

# The Changing Electric System Architecture

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Most electric utilities still rely on “dumb grid” technology to meet and manage load. Yet the passage of the federal Energy Policy Act of 2005 and the 2007 Energy Independence and Security Act (EISA) has provided greater visibility for smart meters, an essential component of smart grid systems. Increasing federal support through the provision of \$4 billion in matching fund grants from the American Recovery and Reinvestment Act of 2009 (Stimulus Act) is expected to further smart grid development, as well as smart grid storage, monitoring, and technology viability. Despite the attention it has received to date, the term “smart grid” remains nebulous. While most market participants have a clear vision of what “smart grid” means to them, any three people are unlikely to have the same vision. For our purposes, we refer to “smart grid” as an electric transmission and distribution system where two-way communication exists between the source and the sink for the electricity.

To date, most of the smart grid deployment initiatives in the United States involve smart meter infrastructure. Before the stimulus funding was authorized, 70 utilities had filed smart meter plans that included some sort of pilot project but only one had a regulatory filing that explicitly included both smart meters and full deployment of smart grid capabilities.<sup>1</sup> Several other utilities have subsequently proposed plans, including Florida Power & Light’s (FPL’s) plan for 1 million customers in Miami-Dade and National Grid’s plan for 15,000 in Worcester, Massachusetts. Due to the current technological limitations, or simply one’s own vision of what smart grid might be, some of the capabilities ascribed to the smart grid may or may not be fully realized in the near future. Stimulus funding will certainly accelerate smaller-scale efforts (the FPL project, if it materializes, being the largest). However, funding

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<sup>1</sup> KEMA, “The U.S. Smart Grid Revolution: KEMA’s Perspectives of Job Creation,” Prepared for the GridWise Alliance, December 23, 2008, p. 2-1, available at <http://gridwise.org/pdf/SmartGridMASTER.pdf>.

may be insufficient to trigger large-scale experimentation.<sup>2</sup> So the jury is out as to the number of large-scale efforts that will unfold.

The degree to which an electric utility transforms its system really depends upon the extent to which it provides more information to its customers so that they can make more informed decisions about consumption patterns, including decisions to generate their own power. Specifically, if customers are expected to actively control their home devices to reduce consumption, the market will have to provide an incentive, such as a price signal, for them to do so. Customers who pay a flat rate for all electricity consumption have no incentive to shift load from a peak time of day, when the cost to generate that electricity may be higher, to another time of day when the cost to generate that electricity may be lower. It seems logical, in this case, that some type of real-time pricing structure will complement the smart grid initiative. For example, customers in the GridWise Olympic Peninsula demonstration project had the option of contracting for three rate structures, including two dynamic pricing schemes. The digital communications technology in their homes was capable of responding to fuel price changes in five minute intervals.

Another expectation of the smart grid is that it will increasingly enable distributed renewable generation and local storage. If not located at remote substations, renewable generators may be connected directly to the smart grid distribution system, bypassing the utility's transmission grid. If the smart grid capability is fully exploited, residential customers could essentially serve as resources for the electric system, and not simply as electricity sinks: they could install interconnected photovoltaic systems on their roofs, plug in their battery-run hybrid vehicles, and install energy storage devices in their basements. The home storage device can play an important role here: the photovoltaic system can feed into the battery pack which can, in turn, power various household appliances during peak demand periods or in the event of a power outage. The battery in the hybrid vehicle itself can also function as a source of

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<sup>2</sup> Initial stimulus funding for approved smart grid projects was limited to \$20 million, but the limit was subsequently increased to \$200 million in response to criticism from the industry and governors.

electricity, powering household appliances as needed when the owner returns from work in the evening.

Excess power from the battery pack might also be sold back seamlessly to the electric grid or perhaps even to other customers, when it is economical to do so.

Federal and state incentives have made smart grid-enabled deployment more feasible. For example, federal electricity production tax credits were originally authorized by the Energy Policy Act of 1992. These credits were extended and their application expanded several times, most recently by the Stimulus Act.<sup>3</sup> To complement the federal credit, six states now offer production incentives for renewable generation. Renewable portfolio standards (28 states and the District of Columbia, many with explicit or implicit “carve out” provisions for distributed generation), statewide net metering policies (40 states), and statewide interconnection standards (37 states) also create conditions for greater activity in distributed renewable generation.

