

# CHALLENGES AND REQUIREMENTS FOR TOMORROW'S ELECTRICAL POWER GRID

*By J. Michael Barrett*  
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## EXECUTIVE SUMMARY

**A**s the United States economy and society have become more reliant on the uninterrupted flow of electricity, the power grid upon which it depends for that supply has experienced deteriorating reliability. The grid loses power 285 percent more often today than in 1984. These power losses impose tens of billions of dollars of losses on American businesses each year.

There is broad agreement among experts that significant infrastructure investments will be required to sufficiently repair and enhance the grid. Estimates of the investment required for adequate modernization within the next two decades often amount to \$2 trillion or more. While that is a huge sum, if current annual expenditures were to be sustained annually over that same period, it would nearly match that investment level within that projected timeframe.

As the grid's modernization continues, the new design, operating model and core objectives of the U.S. power grid are steeped in uncertainty due to emergent technologies, changes to the climate and associated socially and politically-mandated requirements, and terrorism and other man-made threats. And the coming changes and massive modernization costs likely mean that users of the centralized power grid will have to pay more for the electricity they need.

Still, household and non-energy-intensive business users currently enjoy a very manageable total cost for access to electricity from the grid, totaling less than 2 percent of disposable income, on average. This represents roughly the same inflation adjusted per unit cost as they spent in 1959. As a result, for most relatively small users a pure cost-benefit assessment will still settle out in favor of reliance on the grid. However, for major consumers and those with a high need for absolute reliability and resilience (such as military bases), there may be a need to reduce their reliance upon the traditional grid, including new approaches such as microgrids and other distributed energy resource models.

The inexorable growth towards a new and more modern electrical power system will involve not just investment but significant changes for all participants. In an effort to advance the discussion about how best to conceptualize the future of the electrical power industry, three models are discussed: (1) Open Access, (2) Closed Loop, and (3) Islands and Oceans.

*Details follow.*

## INTRODUCTION

*“When you have exhausted all possibilities, remember this — you haven’t.”*

*— Thomas Edison*

America’s electrical power grid encompasses some 5,800 major power plants and over 450,000 miles of high-voltage transmission lines delivering power to more than 144 million end-use customers in the United States.<sup>1</sup> It has dramatically improved the health, safety and economic productivity of hundreds of millions of Americans for over a century.<sup>2</sup>

It also represents the single most capital intensive industry in America, with infrastructure and equipment valued at nearly \$1 trillion. Indeed, the grid stands as an ingenious accomplishment—to some, the single greatest engineering achievement of the 20th century. However, as the 21st century progresses, experts fear that the grid’s ability to meet evolving U.S. energy needs may falter without dramatic modernization.

The U.S. has more blackouts each year than other developed countries; in fact, the grid loses power 285 percent more often today than in 1984. These power losses impose tens of billions of dollars of losses on American businesses each year.<sup>3</sup> The grid’s current decentralized, locally-regulated, and arguably antiquated business operating model continues to generate concern among experts. In fact, it remains an open question as to whether or not the 100 year-old system—originally designed to incentivize power companies to connect new users to a largely non-electrified country using large, heavily regulated firms—can be viable in the modern era when practically everyone is already able to reach the grid and the concern is not connecting more users, but rather in balancing total cost, security, environmental concerns, and systemic resilience. Therefore, policymakers and technical experts would be right to conclude that America’s entire electrical grid is due for a major overhaul.

Indeed, according to the International Energy Agency (IEA), the electrical power sector needs up to \$2.1 trillion of new investment by 2035.<sup>4</sup> Amazingly, if the industry’s 2014

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<sup>1</sup> “Grid Resiliency,” U.S. Department of Energy, available at: [http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report\\_FINAL.pdf](http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf).

<sup>2</sup> Meagan Clark, “Aging US Power Grid Blacks Out More Than Any Other Developed Nation,” *International Business Times*, July 17, 2014, available at: <http://www.ibtimes.com/aging-us-power-grid-blacks-out-more-any-other-developed-nation-1631086>.

<sup>3</sup> *Ibid.*

<sup>4</sup> Jeff St. John, “US Power Sector Needs \$2.1 Trillion in Investment by 2035, Says IEA,” *Greentech Media*, December 19, 2014, available at: <http://www.greentechmedia.com/articles/read/iea-u.s.-power-sector-needs-2.1t-in-investment-by-2035>.

annual expenditure of roughly \$103 billion<sup>5</sup> were sustained annually over the next two decades then the total investment would nearly match the IEA's \$2 trillion figure within that projected timeframe. Clearly, electricity is a highly capital intensive industry—and analysts agree that significant infrastructure investments will be made in the coming

decades to repair and enhance America's electrical power grid.<sup>6</sup>

*The power grid, which could be considered the largest machine on earth, was built after World War II from designs dating back to Thomas Edison, using technology that primarily dates back to the '60s and '70s. Its 7,000 power plants are connected by power lines that combined total more than 5 million miles, all managed by 3,300 utilities serving 150 million customers.*

— *International Business Times*, July 17, 2014

As the government and industry continue to invest a massive amount of resources in a significant redesign of America's electrical grid, the core issue can be boiled down to this: the looming massive investment period presents the opportunity for a *de facto* redesign of the grid, a period during which innumerable decisions will be made about trade-offs, cost optimization, reliability, environmental

impact, continuity of operations, and who pays the associated costs.<sup>7</sup> Making sound decisions will require asking several questions, for example:

1. What could and should be the collective impact of such a large investment, and how will that square with all the emergent policy, legal, financial and technological changes over the coming years?
2. To what degree will distributed generation and other emergent opportunities such as the "smart grid" be integrated throughout the entire power system, and how does that change the fundamental business case for various key industry participants as well as end-users?
3. Will there be, for example, a shift from utilities focusing on growing the amount of power generated and charging per watt of electricity delivered to a more services-based model that focuses on efficiency, surety of service, and other systems-based value-add functions?<sup>8</sup>
4. Specifically, who is ensuring that the whole system is being made resilient against significant service interruptions?

<sup>5</sup> "Briefing at the University Club," Edison Electric Institute, February 12, 2014, available at: [http://www.eei.org/resourcesandmedia/industrydataanalysis/industryfinancialanalysis/Documents/Wall\\_Street\\_Briefing.pdf](http://www.eei.org/resourcesandmedia/industrydataanalysis/industryfinancialanalysis/Documents/Wall_Street_Briefing.pdf).

<sup>6</sup> Brian Warshay, "Upgrading the Grid: How to Modernize America's Electrical Infrastructure," *Foreign Affairs*, March/April 2015, available at: <https://www.foreignaffairs.com/articles/2015-03-23/upgrading-grid>.

<sup>7</sup> Theodore Craver, "Building the 21st Century Power System," *EnergyBiz*, Fall 2015, available at: <http://www.energybiz.com/magazine/article/433519/building-21st-century-power-system>.

<sup>8</sup> Note: this path would be analogous to how the information technology industry has mostly moved from a hardware-based business to one focused on services and cloud-based storage, etc.

5. Are we, as a nation, optimizing these investments by making them in a deliberate, rational fashion, or are they currently being driven by many different actors, each responding to their own imperatives that may conflict with others making related investments?

Designing a grid with the right infrastructure has always been challenging because, “investments in new generation or new transmission facilities can have long lives of 40 to 50 years or more.”<sup>9</sup> Therefore, “the business decision to invest in such projects carries inherent risks that other technologies could prove to be more cost effective over time or that the proposed investment could face premature obsolescence.”<sup>10</sup> The challenge for the future will be to plan for uncertainty—especially regarding the pace of technological innovation and the nature of the infrastructure. Experts evaluating the electrical power grid—a complex, interdependent system—lack the depth of information that typically informs other similarly long-term risk management investments.

*It is a national imperative to collectively and deliberately approach the important task of optimizing the electrical power delivery system of tomorrow by choosing among specific alternatives today, at the beginning of this period of investment in the system's redevelopment.*

Specifically, as the grid's modernization continues, the new design, operating model and core objectives of the U.S. power grid are all steeped in uncertainty due to (1) emergent technologies, (2) changes to the climate and associated socially and politically-mandated requirements, and (3) terrorism and other man-made threats.

Two new innovations represent a particular opportunity—that is, a chance to use targeted investment to dramatically improve the capacity of the power grid:

1. The 'smart grid', comprising the collection of networked sensors located at the point of consumption, which enable two-way information flows for better management of both the supply and demand needs of the grid, and

2. 'Distributed energy' generation, which refers to rapid growth in localized power generation such as rooftop solar or wind farms. A related growing technological opportunity is that of the microgrid, which refers to a highly localized, self-contained power generation, transmission and distribution model.

In fact, many observers agree that investments that harness the potential for near real-time monitoring and control of the power distribution network could usher in a revolution in terms of how energy is managed as well as who provides it, resulting in “improved reliability, increased efficiency, and the seamless integration of renewable power—not

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<sup>9</sup>“Resource Technology,” Western Energy Board website, accessed February 2016, available at: <http://westernenergyboard.org/western-energy-issues/resources/renewables/resource-technology/>.

<sup>10</sup> *Ibid.*



*Old and outdated equipment is a major reason the grid loses power 285 percent more often than it did thirty years ago.*

to mention more stable prices and lower emissions.”<sup>11</sup> However, there is also growing concern over the risks associated with connecting the grid ever more tightly to the vulnerable and inherently at-risk internet which is plagued by malware, cyber terrorists and other threats.

In practical terms, due to the massive scale of investment required to build out and maintain the power grid, each of the issues mentioned above significantly impacts the business case supporting a variety of power grid investment decisions. Because much of the power grid’s infrastructure is designed to last half a century or more, such decisions must be made very carefully. Without deliberate forethought and collective action, the resulting grid will be sub-optimal, one that fails to fully balance overall system cost, security, environmental impact, and surety of service.

With so much at stake it is essential that we appropriately define the parameters of the discussion about the grid’s future—for absent such deliberate effort the future of the grid will continue to be driven forward

by technological advances and regulatory imperatives that foster somewhat disorganized growth. Accordingly, this paper aims to explore the following significant issues:

1. What are the current and future trends in technology that will change the grid? (Section 1)
2. What are the drivers of change in terms of current and emergent technological opportunities as well as major threat types facing the grid, and how can they be effectively managed? (Section 2)
3. How are all the ongoing changes and opportunities affecting the business model of the power grid’s participants, including both energy producers and end-users? (Section 3)
4. How should we conceptualize the future design of the system and who should bear the costs of modernization? (Section 4)

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<sup>11</sup> Brian Warshay, *op.cit.*

## SECTION I:

# THE POWER GRID: PRESENT AND FUTURE TRENDS

*“Not only is electricity essential to the everyday lives of more than 300 million Americans, but our industry is an integral and robust component of our nation’s economy—a \$910-billion industry that accounts for more than 2 percent of GDP... [and directly employs] more than 500,000 men and women...”*

*— Thomas R. Kuhn, President of the Edison Electric Institute*

## THE GRID TODAY

The U.S. electric power grid remains indispensable for continued American prosperity and wellbeing—but the grid’s infrastructure is aging and increasingly outdated. The massive capital needs of this enormous system require constant investment and occasional system-wide overhauls. These represent a particular concern for the investor-owned electric utilities. These investors must make the business case for sustained investments just to tread water, much less innovate and implement large-scale modernization programs.<sup>12</sup>

At the same time, the grid is a very large system, with a long list of items that need to be replaced for a variety of reasons including: physical wear and tear, technical obsolescence, and the critical importance of meeting the security and power surety needs of Americans in the 21st century. This includes everything from integration of environmentally friendly alternative means of power generation to replacing the beyond-expected-service-life equipment such as the large power transformers, as well as the two-way communications built into smart meters and making the move towards interchangeable parts and other standardizations that increase efficiency of ‘spares and repairs.’

The current grid’s relative degradation has occurred gradually, mainly because of lack of clarity over who is responsible for certain investments that improve the overall system and the decentralized economic model of the U.S. power grid, which is comprised of thousands of separate firms crossing many state and local jurisdictions. This decentralization has helped to keep prices low and reliability high, but also slowed down system enhancements by requiring lengthy regulatory approvals in advance of proposed costs being incurred and distorted incentives favoring self-interests as opposed to stewardship of the system as a whole. Thus, relevant actors rarely take a whole-of-system

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<sup>12</sup> Brian Warshay, *op.cit.*

approach, which means that the overall resilience and security are never adequately addressed.

