blackouts.

run short. This "energy-only" paradigm provides additional revenues to influence investment decisions in most of Texas, for example. In other restructured states, RTO/ISOs use capacity markets to supplement energy markets by administratively defining the capability needs of the system and the value of various resources to provide this capability.

New technologies are rapidly changing the abilities of unconventional resources to provide resource adequacy, and even changing the economic designation of resource adequacy as a "common good." In particular, the proliferation of "smart grid" technologies enables the ability to isolate consequences of resource shortfalls to parties responsible for those shortfalls.[2] In other words, the ability to "privatize the commons" is emerging, with significant economic ramifications. The concurrent rise of dynamic production profiles of variable- and use-limited resources – especially wind, solar and energy storage – align far better with the dynamic capabilities of market paradigms for resource adequacy.

Given the advent of unconventional resources and "smart grid" technologies, this paper has several findings with implications for resource adequacy policy:

1. *Low marginal costs place greater emphasis on resource adequacy constructs*. In a market context, a greater proportion of suppliers' net revenues will come from shortage or capacity payments. This amplifies inefficiencies associated with design flaws in capacity markets and price formation flaws in energy markets.[3]

2. *The economic advantage of market-based resource adequacy mechanisms grows.* With conventional resources, a well-designed energy market should economically outperform a capacity market, followed distantly by IRP. These gaps widen with emergent, unconventional technologies.

3. *The economic advantage of market incentives over uniform standards grows.* "One-size-fits-all" resource adequacy is outdated and inefficient. Well-functioning markets reflect what customers are willing to pay for reliability and enable customers to express this willingness through dynamic participation in electricity markets. This requires revising some reliability standards that constrain the ability to enhance reliability incentives and differentiate reliability products.

4. *The North American Electric Reliability Corporation (NERC) is best suited as a technical resource on market design issues, rather than as an economic policy advisor.* Technical input from NERC should feed into resource adequacy policy (e.g., evaluating new technologies and reporting on reliability metrics), but NERC's perspective will not robustly account for economic efficiency. This is because NERC-led resource adequacy policy will be standards-heavy and, in many cases, inconsistent with market principles. Accordingly, reliability organizations such as NERC should consider the effects of new technologies on reliability standards in a manner that accommodates economically efficient curtailments of service.[4]

5. *Potential shortfalls of essential reliability services (ERSs) may justify dedicated market procurement mechanisms*. Market mechanisms will acquire a more efficient level of ERSs at lower cost and with better innovation incentives than a standards-driven approach. Of all market options, to pay for delivered service should lower costs compared to procuring differentiated, specialized forms of capacity.

6. *Evolving technology plays to the strengths of energy-only markets but, at the same time, exposes their vulnerability to any price formation deficiencies*. The dynamics of unconventional resources and the ability to privatize resource adequacy are ideally suited for the energy-only paradigm.

7. *Efficient energy price formation is critical for energy-only markets and beneficial for areas with capacity markets*. Capacity mechanisms should supplement, rather than substitute for measures to improve energy price formation.[5] To this end, the R Street Institute has laid out a series of current price formation priorities for the Federal Energy Regulatory Commission and Texas regulators to consider.[6]

8. *For regions committed to capacity planning, the advantage of using markets grows with the advent of emerging technologies*. Capacity markets have far greater potential than IRP to capture the temporal and spatial dimensions of resource adequacy and to provide superior incentives. Capacity planning must become more sophisticated to value diverse resources accurately, and should also consider flexibility provisions to enable broader adoption of differentiated reliability.

2. James Bushnell et al., "Capacity Markets at a Crossroads," *EI @ Hass WP* No. 278, April 2017, 52. https://sites.hks.harvard.edu/hepg/Papers/2017/WP278Updated.pdf.

3. For example, see Thomas Jenkin, et al., "Capacity Payments in Restructured Markets under Low and High Penetration Levels of Renewable Energy," National Renewable Energy Laboratory, February 2016. https://www.nrel.gov/docs/fy16osti/65491.pdf

4. Bushnell et al., 5. https://sites.hks.harvard.edu/hepg/Papers/2017/WP278Updated.pdf.

5. See, e.g., Michael Hogan, "Follow the missing money: Ensuring reliability at least cost to consumers in the transition to a low-carbon power system," *The Electricity Journal*, 30:1 (January-February 2017), 55-61. https://www.sciencedirect.com/science/article/pii/S1040619016302512.

6. Devin Hartman, "Refreshing Price Formation Policy in Wholesale Electricity Markets," *R Street Policy Study* No. 106, August 2017. http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2017/08/106.pdf.

Put simply, resource adequacy policy should adjust to reflect the evolving state of technology. The most valuable lesson is the growing advantage of market paradigms over monopoly utility IRP. Generally, the value of incentives over standards grows with a more diverse, dynamic suite of technologies that policymakers should leverage to empower consumer choice and unleash competitive forces.

THE ECONOMICS OF RESOURCE ADEQUACY

The reliability of electric service to end-use customers depends on the three physical stages of electricity production and delivery: sufficient aggregate supply to meet demand (generation "resource adequacy"), transmission reliability and distribution reliability.[7] The reliability of an electric system falls on a spectrum that is measurable in terms of the frequency or duration of curtailment of customer service. Blackouts are not uncommon. In recent decades, several major blackouts occurred each year, but they seldom result from insufficient generation.[8] One estimate found that insufficient generation caused 15% of major outages and a smaller percentage of all retail service outages.[9] Furthermore, resource inadequacy rarely results in extended outages (days or weeks) that cause major public health concerns or extensive economic damage. Extended outages more often result from physical damage to transmission and distribution (T&D) systems.

When an electric system lacks adequate generation resources in real-time, system operators take "controlled" actions to reduce demand. This maintains a continual supply-demand balance necessary to avoid uncontrolled loss of service. These controlled actions include public appeals for demand reduction and ceasing service to interruptible demand.[10] If this proves insufficient, operators will enact voltage reductions or "brownouts" and, as a last resort, enact "rotating blackouts," where loss of service rotates among areas, typically on 20-30 minute intervals.[11] A famous example of rotating blackouts occurred in the summer of 2000 in California. This differs from "cascading blackouts," where a series of uncontrolled losses of system elements results in unrestrained expansion of service interruption (as was the case in the Northeast blackouts of 1965 and 2003, and the Southwest blackout in 2011).[12]

Scarcity of electric supply is highly dynamic. The duration of supply shortages often spans a matter of minutes or hours. Transmission constraints can cause supply shortages on subsections of the grid, known as "import-constrained areas." These locational constraints sometimes occur at a granular level and fluctuate rapidly in real-time. As such, in practice, resource adequacy is a highly dynamic state across temporal and spatial dimensions.

The conventional concept of resource adequacy refers to having sufficient generation output to meet maximum demand. However, a more refined suite of generation services is necessary for grid reliability. This breaks down into two categories: frequency support and voltage support.[13] In order to maintain system reliability, operators must balance bulk supply and demand instantaneously within a tight frequency band.[14] Fluctuations in demand and unexpected losses of generation[15] create a need for flexibility in supply output in order to maintain system frequency. One such form of flexibility is "ramp," or the rate at which a generator adjusts its output.

Sufficient voltage control and system "stiffness" [16] is also critical for system reliability.[17] The ability to control production and absorption of reactive power provides voltage control.[18] The North American Electric Reliability Corporation (NERC) considers voltage control, frequency response and generation ramping as essential reliability services (ERSs).[19] Thus, electric systems must have a suite of capabilities to ensure resource adequacy, which may require revisiting its limited conventional definition.