If industrial, commercial, and residential customers become more involved in controlling their electricity consumption, generating and storing their own power, and selling the excess back to the grid, utilities will need to adapt to business models that accommodate greater distributed coordination and supply. This change in role will likely cause them to modify their investment strategies and will spur the formation of complementary activities and businesses to support the new or expanding functions and to aggregate electricity.<sup>4</sup> Regulatory rules will also need to provide incentives for such initiatives, recognizing the risks introduced (or reduced) when customers are less passive in their interactions with utilities. At this time, smart grid applications other than smart meters and phasor measurement units that provide granular time-synchronized data are really not ready for widespread implementation.

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<sup>3</sup> For the history of the renewable electricity production tax credit, see U.S. Department of Energy, Database of State Incentives for Renewables & Efficiency,

[http://www.dsireusa.org/incentives/incentive.cfm?Incentive\\_Code=US13F&re=1&ee=1](http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F&re=1&ee=1).

<sup>4</sup> For example, the KEMA report assumes new utility affiliated companies or energy service companies will be formed to install, service, and operate such technologies as rooftop solar systems, Home Area Network devices, thermostats, display units, 1-3.

Applications such as Home Area Networks (HANs) are still in the early demonstration phase. As the smart grid's capabilities evolve, regulators, electric utilities, and their customers are likely to face new challenges and experience new conflicts. An understanding of the challenges and a framework for dealing with potential conflicts in the short term may facilitate a more efficient transition to a new market structure.

#### *Challenges for Making the Transition*

The transition to a new market structure will probably not be easy or quick. Electric utilities today are at a crossroads, with expectations for their operations varying widely, depending on the point of view. The traditional business model of a vertically integrated utility that provides centralized services still applies to most of its operations. In the 13 states plus the District of Columbia with active restructured markets, retail customers make choices about supply. Seven other states suspended their retail restructuring programs in the aftermath of California's energy debacle in 2000-2001. In the states still under cost of service regulation, the vertically integrated utility is responsible for the entire generation/procurement, intrastate transmission, and delivery system. In states where electric transmission is controlled by an independent system operator, the utility still faces the challenges of managing its load and generation, despite being relieved of the responsibility of physically providing for the load. The retail restructuring initiatives, if anything, have made electric utilities, regulators, and investors more risk averse to structural changes that might threaten recovery of utilities' infrastructure investments. In recent years, growing concerns over climate change and natural gas and oil price volatility have caused policymakers and regulators to expand the types of considerations governing determinations of need for new capacity. In addition to system reliability and cost considerations, fuel diversity and supply reliability, the availability of renewable energy sources and technologies, as well as conservation measures are increasingly important considerations for ensuring the balanced fuel portfolios of electric utilities. In determination-of-need proceedings, regulators face a tough balancing act in weighing those factors. In many states, renewable portfolio standards and carbon reduction policies further shape those considerations.

Why is it so difficult to predict how smart grid deployment will affect an electric utility's operations? Perhaps some insights might be gleaned from the telecommunications sector. Prior to the divestiture of AT&T in 1984, policymakers did not foresee how competition for communications services would evolve. For example, primary concerns at the time were telecommunications manufacturing and equal access for long distance, neither of which seems to have mattered in the long run. Policymakers failed to foresee the importance of competitive access providers and wireless telecommunications.

In 1996, the year of the sweeping federal telecommunications act, policymakers failed to predict that within only a decade there would be Internet-protocol-based telephony, wireless connectivity would overtake landlines, there would be such a large degree of technological convergence, and newspapers would be struggling to survive. Immediately after 1996, competition played out between large incumbent Bell companies and competitive telecommunications carriers. The inter-platform competition between cable companies and telephone companies emerged only a few years later. Arguably, disparate regulatory regimes for cable and telephone companies, if anything, slowed deployment of broadband. Part of the problem was that policymakers could only view change through the prisms of old business models. However, without an externally imposed restructuring of the existing centralized system, AT&T's entrenched power would have likely slowed down the development of innovative communications products and processes.