Interestingly, even though consumers are markedly increasing their use of everything from cell phones to electric cars, the aggregate power demand for traditional (i.e., non-renewable) power plant energy generation in the U.S. is expected to remain essentially flat for the foreseeable future. This is due to the improved efficiencies of modern appliances and other energy-saving technologies, but also reflects the often politically-mandated growth of non-traditional sources of energy through such renewable energy solutions as solar, wind farms, and other alternative 'distributed generation' energies.

Even absent major investments in new traditional generation capacity, however, massive infrastructure modernization investments will continue to be made over the next

*"[The] 'flexible and evolving distribution grid' concept—harnessing the integration of new energy resources, customer solutions and grid efficiency and optimization—points to a central enabling role for utilities as grid builders, operators, and service providers. . . . The challenge is figuring out the institutional, regulatory, and competitive frameworks that will lead to a flexible distribution grid platform that interconnects and enables all of the emerging energy technologies and services that customers want."*

— John Banks and Lisa Woods, *Brookings Institution*

several decades across the generation, transmission, and distribution segments. This is because much of America's current energy infrastructure must be replaced—being either near, at, or beyond its usable service life or due to the older technologies it employs being unable to keep up with modern cleaner energy requirements. This overall obsolescence is hardly surprising given that, according to a 2015 article in *Foreign Affairs*, "80 percent of [the grid], in some areas, has not been upgraded since the Kennedy administration."<sup>13</sup> Perhaps most important of all, the article then notes, "The average age of the country's large power transformers—critical pieces of equipment that transfer electricity between circuits—is around 40 years,

and many have been operating for more than 70 years."<sup>14</sup> And that is despite having spent an average of \$63 billion in annual capital investments each year from 2001-2010, including \$8 billion in transmission, \$35 billion in generation, and nearly \$20 billion in local distribution lines.<sup>15</sup>

<sup>13</sup> *Ibid.*

<sup>14</sup> *Ibid.*

<sup>15</sup> "2013 Report Card for America's Infrastructure," American Society of Civil Engineers, available at: <http://www.infrastructurereportcard.org/>.

Fortunately, while these infrastructure improvements are obviously quite necessary, many parts of the electrical power system have proven themselves to be quite robust over time. For example, much of the generation side of the equation is comprised of power plants that have served the nation reliably for decades using tried-and-true processes and well-established technologies, equipment and supply chains. The long distance transmission and local distribution infrastructure also is well-maintained and regularly serviced thanks to both long experience and well-defined regulations that ensure that it is adequately prepared for the kinds of routine risks and challenges it has faced in the past. Indeed, as the leading industry advocacy group, the Edison Electric Institute (EEI), is quick to point out, many years of significant investment have resulted in a cost-effective and robust electricity delivery system increasingly ready to meet our digitally-enabled future.<sup>16</sup> Much attention also has been paid to more rapid restoration of service following an adverse event, including a tried-and-true process for mutual aid that facilitates the use of power restoration crews from neighboring areas to assist those areas impacted by a severe event.

### ***Fuel Mix of U.S. Electrical Power Generation, 2014***

- Coal, 38.7%
- Natural gas, 27.4%
- Nuclear, 19.5%
- Non-hydro renewables, 6.9%
- Hydro, 6.2%
- Fuel oil, 0.7%

Such well-established, functional aspects of the power grid infrastructure mean that the grid is prepared to withstand routine events that have occurred in the past. However, the power grid now faces many new threats, such as more frequent extreme weather, and physical and cyber terrorism threats. The always-changing nature of these threats negates a lot of the planning that only applies to routine events. Additionally, as the country continues to grow ever more connected and reliant upon always-on energy, the costs of a systemic failure are increasing—at the same time that operational surety across the grid as a whole is looking more and more fragile.<sup>17</sup>

Addressing these issues has to take place while the firms, regulators, and end-users of this industry try to strike the optimal balance among four interconnected but often conflicting industry-wide imperatives: cost, reliability, environmental impact, and operational resilience.<sup>18</sup>

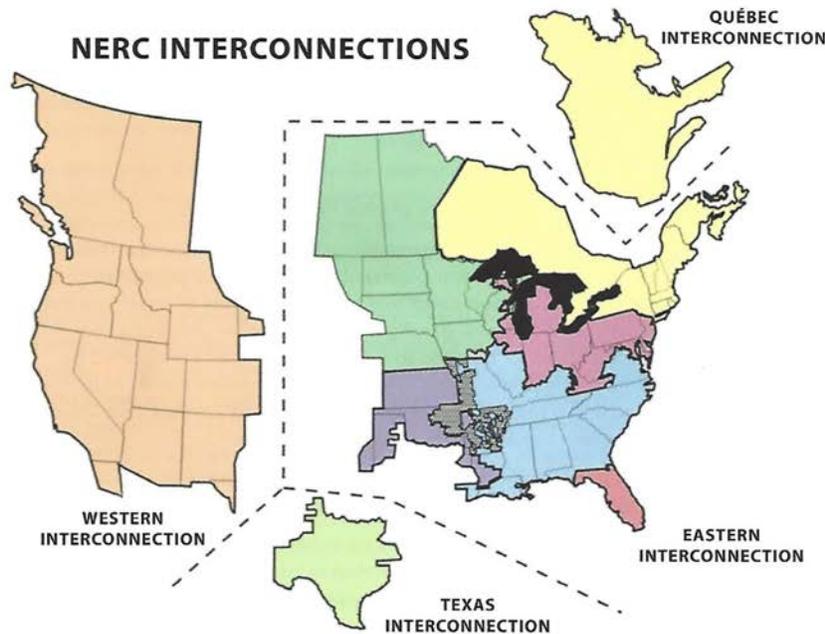
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<sup>16</sup> “EEI 101: Innovation,” Edison Electric Institute, accessed February 2016, available at: <http://www.eei.org/electricity101/Pages/e101.aspx?Page=Innovation>.

<sup>17</sup> Economic Benefits Of Increasing Electric Grid Resilience To Weather Outages, Executive Office of the President, August 2013, available at: [http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report\\_FINAL.pdf](http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf).

<sup>18</sup> In the context of the power grid reliability generally refers to the instant availability and controlled quality of electrical power, as opposed to the more macro issue of resilience, which refers to the system continuing to function following a major disruptive event.

The electric power grid serving the United States is really four interconnected regional grids.



Source: [www.energy.gov](http://www.energy.gov)

The balance that policymakers ultimately settle on has a real and lasting impact on the amount and cost of capital available for infrastructure modernization. This is because the decades-long payback period for a nuclear power plant, for example, makes it hard to justify if there is even a small chance that political considerations may mandate that the plant will be prematurely closed. Similarly, if the economic viability of a coal plant could be significantly changed through some future 'carbon tax,' such economic considerations must be factored into the decision to invest.

Accordingly, it is no surprise that the primary preoccupation of power industry leaders is managing continuity versus change in terms of infrastructure, technological advances, and their overall business model. In assessing long-term challenges for the power grid as currently configured, in 2009 the Government Accountability Office (GAO) determined that: "[t]he reliability and security of commercial electrical power grids are increasingly threatened by a convergence of challenges," among them:

1. Increased user demand,
2. Aging electrical power infrastructure,

3. Increased reliance on automated control systems that are susceptible to cyber attack,

4. The attractiveness of electrical power infrastructure for terrorist attacks,

5. Long lead times for replacing key electrical power equipment, and

6. Increasingly frequent interruptions in fuel supplies to electricity-generating plants.

GAO concluded that, “as a result, commercial electrical power grids have become increasingly fragile and vulnerable to extended disruptions.”<sup>19</sup>

*“Today, utilities’ revenues are directly tied to the amount of electricity they sell. This model reaches back to Thomas Edison’s days when regulators wanted to reward utilities for adding new customers to the burgeoning electric grid.”*

— Ralph Izzo, CEO, PSEG

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<sup>19</sup> “Defense Critical Infrastructure: Actions Needed to Improve the Identification and Management of Electrical Power Risks and Vulnerabilities to DOD Critical Assets,” U.S. Government Accountability Office, GAO-10-147, October 2009, available at: [http://transition.fcc.gov/pshs/docs/clearinghouse/GAO\\_Defense\\_Critical\\_Infrastructure\\_102009.pdf](http://transition.fcc.gov/pshs/docs/clearinghouse/GAO_Defense_Critical_Infrastructure_102009.pdf).

## SECTION II:

# THE TECHNOLOGICAL OPPORTUNITIES AND SPECIFIC RISKS FACING THE POWER GRID

*"The Grid of Things will integrate all of the new energy-related technologies that are being developed... in a way that gives our customers maximum flexibility, maximum choice in how they use energy, and ultimately maximum value."*

— Chris Johns, President of Pacific Gas and Electric Company (PG&E)

*"The U.S. could suffer a coast-to-coast blackout if saboteurs knocked out just nine of the country's 55,000 electric-transmission substations on a scorching summer day."*

— The Wall Street Journal discussing a Federal Energy Regulatory Commission report, 2014

The U.S. power grid is at a critical juncture; it faces many risks but also has many opportunities to improve efficiency, reduce environmental impact, and enhance security and resilience. Fortunately, the design, construction, and functioning of the grid is still within our collective control. Firms, regulators, advocacy groups, and end-users can and should take an active role in determining how to build the power grid of the future. There is still time to determine the appropriate balance among competing interests such as surety of service, economic costs, environmental impacts, and the role of large-scale versus small-scale energy producers. A brief discussion of three key emerging technological opportunities is provided below, followed by a summary of four significant risks facing the grid.

## THREE EMERGING TECHNOLOGIES DRIVING CHANGE

Several emergent technologies are driving change all across the industry, including (1) the 'smart grid', (2) distributed energy resources, and (3) the growing interest in using microgrids as self-contained, localized 'islands' separated from the grid's power generation.

### A. The Smart Grid

The most often discussed and potentially most significant industry-wide technology-enabled changes to the current electrical power grid involve the much celebrated smart grid. While the concept of a smart grid continues to evolve and has over time been used to mean several different things, an industry advocacy group explains it as follows:

To accommodate all of the new technologies coming to market, the grid is evolving from a one-way system to a dynamic plug-and-play platform that is “the grid of things” for new energy services and technologies. The grid increasingly is becoming a multi-directional network interconnecting millions of consuming devices, flexible distributed energy resources including DG [distributed generation], and back-up generation. It is enabling a wide-array of new technologies and innovations, including energy efficiency, electric vehicles, electricity storage, and microgrids to help consumers better manage their energy use.<sup>20</sup>

Clearly, this kind of information-based management of the demand side of the power supply means that industry can now create new ways to optimize the manner in which the grid continues to meet U.S. energy needs. As another industry report notes,

Several utilities have implemented large-scale pilot programs that pay residential customers to cut their electricity use during peak periods, offering rebates of around \$10 per day. Customers can use smartphone apps to control lights, locks, thermostats, and security systems even when away from home—and often in response to a text message or an e-mail from the utility alerting them that peak demand is occurring.<sup>21</sup>

Additionally, the industry is already deploying “machine-to-machine information-sharing technology developed by the Pacific Northwest National Lab that will dramatically improve situational awareness.”<sup>22</sup> As for how this adds value, experts note that: “improving the flow of information is about making sure the right people are getting the right information at the right time.”<sup>23</sup> With all the potential efficiency savings, improved situational awareness, expedited repairs and other advantages of a smart grid, this trend is likely to continue.

