1. Value of a Smart Grid System

Implementing a Smart Grid system is the effort to embed intelligence and communications in the electric delivery system, from the meter to the generator, and utilize significantly improved Communications and Control to make management of the grid more dynamic and adaptive. Smart Grid is also the platform that enables better integration of distributed renewable resources and "behind the meter" automation on the consumer side with the energy markets and grid operations.. Doing so holds the promise of improving the efficiency, reliability, and cost-effectiveness of the electrical system's operations, planning, and maintenance[1] and creates a system that is interactive with consumers and markets. Below we summarize the potential value of Smart Grid development from six perspectives:

Utilities and Grid Operators

Market Efficiency

Economy

Consumers

Environmental

Regulatory

Utilities and Grid Operators

According to the Electric Power Research Institute ("EPRI") a major blackout can cost an affected region in excess of $1 billion in direct costs and socioeconomic impacts. Reducing the probability of a major cascading outage by even a fraction would result in savings in excess of millions of dollars annually[2]. Smart Grid technologies such as synchrophasors (ref the North American Synchro Phasor Initiative) will lead to new methods of grid reliability monitoring and management. Combined with technologies such as FACTS devices and Dynamically Insertable

[1] SB1438, pg 3

[2] EPRI. 2008 Research Summaries. Grid Operations – Program 39 at pg 2.

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Comment [MW2111111]: EAC requested to avoid the terms static and dynamic; also that home automation is not SG itself and to emphasize that SG > AMI.

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Comment [MW2111112]: EAC wanted benefits described as potential rather than "certain"

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Market Efficiency¶
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Reactance, grid operators will have new tools for managing the grid for reliability, congestion management and relief, and economics.

Smart Grid Technologies also will provide more sophisticated monitoring of major transmission assets such as circuit breakers and transformers enabling grid operators to better predict maintenance needs and avoid failures. A 230kV or higher power transformer is a critical multi-million dollar asset with increasingly long lead times for delivery. The nation's transformer fleet was largely installed in the 60's and 70's and is approaching what would otherwise be end of life and expensive replacement. Asset management methodologies offer life extension and the deferral of very expensive replacement as well as avoided failures or "managed" failures with scheduled preventative repairs instead of catastrophic failure.

Some Smart Grid technologies with regard to communications better lend themselves to T&D reliability improvement and asset management than others. There are trade-offs between bandwidth, latency times, and cost which interact with the applications in non-trivial ways. For instance, one technology may be well suited to read meters across a month (the meter can store hourly data) at very low system cost, but is not sufficiently low latency to support gathering specific meter information for purposes of outage detection. Broadband over PowerLine (BPL) by contrast, is relatively high cost but offers greater bandwidth and lower latency – it is inherently better suited to distribution automation applications. Some BPL technologies also can demonstrate (in a controlled setting) the ability to process high frequency signals associated with insulation breakdown in distribution apparatus – an important diagnostic tool which today is cost effective only for high value transmission power transformers.

Comment [MW2111114]: BPL was called out for inclusion during the meeting

The communications field is one where technology life cycles are very short – a fundamental disconnect with utility models where cost recovery is spread over decades. Technology obsolescence is a threat that hinders positive decisions and delays progress, ironically. A combination of greater regulatory tolerance for faster depreciation schedules and support for investments to "future proof" Smart Grid investments (such as stringing optical fiber for future communications along transmission ground wires) is indicated.

Comment [MW2111115]: AEP requested this specifically

At the transmission level, an important Smart Grid technology is associated with digital (microprocessor based) protection. In new construction, this technology has completely replaced the electromechanical protective relays of the past. Digital protection offers the ability to gather a great deal more data about the apparatus condition and performance, as well as fault information, than is available from older relays. This information can be used to bolster reliability and asset maintenance. However, justifying the major costs of replacing functional protection in an older substation can be a difficult task for a utility. Increased R&D aimed at a better utilizing this data will strengthen the business case and speed these replacements.

