Concise, High-Level Response to DOE RFI on Smart Grid Policy

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Abstract
This document responds to DOE questions regarding smart grid policy. The approach followed herein is to write concise comments addressing the overall RFI document at a higher level. This is necessary because:

a) Smart grid is a "systems" problem, where individual technologies are rather irrelevant.
b) Most of the ongoing concerns and immediate policy issues of interest to DOE are related to the architecture of the power grid and of the electricity industry, not to isolated technologies or to specific industry areas.

RFI original text is written in 9-point font. The responses and recommendations are written in 12-point font and are formatted within a box.

Request for Information

The following questions cover the major areas we seek comment on. They are not a determination of the final topics that DOE and the NSTC Smart Grid Subcommittee will address, and commenters may address any topic they believe to have important implications for smart grid policy regardless of whether this document mentions it. In response to any question that asks about smart grid technologies broadly defined, please describe the set of smart grid technologies your response considers. To aid the discussion of the relevant issues, commenters are welcome to use the following categories to classify the technologies they discuss, adding any clarifying language they view as appropriate.

- Instrumenting and automating the transmission and generation system
- Distribution automation
- Upgraded metering, such as AMI or even enhanced technologies that improve the capabilities of traditional AMR
- Consumer facing programs such as feedback, demand response, energy efficiency, and automation strategies
- Integrating new end user equipment like distributed generation and electric vehicles

Recommendation 1: *Policy should not address each individual technology and the traditional industry classifications should be questioned. Policy should address the industry architecture and its functional and performance requirements.*

Traditionally, it has been OK for the various actors of the industry to *classify* various areas of the electricity industry into various domains (generation, transmission, distribution, etc), technologies (nuclear, solar, metering, DMS, EMS, PMU, etc), or processes (planning, real-time control, etc). The tendency to maintain these classifications is historical and pervasive, and it has strong consequences for broader policy efforts. Smart grid is a *system*. In particular it is a *cyber-physical system* composed of devices, device controls and systems controls. Humans interact with this grid at various locations and stages. We want to make the grid smart, which requires formal deployment of intelligent *system controls* as opposed to *device control* mechanisms. One of the underlying objectives is that the intelligence of the system must be superior to the intelligence of the devices combined. Hence smart grid benefits cannot be realized by addressing the only the individual technologies used.

The five mentioned topics are important, but that leaves questions about the other 100+ emerging smart grid technologies unanswered? A policy approach consistent with a cyber-physical architecture point of view should replace classifications and individualized technology policy.

Figure 1: Policy should not focus on all individual technologies. The result will be an untractable policy problem with highly-suboptimal outcomes.

Recommendation 2: *Save at least one decade to the US electricity industry modernization by designing the industry architecture and the control architecture up-front.*

Control System: A set of sensors, communication, information, decision logic, and actuators used to command or regulate the behavior of other systems.

- About 85% of the DOE 4.3 billion smart grid investment was destined to smart meters and AMI. Smart meters by themselves will achieve very little.
- DOE issued a RFI regarding smart grid communications because of communications problems in smart grid. Meters plus communications won't achieve much.
- At the GridWise Global Forum, held in Washington in October, 2010, the DOE Delegate mentioned that one of the key future smart grid topics is handling and processing massive information. This assumes that the communications problems are resolved.
- Several years from now, once massive data is stored and processed reliably, the industry will ask "what can we do with all this information?" And the answer will be not much, because we still require: a) to embed the decision logic, and b) to deploy the actuators to control the infrastructure.
- Once the intelligence is embedded and actuators are deployed the industry may realize that the sensor infrastructure is outdate and does not meet the control requirements, and some of the communications deployment is sub-optimal or in some cases not needed.

In order save significant amount of money and to ensure that the smart grid objectives are realized, policy makers are advised to adopt a systems approach to smart grid problem. A key element of this approach is the architecture (as opposed to the engineering). To estimate the outcome of electricity industry modernization efforts without a clear architecture and policy, imaging the outcome of remodeling a house without an architect. It is important to note that the reference model proposed by the GridWise Council is essentially the same industry model that exists today.