Indeed, the electric utility industry has already deployed more than 50 million ‘smart meters’ covering some 43 percent of U.S. households; such adoption represents the first



<sup>20</sup> “Briefing at the University Club,” *op.cit.*

<sup>21</sup> Brian Warshay, *op.cit.*

<sup>22</sup> “Briefing at the University Club,” *op.cit.*

<sup>23</sup> *Ibid.*

step in establishing the emergent smart grid.<sup>24</sup> Furthermore, following Hurricane Sandy—the 2012 storm that hit New Jersey very hard and generated an estimated \$50 billion of damages, including 8.6 million power outages across 17 states<sup>25</sup>—the New York power utility ConEd developed strategic plans that called for greater smart grid investment. ConEd experts explained the value of smart grid technology, which “give us tools that make the grid more flexible and responsive during extreme weather, which allows us to minimize power outages.”<sup>26</sup> They also noted that “smart-grid measures such as sectionalizing switches allow system operators to identify and isolate problem areas and rapidly bring power back to the surrounding areas, keeping more customers in service.”<sup>27</sup>

### B. Distributed Energy Resources, Including Renewables

Significant industry-wide change is also taking place as a result of greater interest in distributed energy resources (DER) —the official term for the panoply of small-scale, local power generation that exists alongside the centralized large-scale power generation

*“[2015] was a record-breaking year for rooftop solar power. It’s booming across the country. But as more homeowners make their own power, electric utilities are making less money, and that’s shaking up their business model.”*

— Lauren Sommer, NPR News

system—including renewables. In addition to the technology-driven potential of the smart grid, greater public advocacy for renewable energies has had a substantial impact on the power industry in terms of public pressure, political requirements, and outright subsidies for expanded use of low- or no-carbon alternative energies. As the EEI confirms, “Investment in renewable power continues to grow rapidly, and renewable

capacity is expected to more than triple between now and 2040.”<sup>28</sup> This energy revolution is poised for even more dramatic growth now that emergent technologies better support ever-expanding use of DER.<sup>29</sup>

Although often used in referring purely to alternative energies, the Department of Energy has made clear that DERs, “include fossil and renewable energy technologies

<sup>24</sup> John Banks and Lisa Wood, “The Flexible and Evolving Power Distribution Grid,” *Brookings*, December 9, 2014, available at: <http://www.brookings.edu/blogs/planetpolicy/posts/2014/12/09-flexible-evolving-power-distribution-grid-banks-wood>.

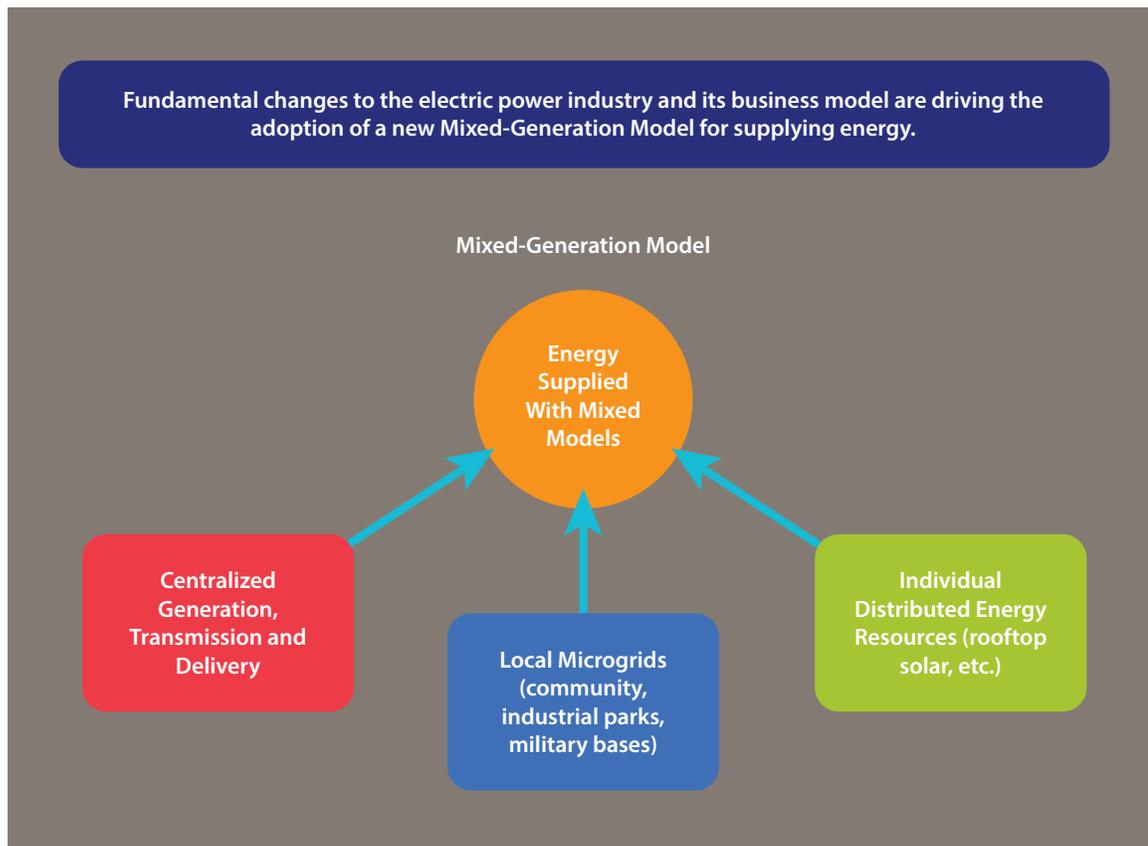
<sup>25</sup> Jeffery Halverson and Thomas Rabenhorst, “Hurricane Sandy: The Science and Impacts of a Superstorm,” *Weatherwise*, March-April 2013, available at: <http://www.weatherwise.org/Archives/Back%20Issues/2013/March-April%202013/hurricane-sandy-full.html>.

<sup>26</sup> Marc Lallanilla, “Smart Grids Could Fix Decrepit US Power Grid,” *Live Science*, December 14, 2013, available at: <http://www.livescience.com/41934-smart-grid-electrical-power-grid.html>.

<sup>27</sup> *Ibid.*

<sup>28</sup> “Briefing at the University Club,” *op.cit.*

<sup>29</sup> Berthold Hannes and Matt Abbott, “Distributed Energy: Disrupting the Utility Business Model” *Bain & Company*, April 17, 2013, available at: <http://www.bain.com/publications/articles/distributed-energy-disrupting-the-utility-business-model.aspx>.



(e.g., photovoltaic arrays, wind turbines, microturbines, reciprocating engines, fuel cells, combustion turbines, and steam turbines); energy storage devices (e.g., batteries and flywheels); and combined heat and power systems.<sup>30</sup> As the requisite technologies continue to improve—and continue to be subsidized by many governments—the total amount of DERs is on the rise.

Proponents of DERs believe they can help solve issues including peak demand and serve as back-up systems in case of a widespread power failure. Indeed, as the Electric Power Research Institute notes, certain DERs, “such as storage and advanced renewable technologies can help facilitate the transition to a smarter grid.”<sup>31</sup> Funding for renewables is growing; EEI notes that of the \$60.6 billion in investments to modernize the transmission system in the next decade, three-quarters of that amount is to support new renewable resources.<sup>32</sup> In fact, as the environmental quality mandates have become more restrictive, utility companies also have begun to consider investing in renewables, asserting that their

<sup>30</sup> “Distributed Energy,” U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability, available at: <http://energy.gov/oe/technology-development/smart-grid/distributed-energy>.

<sup>31</sup> Electric Power Research Institute, accessed February 2016, available at: <http://www.epri.com/Pages/Default.aspx>.

<sup>32</sup> Jeff St. John, *op.cit.*

utility-scale renewable projects can be managed at almost exactly half the total per watt cost of individual installations such as homeowners installing rooftop solar.<sup>33</sup>

However, DER has not been without its critics, mainly because the operating model of selling centrally generated energy—which is transmitted over long distances and fed into local distribution systems to nearly every business and household—requires long-term investments by shareholders that gradually recoup initial investments in technology and infrastructure by being paid back over time. A heavily DER approach challenges this business model of the grid because,

...with enough solar panels, a house can sell enough power back to the grid such that it zeroes out its electricity bill over the course of a year, becoming what is known as a 'net zero' household. However, using solar panels in this way would never allow a house to go completely off-grid, because the residence still needs power when the sky is dark. . . . As a result, many solar users get a free ride by taking advantage of the flexibility the grid provides without paying anything additional in return.<sup>34</sup>

Similarly, one power company executive has observed, "Our national power networks are designed to be able to meet expected peaks in demand, with additional power sources in reserve." This executive expressed the conundrum by remarking:

That helps to guarantee there will always be sufficient power supply, but it also means that much of the time the system is underutilized. In Southern California, only about 48 percent of our electric system is used on average.<sup>35</sup>

While these factors reflect current technological limitations, however, the future may look very different indeed, for the trend toward greater use of DER is likely to drive advances in increasingly affordable energy storage through better and cheaper batteries, thereby allowing DER users to separate from the grid altogether. Over time, it is quite possible the opportunities created by all manner of electricity-based innovations used by new market entrants will continue to reshape the system away from the centralized, closed model we have known for the past century.

### C. Microgrids

Microgrids are the third emerging technology driving change. Microgrids are fully built-out but smaller-scale versions of a more traditional grid system and are specifically focused on localized power generation and delivery for a small community, campus or other contained installation such as a military base.<sup>36</sup> Today's microgrids are typically connected to the main power grid—but also have enough on-site self-generated power

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<sup>33</sup> "Briefing at the University Club," *op.cit.*

<sup>34</sup> Brian Warshay, *op.cit.*

<sup>35</sup> Theodore Craver, *op.cit.*

<sup>36</sup> "The Role of Microgrids in Helping to Advance the Nation's Energy System," U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability, accessed February 2015, available at: <http://energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-system>.

to disconnect (or 'island') off of the grid in the event of a major disruption. They are, in essence, an extension of the DER model already described, with the exception that they include not only localized generation but also localized distribution. Microgrids are generally powered by conventional or alternative fuels, although the U.S. Navy has reportedly also explored the use of the miniaturized nuclear devices used to power part of the nuclear fleet as a potential fuel source for future microgrids.<sup>37</sup>

Microgrids are generally used because they offer enhanced resilience in the face of disruptions by functioning as a separate island that provides greater operational surety. The grid's lack of sufficient operational surety currently represents a major concern for industry as well as for both the military and intelligence agencies, which require energy in order to protect U.S. national security. State governments are also concerned; in the wake of Hurricane Sandy, concerns about operational surety led six affected states to join together in offering over \$100 million in microgrid grants to create reliable islands in the face of power grid disruptions, while California recently announced \$26.5 million in grants for microgrid projects that use renewable energy.<sup>38</sup>



*Microgrid researchers at Maryland's Aberdeen Proving Ground integrate multiple energy sources for use and storage.*

## FOUR EMERGING RISKS DRIVING CHANGE

Four emerging risks to America's power grid are becoming an increasing concern—and will drive change in the next several decades. These risks include: (1) technological obsolescence, (2) changing weather patterns and climate issues, (3) man-made threats, and (4) cybersecurity threats.

### A. Technological Obsolescence

The overall design of the U.S. power grid dates back to the late 1880s, an era before mass transportation, much less the internet, ubiquitous communications, and just-in-time

<sup>37</sup> "Nuclear Facility Capabilities," Lockheed Martin, accessed February 2016, available at: <http://www.lockheedmartin.com/us/products/intelligentmicrogridsolutions/MicrogridsNuclearCapabilities.html>.

<sup>38</sup> Brian Warshay, *op.cit.*

global supply chains. Even the more modern aspects of the grid still rely upon a regulated yet multifaceted system seeking to perfectly balance, at any given time, the exact amount of supply to meet ever-fluctuating demand—over great distances and at the lowest cost. Given the industries' twin mandates of lowest cost and highest reliability, as well as the fact that it is comprised of interlocking and often highly capital-intensive firms that raise funds by promising steady returns and long-term stability, the industry traditionally has approached new technology in a slow and steady fashion. In the current era of rapid technological innovations it is plain to see how the impact of this preference for slow adoption of new technologies could contribute to technological obsolescence.