Just as consumer energy intelligence should lead to avoided peak generation capacity needs, it can also potentially defer transmission investments due to peak requirements. Also, integrating remote renewable resources, especially wind, with the grid will be greatly facilitated by SGT.

Integrating SGT with utility T&D control centers and fully realizing the potential for improved operations will require the development of new analytic applications as well as new IT platforms and communications to make best use of the new information and control capabilities. Bringing new information of new kinds to the existing control center systems without the proper tools to make best use will greatly diminish the value of the Smart Grid investments. More positively, SGT together with modern high performance communications and computing will enable the commercial realization of analysis and control methodologies that were heretofore impractical.

There are highly specialized Smart Grid applications using technologies that include synchrophasors, FACTS devices, dynamically insertable reactances, and gird scale fast storage, which hold the potential of allowing increased transmission circuit utilization when technical limitations such as post-fault transient and dynamic stability limit the power transfers to less than the nominal capacity of the circuits affected. Each of these require careful engineering analysis and modified automation systems and control center applications to realize – but the economic potential in particular cases can be very very high.

There is a real need for increased R&D on control center analytics and applications linked to SGT – this is taken up in the recommendations section.

Market Efficiency

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Lack of information leads to market inefficiencies in all market domains – financial, commodity, and virtually anything that people trade. Energy is no exception. Better forecasting and management of demand and renewable production as well as increased delivery assurance from better reliability all should lead to improved market efficiencies. Furthermore, energy storage technologies offer the promise of finally making electricity like other commodities and not so volatile in price due to moment by moment variability in demand and mismatches with supply. Some studies (cite GE-PNNL renewables studies for CA ISO and CEC) have forecast increased requirements and costs for ancillary services and real time balancing energy due to the variability of high renewable resource penetrations; Smart Grid technologies and storage offer a way of mitigating this impact.

The greatest impact that Smart Grid – especially when linked to Advanced Metering Initiatives (AMI) can have on market efficiency is that end users can have visibility to hourly (and conceivably real time) prices at their location as well as their own instantaneous usage and take actions to adjust their consumption according to their own valuation of energy usage at that moment. In jurisdictions where this information has been made available to the consumer, the general response has been very favorable – people like having the information and frequently choose to act on it to shift their usage to lower priced periods.

Comment [MW2111116]: Paul Allen and I had a back and forth on this question during the meeting and some agreement that it is an issue worth developing.

This contrasts with top-down mandated demand response programs where the technology is used to hierarchically control end user usage without their direct involvement – this has generated consumer resistance in several jurisdictions where it has been piloted. Consumers love being "informed" and dislike being "instructed."

In order for markets to operate effectively in an environment where more and more users are making price responsive decisions, the market operators will need to be able to collect and analyze end user behavior sufficiently to understand the actual real time elasticity of the demand curve. Their have been some studies made on what consumer elasticity is for different customer classes, but in the US we do not have widespread experience with this phenomenon. Today in the day ahead markets the market operator and the suppliers make day ahead load forecasts, primarily driven by weather forecasts, and then clear the market for scheduled energy to meet forecast demand. Real time or balancing energy is used to make up for any errors, up or down, in those schedules. In a world where demand will react to price this process will become more complex, and today the suppliers and market operators do not information or methodologies to deal with end user price sensitivity.

This is very different than a "Demand Response" model wherein aggregators sign up end users for controlled demand response which is sold into the markets as a resource for capacity or energy. When consumers have usage curtailed infrequently by such a mechanism tolerance can be good based on the economics delivered by the aggregator. But as a day-in day-out process the success of "DR" as opposed to "PR" (price response) is unknown.