The policy process should be based on formal systems techniques in order to:
a) Define the measurable and verifiable objectives of the modern electricity industry and the smart grid.
b) Define the industry actors: utilities, consumers, aggregators, retail markets, etc that will participate in this industry.
c) Define the functional and performance requirements: what will the industry actors be able to do. Will consumers be able to sell power, will EVs be able to regulate frequency, etc. What will be possible in the modern grid?
d) Define methods to validate, measure and verify the stated functional and performance requirements.
e) Design the architecture of the industry: interact with the relevant stakeholders and iterate until a solid vision of the modern industry is achieved. Note that this is a power system architecture, not a power system engineering or information architecture process.
f) Design the decision making architecture, control architecture, and information architecture
g) Then identify the technologies needed to implement the architecture.
h) Implement the technologies and verify objectives.

Unfortunately, the US electricity industry has decided to start with step h) above.

Commenters can assume a high degree of general knowledge on the part of DOE and the Subcommittee. Commenters are encouraged to cite or include relevant data and analyses in their responses. In addressing the following questions, we ask stakeholders to be concise. We primarily seek facts and concrete recommendations that can augment that general knowledge. We encourage stakeholders to use concrete examples of benefits, costs, and challenges or to bring novel or underappreciated sources of evidence to our attention wherever possible.

Definition and Scope

The deployment of technology to make the nation's electric grid a more interactive, efficient and responsive system is already underway. At the early stages of any major technological shift, stakeholders often use the same term-of-art to mean different things which can lead to miscommunication. To minimize confusion as we identify policy challenges and recommendations, this RFI uses the broad definition of Smart Grid laid out in Title XIII of the Energy Independence and Security Act of 2007 (EISA). Title XIII mentions that the smart grid uses communications, control, and information technology to optimize grid operations, integrate distributed resources including renewable resources, increase energy efficiency, deploy demand response, support electric vehicles, and integrate automated, interactive interoperable consumer devices. We encourage commenters to reference the full text of EISA section 1301.

We invite comment however on whether this is the best way to define the smart grid. What significant policy challenges are likely to remain unaddressed if we employ Title XIII's definition? If the definition is overly broad, what policy risks emerge as a result?

Recommendation 3: *A formal definition that contains demonstrable, measurable elements should be proposed.*

Smart is synonym to “intelligent”. Literally speaking smart grid is a power grid that has intelligence embedded in it. Based on the discussion following Recommendation 1 above, it is clear that we refer to the *systems intelligence* (the intelligence of the grid as a system), not to a collection individual “intelligent devices”. The artificial intelligence community has attempted to create intelligent agents and systems for many decades. There is massive literature corroborating that creating an intelligent agent is not a trivial task. Realizing a formal intelligent grid will not be a trivial task either. A way to evaluate the progress in smart grid is to ask ourselves: Can we formally prove that the electric power grid has intelligence embedded in it? The answer is probably negative. The proof is that all large-scale grid require human intervention for operation, control and restoration. The problem with the term “smart” is that is very

difficult to demonstrate that something is actually smart (qualitative answer). In addition it is not easy to come up with metric for “smartness”, e.g., the IC of the grid (quantitative answer).
Electricity is a critical infrastructure. Policy makers will be reluctant to accept smart grid concept as will grid operators. DOE can ask any system operator if she will allow any of her functions to be performed by a “smart” system.

We also invite comments on the geographic scope of standardization and interconnection of smart grid technologies. Should smart grid technologies be connected or use the same communications standard across a utility, state, or region? How does this vary between transmission, distribution, and customer-level standards? For example, is there need to go beyond ongoing standards development efforts to choose one consumer-facing device networking standard for states or regions so that consumers can take their smart appliances when they move and stores' smart appliance will work in more than one service area?

Recommendation 4: *Federal regulation should enforce and architecture that enables functional and performance requirements to be met. Implementation variations should be possible at the state level similar as in the communications and internet industries.*

The broad variations in electricity industry from state to state are mostly historical. If the internet had been developed at the end of the 19th century, the regulatory landscape of the internet and IT industry will probably have a similar level of diversity to the current electricity regulation.

Electricity as a physical phenomenon and the engineering process of transmission and delivery are essentially the same everywhere in the World. While states may have different regulatory objectives and historical regulatory processes, there is, technologically no reason for such large variation on regulation practices. A reasonable, long-term target for the electricity industry is to have something similar to what the communications and internet industries currently have: Federal regulation that ensures that the *functionality* of the industry is realized and small variations in *implementation* from state to state.