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7. Johannes Pfeifenberger, "The Economics of Reliability And Resource Adequacy Planning," The Brattle Group, June 12, 2012, 2. http://www.brattle.com/system/publications/pdfs/000/004/447/original/The_Economics_of_Reliability_and_Resource_Adequacy_Planning_Pfeifenberger_June_12_2012.pdf?1378772106.

8. Lester B. Lave et. al., "Worst-case electricity scenarios: the benefits and costs of prevention," in *The Economic Costs and Consequences of Terrorism* ed. James Elliott Moore (Northampton, MA: Edward Elgar Publishing, Inc., 2007), pp. 257-60. https://books.google.com/books?hl=en&lr=&id=wXkAAgAAQBAJ&oi=fnd&pg=PA257&dq=morgan+apt+lave+%22worst+case+scenarios%22+power&ots=nKZJ87XyNk&sig=wM2u4_bpgdFFA2gGlDpeSKMFCo8#v=onepage&q=morgan%20apt%20lave%20%22worst%20case%20scenarios%22%20power&f=false.

9. Ibid.

10. In the latter scenario, customers agree to have their service curtailed in exchange for compensation

11. "Understanding the Grid," North American Electric Reliability Corporation, August 2013, 2. http://www.nerc.com/news/Documents/Understanding%20the%20Grid%20DEC12.pdf.

12. Ibid.

13. "Essential Reliability Services," North American Electric Reliability Corporation, December 2016, vi. http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSWG_Sufficiency_Guideline_Report.pdf.

14. The domestic frequency target is 60 hertz. Excess or insufficient frequency levels can result in collapse of the transmission grid.

15. e.g., when power plants "trip" offline

16. Controlling voltage is necessary to protect an electric system and move power.

17. "Essential Reliability Services," vi. http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSWG_Sufficiency_Guideline_Report.pdf.

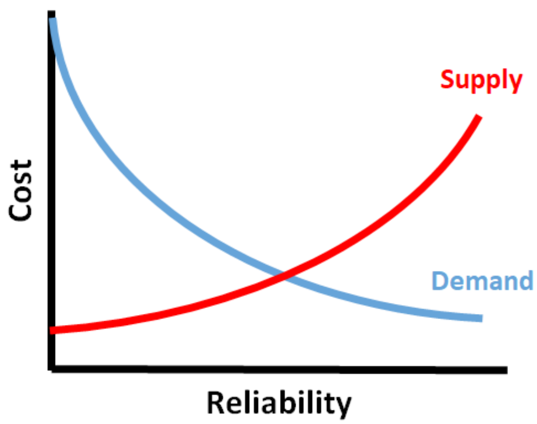
18. "NERC White Paper on FERC NOPR [Docket No. RM16-1-000]," North American Electric Reliability Corporation, 1. http://www.nerc.com/comm/PC/System%20Analysis%20and%20Modeling%20Subcommittee%20SAMS%20201/NERC%20Position%20on%20FERC%20NOPR%20for%20Reactive%20Power%20Capability%20-%20FINAL%20-%20EXTERNAL.pdf.

19. "Essential Reliability Services," iv-v. http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSWG_Sufficiency_Guideline_Report.pdf.

Benefits and costs of electric reliability

As a subset of electric reliability, the economics of resource adequacy stem from a broader characterization of the benefits and costs thereof. On the spectrum, incremental benefits diminish while both costs and reliability increase (Figure 1). Thus, an economic framing of electric reliability recognizes that the optimal level of reliable service maximizes the benefits less the costs. In other words, electricity policy should seek the "Goldilocks standard"– not too little, but not too much – by focusing on whether a system is *efficiently* reliable.[20]

FIGURE 1: BENEFITS AND COSTS OF ELECTRIC RELIABILITY



One way to quantify the benefits of reliability uses the value of lost load (VOLL), which represents a customer's willingness to pay for reliable electricity service—a point on which consumers vary.[21] As such, VOLL depends on numerous factors, including customer class (e.g., industrial, commercial or residential) and the specific nature of the economic activity. For example, a residential customer may be willing to postpone power access to certain appliances but not home lighting. Similarly, the sensitivity of industrial processes to damage from power outages varies considerably, causing differences in VOLL by production activity.

VOLL also varies based on the time and duration of a power outage. For example, retail stores are more concerned about outages during business hours and grocery stores are more concerned about extended outages that may spoil food. Accordingly, some industrial customers place a high value on the avoidance of outages, but low value on the restoration of service (because equipment damage is not repairable in the short-term). The opposite case applies in a public health context, where short outages create inconveniences but multi-day ones can create life-threatening circumstances. VOLL also changes over time and varies by location because of differences in customer class proportions, demographics and economic conditions.

Opportunities to improve electric reliability are virtually endless but increase costs considerably. Ideally, an economic system would weigh disparate consumer preferences with the costs. Thus, the improvement of electric reliability requires trade-offs in electricity system operations and investments, like, for example, deciding whether to pay a steep premium to bury distribution lines in order to improve service reliability. Similarly, improvements in resource adequacy come from the expansion of generation reserves and from undertaking dozens of measures to improve the performance of power plants. However, all of this also elevates costs. Further, costs related to reliable service vary by location and with the state of technology. As such, the cost and benefit dynamics of electric reliability indicate that the optimal reliability level of a system should fluctuate over time.

Economic framing of resource adequacy

Historically, resource adequacy was non-excludable, which meant that suppliers could not limit receipt of their product to those parties that pay for it. In the event a shortage exists, prevailing protocol posits that grid operators indiscriminately cut service to customers regardless of their contributions to resource adequacy. This policy of inducing random outages is predicated on the notion that it is impossible to identify and implement the reliability preferences of customers.[22]

As with other non-excludable, or "common goods," this creates an incentive for market participants to "free ride" the resource adequacy contributions of other participants. The result is that private actors underprovide the service.[23] Such a condition forms the basis for treating resource adequacy as a pooled resource, where participants share equally in benefits and costs. This is accomplished through the enactment of compulsory resource adequacy mechanisms that ensure sufficient resource procurement.

RESOURCE ADEQUACY PARADIGMS

The Federal Energy Regulatory Commission (FERC) and the states share authority for electric reliability. FERC certified the North American Electric Reliability Corporation (NERC) as the organization in charge of enforcing mandatory reli-

20. Historically, many electricity systems had excess resources (i.e., beyond "adequate"), where the costs of excess exceeded the benefits.

21. Typically measured in dollars per megawatt hour ($/MWh). For example, see "Estimating the Value of Lost Load: Briefing paper prepared for the Electric Reliability Council of Texas, Inc.," London Economics International LLC, June 17, 2013. http://www.ercot.com/content/gridinfo/resource/2014/mktanalysis/ERCOT_ValueofLost-Load_LiteratureReviewandMacroeconomic.pdf.