We are somewhat skeptical that the old business model will change rapidly in the electricity sector without an AT&T divestiture-like shake-up. Such a shake-up is unlikely because there is no dominant, AT&T-style electric company that spans the United States. Thus, any divestiture would have to be implemented piecemeal and would likely spur copious (and contentious) litigation. Two additional factors favor the incumbent business model:

First, smart grid deployment projects have been implemented to date largely as pilots and on a small scale. Most of the projects have benefited, and will benefit in the foreseeable future, from some type of subsidy. It remains to be seen if smart meters and the functionalities enabled by them will become commercially and economically viable.

Second, most of this country's energy comes from conventional sources that have been most conducive to centralized distribution and transmission functions. Roughly 92 percent of all existing capacity still comes from natural gas, petroleum, coal, and nuclear power – energy sources more amenable to centralized energy systems.<sup>5</sup> Renewables account for only 8 percent, much of it from large-scale hydropower projects. Admittedly, the share of renewables in the nation's overall electric capacity portfolio, with or without smart grid deployment, is projected to grow over time. In fact in 2007 for the first time more additional capacity came from non-hydropower renewable sources than from fossil-fuels.<sup>6</sup>

Federal and state policies will also provide favorable conditions for more of that renewable capacity to come from distributed generation. Yet, even with more rapid growth in capacity from renewables and from distributed generation, the Energy Information Administration projects this nation's generating capacity to still come predominantly from conventional fuels (coal, natural gas, petroleum, and nuclear) – roughly 86 percent in 2030.<sup>7</sup> Most of these fuels will also continue to be dispatched in a centralized manner. Even with widespread smart grid deployment, electric utilities will still need to rely on centralized systems to provide most of the electricity needed for all customer classes. Thus, it seems that smart grid deployment will continue to serve as a complement to the larger centralized operations. This observation suggests that centralized and distributed business models will increasingly co-exist in the foreseeable future. The electric utility will be instrumental in both and likely the same set of corporate decision-makers will be involved in planning for both.

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<sup>5</sup> Energy Information Administration, U.S. Department of Energy, *Electric Power Annual 2007*, Table 2.2 “Existing Capacity of Energy Source, 2007,” January 2009, [http://www.eia.doe.gov/cneaf/electricity/epa/epaxlfile2\\_2.pdf](http://www.eia.doe.gov/cneaf/electricity/epa/epaxlfile2_2.pdf).

<sup>6</sup> Energy Information Administration, U.S. Department of Energy, *Electric Power Annual 2007*, Table ES1 “Summary Statistics for the United States, 1996 through 2007,” January 2009,

<http://www.eia.doe.gov/cneaf/electricity/epa/epa.pdf>.

<sup>7</sup> Energy Information Administration, U.S. Department of Energy, *Annual Energy Outlook 2009*, Figure 55 “Electricity Generation by Fuel in Three Cases, 2007 and 2030,” March 2009,

<http://www.eia.doe.gov/oiaf/aoe/electricity.html>.

Distributed generation will not be, at least initially, the focus of most of the smart grid pilot projects, in large part because the challenges are more significant. Such challenges include, among others, the lack of uniform and consistent interconnection standards for distributed generation and problems with voltage quality and stability. These challenges may lead to decreased efficiency in the electric system, if the utility is forced to deploy additional equipment to maintain the integrity of its distribution system. Integrating new technologies into “old” distribution systems is likely to require upgrades of some subsystems, including monitoring the impacts of distributed generation on line losses and spinning reserve requirements. The pilots implemented to date have tended to focus on smart meter applications to reduce peak demand, simply because reducing, or shifting, demand requires significantly less specialized equipment (and thus less capital), less specialized labor to install and maintain the equipment, and less regulation to ensure the public safety of the equipment, than does distributed generation. Most of the focus in the short term appears to be “more of the same,” coupled with experiments in various dynamic pricing schemes and various levels of customer participation and responsibility for controlling the devices connected to the smart grid. Funding from the National Science Foundation will also enable some university-industry consortiums to experiment with technological applications of the smart grid. So the path toward expanded smart grid deployment in the United States will probably continue to be incremental: more subsidized pilot projects involving varying degrees of distributed control. Experiences in the European Union and other regions should provide additional insights into how the smart grid will affect costs and the need for new institutional (and regulatory) arrangements.