Consumer Value of a Smart Grid

Smart Grids will provide consumers many benefits, deriving mainly from the consumer's ability to automatically manage their energy consumption. Consumers will benefit from knowing the price of energy at any given point in time and will be able to assess their consumption and determine energy costs at a moment's notice. Most importantly, they will have the opportunity to make more informed energy consumption decisions as a result of the availability of information. In order to encourage overall energy usage reduction we have to change the behavior of each consumer and in order to do that the system has to be able to give the consumer the information they need in order to change their behavior.

An essential component of a completed Smart Grid system is the successful implementation of advanced metering infrastructures ("AMI"), which allow collection and distribution of information such as consumption to individual consumers. States like California and Texas are already well on their way to bringing AMI to their utility consumers. Beginning in 2005, the California Public Utilities Commission ("CPUC") created the pathway for all California utility consumers to have AMI meters.[3]

A Smart Grid system should provide more efficient and reliable energy while providing consumers with valuable information for better decisions on when, where and how to consume energy. The California Public Utilities Commission (CPUC) on July 31, 2008 continued its commitment to empower energy consumers by setting a timetable for Pacific Gas and Electric Company (PG&E) to propose new "dynamic pricing" rate structures for all of its customers. Dynamic pricing will enable PG&E customers to take advantage of the new advanced meters (AMI) that PG&E is installing throughout its service territory. With the new advanced meters, customers will no longer have to wait until the end of the month to see how much energy they have used. The new meters will tell customers how much energy they are using day-to-day and hour-to-hour. Dynamic pricing will give consumers a tool to take advantage of the new meters and reduce their electricity bills.[4]

In response to the Energy Policy Act (cite actual section / language) many other state utility commissions have directed utilities to assess the benefits of AMI. IN many of these states pilot projects demonstrating proof of concept, testing technology, and testing consumer acceptance, are underway. In many others there are utility filings pending Commission approval and final decision. However, it is fair to say that today outside Texas and California the broad consensus that widespread deployment is economically justified and good for consumers has yet to develop, and will certainly be influenced by experience in these two states as well as with local pilot projects.

[3] CPUC Decision 05-09-044

[4] CPUC Decision 08-07-045

In states where full roll out has not been approved to date, a major reason has been the relatively long payback periods developed as part of Smart Grid business case submittals. These business cases are naturally influenced by (a) reluctance on the part of utilities to project dramatic improvements based on unproven technologies and business practices, and (b) a general lack of understanding about how much price elasticity will really manifest itself and how the market will change to reflect that. As the California and Texas deployments other large scale pilots go forward, it will be important to collect as much information as possible about the benefits realized (and as compared to projected) so that the industry can better plan other full scale roll outs for improved cost effectiveness as adapted to particular service territories. There is a potential role for DOE to play in this as a clearinghouse for cost benefit information and models as well as a tracking of end user price elasticity over time. A number of organizations (IBM, McKinsey, as examples) have cost-benefit tools that are available on their web sites. These are naturally reflective of their own engagements and involvement. A DOE clearinghouse would hopefully be more authoritative and comprehensive.

Comment [MW2111117]: EAC wanted DOE to play a clearinghouse role

Better understanding of the economic benefits will also facilitate regulatory developments aimed at creating a more favorable environment for Smart Grid development and deployment – both in terms of cost approvals and incentive development.

Comment [MW2111118]: EAC also wanted support for regulatory environment and incentives; these words attempt to lead that way

Another expectation of a Smart Grid system is that it allows advanced-decision making in order to make efficient and cost effective use of electricity. A fully network-connected system will identify all aspects of the power grid and communicate its status and the impact of consumption decisions (including economic, environmental and reliability impacts) to automated decision-making systems on that network including the consumer's home network. As a result, a Smart Grid system would clear the way for more energy efficiency. California has long supported cost-effective energy efficiency as the resource of first choice for its energy needs. Energy efficiency is the least cost, most reliable, and most environmentally-sensitive resource, and minimizes our contribution to climate change.[5]