22. Bushnell et al., 52. https://sites.hks.harvard.edu/hepg/Papers/2017/WP278Updated.pdf.

23. Devin Hartman, "Wholesale Electricity Markets in the Technological Age," *R Street Policy Study* No. 67, August 2016, 6. https://www.rstreet.org/wp-content/uploads/2016/08/67.pdf.

ability standards for the bulk power system (i.e., generation needed to maintain transmission system reliability). Neither NERC nor FERC have direct authority over resource adequacy, as they cannot order construction of generation or transmission facilities.[24] Instead, FERC uses its authority over the rules of wholesale electricity markets to shape resource adequacy mechanisms, thereby indirectly driving generation investment. FERC primarily promotes robust resource adequacy mechanisms in regions where states have liberalized their electricity system, whereas states that retained regulation of monopoly utilities directly oversee resource investment.

Resource adequacy policy differs markedly between states that retain monopoly regulation and those that adopted competitive electricity markets. Regulated states require monopoly utilities to procure resources on behalf of customers, typically through a cost-minimizing process known as integrated resource planning (IRP), in which utilities invest in resources approved by regulators and earn a guaranteed rate of return. In deregulated or "restructured" states, load-serving entities (LSEs) buy power on the wholesale transmission market and resell it to end-use consumers, who have the option to choose their power supplier. Competitive "merchant" resource owners decide to retire existing resources or build new ones based instead on expected returns from net revenues in the wholesale market.[25]

All competitive wholesale markets operated by regional transmission organizations or independent system operators (RTO/ISOs) employ energy and ancillary service markets. These short-term markets reflect the marginal cost of system operations at granular locational levels and short time intervals. They provide incentives for long-term resource investment (retirement or new entry) by providing a basis for forward price expectations.

The revenues from marginal cost pricing are not sufficient to cover the costs of resources at a level approximating the aggregate VOLL. If customers could reflect their willingness to pay for resource adequacy and suppliers could avoid the free-rider problem, the demand curve for electricity would trigger prices that exceed marginal cost and incentivize sufficient supply investment. Accordingly, customers' bids would reflect their unique VOLL and would form a continuous demand curve, which would result in an accurate long-run equilibrium price that signals the optimal level of supply investment. Currently, however, this is not the case, and instead policy interventions compensate for the "common good" dilemma of resource adequacy through market design.

24. Steve N. Isser, "Generation Investment and Resource Adequacy in Electricity Markets," SSRN, November 13, 2015, 3. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2690408.

25. This includes revenues from the "organized markets," primarily energy and capacity markets, as well as bilateral arrangements.

Resource adequacy mechanisms

To ensure resource adequacy, wholesale electricity markets rely on the "invisible hand" of market design to allow the "visible hand" of the market to function. Specifically, market design sets the rules for how markets operate and participants interact.[26] The primary market design principle is incentive compatibility, whereby market rules "coordinate the economic interests of diverse market participants with the reliable and efficient performance of the shared system."[27] With proper incentives, merchants pursue creative ways to provide reliability services when and where they are needed and in a lower-cost manner than monopoly utilities.

Competitive electricity markets employ two forms of resource adequacy mechanisms: shortage or "scarcity" pricing and capacity markets. The Electric Reliability Council of Texas (ERCOT) relies on shortage pricing exclusively, which is known as the "energy-only" paradigm. This mechanism sends real-time price signals above marginal cost when there is a system-wide shortage of power reserves.

Capacity markets, on the other hand, supplement the price signals sent by energy and ancillary service markets. This mechanism procures a set amount of resources to meet future demand. All of the restructured states, except for most of Texas, participate in RTO/ISOs that operate capacity markets.

Energy-only paradigm

Shortage pricing uses an administrative estimate to represent consumers' willingness to pay for electric service. Typically, this is set at average VOLL. While this fails to recognize the variance in VOLL among customers and economic activities, it constrains administrative judgement to represent consumer interests based on a valid economic concept. If implemented correctly, an energy-only approach should procure an optimal level of resources that balances average resource adequacy benefits and costs.

Well-designed energy-only markets accurately reflect the highly dynamic nature of resource adequacy across temporal and spatial dimensions. This is because they provide price signals commensurate with the duration of scarcity events on the system. Those with refined locational pricing can also send granular price signals for investment that accurately reflect transmission constraints. Altogether, this avoids the need for administrative assumptions about the duration and

26. Devin Hartman, "Disciplined Policy Responses to Nuclear Retirements," *R Street Policy Study* No. 84, February 2017, 4. http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2017/02/84.pdf.

27. Michael Giberson, "Integrating Reliability-Must-Run Practices into Wholesale Electricity Markets," *R Street Policy Study* No. 114, October 2017, 1. http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2017/10/114.pdf.

locational value of resources, which minimizes the costs of resource adequacy.

A major challenge for the implementation of energy-only markets are reliability standards intended to prevent scarcity.[28] A problem arises when prices do not reflect underlying economic fundamentals, including marginal costs and resource scarcity. RTO/ISO pricing models do not fully represent all physical properties of the bulk electric system and thus in an effort to maintain supply-demand balance, RTO/ISO market administrators occasionally dispatch the electricity system in an "out-of-market" manner.[29] As such, if energy-only markets artificially suppress price formation, resource investment may fall below the optimal level.

Capacity markets

Historically, central planners used engineering criteria for resource investments irrespective of economic considerations.[30] The most prominent standard is the "one day in ten years" resource adequacy criterion, under which involuntary curtailments to customers should not occur more than once every ten years.[31] However, this level is arbitrary and is arrived at without respect for VOLL.[32] Accordingly, this formed the basis for mandatory capacity obligations, a staple of electric planning under monopoly regulation.[33] Capacity markets provide a more flexible version of this standards-driven legacy.

In effect, capacity planning is capability planning. This means central planners must define what resource capabilities they need to meet future demand, and traditionally this has meant securing enough supply to meet maximum summer demand. Capacity planning requires extensive administrative judgment around a variety of planning parameters, including eligibility requirements for resources, capacity value of resources, the definition of firm (dependable) capacity, expected demand and transmission constraints and assumptions about the reserve level needed. Overly restrictive or inaccurate assumptions can create artificial barriers to entry and inaccurate compensation for resources as compared to energy-only markets.

Unlike with energy, there is no simple way to measure and observe delivery of a forward capacity product.[34] Such a lack of delivery verification can create performance incentive challenges, as conventional capacity markets compensate for ability but lack an incentive for actual delivery. Recent efforts to peg capacity payments to resource performance in the Mid-Atlantic and New England capacity markets rectify much of this missing incentive, but do so inefficiently. Energy-only markets remain the "economic gold-standard for performance and investment-quality incentives."[35]

While capacity planning has clear limitations, capacity markets have numerous inherent advantages over IRP. IRP attempts to simulate its share of regional resource adequacy requirements, which creates opportunities for error. Further, it leaves some regional issues unaddressed, such as regional transmission constraints that affect locational resource adequacy needs. This is why the aggregated parameters of utility IRPs are less accurate representations of regional resource adequacy needs than those of capacity markets.

Further, IRP represents the cost and capacity value of resources less accurately as compared to a capacity market. For example, IRP makes assumptions about the cost of buying power from third parties, whereas markets facilitate transactions based on actual costs. Markets more accurately determine the capacity value of resources, which vary by location, technology, configuration and other conditions. This is because IRP makes simplistic assumptions about a technology class that misrepresent variations within that class or siting characteristics that affect its capacity value.

