Innovation for Control: Smart Technology to Empower Energy Producers and Users

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While the benefits of greater control over energy use through intelligent technology could be vast, smart policies are needed to effectively drive data-driven innovation and boost empowerment in the sector.

The way we distribute and consume electricity is undergoing a quiet revolution that will lead to lower energy bills, innovation-driven growth and employment, and cleaner electricity production. The groundwork of this revolution has been established by the rise of intelligent technologies: the digital hardware and software embedded within our energy system, from the grid to the home, including sensors, controls, intelligent appliances, and others. Fundamentally, intelligent technology is about providing *control:* creating greater informational awareness to energy consumers and grid operators, and facilitating adaptive actions that empower these stakeholders to reduce their consumption and operate more efficiently. But while the benefits of this greater control over energy could be vast, smart policies are needed to effectively drive data-driven innovation and boost empowerment in the sector. Specifically:

- Congress should pass the Electronic Consumers Right to Know Act (S. 1029), also known as the e-KNOW Act, which would give consumers the right to access their own energy usage data and share it with authorized third parties.
- Congress and the Administration should continue efforts in public-private innovation, including the creation of a Smart Grid Technology and Systems Hub.
- Congress should support Executive Branch efforts to test, evaluate, and adopt cost-saving intelligent technologies, including measures put forth in the Department of Defense Energy Security Act of 2011. The federal government should also continue

efforts to expand utility and consumer education and markets, in collaboration with state public utility commissions.

A 21ST CENTURY "INTELLIGENT" ENERGY SYSTEM

The United States' electricity distribution system is often described as "dumb." This is because it traditionally has only worked in one direction: electricity flows downstream from power plants through power lines and substations to consumers.[1] Upstream, utilities are only aware in real time the total amount of power being consumed by all of its consumers in aggregate. Historically, utilities' main function has been to balance hourly changes in total energy flowing through the grid by turning power plants on and off in response to changing demand conditions. Downstream, consumers are only aware of the total amount of household electricity consumed per billing period, by way of their electric meter and monthly bills. Utilities charge households a flat rate based on the time of year, regardless of the time of day or market conditions when electricity was consumed. And for the last century this "dumb" system worked.

The fundamental purpose of intelligent technology is to give utilities and consumers greater control over their energy production and consumption through the access to and use of energy data, thus opening the door to more efficient, reliable and cleaner electricity generation, distribution, and use.

But the traditional energy system is aging, inadequate in meeting the needs of our modern economy, and requires a significant overhaul. Electricity outages now cost the economy well over $100 billion annually, an increase of nearly 50 percent since 2002.[2] Another $16 billion a year is lost due to transmission congestion, where electricity demand exceeds the maximum capacity of the grid resulting in customers not having access to all the energy they need.[3] And in this age of digital communication, many utilities still rely on monthly or semi-monthly meter readings that require inefficient house-to-house readings conducted on foot, which can lead to missed readings or inaccurate usage estimates that frustrate or confuse consumers, according to surveys.[4] Lastly, the urgent need to reduce emissions requires new grid functionality to control intermittent energy sources, integrate distributed energy, and reliably enable vehicle electrification.

Yet making the energy system more reliable, accessible, and efficient is not an easy task. It will take no less than what electricity industry expert Peter Fox-Penner calls "a paradigm shift" in the way consumers and utilities view, use, and control energy.[5] And the way to facilitate this paradigm shift is to make energy "smart," by harnessing the power of information and communications technology (ICT) through innovative, intelligent energy technologies. Intelligent technology includes both the software and hardware embedded within the energy system: in the grid itself, in households, and in commercial buildings.[6] The fundamental purpose of intelligent technology is to give utilities and consumers greater control over their energy production and consumption through the access to and use of energy data, thus opening the door to more efficient, reliable and cleaner electricity generation, distribution, and use. If realized, four main benefits are expected.[7]

First, intelligent energy technologies *will allow for greater informational awareness and control of energy flows*, by enabling robust data monitoring and two-way communication through the use of advanced sensors, distributed computing infrastructure, and smart appliances. This informational awareness will allow consumers to interface with their energy consumption on a device-by-device basis, providing new levels of detail on how—and how much—electricity is being consumed and at what cost in real time, and give them the tools to increase or decrease their consumption. It will also allow utilities to more effectively monitor real-time energy consumption, giving them more information about energy flows than they traditionally have had. This will allow them to efficiently manage and adjust electricity transmission, reducing the likelihood of outages and congestion while improving billing accuracy for consumers. And it will facilitate dynamic pricing in response to changing electricity market conditions in real time, to provide the market signals that help consumers make more informed energy consumption decisions. All in all, smart energy means consumers and utilities have greater ability to adapt to changing market conditions through digital means for greater energy efficiency.

