Policy Options for Better Service Outcomes from the Future Electric Grid

A Stakeholder Symposium

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Preface

On October 30, 2015, with funding from the Pardee RAND Graduate School's Cazier Initiative, the RAND Corporation hosted a symposium that was intended to identify and discuss important policy questions related to the present and future electric power system in the United States. These proceedings summarize the main themes of the discussion. The meeting brought together diverse stakeholder perspectives on the challenges, solutions, and implementation barriers associated with building a more robust, resilient, reliable, affordable, and clean electric power system. A key intended outcome of this initial meeting was to identify problem areas that could benefit from objective research and analysis at RAND and to begin a long-term and productive engagement with these and other industry thought leaders and innovators.

Pardee RAND Graduate School and the Cazier Initiative for Energy and Environmental Sustainability

Funding and support for this event was provided by the John and Carol Cazier Initiative for Energy and Environmental Sustainability. The Cazier initiative was made possible by a generous gift by the late engineer and philanthropist John M. Cazier to the Pardee RAND Graduate School in May 2014. Pardee RAND administers and oversees the work of the initiative, which helps generate new concepts, tools, and methods to share findings, ideas, and insights clearly and broadly, so that they can improve public policy, foster better practices in the field, and be applied in the commercial sector to benefit people throughout the world. For additional information on the Cazier Initiative and the activities it supports, visit www.prgs.edu/cazier-initiative. Inquiries about the Cazier Initiative should be directed to:

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RAND Infrastructure Resilience and Environmental Policy

The research reported here was conducted in the RAND Infrastructure Resilience and Environmental Policy program, which performs analyses on urbanization and other stresses. This includes research on infrastructure development; infrastructure financing; energy policy; urban planning and the role of public–private partnerships; transportation policy; climate response, mitigation, and adaptation; environmental sustainability; and water resource management and coastal protection. Program research is supported by government agencies, foundations, and the private sector.

This program is part of RAND Justice, Infrastructure, and Environment, a division of the RAND Corporation dedicated to improving policy- and decisionmaking in a wide range of policy domains, including civil and criminal justice, infrastructure protection and homeland security, transportation and energy policy, and environmental and natural resource policy.

Questions or comments about this report should be sent to the project leader, Aimee Curtright (Aimee_Curtright@rand.org). For more information about RAND Infrastructure Resilience and Environmental Policy, see www.rand.org/jie/irep or contact the director at irep@rand.org.

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Summary

The John and Carol Cazier Energy and Environmental Sustainability Initiative at the Pardee RAND Graduate School helps to generate new concepts, tools, and methods to share findings, ideas, and insights clearly and broadly in order to improve public policy, foster better practices in the field, and be applied in the commercial sector to benefit people throughout the world.

Pardee RAND Graduate School is the nation's largest doctoral program in public policy and the only program based at an independent public-policy research organization—the RAND Corporation. RAND is a nonprofit institution that helps improve policy and decisionmaking through research and analysis.

Under the Cazier initiative, the graduate school's goal is to bring important visiting fellows to campus and provide valuable research and dissemination tools to students and faculty members. The visiting fellows—some of the best minds and practitioners in their fields—will challenge, inspire, inform, and educate Ph.D. candidates, faculty, RAND researchers, and the RAND community, with the hope that being part of the RAND community also will broaden fellows' perspectives.

On October 30, 2015, Pardee RAND convened a small, invite-only event for leaders from industry, government, and consumer organizations to explore questions confronting the current and future electric power system. This group comprised six Pardee RAND faculty members, four Pardee RAND students, and seven outside attendees from a range of sectors, including local research institutes, the Electric Power Research Institute, an electric service provider, and the renewable energy industry. This proceedings document serves as the consolidated notes from this stakeholder symposium.

This first Cazier-sponsored convening was intended to begin to scope important policy questions related to the present and future electric power system among a small group of stakeholders. Specifically, the participants discussed and explored:

1. vision and key drivers of innovation in the electric power grid
2. barriers to change, and implementation pathways and solutions to barriers
3. key policy questions and opportunities for analysis.