On the other hand, this 'go-slow' approach is understandable from a business perspective when one acknowledges that an inescapable part of embracing new technologies is the assumption of risk as new materials, processes, and information gathering devices each seek their proper role in the 'new normal', prompting a number of significant issues in embracing any new tools and techniques. For example, as described above, the promise of the smart grid is that real-time information about demand—and potentially even utility-based control over certain elements, such as homeowner thermostats and refrigerators—could radically improve efficiency by seamlessly and automatically matching supply and demand. Some analysts even believe the potential efficiency gains of such a system would alleviate the need for new investment in costly, dirtier, and relatively sparsely used 'peak load' power generation plants. This is because, as the Department of Energy reports,

...[w]ithout a greater ability to anticipate, without knowing precisely when demand will peak or how high it will go, grid operators and utilities must bring generation assets called peaker plants online to ensure reliability and meet peak demand. Sometimes older and always difficult to site, peakers are expensive to operate – requiring fuel bought on the more volatile "spot" market. But old or not, additional peakers generate additional greenhouse gases, degrading the region's air quality. Compounding the inefficiency of this scenario is the fact that peaker plants are generation assets that typically sit idle for most of the year without generating revenue but must be paid for nevertheless.<sup>39</sup>

Even with such benefits, however, these potential advantages must be weighed against an equally significant set of unresolved issues, including:

1. Do smart meters create new cybersecurity vulnerabilities for the entire system?
2. Will users accept the perceived loss of privacy from usage being monitored in real-time? Will consumers cede control to utilities in order to make full use of the two-way flow of communication and remote adjustment of thermostats, etc.?
3. What are the appropriate performance and design standards for the new meters? Will state and local regulators accept the same standards, or will this create a

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<sup>39</sup> "The Smart Grid: An Introduction," U.S. Department of Energy, accessed February 2016, available at: [http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE\\_SG\\_Book\\_Single\\_Pages\(1\).pdf](http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf).

patchwork of further complicating issues? Which meters will regulators accept as part of the base rate, thereby making the associated costs reimbursable?

4. Are the costs of the more expensive digital meters (which may only last five to seven years) justified when compared to analog meters that work, maintenance and upgrade free, for up to 40 years?
5. How much will it cost to manage the new information flows and automate the command and control systems? Will the scale of improved efficiencies offset the increased labor costs for better data analysis and integrated operations management informed by better data?
6. Who will pay for liability and other costs incurred if the installed meters fail or cause harm?

Ultimately, then, the risk of costly technological obsolescence of the power grid remains a significant concern, albeit one driven by understandable business imperatives.

## B. Changing Weather Patterns and Climate Issues

Severe weather must be included in any consideration of the grid's current and planned reliability and performance because, "[n]atural disasters are the single largest cause of blackouts in the United States, responsible for 32 percent of all unplanned outages in 2013."<sup>40</sup> Indeed, a number of recent analyses have concluded that severe weather events are happening more often, and also that those events are having more significant impact.<sup>41</sup> Specifically, as noted by the director of the Technological Leadership Institute at the University of Minnesota,

We used to have two to five major weather events per year [that knocked out power], from the '50s to the '80s... Between 2008 and 2012, major outages caused by weather increased to 70 to 130 outages per year. Weather used to account for about 17 to 21 percent of all root causes. Now, in the last five years, it's accounting for 68 to 73 percent of all major outages.<sup>42</sup>

*"For the most part... a failure in one part of the grid won't bring down the entire network. But in some cases, two or more seemingly small failures that occur simultaneously can ripple through a power system, causing major blackouts over a vast region. Such was the case on Aug. 14, 2003, when 50 million customers lost power in the northeastern United States and Ontario—the largest blackout in North American history."*

— Jennifer Chu, MIT News Office

<sup>40</sup> Brian Warshay, *op.cit.*

<sup>41</sup> "Understanding the Link between Climate Change and Extreme Weather: Changes in Extreme Weather and Climate Events," U.S. Environmental Protection Agency, accessed February 2016, available at: <http://www3.epa.gov/climatechange/science/extreme-weather.html>.

<sup>42</sup> Meagan Clark, *op.cit.*

These events are also having more significant economic impacts than in previous decades. This rise in consequences is driven primarily by two factors affecting the total value-at-risk:

1. People are migrating into more densely packed urban areas, resulting in even a localized event affecting many more people, and
2. The dramatic increase in the interconnectedness and mutual dependencies among sectors of the economy have resulted in efficient but fragile systems where disruptions cost more and more.<sup>43</sup>

The issue of long-term climate change and its environmental impacts also influences the debates about the production and distribution of energy, and the formulation of

*Today's power grid faces an abundance of challenges including technological obsolescence, natural disasters, terrorism, and cyber security threats.*

energy policy. Main issues include the environmental impacts of fossil fuels and other source materials, and the movement of capital from developed countries to less developed ones in order to encourage their investment in cleaner but more expensive power generation. Over the next several decades this debate could have significant

impacts on the regulatory environment, as well as the development of energy policy related to the power grid.

Changing weather patterns and climate issues also are having other more direct effects on the power grid and energy demand because erratic events—such as elongated summers and colder winters—are shifting the energy consumers' demand, changing the location, timing and intensity of their need for energy.

### C. Man-made Threats

Man-made threats to the power grid are frequently discussed in the media and by industry experts, and most agree that there is a range of plausible concerns from international terrorists, radicalized domestic terrorists, or perhaps either anti-government groups or radical anti-fossil fuel industry activists. Despite these concerns, however, progress on comprehensive implementation of effective security and resilience measures has been slow at best. Consider, for example, the still unsolved 2013 sniper attack in Metcalf, California, wherein attackers fired more than 100 shots into Pacific Gas & Electric's Metcalf transmission substation, knocking out 17 transformers. The incident did not cause a blackout because utility officials were able to reroute electricity remotely, but the damage nonetheless included significant power disruptions during the 27 days it took to repair the installation and get it back on line.<sup>44</sup>

<sup>43</sup> "Understanding the Link Between Climate Change and Extreme Weather," *op.cit.*

<sup>44</sup> Mark Snowiss, "Attack Last Year on California Power Station Raises Alarm," Voice of America, February 4, 2014, available at: <http://www.voanews.com/content/attack-last-year-on-california-power-station-raises-alarm/1846303.html>

Perhaps most alarmingly, the perpetrator and motive of the attacks have not been identified. Was it a dry-run to see how quickly the authorities would respond? Is there a team of moderately trained saboteurs that present a real and persistent threat to the nation's power grid? The fact is that we just don't know. The immediate impacts were relatively contained, although this was an isolated event at a single location. A similar attack targeting multiple sites simultaneously would have been much worse. Indeed, as reported in *Time*, "A coordinated attack on just nine of the United States' 55,000 electric-transmission substations on the right day could cause a blackout from Los Angeles to New York City, according to the study conducted by the Federal Energy Regulatory Commission."<sup>45</sup>

At the very least, incidents like the Metcalf attack and the findings of the Federal Energy Regulatory Commission's report should serve as a wake-up call that the real and persistent threat of deliberate domestic or international physical attack against the grid is a concern worth taking seriously. And the ongoing discussions have prompted a reaction, to a degree. Industry utilities and regulators have begun the process of developing new standards that will aim to reduce the likelihood of deliberate terrorist events, as well as identifying and minimizing access to the relatively few key nodes whose loss could cause the most damage. But much work remains to be done, and the threats exemplified by the specific incident in Metcalf only point to a larger systemic problem: the present system relies on thousands of access points that are often remote and/or poorly secured. If they were targeted in a deliberate manner the resulting impacts could present a serious national and economic security threat, as well as create cascading failures across the system.

#### **D. Cybersecurity Threats**

Historically, both the grid and the internet communications system on which it is increasingly reliant were designed as 'open systems' in which, for the most part, security has been an after-the-fact add-on. This is important because in the future, control over all manner of grid operations is expected to rely upon digital commands sent via the internet and even if the power control systems themselves are secure a corrupted communications pathway could lead to intentionally harmful commands or false readings calling for more or less power being injected into the system. This could be especially dangerous if the grid's supply and demand operations continue to move to more automation in order to reduce speed of decisions and increase operational efficiencies.

Cybersecurity presents perhaps the most challenging problem for the power grid because the total number and status of potential network entry points is almost impossible to calculate. This problem is set to increase exponentially as the smart grid continues to emerge and connections to the grid, conceivably, are made by everything from vehicles to household appliances. Indeed, the complexity of cybersecurity concerns associated with a new wave of smart meters and other end-user and demand-control sensors coming

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<sup>45</sup> "U.S. Could be Plunged into Blackout by Minimal Attacks," *Time*, March 13, 2014, available at: <http://time.com/23281/report-u-s-could-be-plunged-into-blackout-by-minimal-attacks/>.

online, each of which necessarily involves two-way communications, is mind-boggling. Further, due to thousands of different companies operating multiple interconnected systems receiving input from untold numbers of far-flung sensors, the oversight necessary for any reasonable level of surety of the system is far from guaranteed.



*Replacing outdated electrical infrastructure like this 1915 power substation is projected to cost over \$2 trillion within the next twenty years. (By Sturmovik at en.wikipedia, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=13473001>)*

Making matters worse, the range of cyber attackers and their differing motives includes everything from criminals seeking credit card information and so-called 'hacktivists' that want to make a statement about environmental or social concerns, to direct terrorist attacks and even state-sponsored actors seeking a deniable and non-military means of settling political scores. Internationally, consider the December 2015 and January 2016 cyberattacks on Ukraine's electric power grid that brought down portions of the system and left millions in the dark—attacks suspected but unconfirmed to have originated in Russia as part of ongoing

political tensions. And, in a sign of things to come, news reports now warn, "researchers studying the attacks say the malware believed responsible—a new version of the so-called BlackEnergy bug—has likely spread to numerous European power grids and is poised to infect many more."<sup>46</sup>

And yet one doesn't even need to look abroad to see the prevalence of cyber threats facing the United States. For example, while serving as the head of the National Security Agency, Admiral Michael Rogers testified that China and one or two other countries have the capacity to shut down the nation's power grid and other critical infrastructure through a cyberattack.<sup>47</sup> Similarly, according to the Associated Press,

About a dozen times in the last decade, sophisticated foreign hackers have gained enough remote access to control the operations networks that keep the lights on, according to top experts who spoke only on condition of anonymity due to the sensitive nature of the subject matter. . . . These intrusions have not caused the kind of cascading blackouts that are feared by the intelligence community. But so many

<sup>46</sup> Doug Bernard, "National Power Grids Increasingly Targeted in Cyber Attacks," *Voice of America*, February 1, 2016, available at: <http://www.voanews.com/content/national-power-grids-increasingly-targeted-in-cyber-attacks/3171551.html>.

<sup>47</sup> Jamie Crawford "The U.S. government thinks China could take down the power grid," *CNN*, November 21, 2014, available at: <http://www.cnn.com/2014/11/20/politics/nsa-china-power-grid/index.html>.

attackers have stowed away in the systems that run the U.S. electric grid that experts say they likely have the capability to strike at will.<sup>48</sup>

If there is any 'good news' in the cyber realm it is that the current worries about the potential damage from the grid's cyber vulnerabilities may be overblown by the media and some outside observers. After all, the system today remains mainly analog in nature and still has numerous physical controls that can be used to stem the damage if a major attack does occur, with the system as a whole surviving even if a portion of the grid had to be isolated and turned off.

However, this good news is fading by the day as more and more new technologies are integrated into the existing grid's infrastructure. The rapid pace of technological change and the mandated integration of distributed energy sources and associated technologies could create literally millions of additional cyber entry points to the grid—and each of these creates the potential for a novel cyber penetration point into the grid's core system. Furthermore, the potential seriousness of the cyber threat moving forward has been made clear from the statements of senior administration officials, security professionals and politicians from across the ideological spectrum.

For example, and perhaps of greatest concern, across more than a decade of experience running the Department of Homeland Security (DHS) and while serving U.S. presidents from both sides of the political aisle, all four of the DHS Secretaries thus far have demonstrated unusual bipartisan agreement on a single fact: the United States faces an ongoing threat of a major cyberattack against the power grid. While former-Secretary Michael Chertoff has been the most vocal about cyber risks, closely followed by Tom Ridge, Janet Napolitano famously stated the issue to be, "a question of 'when,' not 'if'."<sup>49, 50</sup> More recently, Jeh Johnson, the current Secretary of Homeland Security, was quoted as saying it, "is definitely an issue. Of the range of homeland security threats out there that we have to be responsible for, I would characterize this one as low probability relative to others, but high risk, high cost, and so... we do have to be prepared."<sup>51</sup> To conclude, cybersecurity concerns must remain paramount as we build out the power grid of the future.