Capacity markets also enable a wider range of resource participation than IRP, including innovative technologies.[36] This is because IRP only considers a modest number of potential resources, as informational and modeling limitations constrain the ability to represent all eligible resources in the selection process. The ability of capacity markets to facilitate a wider range of resources results in greater innovation in low-cost supplies.[37]

Perhaps most importantly, merchants have strong incentives to reduce costs, whereas monopoly utility regulation motivates the accumulation of capital costs with indifference to operating costs. This, in turn, influences monopoly utility

28. Bushnell et al., 12. https://sites.hks.harvard.edu/hepg/Papers/2017/WP278Updated.pdf.

29. "Refreshing Price Formation Policy in Wholesale Electricity Markets," 3. http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2017/08/106.pdf.

30. Isser, 8. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2690408.

31. Ibid.

32. Ibid.

33. William W. Hogan, "Electricity Scarcity Pricing Through Operating Reserves," April 25, 2013, 3. https://sites.hks.harvard.edu/fs/whogan/Hogan_ORDC_042513.pdf.

34. Ibid, 4.

35. Peter Cramton and Steven Stoft, "The Convergence of Market Designs for Adequate Generating Capacity," Electricity Oversight Board, Apr. 25, 2006, 18. https://drum.lib.umd.edu/bitstream/handle/1903/7056/cramton-stoft-market-design-for-resource-adequacy.pdf?sequence=1&isAllowed=y.

36. Johannes P. Pfeifenberger et. al., "Response to U.S. Senators' Capacity Market Questions," The Brattle Group, May 5, 2016., 13. http://www.brattle.com/system/news/pdfs/000/001/055/original/Brattle_Open_Letter_to_GAO_-_Response_to_U.S._Senators%E2%80%99_Capacity_Market_Questions.pdf?1462477158.

37. Ibid.

inputs into the IRP process—a bias that regulators often fail to correct given the large information asymmetry between utilities and other parties. Recent evidence has made clear that the expectations of utility planners and their regulators do not match those of the market.[38] Furthermore, in some cases, regulators approve utility resource investments for political purposes and abandon IRP principles.

Given such information asymmetries and political motivations, monopoly regulation serves as a greater conduit for government failure than market-based resource adequacy paradigms. Markets remove politics from resource decisions, but the complexity of their design introduces opportunities for government failure. Between market-based resource adequacy paradigms, the complexities of capacity markets likely leave the construct more vulnerable than energy-only markets—both to uneconomical tinkering in RTO/ISO stakeholder development processes and to regulatory error.

TECHNOLOGICAL DISRUPTION

A variety of technological advances has altered the economic characteristics of resource adequacy. Some of these stem from incremental improvements to conventional technology, such as more efficient natural gas-fired turbines. Improved cost and performance abilities for unconventional resources has greatly shifted the landscape, especially of use-limited resources (e.g., energy storage) and variable energy resources (e.g., wind and solar). Advances in "smart grid" technologies and digital customer platforms have potentially transformative implications for demand participation in resource adequacy constructs.

Minimum reliability level

Inexpensive natural gas generation and the improvement of economics and policy support for variable energy resources continue to place downward pressure on marginal costs. To the extent that this continues on fixed costs, resource adequacy constructs will become more influential in driving resource investment decisions. In other words, resources will become more dependent on revenues from shortage pricing and capacity payments.

Rising fixed-cost intensity has reinvigorated arguments that markets will fail to support adequate investment.[39] However, unless performance incentives fail, these concerns are unfounded in capacity markets, which is not evident based on independent market analyses and recent NERC reliability metrics.[40] But, in multiple RTO/ISOs, generators that operate rarely during peak demand periods already recover most of their costs from shortage and/or capacity payments.[41]

Regulated monopoly and capacity market regions have consistently met or exceeded resource adequacy standards.[42] Energy-only markets provide no such guarantee. For example, formerly a capacity-long system, ERCOT recently had over 4,500 megawatts of generation capacity announce retirement. In view of this and based on the "one-day-in-10-years" standard, the independent market monitor expects its generation reserves to fall below its resource reserve target.[43] The resulting reserve margin will likely be closer to the economically efficient level than to the reserve target.[44] Nevertheless, this could cause a violation of NERC standards and subsequent penalties, despite the monitor and an economist on ERCOT's board expressing optimism that this would signal entry of new resources.[45] Indeed, forward prices have risen since the retirement announcements, but market design flaws may depress prices below the efficient level to signal new entry until price formation reforms emerge.[46]

All resource adequacy paradigms have proven capable of supporting resource investment and RTO/ISOs and NERC have strong powers and incentives to ensure resource adequacy. Associated policy questions are therefore about the relative economic efficiency of resource investments and performance.[47]

38. Ibid, 12.

39. See, e.g., Robert Walton, "'Can't be half-pregnant': Power market upheavals prompt states, fed to take action," *UtilityDive*, March 8, 2017. https://www.utilitydive.com/news/cant-be-half-pregnant-power-market-upheavals-prompt-states-feds-to-tak/437362.

40. See, e.g., *State of Reliability: 2017*, North American Electric Reliability Corporation, June 2017. http://www.nerc.com/pa/RAPA/PA/Performance Analysis DL/SOR_2017_MASTER_20170613.pdf.

41. For example, see net revenues for peaking generators in ERCOT and PJM; or "Comments of the Independent Market Monitor for PJM to the Federal Energy Regulatory Commission," Docket No. RM17-3-000, February 18, 2017, 5. http://www.monitoringanalytics.com/reports/Reports/2017/IMM_Comments_RM17-3_20170228.pdf.

42. "Response to U.S. Senators' Capacity Market Questions," 9. http://www.brattle.com/system/news/pdfs/000/001/055/original/Brattle_Open_Letter_to_GAO_-_Response_to_U.S._Senators%E2%80%99_Capacity_Market_Questions.pdf?1462477158.

43. Mark Watson, "ERCOT reserve margins likely to dip below target: IMM," Platts, Oct. 17, 2017. https://www.platts.com/latest-news/electric-power/houston/ercot-reserve-margins-likely-to-dip-below-target-21279598.

44. The reserve target for the "one-day-in-ten-years" standard is 13.75%, but a report by the Brattle Group suggests the economically optimal margin is about 10%. See Samuel A. Newell and Kathleen Spees et al., "Estimating the Economically Optimal Reserve Margin in ERCOT," The Brattle Group, January 31, 2014, vi. http://www.brattle.com/system/news/pdfs/000/000/613/original/Estimating_the_Economically_Optimal_Reserve_Margin_in_ERCOT.pdf?1391445083.

45. Mark Watson and Eric Wieser, "Analysis: Fines likely if ERCOT retirements result in blackouts," Platts, Oct. 30, 2017. https://www.platts.com/latest-news/electric-power/houston/analysis-fines-likely-if-ercot-retirements-result-21395187.

46. For an insightful report outlining price formation flaws in ERCOT see, William Hogan and Susan Pope, "Priorities for the Evolution of an Energy-Only Electricity Market Design in ERCOT," FTI Consulting, Inc., May 9, 2017. https://sites.hks.harvard.edu/fs/whogan/Hogan_Pope_ERCOT_050917.pdf.

47. Bushnell et al., 3. https://sites.hks.harvard.edu/hepg/Papers/2017/WP278Updated.pdf.

Differentiated reliability

The proliferation of emerging "smart grid" technologies enables the ability to isolate the consequences of resource shortfalls to the parties responsible.[48] In particular, advances in smart metering, sensors and monitoring allow RTO/ISOs to distinguish the supply contributions and usage of individual control areas and perhaps retailers.[49] This provides transformative potential to avoid the free-rider problem and ceases to treat resource adequacy as a "common good."