The convening, along with this summarizing document, is intended to be a starting point for an ongoing dialogue with RAND and a broader range of stakeholders. Future discussions will focus on specific policy aspects or regulatory regimes that will achieve the most substantial and equitable social-welfare benefits—within the technical and economic constraints of current and near-term technologies—from the development and deployment of our future electric grid. This first meeting was not intended to capture all stakeholder perspectives, but to start a dialogue with key public- and private-sector leaders. This meeting was also not intended to provide definite answers to technical and policy questions, but rather to identify the most important topics and issues for further analysis and consensus building. As such, themes reported in this document are not meant to be either comprehensive or definitive, but rather to document the discussion and raise ideas for future exploration and examination.

Acknowledgments

Publication of this proceedings document, and the symposium upon which is it based, was supported by the John and Carol Cazier Initiative for Energy and Environmental Sustainability. The authors are very grateful to the symposium participants (listed in Appendix A) for their time and insights, without which the productive dialogue described herein would not have been possible. The authors would also like to thank our colleague Thomas Light, RAND senior economist, for his careful review, which improved the clarity and quality of the document.

1. Session One: Describing the Vision and Challenges

This first session engaged participants in a discussion of the possibilities for, and desired outcomes from, the future grid, including the challenges associated with meeting these goals. Participants were asked to address a number of key questions, with an overarching query posed: "What can and should the future grid look like?" This summary of the discussion is organized around several underlying key questions.

What Are the Drivers of Change for the Electric Grid?

Technological and economic changes are at the heart of what will be possible for, and required from, a future grid (Frades, 2014; and Guo, Bond, and Narayanan, 2015). Participants noted several key techno-economic realities that will dictate what is feasible and desirable from the future grid:

- The existing grid is an aging infrastructure and does not often incorporate cutting-edge technologies (U.S. Department of Energy, 2015).
- Grid-deployable technologies are advancing rapidly (e.g., stationary batteries for power backup, advanced sensors for synchronizing grid components). Utilities will need to balance added cost with functionality and reliability in a changing technological environment.[1]
- The growth of electric vehicles may create new challenges and opportunities to address peak load and unidirectional communication (U.S. Department of Energy, 2014).
- Furthermore, the deployment of intermittent and distributed sources is fundamentally changing supply.

These techno-economic drivers dictate that the future grid will need to be more adaptable to a range of environments and to a changing balance between supply and demand, despite a dated infrastructure but with the help of emerging technologies. In this context, the technological pathway to grid modernization could be accomplished either with incremental changes or with a more bottom-up, fundamental grid redesign. The first approach would be the easier, and, in the near-term, less-expensive approach. A fundamental redesign could, however, reap greater benefits down the road.

Emerging **social and environmental** factors are the backdrop to the techno-economic context. Electricity is expected to make a transition from being largely viewed as a commodity to being widely understood as a multi-attribute service with fundamentally different socioeconomic

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[1] For example, in the case of sensors, companies need to know how close to the margins at which they are operating, which could be helped with sensors, but concerns about the economics of sensor deployment have prevented them from incorporating many of the innovations coming out of the private sector.

metrics by which the grid will be valued and assessed.[2] The various social and environmental forces driving this change may, in fact, imply different desirable outcomes that need to be reconciled. For example, consumers will increasingly expect technology-enabled choice and control. This more-highly differentiated consumer base will view electricity as a service or suite of services, and there will be a market for catering to choice. In this scenario, residential consumers will vary in their relative need and desire for high reliability, low costs, and minimized environmental footprint. At the same time, standards and requirements for decreasing the environmental and social externalities of electricity production, transmission, and use will test the industry's ability to provide uniformly reliable and affordable electricity. Climate change and severe weather are clear examples of this challenge (President's Council of Economic Advisers and Reliability and U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability, 2013), both from the perspective of consumer and broader public expectations and practical day-to-day operations.[3] Within this context, the costs and benefits of the future grid would ideally be distributed equitably, with access to enhanced services allocated in a way that accounts for all stakeholder perspectives and values.