Second, *transforming the old electricity grid to a smart grid will boost economic growth and job creation*. The Electric Power Research Institute (EPRI) estimated that investments in smart grid technology, while cost-intensive upfront, would nevertheless yield returns three to four times that of every $1 invested. In total, fully deploying a smart grid could produce up to $2 trillion in economic benefits over time, on investments of up to $400 billion.[8] ITIF has estimated that just $50 billion in smart grid investment over five years could create, on average, 239,000 jobs, while $100 billion in investment over the same time could create 477,000 jobs.[9] The Working Group for Investment in Reliable and Economic Electric Systems (WIRES) estimates that planned investments in upgrading the transmission infrastructure alone—a key upgrade to the grid that would enable greater adoption of smart and clean technologies—will stimulate up to $40 billion in economic activity and create 200,000 jobs.[10] And the National Energy Technology Laboratory (NETL) estimates that implementing smart technologies could directly create nearly 300,000 additional jobs.[11] Job growth will come directly from government and utility investment, but also from indirect network effects, as related industries grow to take advantage of the new capabilities these technologies offer.[12] For instance, as energy data becomes more readily accessible to consumers, suppliers will step in to provide the retail software and hardware to help customers more effectively use it, creating a virtual “app store” for energy management.

Third, intelligent technology *will reduce carbon emissions*, though it’s hard to know exactly by how much. The Pacific Northwest National Laboratory (PNNL) estimates that fully deploying a smart grid would directly reduce carbon dioxide (CO_2) emissions within the electric power sector by 12 percent in the coming decades.[13] EPRI has estimated that implementing intelligent energy technologies could reduce emissions by up to 211 million metric tons of CO_2 annually by 2030, representing less than 10 percent of electric power sector emissions, while also facilitating integration of cleaner generation and transportation technologies that would yield larger emissions reductions.[14]

Fourth, intelligent technology *enables consumers and utilities more freedom to plug-and-play with emerging clean energy technologies* like distributed solar and wind generation, electric cars, and energy storage. For example, in-home intelligent chargers for electric cars may have the capability to delay charging during times of peak energy demand when electricity prices are highest. Grid integration technology for distributed generation can feed power back up into the grid from the household, allowing consumers to sell energy when possible.

And intelligent technology will make it easier for utilities to balance intermittent and distributed clean generation sources and deploy on-board energy storage capabilities.

A brief review of the benefits of improved energy data access and use to utilities, consumers, and businesses follows.

Control for the Grid: Making Utilities Smarter

The day-to-day challenge for utilities is to provide low-cost, reliable energy to consumers. This typically means balancing energy produced from low cost power plants with higher cost energy sources during periods of peak demand, a task that requires very sophisticated technologies. So from the perspective of many utilities, "the grid's been smart for a while."[15]

But emerging intelligent technology provides a groundbreaking level of grid control for utilities, making them smarter. For instance, power electronics and transmission management technologies would give utilities improved situational awareness of weaknesses in the grid. Load management software would quickly reroute power and change power plant production to ensure a steady supply of electricity. Sensors would be able to locate problematic power lines or substations before an outage occurs, significantly reducing the possibility of blackouts. And when blackouts do happen, due to natural disaster or other cause, power-stabilization software would reduce the amount of time consumers must go without electricity.[16]

Smart transmission sensors and management software readily available today would have allowed grid operators to stop the 2003 Northeast Blackout from spreading and quickly reroute power to effected homes and businesses.

Ultimately, these emerging technologies would drastically increase grid reliability, decrease the direct costs to utilities for maintenance and power failures, and reduce the economic costs of outages. Take for example the 2003 Northeast Blackout. One high-voltage power line failed in Ohio and set into motion a series of events that led to 50 million people without power at a cost to the economy of $10 billion.[17] Smart transmission sensors and management software readily available today would have allowed grid operators to stop the power outage from spreading and quickly reroute power to effected homes and businesses.