Recommendation 5: *Standardization must take place once technologies that meet the smart grid functional and performance requirements are demonstrated. No smart grid technology has been successful in conclusively demonstrating the seven DOE smart grid goals.*

There is no literature conclusively demonstrating that smart grid technology deployments have realized the seven DOE smart grid objectives either in pilot or massive deployment. The reason is that the functional and performance requirements of the smart grid have not been actually stated by DOE (because smart grid has been approached as a technology problem, not as a systems problem). Since there are no formal functional and performance requirements, any measure of demonstration is questionable, and biased toward vendor or utility business case. Because no formal smart grid demonstration has been demonstrate, it is not advisable to set smart grid standards in stone. It is though extremely important to have the infrastructure ready to set and develop standards once smart grid technology benefits are quantified and verified.

Interactions With and Implications for Consumers

Typical consumers currently get limited feedback about their daily energy consumption patterns and associated costs. They also have limited understanding of variations in the cost of providing power over the course of the day and from day to day. Many smart grid technologies aim to narrow the typical consumers' knowledge gap by empowering consumers with greater knowledge of and ability to control their consumption and expenditures. This vision transforms many consumers' relationship with the grid, which prompts us to ask the following questions.

For consumers, what are the most important applications of the smart grid? What are the implications, costs and benefits of these applications? What new services enabled by the smart grid would customers see as beneficial? What approaches have helped pave the way for smart grid deployments that deliver these benefits or have the promise to do so in the future?

How well do customers understand and respond to pricing options, direct load control or other opportunities to save by changing when they use power? What evidence is available about their response?

To what extent have specific consumer education programs been effective? What tools (e.g. education, incentives, and automation) increase impacts on power consumption behavior? What are reasonable expectations about how these programs could reshape consumer power usage?

To what extent might existing consumer incentives, knowledge and decision-making patterns create barriers to the adoption or effective use of smart grid technologies? For instance, are there behavioral barriers to the adoption and effective use of information feedback systems, demand response, energy management and home automation technologies? What are the best ways to address these barriers? Are steps necessary to make participation easier and more convenient, increase benefits to consumers, reduce risks, or otherwise better serve customers? Moreover, what role do factors like the trust, consumer control, and civic participation play in shaping consumer participation in demand response, time-varying pricing, and energy efficiency programs? How do these factors relate to other factors like consumer education, marketing and monthly savings opportunities?

How should combinations of education, technology, incentives, feedback and decision structure be used to help residential and small commercial customers make smarter, better informed choices?

What steps are underway to identify the best combinations for different segments of the residential and commercial market?

Are education or communications campaigns necessary to inform customers prior to deploying smart grid applications? If so, what would these campaigns look like and who should deploy them? Which related education or public relations campaigns might be attractive models?

What should federal and state energy policymakers know about social norms (e.g. the use of feedback that compares a customers' use to his neighbors) and habit formation? What are the important lessons from efforts to persuade people to recycle or engage in other environmentally friendly activity? What are the implications of these insights for determining which tasks are best automated and which should be subject to consumer control? When is it appropriate to use social norm based tools?

How should insights about consumer decision-making be incorporated into federal-state collaborative efforts such as the Federal Energy Regulatory Commission's (FERC) National Action Plan on Demand Response?

Recommendation 6: *The consumer is very busy, it wants to be hands off, and it cannot be taught to optimally schedule its energy utilization (the problem is too complex). Research on technologies that relieve the customer from the complex scheduling task must be promoted.*

The deployment of smart grid technologies for demand response has been based on the assumption that either the utility will have direct control or that the user will very interested in smart grid programs. Direct control has the drawback of privacy, which in the US is a very important issue that poses significant risk. Regarding privacy, it should be assumed that the data belongs to the consumer.

"The customer will…" is the major myth of smart grid. It is wise to assume that the customer won't. Customers (like you and me) and very busy people. They want to save money and they want to contribute to sustainability objectives, but their interaction with any system must be very simple. They don't have enough time to go to the utility portal to do complex appliance analysis or to participate in broader education programs. The differentiated price signal spread needs to be very significant (about 6-8 times the regular rate) in order to induce massive participation. The consumer wants to be hands-off and it needs to perceive direct value. The consumer wants to know about smart grid as much as they want to know how internet packages are routed or where the nearest cellular phone cell is located.