Policy and regulatory frameworks and decisions could either constrain or enable better service outcomes from the grid.[4] It may be difficult for decisionmakers to keep pace with rapidly changing technology. Unintended consequences and creation of perverse incentives could result, limiting or counterbalancing the benefits of the future grid. Economic incentives will need to be targeted to consumers in ways that foster the types of investments that support the flexibility, reliability, and longevity they desire. But, for the market to develop the appropriate technologies, the regulatory environment must be simultaneously well defined and adaptable.

Who Are the Key Stakeholders and Decisionmakers? What Does Each Expect from the Future Electric Grid?

Stakeholders for the future grid include both familiar and new consumers and interest groups, with a range of priorities and interests. Additionally, public decisionmakers (e.g., city governments, statewide regulatory agencies) represent different subsets of these stakeholder groups. Each group will expect and value different attributes from improved electric service. These groups, and their respective priorities, include:

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[2] One participant remarked that this "consumerization of energy" was a grassroots phenomenon that was driving people to view electricity as an "on-demand" service (similar to cell-phone service). The fundamental limitations of grid system dynamics may ultimately make some of these expectations unrealistic, and consumer education may be necessary.

[3] Hurricane Sandy's impact on Jamaica Bay was noted as a defining event responsible for making New York City regulators more accepting of a market-based paradigm. Distributed assets were recognized as a means to lower the cost of maintaining the whole system as well as a means of building in resilience.

[4] For a summary of "Smart Grid Legislative and Regulatory Policies and Case Studies," see U.S. Energy Information Administration, undated.

- **Consumers**, including a new group that both produces and consumes electricity, so-called prosumers.[5] Instead of simply being able to classify consumers as residential versus industrial, the standard service dimensions will expand beyond simple classifications. This heterogeneous group will increasingly expect choice, flexibility, and control, and will be enabled by new technologies. What was previously universal standard access will need to be redefined by the industry itself, unbundled and disaggregated into distinct electricity services. Interest groups that represent groups of consumers with similar concerns and motivations (e.g., environmental organizations, privacy-rights groups) may also have increasing influence.
- **Regulatory agencies**, from state Public Utilities Commissions (PUCs) to federal agencies. Participants seemed to agree that this group is one of, if not the most, important group for the fate of the future grid, especially decisionmakers at the state level. Without clear foresight and a window into technological change, this group may struggle to keep up with rapid advances in technologies and changing consumer attitudes.
- Local and municipal **governments**. This group will be particularly interested in the enhanced resiliency that a future grid could offer, especially in the face of risks (e.g., natural disasters). These decisionmakers could potentially enable and work with other stakeholders to deploy local-level aspects of a future grid, namely microgrid architectures and small-scale power generation.
- The tech **industry**, including producers of both software (e.g., cybersecurity software) and hardware (e.g., stationary batteries) will equip and maintain the infrastructure of the future grid. This group includes established companies and start-ups, and all have interest in regulatory clarity and fair access to the market.
- **Utilities**, including both traditional entities and new archetypes. This group will need to continue to serve customers, and, when relevant, satisfy shareholders. A future smarter grid may present the opportunity for better use of a utility's assets, which would be a win-win for the utilities and their customers.[6] The future electricity system will also increasingly incorporate renewables, including intermittent ones such as wind and solar power. Utilities will therefore need to work with and gain cooperation from their customers to create a more-flexible demand for a possibly increasingly inflexible supply.[7]

What Can and Should the Future Electric Grid Look Like? What Are the Metrics for a Successfully Deployed Smart Grid?

Participants recognized that there is not a widely accepted definition for what a better future electric grid will look like, nor are there standard metrics for assessing the success of a smart

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[5] Community- or regional-level prosumer entities may also emerge.

[6] One participant noted that this means not only a potentially less expensive price of electricity for consumers on average, but it also may lead to revenue streams coming both from and *to* consumers (making them so-called prosumers).

[7] One participant pointed out the challenge of moving from the current system which, based on weather and other known factors, is able to instantaneously estimate the aggregate load to 95 percent accuracy. Presently, only marginal adjustments need to be made instantaneously.

grid. However, broadly speaking and varying by stakeholder, a better grid might have a number of general attributes,[8] which include:

- maintained, improved, or redefined electricity reliability or resiliency
- reduced environmental footprint (e.g., greenhouse gas emissions)
- minimal or no increases in the cost of delivered electricity, significantly improved services for which consumers will be willing to pay more, or a combination of both that varies by stakeholder
- adequate attention to the issues of security and privacy, including deployment of technology that improves security and protects privacy (Electric Power Research Institute, 2016, and Hawk and Kaushiva, 2014)
- equitable distribution of the costs to upgrade the grid, and of the benefits accrued from the changes.