This increased awareness can also facilitate dynamic pricing, a critical capability to enable consumer choice. The logic of dynamic pricing is fairly straightforward. Utilities must ensure adequate generating capacity to meet demand when it peaks, like hot afternoons when everyone runs air conditioning. Turning on more power plants during these times is expensive—the most costly sources of generation tend to be the last brought online. But traditionally, the retail rates charged to consumers are "dumb," in that they remain flat regardless of the time of day or prevailing market conditions. Dynamic pricing counteracts this by allowing retail rates to fluctuate based on levels of demand and generating costs. In periods of high demand, retail prices rise, and during periods of low demand, prices drop. When the utility is able to set prices dynamically, they become powerful market signals to consumers. As Fox-Penner puts it, "Dynamic pricing is poised to take a quantum leap in the next decade. That, in turn, will flatten the price curve and save customers a great deal of money, along with a little carbon."[18]

The catch is that utilities cannot set dynamic pricing without the capacity to monitor exactly how much energy is being consumed in more or less real time, to determine revenue-neutral prices that reflect current generating costs, and to relay those prices back to customers. Intelligent technology provides exactly that two-way communicating capacity to establish dynamic prices for utilities and consumers alike. We'll discuss the consumer end more in the next section.

A common critique of implementing smart grid technology is that the up-front costs are too high. But over time, this investment will likely pay for itself, as a recent Brattle Group report for the Institute for Electric Efficiency found. According to Brattle, the typical million-customer utility in most regions would make up most of the investment costs for smart meters in operational savings alone. For instance, a typical southern utility investing $296 million for smart meters would avoid $240 million costs for meter reading, plus $47 million in avoided costs incurred due to outages.[19] It's a similar story for other utilities elsewhere.

The Pacific Northwest National Laboratory found that widely deploying intelligent energy technologies could reduce peak electricity demand by up to 15 percent, allowing utilities to avoid the $70 billion costs of building new power plants over the next 20 years.

And the costs not covered in operational savings are more than made up for by reduced electricity generation costs, captured through efficiency and consumer choice. We mentioned above the fact that peak power is more expensive, but this is not the only way demand drives higher costs in the power sector. Higher demand peaks over time require more spare capacity to be built, even they're largely kept in reserve and used only infrequently throughout the year. Capacity additions can account for nearly half of all grid infrastructure costs, so reducing the need for such additions is advantageous. Indeed, studies have shown that more efficient energy use through intelligent technologies could reduce peak demand and thus reduce the need to build and activate additional capacity. For example, PNNL found that widely deploying intelligent energy technologies could reduce peak electricity demand by up to 15 percent, allowing utilities to avoid the $70 billion costs of building new power plants over the next 20 years.[20]

Finally, the smart grid is also a key enabling technology for utilities to deploy clean energy. System operation software would enable utilities to synchronize intermittent solar and wind with other baseload power plants. More grid control would allow utilities to deploy advanced energy storage devices as they become available to balance electricity demand and supply, charging storage during off-peak times and rapidly deploying stored energy during peak times. These control systems are also vitally important if the United States is to realize large-scale vehicle electrification without disrupting the grid.

Control for the Home: Empowering Consumers

Naturally, the benefits of improved utility control of the grid would also apply to these homeowners, who would enjoy reduced costs due to reduced need for capital expansion in generating capacity, while enjoying more reliable power. But intelligent technology also means putting more control in the hands of consumers themselves. As investments in these technologies increase and the market grows, the day will likely come when we see an "app store" for energy, with the kind of competitive dynamism we already see in other sectors of the ICT realm.

According to the U.S. Energy Information Administration, there were 125 million residential electricity customers in 2009, accounting for 39 percent of all electricity consumption and 22 percent of total energy consumption. The number of residential customers is expected to grow by 15 percent, reaching 144 million, by 2030. In 2009, these consumers paid $157 billion in electricity bills, a figure that increased to $167 billion in 2010. There is no doubt that this figure could be reduced substantially by providing consumers with clear information about their in-home energy consumption, by giving them the ICT-based tools to act, and by optimizing automated systems that can act for them. Indeed, ensuring consumer ease and convenience is a key goal for intelligent technology developers. As the Alliance to Save Energy put it in a recent white paper, "systems that can analyze the data and give consumers specific and actionable information on energy use and what they can do about it, or can automate responses to the data, may be most useful."[21] And many surveys, like a recent one by Texas utility CenterPoint Energy, show positive consumer feedback to being given these choices.[22]