Because of the high public visibility as well as the large numbers of devices involved, full roll-out of AMI and Smart Grid at the distribution level to residential consumers and distribution circuits gets the most attention. However, energy usage is more concentrated in commercial and small industrial customers which potentially are low hanging fruit for energy savings and market

[5] California Energy Action Plan II at pg 5.

impacts associated with real time pricing, price response, and AMI. In particular, the integration of building automation systems (which control building HVAC and often other energy users in a building such as elevators and escalators as well as lighting) with AMI and the enhancement of building automation systems to take advantage of this integration is not an area of emphasis outside some areas such as New York City and California. These solutions offer shorter paybacks, often, than residential deployments. However, they are technically more difficult to achieve and require buy-in of multiple end user stakeholders – real estate owners, buiilding operators, maintenance, and tenants. For this reason the focus of this activity has tended to be owner-occupied buildings, especially in the non-profit sector such as government, hospitals, and universities.

Comment [MW2111119]: This is our observation based on ongoing experience in this domain. Question – it leads to a recommendation that DOE link enhancments to LEEDS standards with AMI / SG – is this worth considering? Note too that Paul Allen insisted on mentioning C&I as the low hanging fruit.

Environmental Value of a Smart Grid

Smart Grid environmental benefits accrue from several contributing factors:

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- deferral of costly peaking generation (typically natural gas fired combustion turbine)
- mitigation of renewable variability – which if managed with combustion turbines increases the emissions of those units, which are not as "clean" when operated at constantly variable levels. (reference CMU studies)
- more encouragement of renewable distributed generation via two way metering at market pricing and lower utility costs for integrating these resources

The overall value to the environment and society of a Smart Grid will be in the form of a reduced need for additional transmission lines, power plants, and correspondingly less impact on the environment. For instance, the California Independent System Operator (CAISO) has generated historical consumption that shows its system peak usage was 50,085 megawatts.[6] However, usage has reached 45,000 megawatts only 0.65% of the time.[7] This means that California must build peaker plants, additional transmission lines, distribution lines, and even additional power plants to have enough supply to be able to meet demand that occurs less than one percent of the time. Recovering the capital costs of these rarely used assets results in

[6] CAISO
[7] CAISO

extremely high peak energy prices which can be avoided via consumer price response and energy management.

One of the goals of a successful smart grid system is to be able to reduce usage during peak hours so that additional resources are not built. Efficient use of resources helps not only the individual consumer from having to pay for resources that are stranded 99.35% of the time, but also helps keep our environment cleaner and our neighborhoods safer from additional transmission lines and power plants. Fortunately, today consumers are aware of the potential damages that can be caused if we don't reduce our carbon footprint. This is evinced in the rapidly growing deployment of clean distributed generation, especially roof-top photovoltaic solar. Integrating renewable resources that are customer operated as well as utility operated will require an open Smart Grid architecture that can manage the diverse resources for economy and reliability.

Economy

The US has enjoyed a low cost and reliable electricity supply for roughly a century as a key driver for economic growth, productivity, living standards, and environmental compliance. That trend is very much at risk due to aging infrastructure, an unprecedented change in energy resource mix and availability overall, and future carbon regimes in response to the threat of global warming. Every other industrial and commercial sector has seen great benefits from automation, embedded intelligence, and integration into a broader and broader domain of electronic commerce. Electricity will reap the same benefits as a direct result of smart grid with benefits to all walk of American commerce and life. By contrast, to not pursue Smart Grid aggressively condemns the US to dependence upon 20th century grid architecture. In response to the "end of oil" and carbon reduction, many forms of end energy consumption such as transportation and home heating will shift from oil and other fossil fuels to electricity – Smart Grid is essential to national preparedness for this change.

As the US faces increasing electric rates due to fuels cost increases, higher RPS standards, and the expiry of deregulation era rate freezes, it will be necessary to provide more effective consumer education about the role of electricity in a modern society and the costs and benefits of reliable and pervasive electric supply.