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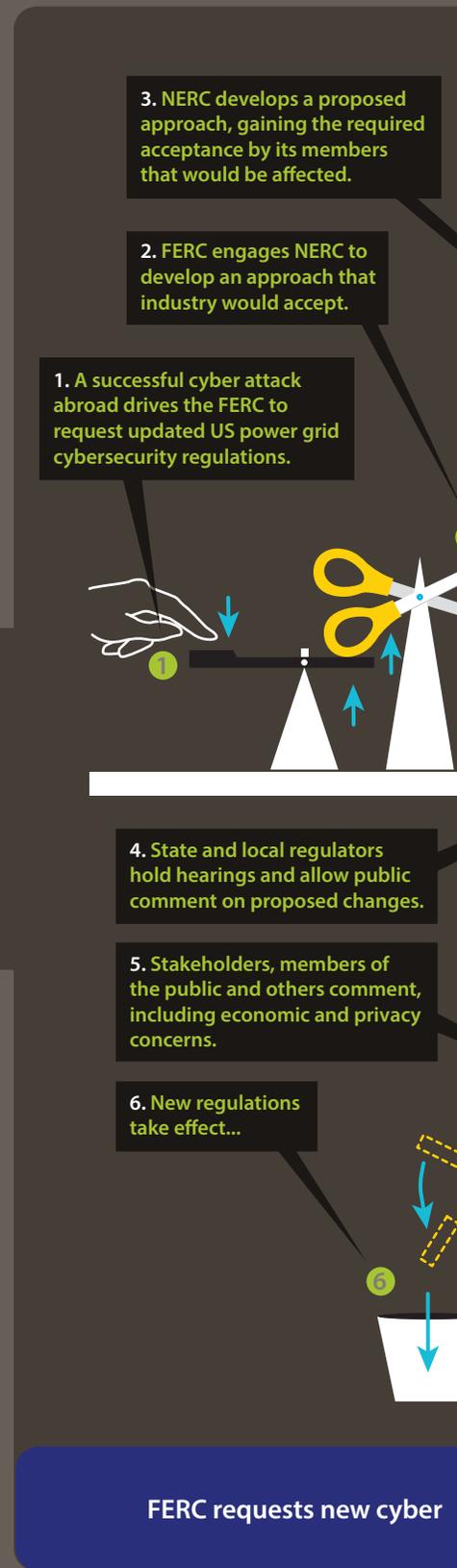
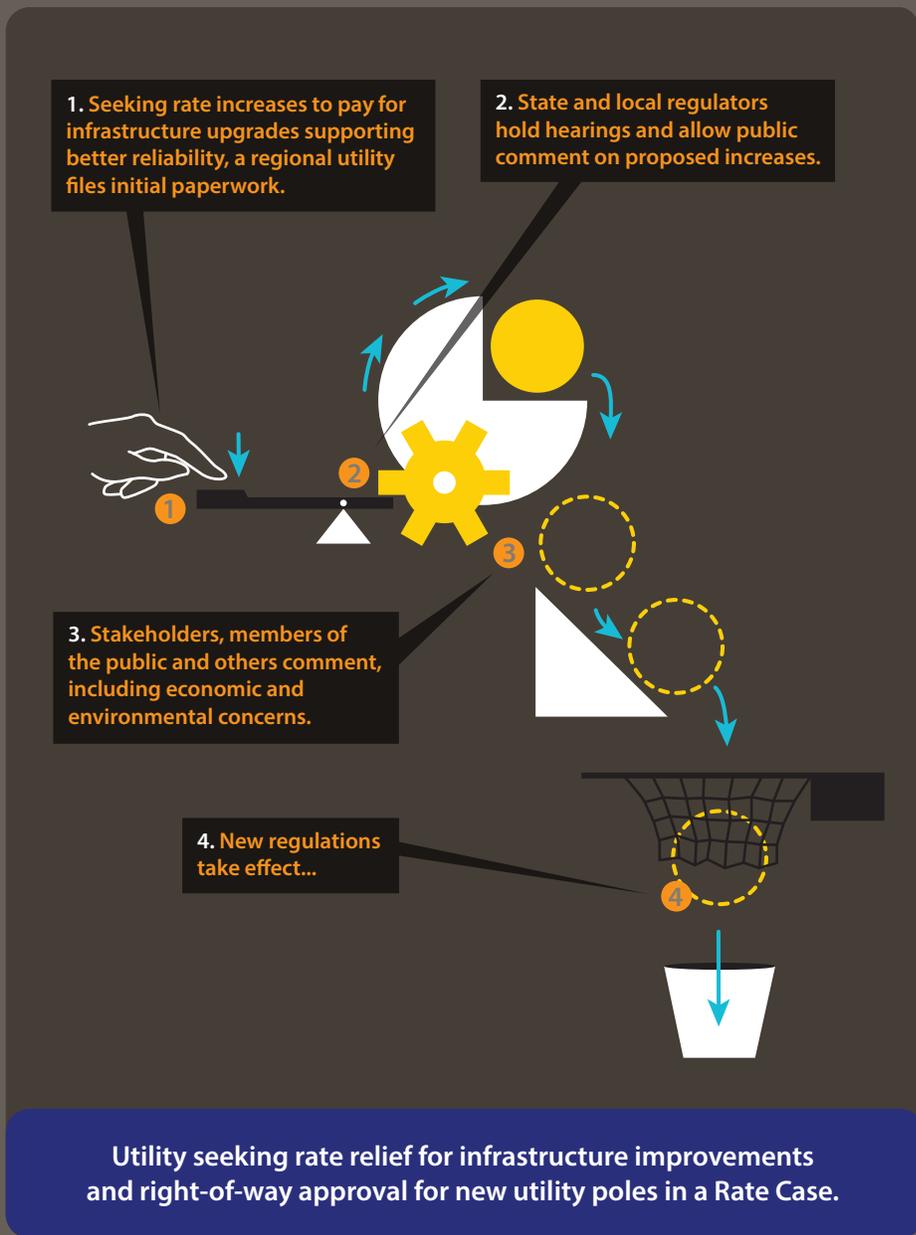
<sup>48</sup> Garance Burke and Jonathan Fahey, "U.S. power grid vulnerable to foreign hacks," *Penn Energy*, December 21, 2015, available at: <http://www.pennenergy.com/articles/pennenergy/2015/12/ap-investigation-u-s-power-grid-vulnerable-to-foreign-hacks.html>.

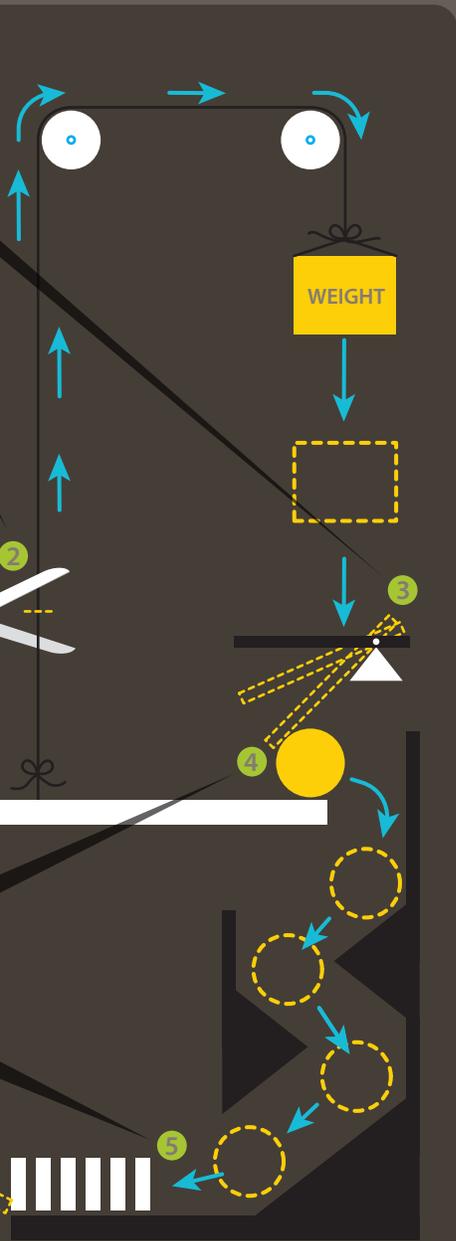
<sup>49</sup> Andrew Maykuth, "Ridge warns utility officials on threat of attack," *Philly.com*, November 14, 2013, available at: [articles.philly.com/2013-11-14/business/44033724\\_1\\_electric-grid-cyber-attack-terry-boston](http://articles.philly.com/2013-11-14/business/44033724_1_electric-grid-cyber-attack-terry-boston); Michael Chertoff, "Building a Resilient Power Grid," *The Chertoff Group*, May/June 2013, available at: <http://www.chertoffgroup.com/cms-assets/documents/164670-923446.epmayjunecyberchertoff.pdf>.

<sup>50</sup> Mike Levin, "Outgoing DHS Secretary Janet Napolitano Warns of 'Serious' Cyber Attack, Unprecedented Natural Disaster," *ABC News*, August 27, 2013, available at: [abcnews.go.com/blogs/politics/2013/08/outgoing-dhs-secretary-janet-napolitano-warns-of-serious-cyber-attackunprecedented-natural-disaster/](http://abcnews.go.com/blogs/politics/2013/08/outgoing-dhs-secretary-janet-napolitano-warns-of-serious-cyber-attackunprecedented-natural-disaster/).

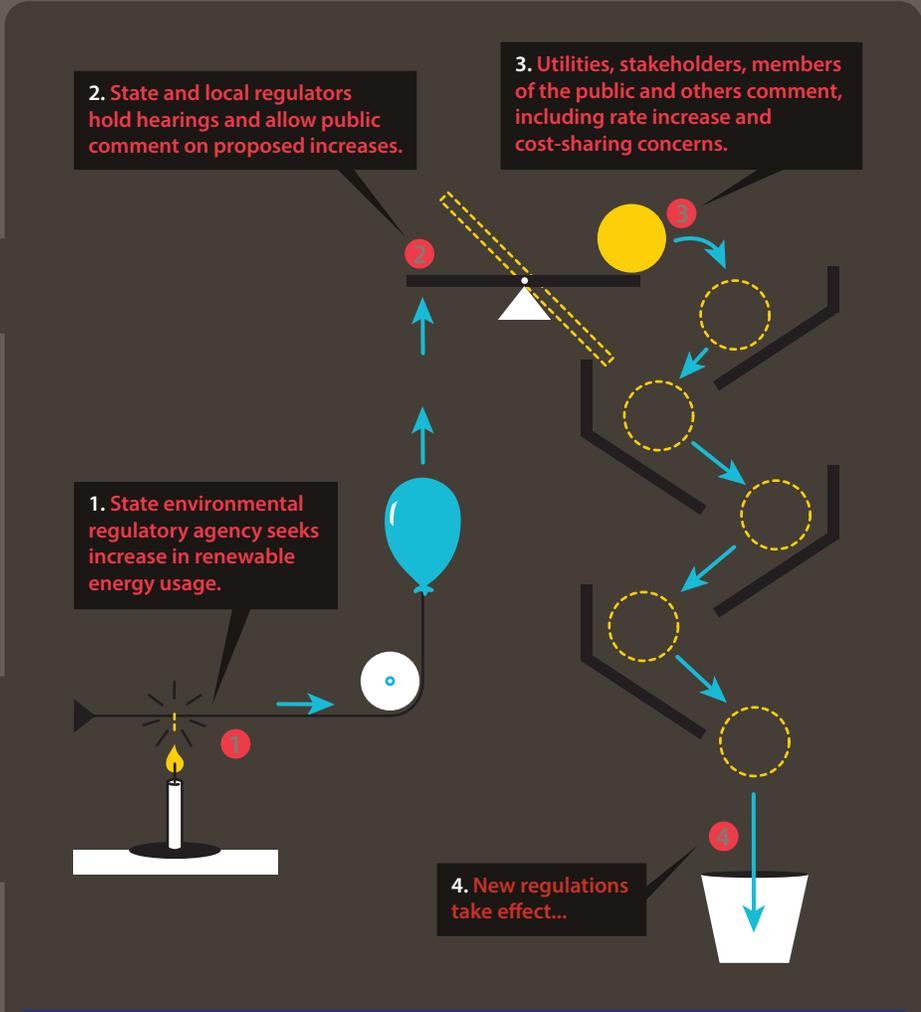
<sup>51</sup> "Jeh Johnson on U.S. Cybersecurity Readiness," *Council on Foreign Relations*, November 4, 2015, available at: <http://www.cfr.org/homeland-security/jeh-johnson-us-cybersecurity-readiness/p37196>.