Accompanying this are advances in digital technology that lower the cost of active demand participation in wholesale markets. Previously, the cost of acquiring equipment and the transactions costs of market engagement limited levels of price-responsive demand. Accordingly, early movers of demand management have been those with the most to gain – namely large, sophisticated consumers.[50] As cost and performance advances in energy management automation continue alongside emerging digital services, the drastic reduction in transaction costs unleashes potential for price responsive demand beyond this smaller group. Expanding price-responsive demand would improve market performance under all system conditions, but especially during peak demand periods.[51]

As smart grid technologies proliferate, they create the potential for flexible resource adequacy constructs to accommodate the diversity of customer VOLL preferences. Flexible approaches at the wholesale level would unleash the potential for differentiated reliability products at the retail level. For example, consumers could sign contracts with their LSE stating their maximum willingness to pay for differing tranches of firm power[52] and thus retail products could account for a customers' usage-specific preferences. In other words, the smart meter would disconnect specified appliances at different price points. Such automatic energy management means customer transaction costs are limited to setup and do not require the manual interfacing with real-time markets that previously proved prohibitive for most customers.

Currently, such potential is highly constrained by uniform resource adequacy standards for capacity. However, a "one-size-fits-all" approach reduces the scope of innovation for retail services and may have contributed to the lack of innovation observed in the retail market to date.[53] To enable greater flexibility in resource adequacy standards is necessary to accommodate variances in customer VOLL. Several pathways exist to accomplish this, all of which replace collective choice with individual choice, although to varying degrees.

Thus, "privatizing the commons" of resource adequacy could take various forms. Migrating to voluntary capacity markets would place responsibility on LSEs to procure sufficient capacity. RTO/ISOs would first need a system to apportion consequences for resource shortfalls, which may require revisiting the notion of non-discriminatory service. If coupled with sufficient shortage pricing and other price formation reforms, increased reliance on energy scarcity signals could lead to the phase-out of capacity markets.

The energy-only paradigm is more amenable to differentiated reliability. Eventually, enabling the ability for wholesale demand bids to reflect their VOLL and set the market price would mark the ability to move beyond administrative shortage pricing. Under either paradigm, a transition to privatized resource adequacy would take years and incremental capacity market reforms would have pronounced benefit.

Capacity market reforms

The growth of variable- and use-limited resources makes it increasingly challenging for central planners to define capacity products for resource adequacy and assign capacity value to unconventional resources. The discord stems from the static nature of administrative assumptions in capacity planning, as compared to dynamic system needs and resource attributes. Capacity markets outperform utility IRP in these regards, but fall short of energy markets in capturing all temporal and spatial dimensions of resource adequacy.

Capacity planning assigns a capacity value or "capacity credit" to a resource based on its expected contribution to resource adequacy. The capability of unconventional resources to contribute to resource adequacy varies immensely, even within the same technology class. Further, the capacity value of weather dependent resources, like wind and solar, varies substantially by location, in-kind resource penetration,[54] sub-class of technology and configuration.[55] For example, one study found that the capacity value of

48. Ibid, 52.

49. Ibid.

50. For example, see Galen Barbose et. al., "A Survey of Utility Experience With Real Time Pricing," Lawrence Berkeley National Laboratory, December 2004, 23. https://eetd.lbl.gov/sites/all/files/publications/report-lbnl-54238.pdf.

51. Devin Hartman, "Pathways to Competition in Demand Response," *R Street Shorts* No. 30, July 2016, 1. http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2016/07/RSTREETSHORT30.pdf.

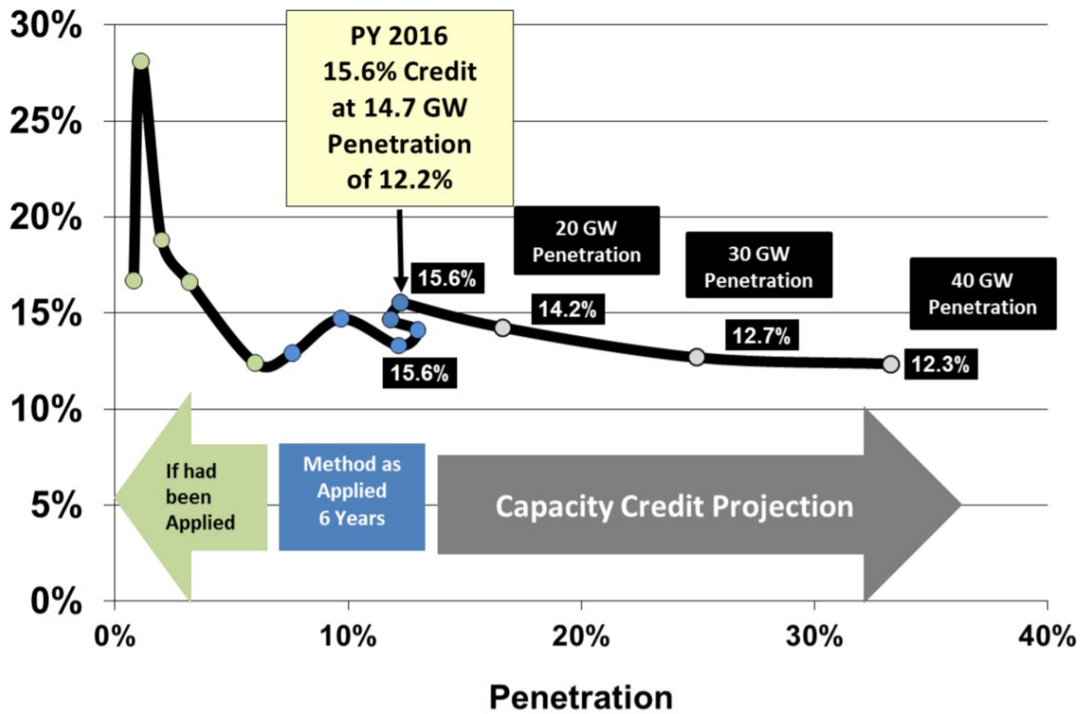
52. David Newbery, "Missing Money and Missing Markets: Reliability, Capacity Auctions, and Interconnectors," Symposium on Energy Markets and Sustainability, February 3, 2015, 7. http://www.eprg.group.cam.ac.uk/wp-content/uploads/2015/03/1508_updated-July-20151.pdf.

53. Bushnell et al., 54. https://sites.hks.harvard.edu/hepg/Papers/2017/WP278Updated.pdf.

54. For example, the amount of wind or solar on a system affects the capacity value of a new wind or solar project because their output correlates because of a common, weather-dependent fuel source.