Trade-offs between these desirable attributes will need to be understood and valued quantitatively. Appropriate metrics of success will need to factor and weight these goals, including relative to how well the existing grid satisfies the needs of stakeholders. For example, some stakeholders may be satisfied with the attributes of the existing system, so the cost to these stakeholders for changes will be harder to justify. Increasing system resilience will need to be measurable and quantifiable to both justify the changes and assess the success of these changes. While limited aspects of this have been addressed by specific stakeholder groups, to date, a systematic, widely accepted metrics development has not occurred.

To meet these objectives in a cost-effective way, stakeholders will need to work together to define pathways and overcome barriers. Participants in this first meeting began to discuss these topics in the first session, with a continuing, deeper discussion in the second session (as described in Chapter Two). We note that further analysis will be required with a broader range of stakeholders, but highlighting the need to define pathways is a key step forward.

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[8] As one participant put it, the future grid should achieve what we *already have* in terms of reliability with fewer externalities and without dramatic increases in cost or decreases in service.

2. Session Two. Identifying Solutions, Implementation Pathways, and Barriers

Many of the questions raised in the first session naturally led into a discussion of the topics in the second session, which more-explicitly addressed potential implementation pathways as well as barriers to and solutions for implementation. Although the conversation was informal and only semistructured, this summary of the substance discussed has been organized around the key questions addressed in the session.

What Is the Best Implementation Pathway for the Future Grid?

Participants were asked to imagine and describe potential future grid deployment pathways that were both technically realistic and economically cost effective. Two extreme models that bound the range of options for planning and deploying the future grid were discussed. At one end of the spectrum, only incremental improvements to modernize the existing grid might be undertaken; this is already occurring to varying degrees, depending on geographic location, regulatory regimes, and the availability of funding, and can and will continue.[9] The alternate extreme pathway would be a totally disruptive approach, a full-scale grid redesign that represents a step-change to a truly new infrastructure. In reality, what is feasible from a technical, economic, and policy standpoint will likely be something in between.[10] Considerations and arguments for and against the respective pathways included the following:

- Since barriers exist even for incremental change, a step change may not be realistic. The existing infrastructure represents huge sunk costs.
- On the other hand, some participants argued that the barriers to incremental change may not be much easier to surmount than those for more-disruptive change. Because tens of billions of dollars already flow into annual upgrades in the existing infrastructure, a more-holistic approach might enable these substantial funds to be channeled in a more forward-looking and less piecemeal way.[11] In both cases, regulators may remain skeptical of cost, and they may be easier to justify if accompanied by a longer-term vision.

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[9] One participant described this as "smart grid 1.0," where you move forward with the existing infrastructure and add sensors and devices, integrating these as best you can, in an ad hoc way. Then new devices could be integrated going forward. Another participant described the incremental approach as a "Band-Aid" for, but also a potential path toward, a bigger grid change.

[10] Participants noted that, in the past, it has often required an extreme event (e.g., natural disasters) to catalyze new thinking at the level required for a paradigm shift.

[11] One participant estimated about $22 billion in annual upgrades and wondered if an incremental increase in funding, for example to $25 billion, that was well coordinated would enable a more rational, directed approach that would be more disruptive than incremental.