What are the specific tools at the customer's disposal? Commonly discussed components include advanced metering infrastructure (AMI), or smart meters, which monitor consumption at faster intervals than traditional meters. Such meters feed the information to electronic in-home displays (IHDs) that provide consumers with real-time and historical data about pricing and consumption, including notification of peak pricing periods when demand is high versus lost-cost periods when demand is low, and may also include emissions data calculations. Such devices that make energy consumption data clear and understandable can help individuals make more economically informed or environmentally friendly decisions, and with tangible benefits. For example, an oft-cited globe-spanning study of several pilot programs by the Brattle Group found that "consumers who actively use an IHD can reduce their consumption of electricity by an average of seven percent," and can double that savings when they enroll in programs that allow them to pay for their electricity consumption in advance.[23] These reported benefits match those of several other studies, including from Oxford's Environmental Climate Institute and from the American Council for an Energy-Efficient Economy.[24]

Combining smart meters and IHDs with intelligent appliances, thermostats, and other such devices able to monitor energy use and price data and self-regulate for greater efficiency, can yield substantial gains for consumers. The Pacific Northwest National Laboratory's Gridwise project has found that real-time pricing coupled with intelligent appliances and automatic response lowered consumer energy bills by 10 percent.[25] And Brattle Group has found that this combined approach can lower peak demand by up to 44 percent in the right circumstances, more than twice the reduction seen in systems that employ real-time pricing without the complementary suite of intelligent technologies to actively manage consumption.[26] Many companies are addressing pieces of the intelligent energy puzzle. For example, startup EcoFactor is providing a data-driven service in conjunction with utilities that will make automated, unobservable adjustments to broadband-connected intelligent thermostats in homes, reducing residential consumption and energy bills. Recent tests in Las Vegas have demonstrated load reductions of 36 percent.[27] And GE and Best Buy recently announced a partnership to market intelligent devices that can control household air conditioning levels automatically and adjust power flows into the home.[28]

Substantial advantages for consumer control may also come when these discrete technologies are rolled into single in-home energy management systems (EMS); allowing third parties to more directly build energy management services into consumers' daily life. As a Direct Energy executive put it, "If it's going to work, it's got to be something that integrates into what the consumer is already doing."[29] Pike Research has estimated that worldwide use of home EMS will reach 63 million by 2020.[30] Notwithstanding the high-profile exits of Microsoft and Google, more than 80 companies are pursuing this potentially large market. For example, Verizon's new Home Control system enables full consumer energy use monitoring and control in connection with smart phones, personal computers, or their FiOS network.

Not only will these innovations for control drive cost savings for consumers, but emissions savings for the planet. Per EIA data, residential emissions accounted for 38 percent of all electricity-based emissions in the U.S. in 2009. The Climate Group has estimated potential emissions reductions in buildings to be 15 percent by 2020.[31]

The same package of two-way communicating devices, sensors, and other technologies that put energy control in the hands of residential consumers can also help businesses' energy use—and bottom line.

Control for Businesses: Boosting the Bottom Line

Commercial and industrial businesses, which together account for half of all energy consumed in the United States, can likewise benefit from these and other innovations, beginning in the design phase. Dozens of energy simulation and modeling tools are on the market to help design and construction firms optimize new commercial buildings' energy usage. And the same package of two-way communicating devices, sensors, and other technologies that put energy control in the hands of residential consumers can also help businesses' energy use—and bottom line.

For example, Chicago-based Clean Urban Energy employs software and a monitoring system that regulates heating and air conditioning in commercial buildings, making adjustments based on usage patterns, and ultimately reduces energy bills by up to 30 percent. California firm Serious Energy has a cloud-based EMS that achieves similar functions. And Massachusetts company EnerNOC has combined multiple businesses—including supermarkets, office buildings, and industrial facilities—in demand response programs that create a kind of "virtual power plant" based on willingness to reduce load when called upon. When electricity prices rise during peak hours, or during system emergencies, EnerNOC's participants are paid by utilities to voluntarily reduce consumption, thus obviating the need for additional generation. All of these initiatives are dependent upon data access and embedded ICT.

One area in particular that could substantially benefit from data-driven energy management and intelligent technologies is manufacturing. The domestic manufacturing sector consumed 21 quadrillion BTUs, or 21 percent of the national total, as of 2006. Advanced sensing and monitoring equipment, performance indicators, control algorithms, and dashboard displays can help production managers make real-time adjustments to maximize efficiency and boost energy productivity, if not automate these decisions outright. The role of ICT in smart manufacturing has received particular attention in Europe, as a means to maintain the competitiveness of European manufacturers. The European Commission has estimated that ICT-enabled efficiencies could reduce energy consumption for industrial production by 25 percent by 2020, with additional gains available in transportation and logistics.[32] The European Factories of the Future Research Association, a nonprofit industry-driven entity focused on productivity, has funded several experimental projects incorporating ICT networks into manufacturing processes for improved energy efficiency, in partnership with industry and academia.