If the past is any indicator, electric utilities will be viewed as the most important means of realizing federal and state policy goals for smart grid deployment. If that is the case, and to date it appears to be, we might expect utilities to embrace regulatory policies that will reduce their investment risk. Regulators will need to balance the risk incurred for smart grid investments with consumer risks in participating or not participating in smart grid programs. Incentives for utility participation need to be aligned with public policy objectives, such as reducing peak demand, improving the quality and reliability

of electric service, deferring the construction of new plants, promoting energy conservation and energy efficiency, and reducing carbon emissions. At the same time, regulators will need to make sure that customers see tangible benefits from these pilots or the business case for expanding smart grid deployment will be harder to make.

The optimal strategies for making that business case will be those that save utilities money, save customers money, meet federal and state policy objectives, and result in a net addition of jobs. Strategy development may benefit from an understanding of the areas of conflict likely to emerge as electric utilities move toward more distributed systems.

#### *The Framework for Resolving Conflict and Identifying Trade-offs*

The transition to new institutional arrangements required by smart grids will affect stakeholders differently. Anticipating conflicts can save time and resources that would otherwise be absorbed by turf wars and legal battles. It is possible to identify four potential sources of conflict in the design and implementation of smart grids: authority conflicts (reflecting jurisdictional disputes over who has the last word), cognitive or factual conflicts (based on technical disagreements regarding the analysis and interpretation of performance data), values conflicts (involving ideological differences or differential preferences for sector outcomes), and interest conflicts (where different groups—utilities, customers, unserved citizens, regions, and unions—benefit or lose, depending on the decision).<sup>8</sup> Stakeholders must have a clear understanding of facts, procedures, objectives, and responsibilities.

What conflicts will need to be resolved to implement smart grid technologies and applications, including distributed generation, on a large scale? In moving toward more distributed generation, electric utilities and their consumers will need to change their behavior. The term often used in this context is

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<sup>8</sup> The four sets of conflicts were identified by Leonard Shabman, “Water Supply Conflict and Government Response: the Challenge for Florida,” *How Should Florida’s Water Supply be Managed in Response to Growth?* Report on the 2005 Meeting of the Reubin O’D. Askew Institute on Politics and Society, University of Florida, 2005, [http://www.cba.ufl.edu/purc/docs/resources\\_2005AskewReport.pdf](http://www.cba.ufl.edu/purc/docs/resources_2005AskewReport.pdf).

“adaptive behavior” to respond effectively to changes in technology and policy objectives. Therefore, it is useful to consider what is or is not a factual conflict. Specifically, conflicts that are not based on fact but reflect different values or interests will not be remedied by technological “fixes.”

1. Authority Conflicts: Resolution gets to the heart of the question: *who* should make decisions? Federal-state disputes over this set of issues are likely to arise as regulators have different views regarding optimal jurisdictional responsibility.
2. Cognitive (Factual) Conflicts: Resolution gets to the heart of the question: what *can* be done? Engineering information regarding the impacts of smart grids on current operations is central to this issue.
3. Values Conflicts: Resolution gets to the heart of the question: what *should* be done? Here, the debates tend to reflect different views regarding trade-offs between the impacts of higher electricity prices on low-income groups and the impacts of environmental neglect.
4. Interest Conflicts: Resolution gets to the heart of the question: who should *benefit* from decisions? Of course, for smart grids, who should bear the risk associated with new technological initiatives is a key issue.