If microgrids represent a small-scale example of a redesign approach, the microgrid is a potential bridge to a broader full-scale bottom-up design. The microgrid would enable more-efficient and effective function at the local scale, but in the long term would most logically be connected to a system of interconnected microgrids. After all, an isolated microgrid represents poor asset-use and is inherently not resilient if it cannot rely on interconnection in times of stress.[12] In the view of a participant, overall grid optimization should be the engine and framework that enables add-ons and modifications. In general and in the long term, it will not be most efficient to have everything on microgrids, but these add-ons might be a necessary step to the future grid.[13]

In order to evaluate the desirability and feasibility of different deployment pathways, it will be important to understand and anticipate the pace of innovation for both hardware and devices and systems to monitor, measure, and react to changes in supply and demand.[14] Understanding these timelines will enable smarter choices between incremental and large-scale investments. A related issue will be to understand the path dependency of the expected costs. The incremental cost-curve model that determines electricity dispatch may mesh more naturally with an incrementally changed grid than it would with a step-change plan. Understanding the relative value of adding capacity and reliability to a relatively robust grid versus adding capacity at the edge of or off the grid will also enable better investment and regulatory choices. This includes whether or not the consumer is seeking to avoid or add needed capacity (kilowatts) or supply (kilowatt hours).

What Are the Barriers to Implementation of the Future Grid?

Participants identified a number of technological, policy, and economic barriers to the successful deployment of a future grid that produces the most social-welfare benefit with minimized costs. One major barrier is a lack of understanding and articulation of the value of the attributes of an advanced grid. This, in part, reflects a lack of clarity of objectives within and across stakeholders, but it is also a failure to articulate, codify, and quantify known objectives. For example, in the United States, there is no national mechanism for valuing avoided greenhouse-gas emissions, and therefore any benefits in efficiency and reduced use of electricity that would

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[12] It was noted that the current low use rates (about 50 percent) for the industry, given the capital-intensive nature of the sector, would make even less economic sense going forward with a future grid. Another participant imagined a future in which electricity starts to look more like natural gas by offering storage capacity and demand response via assets such as batteries. Even in this case, an isolated microgrid would be limited in the ability to call on such assets from a larger network.

[13] This picture is obviously different outside of the United States and especially in developing economies. In these cases, a remote or disconnected microgrid may actually be the stopgap until the big grid can be built.

[14] The innovation cycle for new technologies is approximately two years, while the regulatory cycle for describing the conditions of its use is seven years.

come from a smarter grid are not valued by the market.[15] Similarly, there is no clear definition of, or agreement on the value of, resiliency. There would be value in defining alternative and more-concrete metrics.[16] It is important not only to understand the aggregate costs and benefits of changes to the grid, but also the distinct benefits to different stakeholders at a more-granular level. Benefits to one stakeholder may, for example, not be important to or even at odds with the needs of other stakeholders.

A lack of sufficient data and improper or underuse of available data further exacerbate the problem. Presently, stakeholder-specific preference data are hard to obtain, making the impacts of new technology deployment and changing policies inherently difficult to quantify. Often, utility companies do not have good access to granular usage data and therefore are unable to use consumer data to inform their investments and policies. Perhaps more importantly, the question remains as to what level of data aggregation is required to make the best decisions. Issues of lack of data access and potential security and privacy implications of data acquisition should really be addressed after the *need* for such data is first established.

Some barriers to the success of the future grid are not uniformly shared and are specific to a particular stakeholder group. Participants identified many stakeholder-specific barriers and concerns, which are summarized here.

- Industry and Utility Barriers
    - culture of risk aversion is inherent and reinforced by regulatory structure[17]
    - a lack of understanding of the heterogeneity of the customer base. Rather than just looking to meet the needs and wants of the average customer, industry needs to better differentiate and satisfy distinct groups and subgroups
    - inability of individual firms to think in cross-cutting ways, resulting in siloed thinking only about their own products or own geographic regions[18]
    - limited view of service return on investment as an efficiency benchmark. This metric ignores contributions to performance by distributed sources
    - reluctance to engage in new business models that require profit sharing
    - a need to reconcile the disparity between the life span of assets and the benefits they offer. Technological progress may render assets obsolete before they have reached the end of their usable life, and this must be factored into lifecycle costs and considered as an opportunity cost

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[15] One participant noted that, by modifying the grid to achieve climate-change mitigation benefits, we are ultimately “going about it backwards”; a more-straightforward approach would be to value the emissions (e.g., implementation of a carbon tax) and let innovation and the market respond.

[16] For example, one participant advanced the idea of an alternative metric of “service return on inventory”; another mentioned that improving “system utilization” might be an important metric for success of the future grid.