Lastly, additional advantages could eventually come via on-site energy storage and distributed generation like rooftop solar. These technologies, integrated via ICT to monitor and manage power flows and consumption like a miniature grid, would allow buildings to generate their own energy, thus reducing or eliminating energy bills and allowing commercial and industrial facilities to become independent of the public grid.

POLICIES TO DRIVE INNOVATION

There are several steps policy makers must take to harness the benefits described above; many of these were outlined in the Administration's recent smart grid policy framework, which itself represents an effective roadmap for intelligent technology progress, and in the National Broadband Plan. However, a few key areas are worth highlighting.

The Electronic Consumers Right to Know Act (S. 1029), also called the e-KNOW Act and sponsored by Senators Mark Udall (D-CO) and Scott Brown (R-MA), ensures that consumers and their authorized third parties are able to access and employ this data to make informed choices about how they use energy.

Unleash the Data

None of these new technologies will work without a key ingredient: consumer access to data, including historical usage and real time information on consumption and current prices. To that end, the Electronic Consumers Right to Know Act (S. 1029), also called the e-KNOW Act and sponsored by Senators Mark Udall (D-CO) and Scott Brown (R-MA), ensures that consumers and their authorized third parties are able to access and employ this data to make informed choices about how they use energy.

As the Administration's smart grid strategy puts it, "Energy usage data can help consumers detect malfunctioning appliances, provide input to smart grid devices and applications, improve home or building energy efficiency, and help consumers lower their bills."[33] To accelerate the advantages of intelligent technology and promote the development of an "app store" for energy, consumers no doubt should have the ability to access their own energy data in a machine-readable format, and decide whether or not to allow third party access rights. This access should be uniform and nationwide. Unfortunately, each state has different rules on energy consumption data ownership, and in states where timely and machine-readable access is not the law of the land, access can be challenging for consumers. The California Public Utility Commission recently issued a ruling requiring the state's utilities to provide consumers with data access,[34] and other states like Texas are also moving in the right direction, but many still lag.

In states that are not providing clear leadership, it falls to utilities to implement data access policies and make the necessary investments in intelligent technologies to provide it—yet most utilities are unlikely to actually take these steps unless pushed. The electric power distribution sector is not known for high levels of innovation, compared to other industries, and while select utilities may be taking aggressive leadership in technology investment and data access, these are the exception to the rule. Utilities may be unable to provide the data in sufficient detail, in a useful format, or in a timely fashion, especially those that are unwilling to make the necessary up-front investments in intelligent technologies. Utilities may also be skeptical of consumer receptivity or ability to utilize such data, even though many firms are aiming for simplicity and convenience in their consumer-facing products, let alone in technologies that automate energy management entirely. And utilities may also hesitate to provide data to third-party service companies that could act as competitors, especially where misaligned incentives make utilities uninterested in energy efficiency. These problems lead to a fragmented market that present a challenge to broad innovation and broad-based consumer empowerment, when in reality innovation would be much better served by a single, uniform market with clear national standards.

Adding to these challenges may be unfounded concerns about privacy. In truth, such concerns are likely overblown.[35] There are minimal risks to consumers for third-party use of their energy data. Energy usage data already exists and is in the possession of utilities—this is how they are able to bill their customers. And the amount of kilowatts consumed in a given week is unlikely to reveal more sensitive information about the average consumer than the average person could glean from driving by a home at night. Ultimately, if access to energy data is made the law of the land, it should include privacy rules and standards that prevent utilities from selling or otherwise sharing consumer data with unauthorized parties, but these rules should in no way limit the ability of consumers to obtain and share their data with authorized third parties of their choice.[36]

Ultimately, the lack of energy data access and innovative inertia in the energy sector prevents consumers from making full use of their data, constricts consumer choice, and provides unclear market signals to intelligent technology manufacturers. This situation leaves room for Congress and the Federal Energy Regulatory Commission to step in and provide a solution. The e-KNOW Act is exactly that solution. It would amend the Public Utility Regulatory Policies Act of 1978 to give consumers across the country the right to access their detailed energy consumption and price data electronically in machine-readable format quickly and free of charge, including the right to access this data directly from their on-site smart meters. It also requires electricity data retention by utilities for at least 13 months. And to address privacy concerns, it requires this data retention to adhere to adequate privacy and security standards, and requires the Federal Energy Regulatory Commission to work with the National Association of Regulatory Utility Commissioners, the National Institute of Standards and Technology, and outside organizations to develop guidelines for access and security standards within 180 days.