Regulatory

The grid has morphed from being the wires that utilities used to deliver power from their own generators to today's (partially) deregulated model where the wires are provided by utilities to

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customers so that independent and utility generators can deliver power to them. Regulators have wrestled with questions of open grid access and cost recovery mechanisms as well as determination of what are prudent and necessary investments through this transition. The explosion of new technologies for renewable and distributed generation means that the "wires" broadly speaking now must integrate new technologies, bi-directional energy flows, and the information to make it all work.

Conclusion

When the original power grid was built over 100 years ago it wasn't necessary to think of consumer choice and distributed generation. However, today we are faced with limited resources, higher demand for energy, a need to have cleaner energy, and to better protect our environment. It is not realistic for us to expect a grid that has reached the end of its useful life to give us two-way communication and to be adaptable to today's needs. Therefore, we expect a Smart Grid system to provide tangible and intangible benefits to all stakeholders, including consumers, shareholders, and regulators. It will bring environmental benefits through efficient use of energy and existing capacity; it will give customers options and choices to change their behavior when it comes to the amount and type of power they use, and when to use those energy resources. Utility operating costs should be lower as a result of automation and better visibility into operational aspects of the grid, leading to more efficient and effective use of resources. We cannot ignore the reality that our grid is old and it needs to be upgraded.

Appendix A – Smart Grid Benefits Matrix

Comment [MW21111110]: I will get someone to format this nicely

Potential and Real Benefits to be Realized by Building and Implementing Smart Grid

Benefit	Stakeholder					
	Utility	**Independent Generator**	**Residential**	**Commercial**	**Industrial**	**Future Generations**
System Reliability and Economics						
Smart Grid technologies allow faster diagnosis of distribution outages and automated restoration of undamaged portions of the grid, reducing overall outage times with major economic benefits	X		X	X	X	
Smart Grid's automated diagnostic and self-healing capability prolongs the life of the electric infrastructure.	X					X
Distributed generation is supported because the grid has the ability to dynamically manage all sources of power on the grid.	X	X	X	X	X	X
Price sensitive peak shaving defers the need for grid expansion and retrofit.	X					
Price-sensitive peak shaving reduces the need for peaking generation capacity investments.	X		X	X	X	
Smart Grid technologies may allow better utilization of transmission paths improving long distance energy transfers	X	X				
Positive Environmental Impact						
Smart Grid can reduce distribution losses thus reducing power generation demands	X		X	X	X	X
Grid integration of high levels of renewable resources as called for in many state RPS standards will require Smart Grid to manage extensive distributed generation and storage resources.	X	X	X	X	X	X
A high penetration of PHEV will require Smart Grid to manage grid support of vehicle charging. Potential use of PHEV as Vehicle to Grid will absolutely require Smart Grid technologies.	X		X			X
A Smart Grid enables intelligent appliances to provide feedback through the system and the ability to sense grid stress and reduce their power use during peak demand periods.	X		X			
Advanced metering technology can be used to help measure electricity use and calculate the resulting carbon footprint..			X	X	X	X
Increased efficiency of power delivery						
Direct operating costs are reduced through the use of advanced metering technology (AMR/AMI) such as connects/disconnects, vehicle fleet operations and maintenance, meter reads, employee insurance compensation insurance, etc.	X					
SG technologies such as synchrophasors offer the promise of reducing transmission congestion	X	X	X	X	X	
Economic Development						
Standards and protocols supporting interoperability will promote product innovation and business opportunities that support the Smart Grid concept.	X	X	X	X	X	X
Consumer Choice						
Provide consumers with information on their electric usage so they can make smart energy choices.			X	X	X	X
Real time pricing offers consumers a "choice" of cost and convenience trade-offs that are superior to hierarchical demand management programs			X	X	X	
Integration of Building Automation Systems offers efficiency gains, grid expansion deferral, and peak shaving.	X			X		

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Utilities and Grid Operators

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