[17] One participant described the industry historically as a “heroic engineering force” with a duty of keeping a public good alive, not of taking risks and being innovative.

[18] One participant noted the Department of Energy now has a “cross-cutting” program to address these issues at the government and basic research level, and this might be a model for industry.

  - traditional approaches to distribution planning, unsuitable for the modern grid. Changes in the structure of the power-distribution system should be reflected in the models being used by planners.

- Regulatory Agency Barriers
  - legacy regulation often mandates by technology type, not by the ultimate policy goals. This can reduce market competition, lock-in undesirable technologies, and misalign proper incentives
  - regulatory bodies' incomplete knowledge of changing technologies and inability to react quickly to overturn precedents, making the adoption of technology innovation a difficult task
  - difficulty arriving at appropriate metrics for the value of new technology added to the existing grid. Best-fit, least-cost may be appropriate in some circumstances, while cost effectiveness may be better for others
  - lack of sufficient differentiation among rulings in different areas of the country based on notable differences in the utility landscape and availability of renewable resources
  - lack of clarity as to who should be setting the standards and defining principles and what appropriate policy, regulatory, and legal frameworks for the smart grid should look like
  - regulators will need to decide how much market access should be open to third-party bid. This will impact the all-in costs to customers

- Residential Customer Barriers
  - high upfront capital costs of smart-grid upgrades may be hard to justify, especially if customers do not see the value or have concerns about security or privacy
  - consumer responses to smart-grid updates are likely to vary and ultimately may not align with utility or industry goals. Variation in consumer response may be exacerbated with growing costumer heterogeneity[19]
  - Individuals tend to discount in nonrational ways. Failure to adequately or rationally value grid modernization that costs more now, but helps mitigate climate change down the road, is just one example.

- Commercial and Industrial Consumer Barriers
  - reluctance to adopt due to high capital costs of smart-grid upgrades when value is unclear
  - heightened reluctance in cases where infrastructure and policy changes are likely to have a disproportionate impact on operations, e.g., commercial customers who are less able to be flexible with their electricity use in the face of time-of-use pricing.

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[19] Several participants mentioned the potential for an increasingly heterogeneous consumer base, and no participants questioned this assumption. However, the assumption would itself be worth better assessing and quantifying through consumer surveys and analysis.

3. Key Policy Questions and Opportunities for Analysis

The day's discussion concluded with participants identifying key policy questions that would need to be addressed to enable a successful transition to a future grid that provides better outcomes, both in terms of enhanced services and in terms of cost effectiveness. Three important policy questions emerged from this first discussion (described in the next section), along with a discussion of important considerations and potential approaches to tackling the questions.

Why Does Society Need or Want a Smart Grid?

One concern that emerged in this discussion was the lack of a clear articulation of the motivations and driving forces behind deploying a smarter future grid. Without this clarity, it will be difficult to specify and incentivize the desired attributes of the future grid and even harder to assess the successes. This group was able to articulate some notional objectives and metrics at a high level (summarized in Session One), but prioritizing and quantifying these was beyond the scope of this symposium and are clear needs for industry and society to move forward in the most beneficial way.

Several participants noted the value of constructing an overarching framework for decisionmaking in structuring and deploying future-grid technologies and policies, especially at a local and regional level. Such a framework might identify objectives, provide a menu of technology-attribute choices, and map alternative pathways to achieving goals. A multi-stakeholder group, working with a neutral mediator, might be well suited to developing an inclusive, action-oriented framework for these purposes. Some important characteristics to include in this framework would include:

- Clearly defined **objectives and attributes.** Participants seemed to agree that the structure of the future grid should follow naturally from functionally desirable attributes, rather than being in support of predefined attributes that do not clearly align with functional needs.[20] The first step in this process of setting form to follow function would be to define the goals of a better grid, followed by articulating the required attributes to meet these goals, and finally by specifying the appropriate structure to meet the desired goals.
- Explicitly articulated **incentives and barriers.** Once the goals and attributes are understood, the next step would be to identify barriers and ways to reduce them. A related step would be to determine how to actively incentivize the behaviors and

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[20] One participant cited a recent grid-architecture analysis from the Department of Energy's Pacific Northwest National Laboratory (see Taft and Becker-Dippmann, 2015). This analysis defined objectives first, and then developed implied system attributes (not vice versa) by first articulating "Why Grid Architecture Should Be Used" and providing a "Desired Qualities List" *before* describing the engineering and architectural "Key System Properties Supporting These Qualities."

investments that contribute to the goals. These would need to be enumerated for all relevant stakeholders that have a role to play in deployment and adoption.