55. For example, the direction a solar panel faces affects its production profile during peak demand periods.

FIGURE 2. MISO WIND CAPACITY CREDIT



Source: Midcontinent Independent System Operator[1]

concentrated solar power ranged between 45%-90% of its maximum output potential.[56] Furthermore, major uncertainties exist about the appropriate methodologies for capacity accreditation.[57] In particular, experts emphasize that capacity accreditation that reflects a resource's marginal value becomes increasingly important as penetration levels of variable resources grow.[58]

Increasing variances in these variables make capacity planning extremely difficult, which leads to "representative" estimates of a resource to determine its capacity value. Extensive opportunities for error in capacity accreditation exacerbate their underlying shortcomings. Namely, inaccurate capacity credits can distort investment between renewables and non-renewables but also among different locations and types of renewables.[59]

IRP makes very simplistic, static assumptions about a "representative" capacity resource for a given technology and usually applies this to new and existing resources. Capacity markets often use this approach for new resources but adjust the value for actual performance after several years. Capacity markets also use a more refined representative unit based on sub-regional production patterns. In contrast, IRP typically uses a uniform value by location and over time. Capacity markets use a methodology that provides a basis to project future capacity value, which sends a more accurate signal to investors. For example, the Midcontinent Independent System Operator (MISO) assigns a wind capacity credit value for ten zones based on the penetration level of wind, which market participants can project over time (Figure 2).[60]

56. Seyed Hossein Madaeni et. al., "Capacity Value of Concentrating Solar Power Plants," National Renewable Energy Laboratory, June 2011, 5. https://www.nrel.gov/docs/fy11osti/51253.pdf.

57. In particular, perspectives on the optimal use of the Effective Load Carrying Capability (ELCC) method differ. Different methods have resulted in a wide range of capacity credit values. See, e.g., Johannes Pfeifenberger and Kathleen Spees, "Characteristics of Successful Capacity Markets," The Brattle Group, October 13, 2013, 22. http://www.brattle.com/system/publications/pdfs/000/004/951/original/Characteristics_of_Successful_Capacity_Markets_Pfeifenberger_Spees_Oct_2013.pdf?1383246105.

58. Ira Shavel et al., "Diversity of Reliability Attributes: A Key Component of the Modern Grid," The Brattle Group, May 17, 2017, 10. https://sites.hks.harvard.edu/hepg/Papers/2017/Brattle_20170517-API-Diversity-of-Attributes.pdf.

59. Cynthia Bothwell and Benjamin F. Hobbs, "Crediting Renewables in Electricity Capacity Markets: The Effects of Alternative Definitions upon Market Efficiency," Johns Hopkins University, June 2016, 1. https://www.caiso.com/Documents/Brief-ingonRegionalResourceAdequacyInitiative-MSCBothwellHobbs_WorkingPaper-June2016.pdf.

60. "Planning Year 2016-2017 Wind Capacity Credit," Midcontinent Independent System Operator December 2015, 4. https://www.misoenergy.org/Library/Repository/Report/2016%20Wind%20Capacity%20Report.pdf.

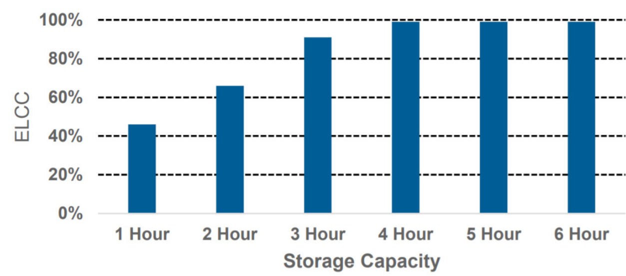
The challenges of capacity accreditation raise a larger concern with the definition of capacity products. This largely stems from poor representation of the temporal dynamics of resource adequacy and the time-varying contributions of unconventional resources. The traditional approach to capacity planning procured an annual capacity product to meet summer needs only. This was less problematic for conventional resources, most of which provide services fairly consistently year-round. But this poorly aligns with the time profile of unconventional resources and causes over-accreditation of resources that perform well in summer and poorly in other months, as well as under-accreditation of those with a reverse seasonal performance profile. As such, in an era of competitive unconventional resources, the standard capacity product will become increasingly unrepresentative of the economic characteristics of resource adequacy. Capacity markets have more potential than IRP processes to accurately redefine the temporal capacity needs of the system.

One temporal adjustment that is currently attracting considerable attention is to account for seasonal variability in resource adequacy needs and resource production profiles. One approach is to segment annual capacity markets. This carves-out an administratively defined limit for seasonally-variable products, such as summer demand response resources—like, for example, the off-and-on cycling of air conditioning units. Several capacity market iterations in the PJM Interconnection demonstrate the challenge – and benefit – of capturing the value of summer-only demand response.[61]

Other areas, like MISO, have considered moving entirely to seasonal capacity products to more accurately represent all resources and system needs. This may prove valuable as the economics of resource adequacy become more seasonally sensitive. Even conventional resources like hydroelectric and natural gas power plants have demonstrated seasonal variation in output capability costs. For example, some gas plants incur large expenses to "firm" fuel supply during peak winter demand periods. Since summer demand exceeds winter demand, some of these resources do not need to incur this expense for the system to maintain sufficient generation reserves. This highlights the cost of defining a capacity product as a year-round, continuous product that results in over-procurement in non-summer months. Variable resources typically show even greater seasonality in output capability, indicating that a seasonal capacity construct would result in very different capacity credit valuations for the same resource across seasons.[62]

Capacity values also vary on a timeframe much shorter than seasons. Since many resource shortages span a matter of minutes or hours, use-limited resources with output durations of minutes to hours may offer considerable capacity value that some capacity product definitions ignore. The most difficult case is energy storage, which has an immense diversity of technologies with use-limitations ranging from minutes to days. Recent research suggests energy storage devices with three hours of storage may qualify for capacity credit comparable to conventional power plants (around 90% of installed capacity), while one with four or more hours may achieve nearly 100% capacity value (Figure 3).[63] Resources with less than three hours still hold substantial, although rapidly diminishing capacity value.[64]

FIGURE 3: CAPACITY VALUE OF STORAGE AS A FUNCTION OF STORED ENERGY



Source: ICF International

Given the sensitivities to regional resource adequacy dynamics, the varying degrees of capacity value for use-limited resources are more difficult to estimate accurately under IRP. This puts capacity markets at a decided advantage, however, current market designs preclude or heavily undervalue many forms of energy storage. As such, market design improvements have considerable value as energy storage becomes more economical. Still, accurate capacity valuation of use-limited resources has limitations, whereas energy markets have a far superior structure to represent the temporal value of short-term scarcity.

Essential reliability services

As the fuel and technology mix of electricity systems evolves, NERC has monitored and reported on changes in ERSs. They note the well-documented behavior of conventional generators, but indicate that newer technologies offer different

61. This includes a series of proposed and enacted capacity market design changes with respect to summer demand response prior to and after capacity performance reforms.

62. This assumes the capacity market has strong performance incentives, which is the case in PJM and ISO-NE.

63. Harjeet Johal et al., "Unlocking the Hidden (Capacity) Value in Energy Storage," ICF International, 2016, 8-9. https://www.icf.com/-/media/files/icf/white-papers/2016/unlocking-the-hidden-capacity-2016.pdf.

64. Ibid.

reliability characteristics that are not as well documented.[65] Conventional generators provided most ERSs as a by-product in sufficient quantities to meet reliability standards and thus avoided the need for dedicated procurement mechanisms. However, some new technologies do not possess all these capabilities, which could result in the shortfall of some ERSs. If current market design does not compensate all necessary reliability services, incomplete markets result.