# HOW GOVERNANCE OF TODAY'S POWER GRID WORKS: THREE EXAMPLES





security regulations.



State Agency seeks new renewable usage to reduce greenhouse emissions.

## SECTION III:

# THE FUTURE FOR ENERGY PRODUCERS AND CONSUMERS

*“Going forward, we need a new way of thinking, with greater partnering between regulators and utilities. If all parties can work together—and not against each other—the rewards to customers, our economy, and our environment will be enormous. This new framework must align the interests of our consumers, shareholders, and society.”<sup>52</sup>*

*— Ralph Izzo, Chairman, President, and CEO of PSE&G*

Over the next several decades, the total cost of upgrades to the power distribution system will be enormous, and naturally most or all such costs will be borne by the users of the system. As a result, some users may instead choose to pursue microgrids. If even a relatively few users choose to cut costs by moving to self-generated power, what will that mean for the rest of the system? As a recent briefing by the global consulting firm Bain & Company reports, “The rise of distributed energy represents a significant disruption for large utilities, one that will put their current business models under severe pressure. Some already feel the impact on profitability as these systems reduce their revenue from usage-based rates.”<sup>53</sup>

Clearly, one unintended by-product of this process will be the need to raise even further the average cost for all users who stay in the system. But what else will it mean for the various different types of producers and consumers moving forward? The following section explores the impacts for power utilities, DERs and regulators, as well as each of the major categories of consumers.

## THE SUPPLY SIDE – ELECTRICAL POWER PRODUCERS AND REGULATORS

On the supply side, the three key types of participants are: (1) power utilities, (2) distributed energy resource producers, and (3) industry regulators. Ongoing changes in the energy sector and the power grid will have important implications for how these electrical power producers and regulators operate—and the extent to which they can

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<sup>52</sup> Ralph Izzo, “Unleashing the Power of the Modern Electric Grid,” *Energy Talk*, July 2015, available at: [http://eei.org/mwg-internal/de5fs23hu73ds/progress?id=Q9m\\_8\\_NU4AyBpjsOIYVq8HZei1MDPxksJGPSvBR7bOg](http://eei.org/mwg-internal/de5fs23hu73ds/progress?id=Q9m_8_NU4AyBpjsOIYVq8HZei1MDPxksJGPSvBR7bOg).

<sup>53</sup> Berthold Hannes and Matt Abbott, *op.cit.*

help to achieve the long-term balance among cost, security, environmental impacts, and systemic resilience.

### A. Power Utilities

The discussion about the future roles and responsibilities, business model and even viability of the modern electric utility is so widespread that industry executives openly discuss it, albeit with assurances that their firms are the best means of ensuring continued widespread access to affordable, reliable electricity. For example, Ralph Izzo, the Chairman, President, and CEO of Public Service Electric and Gas (PSE&G), writes,

Some in our industry say... that we are entering a new, fundamentally different age of energy; that utilities are headed the way of the dinosaurs; and that centralized power is doomed. I agree that change is coming—and already is underway—but I believe that utilities and central power will be at the center of the 21st-century grid.<sup>54</sup>

Mr. Izzo's confidence apparently stems from his belief that, "Utilities have scale and access to customer information that will allow for optimal deployment of these new technologies in a way that maximizes benefits at the lowest cost," further noting, "The utility model has been very powerful in bringing universal access to natural gas, electricity, and water. The utility of today and tomorrow can play a similarly critical role in ensuring universal access to new technologies, from thermostats that promote energy efficiency to solar panels, batteries, and other devices."<sup>55</sup>

These sentiments are echoed by other current and former industry leaders, including former Duke Energy CEO Jim Rogers, who explains, "Today, we [power utilities] are a battery. We have tens of millions of customers making random decisions every second—turning lights on, turning on their TVs. And we handle that because we have an infrastructure that acts like a battery. We're always there."

Because utilities have been doing it on the demand side for a long time, the sector's ability to balance, to optimize on the supply side and demand side is doable.<sup>56</sup> Yet another common line of thought is that renewables and small-scale power generation have limits to their growth, as demonstrated by former Chairman of the Colorado Public Utilities Commission, Ron Binz, who believes that utilities will still be big actors because distributed generation has a 'natural ceiling' of about 30 percent.<sup>57</sup>

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<sup>54</sup> Ralph Izzo, *op.cit.*

<sup>55</sup> *Ibid.*

<sup>56</sup> "Experts Address the Future of Electric Utilities," Brookings, February 4, 2018, available at: <http://www.brookings.edu/blogs/brookings-now/posts/2014/02/experts-address-the-future-of-electric-utilities>.

<sup>57</sup> *Ibid.*

**Implications of Ongoing Changes:** *With so much money and power invested in the current model it seems that the utilities will continue to be the main players for years to come, albeit with the coming years potentially witnessing a transformation of the power utility model into one that embraces a shift from delivering power to one focused on a comprehensive 'service as a product' approach, much as recently happened to the information technology sector and a shift from hardware into remotely delivered services. Even if industry leaders believe they can successfully navigate the upcoming changes, there is still a recognition by many that their business models will have to expand, with two important aspects potentially taking the lead: (1) investing in distributed generation by leveraging relatively affordable access to capital, and (2) managing the demand side of the power equation by remotely adjusting customer thermostats and other efficiency or time-shifting measures.<sup>58</sup>*

## B. Distributed Energy Resources

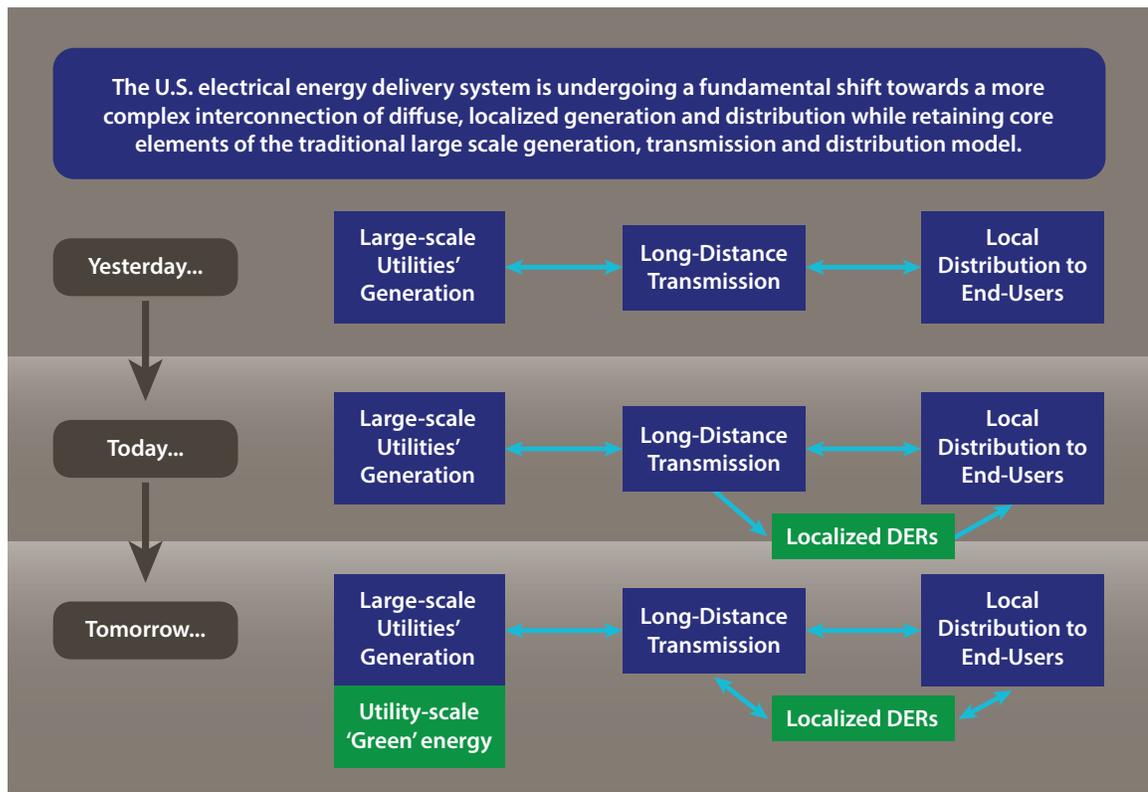
The myriad individuals and entities involved in the distributed energy resources field are perhaps best considered 'micro-producers'. As such, many of the market drivers listed above for the power utilities will affect these producers too, albeit from a different and often opposite perspective. For example, if the large legacy power utilities will be forced to reorient themselves towards a dynamic market that demands reliability as well as low costs, environmental stewardship, technology innovations, and security, it will be in large part because the market's DER owners are driving those changes by demonstrating new approaches to power generation, distribution, and consumption.

It is precisely because they are often the nimble, agile actors that show the power of innovation and new ways of doing business, that the DERs are at the forefront of the necessary trial and error to drive innovation cycles and demonstrate the viability of new approaches. Indeed, perhaps the DERs' greatest promise is their ability to help redefine the energy business as being less about delivering watts of energy to end-users and more about managing the customers' power needs at an appropriate balance among cost, reliability, environmental impact, and resilience. Similarly, as the DER community grows it may be able to drive towards better large-scale energy storage solutions that would release them from the tyranny of only being able to provide power real-time as it is produced, thereby freeing them from the need to connect to the grid for power during their non-productive periods.

At the same time, as the DER community becomes more mainstream it may face a lessening of the somewhat automatically positive reception they receive from the public, politicians, and regulators. In other words, the collective community of DER participants

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<sup>58</sup> *Ibid.*



may need to become more organized in order to efficiently grow, and yet as it becomes big enough to require some dedicated infrastructure investments it then will have to act more like traditional business with the need for longer-term stability and planning of their economic model. Also, will the DER producers continue to focus mostly on self-sufficiency or highly localized distribution, or will they position themselves to harness new technologies to be able to serve an ever larger customer base?

These kinds of issues require centralized, coordinated messaging. This need will become ever greater as DERs are seen to directly threaten vested economic interests—such as how they essentially are subsidized by other users as they 'freeload' from the grid by having 24/7 connectivity and net zero power bills even though they can only produce power

**Implications of Ongoing Changes:** *The outlook for strong growth in the size and importance of the DER community is very positive. There is a market need for the kinds of innovations and new thinking that DERs can bring about, as well as a general public demand for the kind of 'clean and green' power they represent. However, along with the potential positives, there is also potential peril should the DER producers fail to better align themselves to some common standards in terms of where they see the future, how to define their role within the energy market as they become more mainstream, and how best to define their collective approach to the market.*

during portions of the day. Similarly, as the scale of DER grows it will be important to lock down certain standards such as security protocols for interoperable but reasonably secure two-way communications required by the smart grid of the future.

### C. Regulators

Industry regulators have perhaps the most difficult job of all the actors discussed in this paper. Their primary operational imperative is to safeguard the interest of the public relative to the overall operation of the grid. This is often construed, first and foremost, to mean keeping rates low.

Regulators attempt to keep rates low by ensuring that utilities do not waste money on unnecessary investments by using their power to approve or disapprove certain expenditures as able to be recouped from the bills paid by customers. And yet the general public also wants to see more clean and green power being produced, and in many instances has pressured politicians to mandate changes that are costly to implement. In so doing, the regulators are generally caught in the middle, forced to mediate between the potential benefits of innovative technologies and the imperative to keep costs down for all users. Making it all the more complicated, regulators also face persistent pressure to focus on maintaining highest levels of 'up time' for the grid, for consumers are very vocal about their demand for always-on access to electricity. And in today's world of numerous threats emanating from both man-made actors as well as rare but severe weather events, the long-term security of the grid also competes for regulatory time and attention.