Develop the Technology

Government should encourage technological development within the private and public sectors. Indeed, government has historically played a key role in catalyzing radical public-private innovation for new technologies, including in the ICT sector. This remains the case in more advanced or high-risk technology areas requiring substantive research and development. Fortunately, the federal government is making substantive investments in this area. For example, the Department of Energy's National Renewable Energy Laboratory and the Buildings Technology program have taken a lead developing and distributing building modeling tools for energy flow simulation and building design. On the grid side, DOE's Office of Electricity Delivery and Energy Reliability (abbreviated OE) has led efforts via, for example, R&D into integration of two-way digital devices and other smart grid technologies into the existing grid.

But some of the most exciting activities are happening in the advanced technology realm. In its FY 2012 budget proposal, the Administration proposed creating a Smart Grid Technology and Systems Hub, housed within OE. The Hub would convene a multidisciplinary team of exports to conduct R&D on novel grid control devices, components, sensors, and software.[37] And the Advanced Research Projects Agency-Energy (ARPA-E) is also pursuing building efficiency technology, power electronics—to replace existing electromechanical technology with digital grid technologies—and in advanced grid control technologies. ARPA-E is able to bridge the gap between basic and applied research, bringing it all under one roof to more effectively accelerate radical innovation on a short timetable.[38] Continued support for these activities is critical.

Foster the Markets

It can be a challenge for new technologies to enter the market, due to risk, inertia, and uncertainty. For new intelligent technologies that offer significant social returns in emissions reductions as well as private returns in reduced energy consumption, government can step in as an early user, and thus create an early market through procurement. Creating these early markets can allow technology suppliers to gain productive experience and drive cost reductions and performance improvements. And acquiring and employing intelligent technology in government buildings reduces their energy footprint and saves taxpayer dollars.

The General Services Administration is already taking steps to adopt intelligent technologies, but perhaps the most important and potentially huge venue is the Department of Defense, the world's largest single consumer of energy. DOD has over 500 installations worldwide, with over 500,000 buildings and other structures, and pays approximately $4 billion a year in energy bills for its permanent installations. The Department recognizes energy efficiency as strategically advantageous, freeing up resources for other important uses, and has been improving metering to obtain better energy consumption data in recent years with this goal in mind. The test-bed function for advanced building energy technology is being fulfilled by DOD's Environmental Security Technology Certification Program, a testing program for new technologies on the verge of deployment but in need of validation.[39] The program recently announced a major new initiative exploring an array of technologies related to installation efficiency: microgrids, energy storage, building efficiency and control technologies, and energy-use design tools. Continued support for this program, as proposed in Section 201 of the Department of Defense Energy Security Act of 2011, is critical to both intelligent technology and to national security.

But procurement is only one pathway for market expansion. The ultimate market destinations are utilities and consumers themselves, and policy can step in here as well, by encouraging investment and ensuring incentives are properly aligned in the utility sector, and by supporting efforts to promote residential and commercial consumer education about the advantages of new technologies. The federal government can work most effectively in partnership with state public utility commissions (PUCs). The utility sector is not known to be particularly innovative historically, and this tendency has grown with deregulation. With their direct lines of authority over utilities, PUCs are in a key position to foster the kinds of investments utilities need to pursue to accelerate intelligent technology innovation and market development. PUC leadership is particularly necessary in those instances where utilities are slow to act by themselves out of up-front cost concerns, or face adverse incentives that make energy efficiency less attractive due to lost revenues from reduced energy sales. A progressive PUC, like those in California and elsewhere, can make the difference between a statewide electricity sector that embraces innovation and one that remains resistant to it.