Let us consider a residential consumer who is trying to minimize cost given a time differentiated rate from the utility and owning a solar panel, a hybrid car, and some schedulable appliances. This is a very complex stochastic optimization problem that the common customer will not be able to solve. In particular, Ph.D. students equipped with detail information of appliance consumption, the time and incentives to do it and deep knowledge about electricity produced sub-optimal scheduling. The common user will not be able to solve this problem and will obtain highly sub-optimal responses [1]. The common user is not smart enough to address this issue, it needs to be bypassed. Note that this implies that any solution that heavily relies in the customer alone trying to figure it out how to optimize it energy use, such as utility web portals is likely to be fail.

A solution to both the problem of privacy and complexity must be addressed by optimization algorithms embedded in the home, building, etc. The cost of deploying these algorithms is a fraction of deploying smart meters, HANs, or smart appliances and should be given seriously consideration. The interface for the user must be simple and have three controls: "minimize cost, maximize sustainability objectives, or override controls (because "guests are coming for dinner and I don't want the system messing with my comfort").

[1] T. Hubert, S. Grijalva, "Home Energy Manager: A Consumer-Oriented Interactive Tool to Optimize Energy Use", IEEE International Conference on Consumer Electronics, Las Vegas, Jan 9-12, 2011, Accepted Paper.

Interaction With Large Commercial and Industrial Customers

Large commercial and industrial customers behave differently than residential consumers and small businesses. They regularly use sophisticated strategies to maximize their energy efficiency, to save money and to assure reliable business operations. Indeed, some already are or others are seeking to participate directly in wholesale energy and ancillary services markets. Please identify benefits from, and challenges to, smart grid deployment that might be unique to this part of the market and lessons that can be carried over to the residential and small business market. Please identify unmet smart grid infrastructure or policy needs for large customers.

Recommendation 7: *The consumer will become the "prosumer": an entity that can consume, produce and store electricity, and that has its own economic incentives and objectives. The new architecture for the electricity industry must be based on this reality.*

Managing distributed energy sources, energy storage, and consumer's active behavior coupled with sustainability objectives, requires significant changes in the architecture and technologies used to control the electricity infrastructure. Electricity consumers are evolving into economically motivated "prosumers" that not only consume, but can also produce and store electricity. Prosumers can become smart energy ecosystems if they are equipped with technology and intelligence that allow them to achieve their own objectives.

Any electric power system, from large interconnections to microgrids, to buildings, homes and appliances can be modeled as a prosumer. All the emerging interactions and transactions related to electrical energy can be implemented using a prosumer-based architecture, which would replace the traditional, one-way, generation–transmission–distribution-consumer model. A prosumer-based, service-oriented architecture, is remarkably flexible and scalable, and will ultimately enable a highly efficient business paradigm across the industry. This paradigm can be implemented through off-the-shelf technology. The prosumer architecture is illustrated in Figure 2

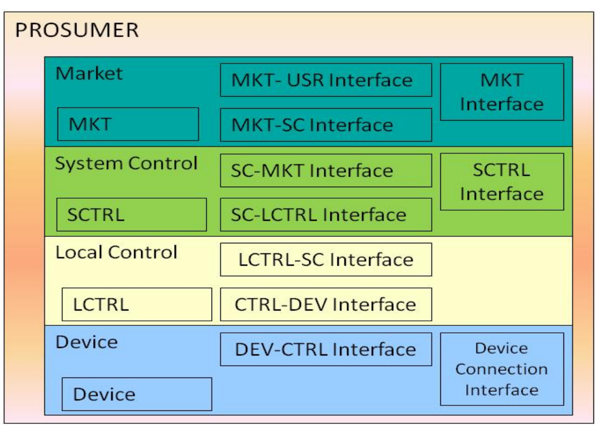

Figure 2: Layered prosumer architecture

The following are the unmet needs:
- Electricity production: the consumer wants to sell any excess electricity produce, e.g., by solar panels, etc to the utility (currently this is extremely cumbersome).
- Electricity storage: the consumer wants to provide storage services, e.g., through EVs
- Flexible load: the consumer wants to be recognized by absorbing production variability through flexible loads (EV, pumps, etc)
- Ancillary Services: the consumer wants to be recognized for being able to provide ancillary services: frequency regulation, reserve, restoration.
- Product differentiation: The producer wants time differentiated rates
- Choice: the consumer wants to choose its electricity provider either to the retail market, wholesale market or through bilateral contracts.