***Implications of Ongoing Changes:*** Two primary challenges face the regulatory community:

- 1. Regulators from various states and localities need to become better aligned internally so that decisions made in one locality are aligned with those in the neighboring localities, and*
- 2. The regulatory community must find ways to support innovative pilot programs in order to allow for the trial and error risk-taking that inevitably accompanies innovation.*

*An important example of this latter issue is for regulators to better interact with the utilities as part of the large-scale solution for distributed energy through acceptance of utility-scale renewable energy projects that reward utilities for managing supply and demand or achieving emissions savings, as opposed to only rewarding them per watt of power sold.*

*The potential gains from a shift to this type of enlightened regulatory approach would require time and risk-taking as new boundaries are tested and approved, but could play a major role in the inevitable and necessary shift from the current business model of utility as 'provider of power' to one of utilities (and other providers) as 'deliverer of managed services' that include the efficient, clean, and secure power the consumers both need and want.*

## THE DEMAND SIDE – ELECTRICAL POWER USERS

### A. Energy-Intensive Businesses

Highly energy-intensive businesses—including many manufacturing firms and those providing massive computing power such as server farms—will soon face a decision they perhaps have not had to deal with, or at least not as a primary economic consideration: If the price of all this modernization ultimately is to be borne by the power grid user base, as a large electrical consumer could or should they move to self-generated energy vice continuing to purchase power from the grid? The two main drivers of this cost-benefit decision include the increasingly viable option of distributed energy and/or full-up microgrids as well as the very real concern that, depending on how costs are allocated, the price of intensive energy consumption could become unaffordable if large-scale users have to bear the brunt of the industry's infrastructure modernization bills. In other words, just as the cost of labor or high local taxes drive business investment and infrastructure location decisions, energy-intensive businesses will have to increasingly ask themselves, "what's the cost of self-sufficiency, especially if I were able to sell back any surplus energy production to the grid?" Additionally, for some firms, another aspect of this decision will be the degree to which a prolonged outage might present an existential economic threat due to lost production or broken customer service agreements. For such firms, the considerations around resilience may well be enough to justify a move off the grid in favor of a microgrid, be it as a stand-alone or a shared community of similarly positioned firms.

*[Existing regulatory incentives] "are out of step with what our customers and society need today. Utilities need incentives to reduce energy use and customer bills, not sell more. Utilities need a construct that supports long-term plans to make existing infrastructure smarter and more resilient—investments that make the grid work better but do not necessarily add new customers. Modernizing the way we regulate utilities will help make energy more reliable, cleaner, and more affordable for all customers."*

*— Ralph Izzo, Chairman, President & CEO, PSE&G*

***Implications of Ongoing Changes:*** *The increasingly plausible movement to self-generation of power in a localized way enabled by technological advances—and, increasingly, by the prospect of future rate increases for grid-delivered power—is changing the calculus for some or all manufacturing needs. The decision to shift from energy consumption to energy self-sufficiency is a significant one, but as new technologies continue to emerge and the growth of shared investments such as a business park with a self-contained, shared microgrid become more plausible, these kinds of decisions should be on the agenda for anyone for whom the cost of energy is a major economic driver.*

## B. National Security Entities

The U.S. national security community includes the Department of Defense (DoD), Department of Homeland Security, and the Intelligence Community, among others. DoD alone spends more than \$600 billion on ensuring it is ready and able to defend American interests globally, including the costs of maintaining more than 300 domestic military installations—at a staggering global energy bill of some \$4 billion per year.<sup>59</sup> And yet, according to a 2009 GAO report, “All 34 of [the Department of Defense’s] most critical assets require electricity continuously to support their military missions, and 31 of them rely on commercial power grids—which the Defense Science Board Task Force on DOD Energy Strategy has characterized as increasingly fragile and vulnerable—as their primary source of electricity.”<sup>60</sup>

The GAO’s conclusion means that several hundred domestic U.S. installations—including potentially those providing everything from support for the President’s plane at Joint Base Andrews to the Special Operators at Fort Bragg and MacDill Air Force Base to Fort Meade’s National Security Agency—depend upon the same grid as every other electricity consumer in America. This concern also was echoed by the then-Assistant Secretary of Defense for Homeland Defense and Americas’ Security Affairs, Paul Stockton, when he stated in 2012 that the risks to the DoD from a prolonged power outage, “keeps him up at

**Implications of Ongoing Changes:** *As with the energy-intensive industries discussed above, the potential shift to some or all assets operating in self-contained microgrids may increasingly make sound financial sense. But even more importantly it may fulfill a national security imperative to ensure that the nation’s defense establishment remains at the ready, come what may. While reliance upon the grid has served the DoD and related entities well, for much of the national security world the top priority is continuity of operations with economics a secondary consideration. According to the GAO report cited above the DoD has some potential vulnerabilities it needs to address. While not every facility is of the same level of criticality and some would probably be well-enough prepared by connecting to the grid and using generators as back-up, for select tier-one facilities the defense establishment may be well served to consider isolating itself from the security and economic burdens of the future national power grid.*

<sup>59</sup> War College paper, which cited Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP), “Installation Energy Test Bed,” linked from the Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP) Home Page at “Featured Initiatives, Installation Energy,” accessed November 21, 2011, available at: <http://www.serdp-estcp.org/Featured-Initiatives/Installation-Energy>.

<sup>60</sup> “Defense Critical Infrastructure: Actions Needed to Improve the Identification and Management of Electrical Power Risks and Vulnerabilities to DOD Critical Assets,” *op.cit.*

night,” adding “The DOD depends on [civilian] infrastructure in order to be able to operate abroad. And to make those operations function, we depend on the electric grid.”<sup>61</sup>

With such a significant annual expenditure, massive operational footprint, and high reliance on assured access to electrical power, it is no wonder that DoD is actively seeking to redefine its approach to acquiring and ensuring the flow of the electricity it requires to carry out its missions. This has taken the form of numerous pilot projects including several microgrids.

### C. ‘Regular’ Consumers and Businesses

As relatively minor users, for household use and non-energy intensive businesses the total cost of access to electricity from the grid is actually quite manageable, totaling less than 2 percent of disposable income, on average, and at roughly the same inflation adjusted per unit cost as in 1959.<sup>62</sup> Given this fact, for the near term the reality is that most typical users of the grid will opt to continue to rely upon it as their main source of power, even if the costs do increase over time as the utilities try to recover their modernization outlays. As a result, for most relatively small users a pure cost-benefit assessment will still settle out in favor of reliance on the grid.

However, even if the pure business case would lean towards continuity of service via the grid, there are nonetheless current market subsidies that can alter that decision, as well as those who may choose to embrace alternative energy for reasons such as reducing their total emissions footprint, as opposed to pure cost-benefit analysis. Therefore, it is

**Implications of Ongoing Changes:** *For most typical residential and business consumers the grid remains a simple and relatively cost-efficient means of accessing the required electrical power. Microgrids and other solutions each still have their own sets of drawbacks and limitations, and especially for the small-scale individual business or person the ease of access and lack of requirement for specialized electrical energy knowledge means it is cheaper to maintain the status quo. Again, on a case-by-case basis this may vary owing to subsidies, personal philosophical beliefs about the environment, or other incentives, but from a practical and efficiency standpoint the grid will continue to be the preferred source of electrical power.*

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<sup>61</sup> Dan Merica, “DoD official: Vulnerability of U.S. Electrical Grid is a Dire Concern,” *CNN*, July 27, 2012, available at: <http://security.blogs.cnn.com/2012/07/27/dod-official-vulnerability-of-u-s-electrical-grid-is-a-dire-concern/>.

<sup>62</sup> According to the EEI’s February 10, 2016 Wall Street Briefing, “[W]hile American homes use 55 percent more electricity today than they did in 1970, U.S. electricity prices have, in fact, increased at a lower rate than the prices for other consumer goods. . . . According to the latest data from the U.S. Departments of Commerce and Labor, electricity totaled 1.485 percent of personal consumer expenditures, or less than a penny and a half of every dollar spent, in 2014. This is the exact same percentage as in the year 1959, and is equivalent to \$1.56 per person, per day.”

reasonable to expect two trends to continue: local use of renewable energy and small-scale back-up generators. Consequently, as long as the prices continue to drop and the subsidies continue, some individuals will likely continue to pursue localized distributed energy, most typically rooftop solar, while the concerns about resilience and the impacts of seemingly more frequent severe weather also will keep many others relying on back-up generators.

## SECTION IV:

# MODELS FOR THE FUTURE OF THE GRID

*"Change is the Only Constant"*

— *Heraclitus, Greek Philosopher*

There can be little doubt that the inexorable growth towards a new and more modern electrical power system will involve significant changes for all participants, even though systemic change is inherently difficult because the existing system has a number of incumbent power centers that will want to ensure their role and relevance moving forward. Nonetheless, as the nation's energy needs continue to evolve and significant capital is expended in modernizing key parts of the power grid, the opportunity has arisen for us to give deliberate consideration to the optimal future operating construct of the system as a whole.

Ultimately the potentially massive economic, security and environmental benefits from such new opportunities as improving the use of real-time smart grid data, efficient and cleaner distributed energy resources, and real world resilience will continue to drive change. What is less clear is whether we will work together to ensure the outcome is deliberate, efficient, and representative of our desired outcome, or if the changes will appear more organically and without deliberate regard for 'whole-of-system' optimization. For example, who will pay for the improvements, how will everyone from producers to consumers be impacted, and will safety and security be properly built-in up front? All these issues remain to be resolved.

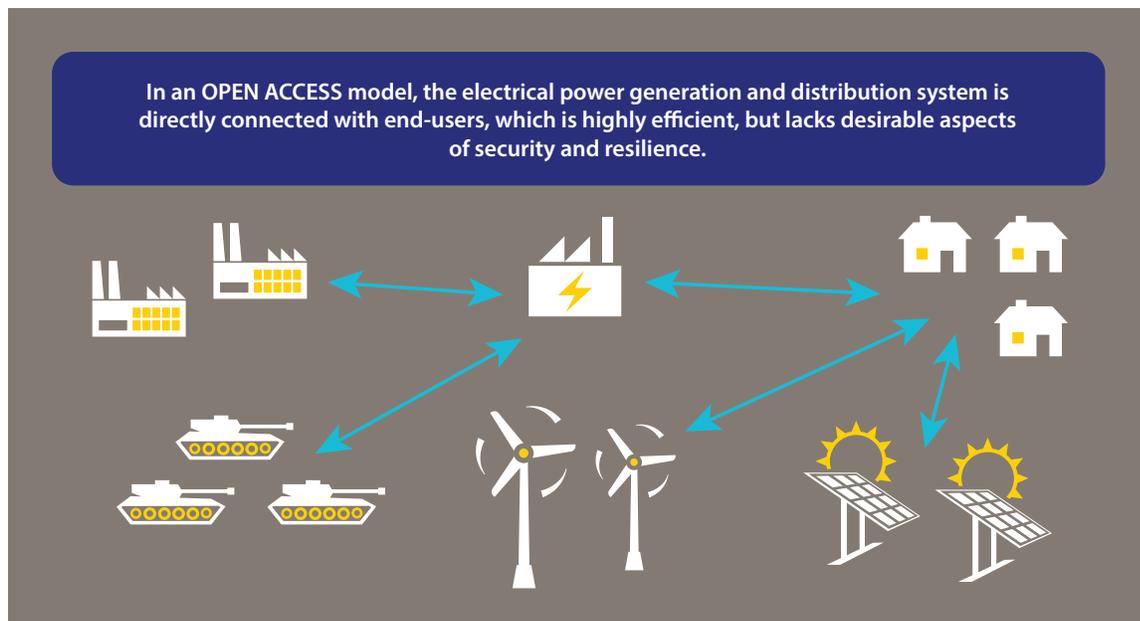
But what is certain is that the future of the grid will be a product of our own creation, albeit one with potentially significant unintended consequences. Further study remains to be done, and perhaps most importantly there needs to be a call for much more significant and robust testing of promising new systems architectures to determine the viability and proper role of such new approaches as microgrids, real-time secure monitoring, and the like.