To remedy incomplete markets, an invocation of the incentive compatibility principle indicates that a product should exist for each scarce, discrete reliability service.[66] In theory, the most efficient approach is to compensate based on delivered service (i.e., an extended version of the energy-only paradigm). In some cases, fixing flaws in energy markets may remedy compensation for some ERSs without creating a new product. For example, the adjustment and alignment of energy dispatch and settlement intervals may avoid the need to create a ramp product. On the other hand, some evidence suggests a ramp capability product integrated with energy and conventional ancillary service markets may address ramping needs more efficiently.[67]

An alternative market approach is to procure the forward capacity to provide an ERS. This method could apportion capacity markets into tranches based on the defined resource capabilities needed.[68] However, capacity mechanisms for ERSs pose serious conceptual and practical challenges.[69] To procure resource flexibility characteristics like ramp capability, the most prominent case is California's Flexible Resource Adequacy Criteria and Must-Offer Obligation (FRAC-MOO). The product has proven difficult to operationalize as resource flexibility attributes like ramp rate, start/stop rate, dispatch range, ramp duration and others make the creation of a single flexibility product impossible.[70] While capacity markets have far greater potential to procure ERS capability than IRP processes, the complexity in defining ERS capabilities and implementation challenges suggest improvements to energy and ancillary service markets should take priority.

Irrespective of market design, the least efficient way to procure ERS is through uniform standards and this particular issue has surfaced in a major ERS policy decision currently pending before FERC on primary frequency response (PFR). Potential NERC-identified shortcomings in PFR led FERC to issue a notice of proposed rulemaking (NOPR) in November 2016.[71] The NOPR would require all new interconnecting generators to provide PFR capability.[72] NERC supports the NOPR.[73] In a FERC filing, the R Street Institute noted the reasons why this mandate would likely result in higher costs compared to the creation of a market product. These included:

1. At least initial, over-procurement of PFR capability;
2. Cost-inefficient procurement of PFR capability;
3. Diminished incentives to innovate;
4. Preclusion of demand-side resources; and
5. Deterrence of co-optimized investment.[74]

This also provides a case-in-point for the appropriate role of NERC. NERC provides excellent technical insight into current reliability trends and implications of resource changes. This is vital input to market design conversations. However, NERC is not charged with the role of evaluating market efficiency, as is the case with independent market monitors. As indicated by their charge and various statements,[75] a NERC-led approach to resource adequacy policy will be standards-heavy and in many cases inconsistent with the incentive compatibility principle. For these reasons, on market design issues, NERC is best suited as a technical resource, rather than as an economic policy advisor.

While NERC identified three primary ERSs, a broader examination of resource adequacy attributes has merit.[76] If current market design does not support all relevant attributes, an exercise in operationalizing these in distinct ser-

65. "Essential Reliability Services," iv. http://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSWG_Sufficiency_Guideline_Report.pdf.

66. This holds true if the resource efficiency benefits of a market product outweigh the implementation costs.

67. See various reports from Potomac Economics on MISO's ramp capability product on price levels and volatility.

68. Mike Hogan, "What Lies "Beyond Capacity Markets?", Regulatory Assistance Project, 13. http://www.raponline.org/wp-content/uploads/2016/05/rap-hogan-whatliesbeyondcapacitymarkets-2012-aug-14.pdf.

69. For e.g., see James Bushnell et. al., "Opinion on Flexible Resource Adequacy Criteria and Must-Offer Obligation," Market Surveillance Committee of the California ISO, March 11, 2014, 17. https://www.caiso.com/Documents/FinalOpinion-FlexibleResourceAdequacyCriteriaMustOfferObligation.pdf.

70. Benjamin F. Hobbs, "Dealing with Variability & Uncertainty in Electricity Markets," IAEE North American Meeting, November 15, 2017, 13. http://www.usaee.org/usaee2017/submissions/presentations/Hobbs_USAEE17.pdf.

71. Federal Energy Regulatory Commission, *Essential Reliability Services and the Evolving Bulk-Power System – Primary Frequency Response*, Notice of Proposed Rulemaking, Docket No. RM16-6-000, November 17, 2016. https://www.ferc.gov/whats-new/comm-meet/2016/111716/E-3.pdf.

72. Ibid, p. 1.

73. "Comments of the North American Electric Reliability Corporation in Response to Notice of Proposed Rulemaking," Docket No. RM16-6-000, January 24, 2017, 11. http://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Frequency%20Response%20NOPR%20Comments.pdf.

74. "Comments of the R Street Institute," Docket No. RM16-6-000, February 1, 2017, 3-4. http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2017/02/PFR-Comments-FINAL.pdf.

75. For press statements and Congressional testimony of NERC officials emphasizing that all new resources should have the capability to support reliability services comparable to conventional generators, see, e.g., Gavin Bade, "Baseload compensation a high priority for FERC Chatterjee tells Congress," *UtilityDive*, Sept. 15, 2017. https://www.utilitydive.com/news/baseload-compensation-a-high-priority-for-ferc-chatterjee-tells-congress/505031.

76. For example, see Shavel et. al. https://sites.hks.harvard.edu/hepg/Papers/2017/Brattle_20170517-API-Diversity-of-Attributes.pdf.

TABLE I: RELATIVE ECONOMIC ATTRIBUTES OF RESOURCE ADEQUACY PARADIGMS

	Energy-only	Capacity Markets	Monopoly IRP
Reliability optimization	Best suited to account for dynamic costs and VOLL. Some error tied to average VOLL assumption in shortage pricing.	Achieves lower costs than IRP. Based on standards inconsistent with VOLL, which can be modestly mitigated by sloped demand curves.	Based on standards inconsistent with VOLL. Higher cost than capacity markets.
Demand participation	Strong, efficient price-responsive demand incentives.	Some incentives and artificial constraints on demand-side participation.	Only permits administratively determined demand preferences.
Spatial resource valuation	Potential for granular, accurate price signals.	Capacity zones capable of moderately accurate representation of chronic transmission constraints.	Does not reflect locational value of resource adequacy.
Temporal resource valuation	Provides granular, accurate price signals.	Potential to represent seasonal needs well, but poorly for shorter periods.	Poorly represents the timing of resource valuation.
Unintentional barriers to entry for unconventional technologies	Few restrictions.	Imposes some barriers to entry and mild-to-moderate resource valuation challenges.	Imposes extensive artificial barriers. Poor valuation of unconventional technologies.
Performance incentives	"Gold standard" for rewarding delivered service, but requires robust market power mitigation.	Creates missing incentives for performance for which corrections (e.g., penalties) carry their own unintended consequences.	Sufficient reliability incentives. Perverse economic incentives for self-build, excessive capital intensity and operating plants at lower efficiencies.
Minimum resource adequacy	If artificial price suppression exists, levels will fluctuate potentially below optimal level. Small "room for error" under low marginal cost conditions.	Guarantees total nominal resources but may have performance problems in practice.	Guarantees total resource levels but exposed to locational shortages in resource adequacy.[77]
Amenability to dedicated ERS procurement	Potential to co-optimize with energy and ancillary service markets.	Complex, likely suboptimal co-optimization of capacity tranches.	Difficulty identifying and planning for share of regional ERS.
Amenability to privatized resource adequacy concept	Readily adjustable.	Could adjust to offer differing, voluntary reliability products or phase-out.	Poorly suited. Some degree of service differentiation possible but with major administrative constraints.

vice products would provide a basis for future market design. By contrast, a standards-driven policy agenda for ERS will set a precedent for inefficient resource allocation with unintended consequences, including higher costs and suppressed innovation.