- Quantifiable **metrics.** Participants seemed to agree that the lack of a set of defined metrics and language to articulate the value of a future smarter grid was a problem for deployment. Metrics such as system utilization were discussed as well as whether efficiency is inherently a metric to monitor or if it should be viewed as a means to an end. Metrics can help quantify cost effectiveness, reliability, affordability, system utilization, or resiliency, and facilitate the assessment of tradeoffs among these attributes.
- Objective, fact-based **analysis.** Systematic analyses held using a structured approach (that clearly incorporates objectives, incentives, and metrics) to understand and assess implication outcomes would complete the framework. A key element of this analytical step is identifying the right tools and method on a case-by-case basis. For instance, even if not the most rigorous approach, conducting a best-fit, least-cost analysis,[21] might the best option in some instances.

What Do Customers Want from Their Electricity Services, and How Will They Respond to Smart Grids?

This second set of key questions focuses on a specific stakeholder group: the increasingly diverse electricity customer base. Regulatory and industry entities will need to better understand customers if they hope to meet their needs and get their support to transform the grid. More specifically, it will be important to understand:

- What offerings will a heterogeneous customer population value when provided with choices in a differentiated or disaggregated electricity product (e.g., differing levels of reliability, demand response, different green options)?
- What attributes will they accept universally (e.g., system-wide greenhouse gas–intensity rules), and what incentives and policies will be acceptable and effective?
- What incentives and pricing will influence customer behavior,[22] and what is their demand elasticity?
- What will they require and allow in terms of communication with an interactive grid?
- How interested will they be in becoming prosumers? How much will they want to actively engage in this two-way market? How might consumers join in neighborhoods to advocate for specific options?

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[21] This was in contrast to and distinguished from a cost-benefit analysis, which more often involves presuming a solution or suite of solutions and then tabulating the attendant costs and benefits. Additionally, given the difficulty of calculating the true cost of electricity (as opposed to just the price point), a calculation of cost effectiveness may not be tractable.

[22] For example, utilities will need to pay residential consumers the value of any flexible power that they provide to the grid (e.g., residential-level battery capacity). It will not be realistic to expect that customers will invest in, and allow access to, their assets in the spirit of contributing to system reliability alone. And given that a microgrid is most valuable when it is connected to the larger grid, the social value should be financially compensated to incentivize participation.

Participants agreed that consumers will increasingly expect customization of the electricity product rather than one homogenous universal service. But how can the grid be designed to incorporate and value the attributes they seek, such as resiliency, reliability, or environmental friendliness? And how will consumers respond to buying electricity as a differentiated service in a disaggregated, two-way market? Will this new system better meet their needs, create new challenges, or some of both?

How Can Regulatory and Industry Stakeholders Communicate Better and Arrive at Better Policies?

A final set of questions emerged around building better lines of communication between regulators and a diverse set of industry stakeholders, including both the high-tech industry that designs and makes the next generation of technologies as well as the utility industry that will need to deploy and integrate these technologies into the grid. While participants acknowledged that many high-level drivers of change come from the federal policy level (e.g., U.S. Environmental Protection Agency's Clean Power Plan),[23] each region and state will need to decide how to react to these policies in the local context and with the local drivers and obstacles. The policy framework within which the future grid will be designed and deployed will be largely dictated by state-level regulators such as Public Utilities Commissions. This will occur within the context of the top-down framework. If done right, the relative autonomy and flexibility at the local level can ultimately lead to innovative, well-tailored solutions.[24]

One major reason cited in this discussion for the disconnect between regulators and industry is the discrepancy between the pace of innovation, which can be as short as 12 to 18 months for some of the technologies at the cutting edge of development or many years and even decades, in the case of policy and regulatory change.[25] It may not be possible or even desirable to speed the pace of regulatory change, but flexible policy frameworks may be able to accommodate change if broad trends for the future technologies are understood.[26] The key will be setting policies that are both sufficiently defined and sufficiently descriptive with respect to the desired social

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[23] The history and language of the "Clean Power Plan for Existing Power Plants" and any regulatory and legal updates on the plan's status can be found at the U.S. Environmental Protect Agency's website (see U.S. Environmental Protect Agency, 2016).