*Authority Conflicts* are most likely to be minimized but not totally resolved in state statutes or regulatory orders. As electric utilities assume a growing role in distributed generation projects, the following policy questions arise: how much of the distributed generation and stored power will electric utilities be able to control and integrate into their overall systems? How much distributed generation would be available for utility use as opposed to consumer use? How much of the transmission and distribution assets will be owned and controlled by the utility as opposed to the consumer? State laws and commission orders authorizing net metering and interconnection can either limit or expand customers’ control over the amount and type of power subject to distributed generation.<sup>9</sup> Different jurisdictional authorities might be expected to resolve such interest conflicts in different ways.

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<sup>9</sup> For a perspective favoring consumers with respect to state net metering and interconnection policies, see New Energy Choices, “Freeing the Grid,” October 2008,

[http://www.newenergychoices.org/uploads/FreeingTheGrid2008\\_report.pdf](http://www.newenergychoices.org/uploads/FreeingTheGrid2008_report.pdf).

*Cognitive Conflicts* are perhaps best addressed through research-driven forums held by regulators and industry groups. Many technological issues may be resolved as more information becomes available. For example, what factors should determine where distributed generation should be located and what are the implications of such locations? How can distributed generation be aggregated and what are the implications? What happens to load management when generation is distributed and under what scenarios? For example, if plug-in vehicles are part of the smart grid system, how should load be managed to ensure that it is flattened? However, the views of customers may differ from those of the utility in terms of optimal plug-in times. Research might lead to some consensus by providing data on load shifts under various plug-in scenarios, or analyzing the efficacy of price signals on consumer behavior.

*Values Conflicts* may be resolved through carefully conceived utility and consumer surveys because priorities are often revealed in response to willingness to pay questions. For example, consumer advocates have raised several concerns that speak to the question of whether smart grid projects are the cheapest way of reducing load. Meters costs \$250-\$500 each when related expenses are included. Consumer advocates might argue that air conditioner controllers would be much cheaper in reducing peak load. What do consumers want? Do they perceive that benefits from smart meters will exceed costs or would they rather see other options such as air conditioner controllers more seriously explored? What about the 40 percent of Americans who do not have central air conditioning and a programmable thermostat? How would their consumption be reduced and what would they prefer? How do consumer preferences correspond to real cost savings for utilities?

There are also different ways of managing load: some demand side programs allow utilities more control in deciding how to reduce electricity to households during peak, and others provide customers with far more discretion in controlling devices on the smart grid. Surveys and research from pilot projects may reveal what customers are willing to trade off in terms of more or less control for different management schemes.

Another issue deals with consumer protection policies and what should be done if electric bills are in arrears. Smart grid technology enables utilities to remotely disconnect and reconnect people but should there be added protections or different protections for customers who participate in smart grid programs? Utilities might value policies that expedite disconnections and reconnections from a business efficiency perspective, but consumers might find such efforts more cumbersome and unfair.

*Interest Conflicts* may be best addressed through stakeholder forums, informed by academic research, that encourage negotiations among electric utilities, consumers, affected smart grid business suppliers, and advocacy groups. Costs for smart grid initiatives – who should pay what and who benefits – will probably be the most difficult to resolve for several reasons. Smart grid deployment is an expensive proposition. For example, changing out meters to enable dynamic pricing carries a price tag of approximately \$40 billion in the United States. Much of that amount could be offset by reductions in utility distribution cost, but the remainder would likely come from reduced demand. Therefore, the prospect of stranded assets is likely to be a utility concern if demand falls off more than projected. Advocacy groups might resist proposals that are committed to holding the utility harmless if conservation results from smart grid initiatives. However, utilities may be less willing to engage in smart grid initiatives and to actively encourage customer participation if they perceive that they will be adversely affected. A more moderate strategy might be to upgrade the grid while selectively and strategically installing smart meters.

Finally, in preparing for the transition to a new set of institutional arrangements with their attendant conflicts, regulators, the electric industry, consumers, and suppliers of smart grid equipment might do well to recall another lesson from the post-divestiture years of the telecommunications industry – the importance of interoperability. A common open standard for device attachments and software would likely expedite the development of smart grid enabled applications. And who would want to miss the emergence of the new energy management iPhone?