HARMONIZING RESOURCE ADEQUACY POLICY AND EMERGENT TECHNOLOGIES

This analysis reveals several comparative characteristics of resource adequacy paradigms going forward. From an economic perspective, the energy-only paradigm has the greatest potential efficiencies with conventional resources and even greater efficiencies with emergent technologies. However, it also has less room for error in price formation as low marginal cost resources become more popular. On balance, capacity markets have demonstrated a strong net advantage over utility IRP both in achieving resource adequacy needs at lower cost and driving efficient innovation. Markets also have greater potential to evolve capacity planning to capture the economic value of emergent technologies.

In addition to the aforementioned comparative resource adequacy features, a broader set of findings with implications for resource adequacy policy include:

1. *Low marginal costs place greater emphasis on resource adequacy constructs*. In a market context, a greater proportion of suppliers' net revenues will come from shortage or capacity payments. This amplifies inefficiencies associated with design flaws in capacity markets and price formation flaws in energy markets.[78]

2. *The economic advantage of market incentives over uniform standards grows*. "One-size-fits-all" resource adequacy is outdated and inefficient. Well-function-

77. Kathleen Spees et al., "Enhancing the Efficiency of Resource Adequacy Planning and Procurements in the Midcontinent ISO Footprint," The Brattle Group, November 2015, p. 6. http://www.brattle.com/system/publications/pdfs/000/005/221/original/Enhancing_the_Efficiency_of_Resource_Adequacy_Planning_and_Procurements_in_the_MISO_Footprint_Newell_Spees_1115.pdf?1448034421.

78. For example, see Thomas Jenkin et al., "Capacity Payments in Restructured Markets under Low and High Penetration Levels of Renewable Energy," National Renewable Energy Laboratory, February 2016. https://www.nrel.gov/docs/fy16osti/65491.pdf.

ing markets reflect what customers are willing to pay for reliability and enable customers to express this willingness through dynamic participation in electricity markets. This requires revising some reliability standards that constrain the ability to enhance incentive compatibility. Reliability organizations, such as NERC should consider the effects of new technologies on reliability standards in a manner that accommodates economically efficient curtailments of service.[79]

3. *On market design issues, NERC is best suited as a technical resource, rather than an economic policy advisor.* Technical input from NERC should feed into resource adequacy policy (e.g., evaluating new technologies and reporting on reliability metrics), but NERC's perspective will not robustly account for economic efficiency. NERC-led resource adequacy policy will be standards-heavy and, in many cases, inconsistent with market principles.

4. *Potential shortfalls of ERSs may justify dedicated market procurement mechanisms*. Market mechanisms will procure more efficient levels of ERSs at lower cost and with better innovation incentives than a standards-driven approach. Among market options, to pay for delivered service should lower costs as compared to the procurement of differentiated, specialized forms of capacity.

5. *Evolving technology plays to the strengths of energy-only markets but, at the same time, exposes their vulnerability to any price-formation deficiencies*. The dynamics of unconventional resources and the ability to privatize resource adequacy are ideally suited for the energy-only paradigm.

6. *Efficient energy price formation is critical for energy-only markets and beneficial for areas with capacity markets*. Capacity mechanisms should supplement, rather than substitute for measures to improve energy price formation.[80] To this end, the R Street Institute has laid out a series of current price formation priorities for FERC and Texas regulators to consider.[81]

7. *For regions committed to capacity planning, the advantage of using markets grows with the advent of emerging technologies*. Capacity markets have far greater potential than IRP to capture the temporal and spatial dimensions of resource adequacy and provide superior incentives. Capacity planning must become more sophisticated to value diverse resources accurately. Capacity planning should also consider flexibility provisions to enable broader adoption of differentiated reliability.

The next policy step for the energy-only paradigm is relatively straightforward: improve price formation. Those for capacity markets are more complex. Perhaps most prominently, the rationale for mandatory capacity obligations is diminishing. As noted by Rob Gramlich, in the early 2000s, FERC reluctantly placed mandatory capacity obligations on LSEs for three reasons that may no longer exist: 1) long (multi-year) resource development times; 2) the inability of energy and ancillary service prices to produce an adequate level of investment; and 3) the inability to curtail customers that failed to procure enough resources.[82]

However, new supply technologies (like batteries), along with more price-responsive demand diminish the "barriers to entry" argument for mandatory capacity obligations.[83] As to the inability to produce investment, if ERCOT passes its current stress test, policymakers should have confidence that price formation reforms in other RTO/ISOs would result in the ability to attract sufficient investment within the energy-only paradigm. The "common good" rationale behind the third reason weakens with the proliferation of smart technologies that enable grid operators to enact targeted service curtailments.

Even if the energy-only paradigm overcomes price formation challenges, the inertia of capacity markets makes iterative reforms a necessity. As guidelines, capacity mechanisms should:

1. Supplement rather than substitute for alternative reforms that improve energy price formation;

2. Accommodate all resources equitably;

3. Recognize and compensate resources based on necessary capabilities; and

4. Be designed with the objective of eventual phase-out.[84]

A critical concept for policymakers and regulators is path dependency, where one set of foundational reforms leads to

79. Bushnell et al., 5. https://sites.hks.harvard.edu/hepg/Papers/2017/WP278Updated.pdf.

80. See, e.g., "Follow the missing money." https://www.sciencedirect.com/science/article/pii/S1040619016302512.

81. "Refreshing Price Formation Policy in Wholesale Electricity Markets." http://2o9ub0417chl2lg6m43em6psi2i.wpengine.netdna-cdn.com/wp-content/uploads/2017/08/106.pdf.

82. Rob Gramlich, "Organized Markets for the Future," *RTO Insider,* May 16, 2017, 1. https://www.rtoinsider.com/ferc-technical-conference-mandatory-capacity-obligations-43096.

83. Ibid.

84. "Follow the missing money." https://www.sciencedirect.com/science/article/pii/S1040619016302512.

subsequent ones. Market design reforms should center on incentive compatibility with the goal of maximizing economic performance for delivered service. Deepening a standards-driven approach to resource adequacy will undermine the pathway to incentive compatibility.

CONCLUSION

Resource adequacy policy should adjust to reflect the evolving state of technology. The most valuable lesson for policymakers and regulators is the growing advantage of market paradigms over monopoly utility IRP. Generally, the value of incentives over standards grows with a more diverse, dynamic suite of technologies that policymakers should leverage to empower consumer choice and competitive forces.

To date, market design reforms have had mixed results, but better, if not best practices are emerging. Early lessons indicate that market products that reward delivered reliability services offer the most economical pathway forward. With incentive compatibility as the guiding principle, movement to liberate market forces and limit the role of central planners will result in electric resources being put to their most productive uses.

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Devin joined R Street in January 2016, having previously conducted economic analysis of wholesale electricity markets at the Federal Energy Regulatory Commission (FERC). His areas of focus included renewables integration, environmental regulation, coordination of natural gas and electric industries, and using markets to procure resources to meet reliability needs.

Before FERC, Devin worked at the Indiana Utility Regulatory Commission, where he spearheaded the initiative to modernize Indiana's electric-resource planning rule. He led research on risk and uncertainty management, as well as advanced technologies, including electric vehicles, carbon capture and storage, energy storage and distributed generation.

Devin previously served as a fellow at the U.S. Environmental Protection Agency, conducting air-emissions cost-benefit analysis. He has also advised, provided research for and worked on issue-based campaigns for various energy and environmental nonprofit organizations.

He graduated from Iowa State University with majors in economics, political science and environmental studies. He completed an M.P.A. and M.S. in environmental science at Indiana University, concentrating in environmental policy, policy analysis and energy systems and policy.