Assessing and Allocating Costs and Benefits

Regulators pay a great deal of attention to the costs and benefits of new investments, appropriate allocation of risk and protection of vulnerable customer segments. The many unknowns associated with smart grid programs make these ubiquitous questions particularly challenging, which suggests a great need to share perspectives and lessons.

How should the benefits of smart grid investments be quantified? What criteria and processes should regulators use when considering the value of smart grid applications?

When will the benefits and costs of smart grid investments be typically realized for consumers? How should uncertainty about whether smart grid implementations will deliver on their potential to avoid other generation, transmission and distribution investments affect the calculation of benefits and decisions about risk sharing? How should the costs and benefits of enabling devices (e.g. programmable communicating thermostats, in home displays, home area
networks (HAN), or smart appliances) factor into regulatory assessments of smart grid projects? If these applications are described as benefits to sell the projects, should the costs also be factored into the cost-benefit analysis?

How does the notion that only some customers might opt in to consumer-facing smart grid programs affect the costs and benefits of AMI deployments?

How do the costs and benefits of upgrading existing AMR technology compare with installing new AMI technology?

How does the magnitude and certainty of the cost effectiveness of other approaches like direct load management that pay consumers to give the utility the right to temporarily turn off air conditioners or other equipment during peak demand periods compare to that of AMI or other smart grid programs?

How likely are significant cost overruns? What can regulators do to reduce the probability of significant cost overruns?
How should cost overruns be addressed?

With numerous energy efficiency and renewable energy programs across the country competing for ratepayer funding, how should State Commissions assess proposals to invest in smart grid projects where the benefits are more difficult to quantify and the costs are
more uncertain?

What are appropriate ways to track the progress of smart grid implementation efforts? What additional information about, for example, customer interactions should be collected from future pilots and program implementations? How are State Commissions studying smart grid and smart meter applications in pilots? In conducting pilots, what best practical approaches are emerging to better ascertain the benefits and costs of realistic options while protecting participants?

How should the costs of smart grid technologies be allocated? To what degree should State Commissions try to ensure that the beneficiaries of smart grid capital expenditures carry the cost
burdens? Which stakeholder(s) should bear the risks if expected benefits do not materialize? How should smart grid investments be aligned so customers' expectations are met?

When should ratepayers have the right to opt out of receiving and paying for smart grid technologies or programs like meters, in home displays, or critical peak rebates? When do system-wide benefits justify uniform adoption of technological upgrades? How does the answer depend on the nature of the offering? How should regulators address customer segments that might not use smart grid technologies?

How might consumer-side smart grid technologies, such as HANs, whether controlled by a central server or managed by consumers, programmable thermostats, or metering technology (whether AMR or AMI), or applications (such as dynamic pricing, peak time rebates, and remote disconnect) benefit, harm, or otherwise affect vulnerable populations?
What steps could ensure acceptable outcomes for vulnerable populations?

Recommendation 8: *Base the economic valuation of technologies, solution, policies, practices, etc on how they meet formal smart-grid functional and performance requirements.*

Please refer to Figure 1 above. All the 20+ questions in this section can be asked about all the technologies shown in the Figure and about the other 100+ emerging smart grid technologies. Policy makers will have to answers 2000+ questions. Obviously, this is the wrong approach. An outline of a more effective approach is the following:

1. Define smart grid including a concise set of verifiable objectives
2. Set functional and performance requirements and metrics to measure performance
3. Propose an architecture for the industry that can enable those objectives and requirements. A prosumer-based layered architecture would drastically simplify the efforts [1]
4. Determine the economic value to meet each functional and performance requirements: for example reducing the number of disconnections of residential consumers per year to one half has a value of 30 billion dollars.
5. Determine how the proposed smart grid technology, solution, practice, business process, etc meets the requirements and at what level.