In an effort to advance the discussion about how best to conceptualize the future of the electrical power industry, the following section presents three models: (1) Open Access, (2) Closed Loop, and (3) Islands and Oceans. Each approach offers its own balance of cost, reliability, environmental impact and resilience, as explored below.

### **A. Open Access**

An Open Access model is essentially an extension of the current model, one which allows for all (or almost all) sources of generation to become a part of the national grid

for distribution to end-users across a single open system. This model offers the benefits of continuity with the current model and builds on the legacy of high degrees of access at relatively low cost. This enables a myriad of end-users to receive affordable electrical energy without undue burden and spreads the costs of maintaining the system across all paying customers.



On the other hand, an Open Access model also means that the system as a whole remains very much decentralized, which in turn complicates the ability to ensure widespread use of appropriate controls and reasonable security standards such as physical and cybersecurity measures that protect the grid itself and, in turn, the needs of the end-users for a reliable and resilient power grid. Furthermore, the Open Access model does not differentiate between a user for whom the grid is important but less essential than it is for others such as the military, airports, hospitals, or critical manufacturing hubs.

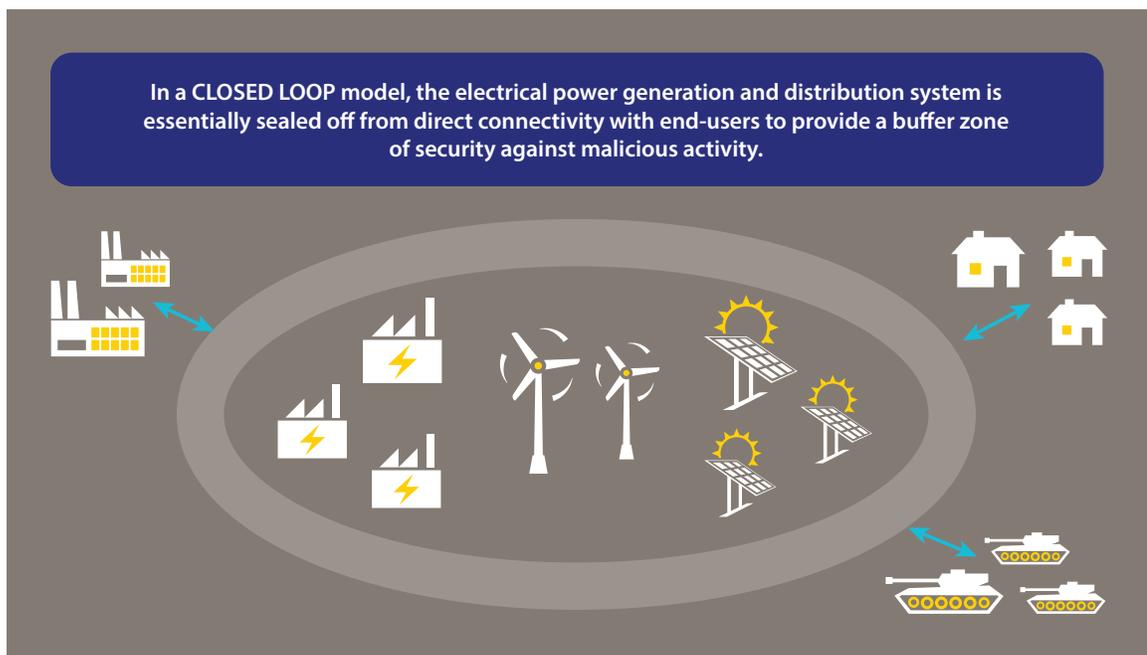
The Open Access model also does little to advance the scalability and growth of the microgrid market, making it impractical for most users to opt-out of the single main system and resulting in customers of all stripes and risk portfolios facing the same costs but also the same exposure to risk as all other participants in the system. In fact, at its worst, this kind of model can result in a 'race to the bottom' in terms of security for the system as a whole, for each individual firm has little incentive to put more security in place than the least secure member of the combined system. Again, however, an Open Access model is well suited for optimizing costs and routine reliability, as well as addressing environmental concerns through the open integration of distributed energy resources.

## B. Closed Loop

As opposed to the current one-size-fits-all and open structure described above, a Closed Loop approach to the power grid would entail placing an intermediary 'man in

the loop' command and control function to separate the operations and management of the system from all the various entities, sensors and other systems that would otherwise directly interact with the network. Of note, many industry operators state that they already employ a variation of this approach by isolating their routine customer-facing and administrative computer systems from those critical operational systems that control the main functioning of the grid. However, deliberately adopting the Closed Loop concept would ensure that critical and sensitive operational systems are closed off from the general purpose internet and that this isolation is achieved not at the individual but rather at the system-wide level.

Importantly, the Closed Loop concept creates a buffer from the prevalent risks created by the Open Access model by centralizing access control and ensuring streamlined security and operational protocols, albeit at the unavoidable cost of inefficiencies from having to route operations through the central authority that controls access to the grid's operational systems. This loss of efficiency due to the need for a centralized command and control process also involves delays inherent in isolating otherwise automated adjustments and direct feeds from all the many external sensors and other systems connected to the grid.

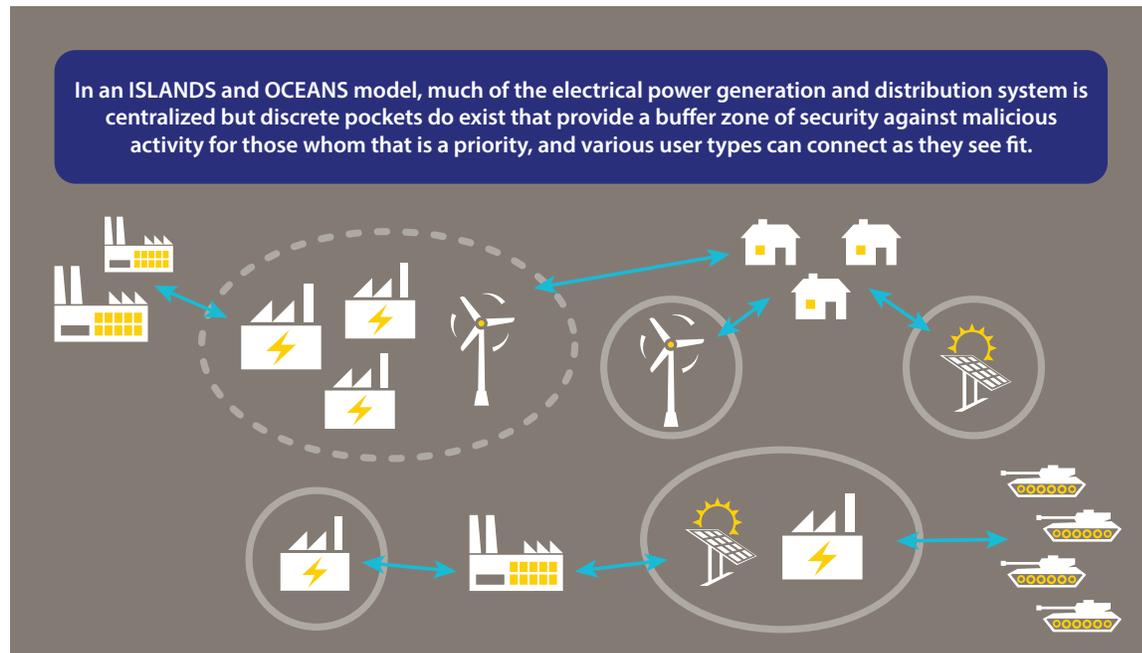


However, the trade-off is that the entirety of the system is more secure for all end-users, and this security benefit is present both for day-to-day operations and also in terms of resilience because it reduces the likelihood of a prolonged outage. In fact, this model is akin to the way that the military and intelligence communities address cybersecurity and espionage risks associated with highly classified materials by operating two parallel systems and requiring the user to deliberately process inputs from each and take actions on each system as appropriate while never actually putting classified materials on the

unsecure network. As with any trade-off consideration, the inefficiency of having greater access control through a centralized authority must be contrasted against the level of security and operational risks that the industry faces, and also must account for the potential loss of innovation that comes when centralized authority becomes entrenched in the status quo.

### C. Islands and Oceans

The Islands and Oceans approach is essentially a hybrid combination of the other two models in that it could retain the cost, reliability, and openness of the current Open Access model for the preponderance of users (the 'ocean'), but would also deliberately support the addition of a series of discrete 'islands' that enable select users to operate separate and apart from the main power grid. This approach could maintain the current mandate to provide electrical power to anyone who wants it at a relatively low cost by joining the main system while also recognizing the need for additional protections for some users.



The most practical implication of this approach would be to focus on building out a series of larger-scale microgrids—for by deliberately carving out islands of more highly protected generation and delivery services for specific segments of the user-population this approach could support the scale needed to drive forward the microgrid movement while meeting the additional reliability and security needs of select users. It also could include the ability for many of the microgrid users to connect to the main grid—at additional cost—in order to provide them the grid as a backup power source. Importantly, this kind of approach also could be designed to be relatively clean, depending on the nature of the microgrid, and would also reduce any growth demand on the system overall, while enhancing resilience for the subset of the end-user base that deems security and assured operations to be a priority over cost.

## CONCLUSION

The United States has just begun a massive multi-billion-dollar reinvestment in the national power grid. During this process, the opportunity to architect the future power grid presents itself in a way more in line with today's needs, without necessarily making it just a 'user-pays' model driven by large utilities that are forced to focus only on selling power, not offering power as a 'managed service'. We also have the opportunity to better assess the desired balance among cost, security, environmental impact, and systemic resilience against disruptions. Given this backdrop, how best should we proceed among the options of Open Access, Closed Loop, and Islands and Oceans?

Perhaps the most important aspect of each of the three models described above boils down to a single question: Who determines what we want from the grid, and who should pay for the changes required for achieving that end-state? Fair arguments can be made that if national security or shared environmental issues are the root cause of significant risks and the changes needed, then there ought to be both federal funds made available for the changes and also some greater degree of standardization and systemic alignment around a more orderly system that can respond efficiently to these key issues. On the other hand, local control and allowing states and localities to dictate what they want is an important facet of the American tradition.

Another way to think of the issue at hand is to determine if the power grid is best viewed as a public good, one that is so essential and beneficial to the entire society that upgrades and modernization should be paid for from the national treasury, or is it more appropriate to continue the user-pays model wherein each customer is charged more for their energy as it is delivered to them in order to recover the costs of the upgrades? The former model is seen as more progressive, for it spreads the costs across all taxpayers, whereas the latter model of user-pays does, inevitably, more directly impact those for whom energy costs are a more significant portion of their disposable income.

In the end, whichever way it is viewed, given the significant risks facing the grid one can fairly conclude that in the unknown risk environment of the future the fully Open Access model lacks necessary systemic safeguards. At the same time, the Closed Loop approach seems likely to be unable to take full advantage of the potential presented by emergent technologies because the risks required in order to try out new approaches are often not feasible under a heavily centralized command structure.

As a result, the middle ground alternative of Islands and Oceans seems to be a smart bet—for it fosters the necessary innovation, harnesses the power of recent technological improvements, and allows for a self-directed but still coordinated approach to the delivery of electricity through means that achieve a reasonable balance among the imperatives of being affordable, reliable, clean and resilient. And if we can agree that this is a smart approach, then all that remains is to get to work developing the business cases and technologies that support both a more modern mainstream 'ocean' alongside increasingly capable microgrids in order to allow for greater distributed generation within secure 'islands'.

## Acronyms

DER	Distributed Energy Resources
DG	Distributed Generation
DHS	U.S. Department of Homeland Security
DoD	U.S. Department of Defense
EI	Edison Electric Institute
FERC	Federal Energy Regulatory Commission
GAO	U.S. Government Accountability Office
NERC	North American Electric Reliability Corporation

## ABOUT THE AUTHOR



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