ENDNOTES

1. Peter Fox-Penner, *Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities*, 1st ed. (Island Press, 2010).
2. Khosrow Moslehi and Ranjit Kumar, "Smart Grid: A Reliability Perspective" (presented at the Innovative Smart Grid Technologies, Washington, D.C.: IEEE, 2010), http://www05.abb.com/global/scot/scot221.nsf/veritydisplay/bd10435e59f612ee852576740078a7e2/$file/moslehi%20-%2010sg0068%20-%20smart%20grid%20-%20a%20reliability%20perspective%20ieee%20sg%20cof%20jan%202010%20-%20dc.pdf.Khosrow Moslehi and Ranjit Kumar, Smart Grid – A Reliability Perspective, IEEE PES Conference on Innovative Smart Grid Technologies, January 2010.
3. James Greenberger, "Smart Energy Investment and the Smart Grid," *The Energy Collective*, January 23, 2011, http://theenergycollective.com/jim-g/50319/smart-energy-investment-and-smart-grid.
4. For example, see survey results from *Automated Meter Reading Business Case, 2006/2007 Distribution Tariff Application,* Fortis Alberta, http://sedc-coalition.eu/wp-content/uploads/2011/06/Fortis-05-12-20-AMR-Business-Case.pdf.
5. Fox-Penner, *Smart Power*, 37.
6. For a discussion on how ICT is improving these industries see Robert Atkinson and Daniel Castro, Digital Quality of Life: Understanding the Personal & Social Benefits of the Information Technology Revolution, Information Technology and Innovation Foundation, 2008, http://www.itif.org/files/DQOL.pdf.
7. For a good breakdown of these benefits, see U.S. Department of Energy Electricity Advisory Committee, Smart Grid: Enabler of the New Energy Economy, December 2008, http://www.oe.energy.gov/DocumentsandMedia/final-smart-grid-report.pdf.
8. Electric Power Research Institute, Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid (Palo Alto, CA, March 2011), http://my.epri.com/portal/server.pt?Abstract_id=000000000001022519.
9. Robert D. Atkinson, Daniel Castro, and Stephen J. Ezell, *The Digital Road to Recovery: A Stimulus Plan to Create Jobs, Boost Productivity and Revitalize America* (Washington, D.C.: The Information Technology & Innovation Foundation, January 2009), 14-15, http://www.itif.org/files/roadtorecovery.pdf.
10. *Employment and Economic Benefits of Transmission Infrastructure Investment in the U.S. and Canada* (WIRES in conjunction with The Brattle Group, May 2011), http://wiresgroup.com/images/Brattle-WIRES_Jobs_Study_May2011.pdf.
11. *Understanding the Benefits of the Smart Grid* (National Energy Technology Laboratory, June 18, 2010), http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/06.18.2010_Understanding%20Smart%20Grid%20Benefits.pdf.
12. Atkinson, Castro, and Ezell, *The Digital Road to Recovery: A Stimulus Plan to Create Jobs, Boost Productivity and Revitalize America*.
13. RG Pratt et al., *The Smart Grid: An Estimation of the Energy and CO2 Benefits* (Richland, WA: Pacific Northwest National Laboratory, January 2010), http://www.smartgrid.gov/sites/default/files/resources/co2_benefits.pdf.
14. Electric Power Research Institute, Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid.
15. Fox-Penner, *Smart Power*, 35.
16. U.S. Department of Energy, *Utilities: Smart Grid Stakeholder Book*, 2008, http://www.oe.energy.gov/DocumentsandMedia/Utilities.pdf.
17. U.S. Federal Communications Commission, *Connecting America: National Broadband Plan* (Washington, D.C., n.d.), 267, http://download.broadband.gov/plan/national-broadband-plan-table-of-contents-exhibits-preface.pdf.
18. Fox-Penner, *Smart Power*, 49.
19. Brattle Group, "The Benefits of Smart Meters," presentation at the NARUC Winter Meetings, February 16, 2011, http://www.brattle.com/_documents/UploadLibrary/Upload917.pdf.
20. Steve Lohr, "Digital Tools Help Users Save Energy, Study Finds," The New York Times, January 10, 2008, sec. Technology, http://www.nytimes.com/2008/01/10/technology/10energy.html.