Utilities, Device Manufacturers and Energy Management Firms

Electricity policy involves the interaction of local distribution utilities, bulk power markets and competitive markets for electrical appliances and equipment. Retail electricity service is under state and local jurisdiction. Generally, bulk power markets are under FERC jurisdiction. Appliances comply with federal safety and efficiency rules. Smart grid technologies will change the interactions among these actors and should create new opportunities for federal-state collaboration to better serve citizens.

Greater collaboration seems essential. Some state regulatory agencies already oversee energy efficiency programs that help ratepayers acquire equipment like energy efficient appliances. Those appliances also are subject to federal regulatory oversight. As the smart grid evolves, these types of ties are likely to deepen. Moreover, EISA foresees a federal role in developing potentially mandatory standards for some smart grid equipment and voluntary standards for smart-grid enabled mass-produced electric appliances and equipment for homes and businesses. Many commentators suggest that utilities may lack appropriate incentives to invest in the most cost effective smart grid infrastructure and allow that infrastructure to be used to conserve energy, because most service providers generate revenue based on the number of kilowatt hours sold and pass through the capital costs of things like smart grid infrastructure. If this is accurate, then those disincentives are an impediment to achieving national and state goals and, therefore, merit state and federal policy makers' attention. In issuing this RFI, DOE is mindful that the states oversee retail electric service and that state regulation differs state by state. Within states different types of service providers may be subject to different regulatory schemes depending, for example, on whether the service provider is investor owned, publicly owned or a cooperative.

Please refer to recommendation 4 for a discussion of Federal vs. State Regulation.

Recommendation 9: *If at all possible, a robust, market-based industry must be pursued, where all the participants have the opportunity to compete and succeed.*

A key objective of smart grid is consumer empowerment. Mandate efficiency standards empower the Government not the consumer. DOE should be cautions to massively enforce efficiency standards because a) Need to make sure that the cost of massive retrofitting (including rebates, taxes credits, etc) pays for itself in the long term, b) Pass the opportunity to implement market based mechanisms. There are many options regarding market based mechanisms for efficiency, which should be considered.

If the United States wants to empower the energy consumer, then it must be prepared to dis-empower to some extent the utilities. Consumers and utilities have conflicting interests. Please refer to recommendation 7 for a discussion about the emerging prosumer entity. Notice that the transition to a prosumer is in part due to the need of more distributed control, and in part by a “natural change” industry similar to the one that has taken place in the communications and information industries. If DOE wants to empower buildings, industries, microgrids and homes to evolve from being entirely predictable, passive and “dumb” loads to schedulable, active, flexible and smart loads, then the utility will have to yield some control.

Recognizing the primary role of states in this area, we ask the following questions:

How can state regulators and the federal government best work together to achieve the benefits of a smart grid? For example, what are the most appropriate roles with respect to development, adoption and application of interoperability standards; supporting technology demonstrations and consumer behavior studies; and transferring lessons from one project to other smart grid projects?

How can federal and state regulators work together to better coordinate wholesale and retail power markets and remove barriers to an effective smart grid (e.g. regional transmission organization require that all loads buy ``capacity'' to ensure the availability of power for them during peak demand periods, which makes sense for price insensitive loads but requires price sensitive loads to pay to ensure the availability of power they would never buy)?

How will programs that use pricing, rebates, or load control to reduce consumption during scarcity periods affect the operations, efficiency, and competiveness of wholesale power markets?

Will other smart grid programs have important impacts on wholesale markets? Can policies improve these interactions?

Do electric service providers have the right incentives to use smart grid technologies to help customers save energy or change load shapes given current regulatory structures?

What is the potential for third-party firms to provide smart grid enabled products and services for use on either or both the consumer and utility side of the meter? In particular, are changes needed to the current standards or standard-setting process, level of access to the market, and deployment of networks that allow add-on products to access information about grid conditions? How should the interaction between third-party firms and regulated utilities be structured to maximize benefits to consumers and society?

How should customer-facing equipment such as programmable communicating thermostats, feedback systems, energy management systems and home area networks be made available and financed? Are there consumers behavior or incentive barriers to the market achieving efficient technology adoption levels without policy intervention?