[24] One participant commented that some of the most innovative tariff structures have come from entities that do not have state regulators.

[25] One participant noted that there is a disconnect between the disparate views of engineers and financial experts *within* industry and even within a single firm; this is another area where dialogue could usefully be advanced. Timescale attribution is further aggravated by shifting definitions of appropriate long-term cost. One participant noted that technology investment has evolved to consider the next generation versus the likelihood of failure, and long-term timescale can be disrupted by climate change events.

[26] One participant cited California Public Utilities Commission workshops, such as an upcoming "Rule 21" workshop, as a way to convey technology trends to the decisionmakers.

outcomes without being overly prescriptive.[27] Additionally, the timescale of change and response should be set by rational thinking and calculation and not necessarily driven by disaster response.

Several participants in this meeting suggested that a specific near-term area of focus for advancing a regulator-industry dialogue might be around the issue of net metering.[28] This conversation should include exploring the issue of a tariff structure and the associated policy goals and context, in both the near term (about 0–5 years) and the longer term (about 15–20 years). For example, tariff design should align the true costs of a service with the fees that are collected for the service or incorporate nonmarket value in technology deployment (e.g., the less tangible value of adding a distributed energy service at a local level compared with the same capacity from a more centralized source). It should also drive the system to evolve in a way that stakeholders can agree will benefit them in a multi-decade time frame. This may mean that rate-design changes need to be more dynamic and work within a construct that broadly defines safeguards for all customer segments, but that is also flexible.[29] As one participant put it, "rate design is where everything comes together for all the stakeholders."

Next Steps

Participants in this first discussion agreed that tackling one or more of these questions in greater depth would be a worthwhile next step. As noted, this first meeting was purposefully designed as small group discussion in order to outline some of the key issues facing broader application of the smart grid. However, it was not intended to result in comprehensive analysis or definitive recommendations. Rather, the meeting was a first step in a broader and deeper discussion with a larger and more diverse set of stakeholders. This summary helps the RAND team outline the framework and content for follow-up meetings to delve into some of these issue areas.

RAND has subsequently engaged with several members of the group to discuss next steps for framework development, analysis, and convening of other stakeholder groups. In the near term, several of the participants have agreed to additional, more-extended sessions with Pardee RAND faculty and students to take a deeper dive into these topics, and the outcomes of these discussions will be made publicly available.

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[27] As one participant put it, the industry and entities such as Institute of Electrical and Electronics Engineers (IEEE) and Advanced Research Projects Agency-Energy (ARPA-E) have the technology development and associated technology standards well covered. However, they need a way to convey the technological progress and the implications for regulation to the regulatory agencies. If regulators are not able to discern between different technologies, the policies and regulations that result could stymie start-ups and innovation.

[28] This example reflects the interests and perspectives of the group of experts present at the meeting and the resulting emphasis and dynamic of that conversation. There are other important policy questions that might be usefully addressed. One expert who was unable to attend our meeting, for example, cited a need for comprehensive transmission, citing reform as a policy area of top importance. This topic would require a dialogue between a different set of industry and regulatory entities than, e.g., those engaged in state-level net metering policies.

[29] One participant wondered about the possibility of marginal rate bases and whether or not the market can or should become a truly competitive dynamic market.

Appendix. Meeting Participants

New Tech Industries, Energy Providers, and Academia (Non-RAND)

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Sergej Mahnovski
Director, Utility of the Future, Con Edison of New York
Adjunct Associate Professor, School of International and Public Affairs, Columbia University

Mark McGranaghan
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Catherine Von Burg
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Kathleen Loa
Ph.D. Candidate and Assistant Policy Analyst

Zhimin (Min) Mao
Ph.D. Candidate and Assistant Policy Analyst

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