21. Tom Simchak and Lowell Ungar, Realizing the Energy Efficiency Potential of Smart Grid (Washington, D.C.: Alliance to Save Energy, May 2011), http://ase.org/sites/default/files/ASE-smart_grid_white_paper_0.pdf.
22. Chris King, "Study: Texas consumers like in-home displays of energy information," *eMeter*, June 10, 2011, http://www.emeter.com/smart-grid-watch/2011/study-texas-consumers-like-in-home-displays-of-energy-information/.
23. Ahmad Faruqui, Sanem Sergici, and Ahmed Sharif, The Impact of Informational Feedback on Energy Consumption: A Survey of the Experimental Evidence (The Brattle Group, 2009), http://www.brattle.com/_documents/uploadlibrary/upload772.pdf.
24. See Sarah Darby, The Effectiveness of Feedback on Energy Consumption (Oxford, UK: Environmental Change Institute, University of Oxford, April 2006), http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf, and Karen Ehrhardt-Martinez, Kat A. Donnelly, and John A. "Skip" Laitner, Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities (Washington, D.C.: American Council for an Energy-Efficient Economy, June 2010), http://www.aceee.org/sites/default/files/publications/researchreports/e105.pdf.
25. Robert D. Atkinson and Daniel Castro, *Digital Quality of Life: Understanding the Benefits of the IT Revolution* (Washington, D.C.: The Information Technology & Innovation Foundation, October 1, 2008), 93, http://www.itif.org/publications/digital-quality-life-understanding-benefits-it-revolution.
26. Ahmad Faruqui, Ryan M. Hledik, and Sanem Sergici, Piloting the Smart Grid (The Brattle Group, June 1, 2009), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1414387.
27. Heather Clancy, "In home energy management, progress despite high-profile failures," *ZDNet*, July 7, 2011, http://www.zdnet.com/blog/green/in-home-energy-management-progress-despite-high-profile-failures/17942.
28. Leslie Guevarra, "GE, Best Buy Partner to Market Smart Grid Home Energy Controls," Reuters, June 24, 2011, http://www.reuters.com/article/2011/06/24/idUS221127964820110624.
29. Martin LaMonica, "Home energy management a hot topic at show," *CNET*, January 6, 2010, http://ces.cnet.com/8301-31045_1-10426301-269.html.
30. "Home Energy Management Users to Reach 63 Million by 2020," *Pike Research*, June 8, 2011, http://www.pikeresearch.com/newsroom/home-energy-management-users-to-reach-63-million-by-2020.
31. The Climate Group, SMART 2020: Enabling the low carbon economy in the information age (Global E-Sustainability Initiative, 2008), 41, http://www.gesi.org/ReportsPublications/Smart2020/tabid/192/Default.aspx.
32. European Commission, ICT and Energy Efficiency: The Case for Manufacturing (Brussels, 2009), 17, http://ec.europa.eu/information_society/events/ict4ee/2009/docs/files/ec/ec/infso/g2/SmartManufacturing.pdf.
33. U.S. National Science and Technology Council, A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future (Washington, D.C.: Executive Office of the President, June 2011), 40, http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc-smart-grid-june2011.pdf.
34. Michael Kanellos, "California Orders Utilities to Give Up Consumer Data," *Greentech Media*, April 21, 2010, http://www.greentechmedia.com/articles/read/california-orders-utilities-to-give-up-consumer-data/.
35. Daniel Castro, "Smart Grids, Not-so-smart Bloggers," *Innovation Policy Blog*, September 24, 2009, http://www.innovationpolicy.org/smart-grids-not-so-smart-bloggers.
36. For a broader discussion of these issues, see Daniel Castro, *Data Privacy Principles for Spurring Innovation* (Washington, D.C.: The Information Technology & Innovation Foundation, June 2010), http://www.ntia.doc.gov/comments/100402174-0175-01/attachments/ITIF%20Comments.pdf.
37. U.S. Department of Energy, *FY12 Budget Request*, Volume 3, 377-378, http://www.cfo.doe.gov/budget/12budget/Content/Volume3.pdf
38. See Matt Hourihan and Matthew Stepp, A Model for Innovation: ARPA-E Merits Full Funding (Washington, D.C.: The Information Technology & Innovation Foundation, July 6, 2011), http://www.itif.org/publications/model-innovation-arpa-e-merits-full-funding.
39. See Matt Hourihan and Matthew Stepp, Lean, Mean and Clean: Energy Innovation and the Department of Defense (Washington, D.C.: The Information Technology & Innovation Foundation, March 31,

2011), http://www.itif.org/publications/lean-mean-and-clean-energy-innovation-and-department-defense.

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The Information Technology and Innovation Foundation (ITIF) is a Washington, D.C.-based think tank at the cutting edge of designing innovation strategies and technology policies to create economic opportunities and improve quality of life in the United States and around the world. Founded in 2006, ITIF is a 501(c) 3 nonprofit, non-partisan organization that documents the beneficial role technology plays in our lives and provides pragmatic ideas for improving technology-driven productivity, boosting competitiveness, and meeting today's global challenges through innovation.

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