Given the current marketplace and NIST Smart Grid Interoperability Panel efforts, is there a need for additional third-party testing and certification initiatives to assure that smart grid technologies comply with applicable standards? If there is a need for additional certification, what would need to be certified, and what are the trade-offs between having public and private entities do the certification? Is there a need for certifying bodies to oversee compliance with other smart grid policies, such as privacy standards?

Commenters should feel free to describe current and planned deployments of advanced distribution automation equipment, architectures, and consumer-facing programs in order to illustrate marketplace trends, successes, and challenges. And they should feel free to identify any major policy changes they feel would encourage appropriate deployment of these technologies.

Recommendation 10: *Decouple architecture and functional and performance requirements form technologies. Regulation should enforce the former. Technology implementation depends on cost and innovation.*

In order to answer most of these questions we proposed the following mental experiment (Einstein used mental experiments often). Assume for a second that the transmission system is very strong and that most congestion path have been reinforced, i.e., there National Electricity Super-highway is a reality. Then what prevents a customer from physically purchasing her electricity from any provider in the interconnection and have that electricity delivered? The answer is nothing. The information systems are evolving to the point where these transactions are very possible. Amazon.com processes millions of transactions a day. Back to reality, with congestion, transmission provides can charge prices (shipping and handling). Congestion charges are well understood in electricity markets. Thus the actual limitation is not physical or informational. It is architectural, regulatory, and political.

Ideally State and Federal regulators would reach agreement on a vision for the future grid. However, various stakeholders may not be willing to get out of their comfort zone. DOE must determine whether the price of maintaining the status quo is prohibitive.

The following elements can help address this problem:

1. The possibility that U.S. looses leadership in energy technology if the grid is not modernized at all functional, management and performance levels.
2. Decouple architecture and functional and performance requirements form technologies. Federal regulation should enforce the former and state should address implementation.

3. Use university research to conduct comprehensive simulation of various industry architectures, including economic analysis.

Long Term Issues: Managing a Grid With High Penetration of New Technologies

Significant change in the technologies used to generate power and to keep supply and demand balanced is likely to occur over the foreseeable future. We invite comments on the steps that should be taken now to give the grid the flexibility it will need to deal with transitions that are likely in the next few decades. Commenters might address the following questions, some of which have more immediate implications.

What are the most promising ways to integrate large amounts of electric vehicles, photovoltaic cells, wind turbines, or inflexible nuclear plants? What approaches make sense to address the possibility that large numbers of other consumer devices that might simultaneously increase power consumption as soon as power prices drop?

For instance, what is known about the viability of and tradeoffs between frequently updated prices and direct load control as approaches to help keep the system balanced? How do factors like the speed of optimization algorithms, demand for reliability and the availability of grid friendly appliances affect those trade-offs?

What are these strategies' implications for competition among demand response, storage and fast reacting generation? What research is needed to identify and develop effective strategies to manage a grid that is evolving to, for example, have an increasing number of devices that can respond to grid conditions and to be increasingly reliant on variable renewable resources?

What policies, if any, are necessary to ensure that technologies that can increase the efficiency of ancillary services provision can enter the market and compete on a level playing field?

What policies, if any, are necessary to ensure that distributed generation and storage of thermal and electrical energy can compete with other supply and demand resources on a level playing field?

What barriers exist to the deployment of grid infrastructure to enable electric vehicles? What policies are needed to address them?

Recommendation 11: *Research needs for long-term issues:*

1. Desired functionality of the electricity industry and smart grid
2. Autonomous (no-communication) control
3. Dynamic stochastic optimization to address uncertainty
4. Building, home, microgrid energy scheduling
5. Real-time software (software that has formal timeliness)
6. Electric power system model unification
7. Handling massive data
8. Visualization of multi-dimensional, multi-scale datasets to be able to understand emerging complexity
9. Smart grid simulators

Reliability and Cyber-Security

We invite comment on the reliability opportunities and challenges that smart grid technologies create, including: What smart grid technologies are or will become available to help reduce the electric system's susceptibility to service disruptions?

What policies are needed to facilitate the data sharing that will allow sensors (e.g., phasor measurement units) and grid automation to achieve their potential to make reliability and performance improvements in the grid? Is there a need to revisit the legal and institutional approaches to generation and transmission system data collection and interchange?

What is the role of federal, state, and local governments in assuring smart grid technologies are optimized, implemented, and maintained in a manner that ensures cyber security? How should the Federal and State entities coordinate with one another as well as with the private and nonprofit sector to fulfill this objective?

Recommendation 12: *A prosumer-based architecture enables energy and information services to be exposed. The information provider and owner is the prosumer. Only the information necessary to enable a standardized service must be provided.*

The various organization and entities that handle electricity (utilities, microgrids, buildings, homes, etc) are evolving into prosumers (as discussed in Recommendation 7). These entities evolve into electric power ecosystem with evermore sophisticated intelligence for self-monitoring and control. The prosumer provides generation, storage, load, frequency regulation, etc. as well as information required for control, negotiation protocols, etc. In this architecture metering may be two-directional and metering information must be exchanged between the interacting entities (possibly through a third party provider). The default is that the prosumer is the owner of its data, which is shared with the metering provider in a similar fashion as a banking service. Account IDs and services available may be broadcasted to other industry players but not detailed consumption. PMU data may be an example of this.

This architecture provides an efficient mechanism to firewall all information interaction, which does not require massive regulation of customer or other metering data.

Managing Transitions and Overall Questions

The following questions focus on managing incremental change during the gradual evolution of the grid that may transform the power sector over the next few decades.

What are the best present-day strategies for transitioning from the status quo to an environment in which consumer-facing smart grid programs (e.g., alternative pricing structures and feedback) are common? What has been learned from different implementations? What lessons fall into the ``it would have been good to know that when we started'' category? What additional mechanisms, if any, would help share such lessons among key stakeholders quickly?

Answer 1:

Recognize that the consumer needs simplicity. If it is not extremely simple, it won't be used.

Make sure the US has a clear vision of the future grid and electricity industry architecture in place.

Do not focus on technology, focus on functionality

Recognizing that most equipment on the electric grid, including meters, can last a decade or more, what cyber security, compatibility and integration issues affect legacy equipment and merit attention? What are some strategies for integrating legacy equipment into a robust, modernized grid? What strategies are appropriate for investing in equipment today that will be more valuable if it can delay obsolescence by integrating gracefully with future generations of technology?

Answer 2:

Do not deploy massive technology until all stakeholders are convinced of the benefits and the objectives have been demonstrated "from turbine to toaster". Note that often inexpensive engineering simulations can avoid millions of dollars in losses.

It is extremely important to have a long-term vision that enables all technologies to be designed aligned with the long-term vision and with scalable design.

How will smart grid technologies change the business model for electric service providers, if at all? What are the implications of these changes?

Answer 3:

Note that the current architecture of the industry is essentially the same (except for 90s deregulation) that was created at the beginning of the century. The current electricity industry is not able to support the ambitious seven goals identified by DOE. There is vast literature supporting this. A major concept is evidence of saturation of the centralized control architecture.

There must be significant changes in the business processes of electricity providers.

What are the costs and benefits of delaying investment in metering and other smart grid infrastructure while the technology and our understanding of it is rapidly evolving? How does that affect the choice of an appropriate time to invest?

Answer 4:
It is not a matter of technology. Demand meters exist in the industry since 20 years ago. Thus the smart meter concept is not new. Neither is the communications deployed. Core network applications in EMS and DMS code is FORTRAN or at most C based and was coded during the 80s, some during the 70s.
To maximize return on investment, job creation is important to draft a vision that the Nation can relate to, feel proud about it and contribute. That clear vision of the future grid does not exist today.

What policy changes would ensure that the U.S. maintains global competiveness in smart grid technology and related businesses?

Answer 5:
The policy focus should not be on technology or devices. It should be on vision, architecture, requirements, metrics, verification processes, economic value, and value to customer. The technologies will be developed if they provide value to the customer.

What should be the priority areas for federally funded research that can support smart grid deployment?

Answer 6:
DOE current policy and investment focuses on core technologies (for a quick example see DOE SBIR I 2011 solicitation topics). Suggested areas of research were listed in Recommendation 11.

Finally, as noted at the outset, we invite commenters to address any other significant issues that they believe implicate the success or failure of the transition to smart grid technology.

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Patricia Hoffman,
Assistant Secretary.
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