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Is It Smart If It's Not Clean?

Smart Grid, Consumer Energy Efficiency, and Distributed Generation

Part

2

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Is It Smart if It's Not Clean?

Smart Grid, Consumer Energy Efficiency, and Distributed Generation

PART TWO

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What does a smart grid have to do with a clean grid? Part one of this series described strategies for improving efficiency of utility distribution systems, with and without a smart grid. It explained how smart grid capabilities – real-time sensing, communication and control – might allow utilities to optimize voltage and reactive power, minimizing energy losses on the distribution system and reducing energy use by some types of consumer equipment.[2]

In the second part of this series, we explain smart grid opportunities to advance end-use energy efficiency and clean distributed generation. Potential benefits for energy efficiency include:

1. Providing detailed information on electricity use and costs to help consumers understand how to save energy and money
2. Enabling ongoing building diagnostics to help find and alert building owners to problems in heating and cooling systems
3. Improving evaluation of energy efficiency programs

For distributed generation, smart grids can mitigate the impacts that high penetration levels can have on the utility system – helping cities and states to reach renewable energy goals at a faster pace. Smart grids also can unlock additional benefits of distributed generation for owners and utilities.

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The Smart Grid and Energy Efficiency

Information-Driven, Behavior-Based Savings

1 Standard Billing	2 Enhanced Billing	3 Estimated Feedback	4 Daily/Weekly Feedback	5 Real-Time Feedback	6 Appliance-level Real-Time Feedback
Monthly, bi-monthly or quarterly bill	Household-specific info, advice, and/or comparisons; monthly or quarterly	Web-based energy audits with info provided on ongoing basis	Household-specific info, advice, and/or comparisons; daily or weekly	Real-time premise-level info	Real-time info down to appliance-level detail
"Indirect" Feedback (Provided after consumption occurs)				**"Direct" Feedback** (Provided real-time)	

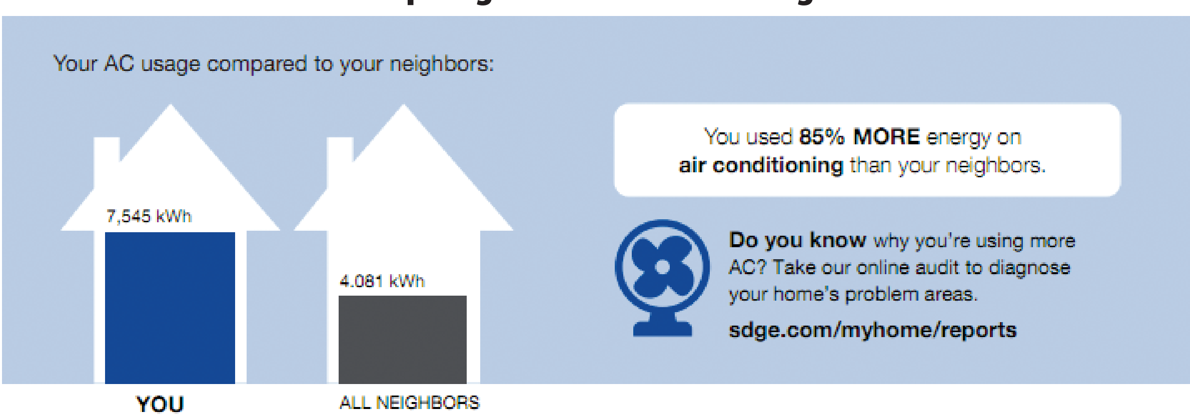
Figure 1. *Types of information feedback, from Electric Research Power Institute[3], characterized by* ***when*** *and* ***how often*** *the customer receives it. Timing and specificity of feedback are influential variables in studies to date, lending support to advanced metering infrastructure with two-way communication – smart grid technologies.*

Today, most consumers simply receive a monthly electric bill that shows their energy use, prices and costs for the period – sometimes with comparisons to historic use. Customers can't easily correlate specific actions they take in their homes and businesses with their energy consumption or energy bills.

Using weather, demographic and other data, some utilities provide enhanced billing through third-party providers that includes:

- An estimated breakdown of consumption by end-use
- A comparison of total usage to neighbors
- Customized energy-saving tips with links to relevant energy efficiency programs

Spotlight on Air Conditioning



Your estimated AC usage is based on last summer's energy use and temperature. For more details, visit sdge/myhome/reports

Figure 2. *Comparing a customer's consumption to their neighbors' can be a powerful motivator for energy-saving actions. With hourly meter data, customers can receive a more accurate picture of energy use for air-conditioning and other end uses. Such "interval" data also can provide accurate information on a customer's energy use during peak demand hours, when electricity costs are highest. Graphic courtesy of OPOWER.*

Like traditional electric bills, these enhanced energy reports typically arrive by mail, monthly or less frequently.

Advanced metering infrastructure – solid-state digital meters with two-way communications between the meter and utility – enables more frequent "feedback" to consumers. It also can be used to provide consumers with their consumption by time of use, as well as improved analysis of consumption by end use and targeted energy-saving recommendations for each customer. Programmable communicating thermostats (PCTs) can provide additional data on heating and cooling loads, further enhancing these energy reports.

Instead of waiting for a monthly bill or energy report, Web-based portals can provide customers with current information on energy use – by hour, for example – typically with a day's lag. Or meter data can be provided in real time or near real time at the customer's premise using a PCT with information display, pre-payment meter or a stand-alone display.[4] Some systems can provide alerts to customers when consumption or costs exceed the values customers specify, or when a customer is projected to cross into a higher-cost tier of usage under inclining block rates.[5]

While energy-use feedback is relatively new for households, large commercial and industrial customers have for many years been able to choose utility or third-party services that provide current and historical energy and demand data, along with reports and analysis, to help detect malfunctions in energy-related systems, optimize their operation, guide investments in equipment and systems, and reduce energy bills.

Experience with residential customers to date reveals that feedback as soon after the consumption behavior as possible and specificity (such as breakdown by appliance) are influential variables in helping consumers change their energy consumption behavior.[6] Those findings tend to favor advanced metering infrastructure with two-way communication – smart grid technologies.

Studies also have shown a preference by residential customers for "pushed" information – for example, the utility sends energy usage reports by mail or email, instead of requiring the customer to log into a Web site to retrieve the information (but having a Web option for more detailed analysis).[7]

Savings Estimates

Giving feedback to customers on their energy use can motivate them to change their consumption behavior, influence purchase decisions for appliances and equipment, and help target investments in the most cost-effective measures.

A recent literature review by the American Council for an Energy-Efficient Economy on the value of various types of energy-use feedback concluded that it could help households reduce electricity consumption by 4 percent to 12 percent.[8] A 2009 report for the Electric Power Research Institute found overall conservation effects of a wide range of energy-use feedback methods ranging from negative to 18 percent, with some indication that savings persist for at least one year.[9]

A recent study for the Sacramento Municipal Utility District on home energy reports mailed monthly (to high-consumption households) or quarterly (to low-consumption households) found that energy savings persisted, and even increased, in the second year of the program – from 2.32 percent to 2.89 percent for high-consumption households, and from 1.25 percent to 1.70 percent for low-usage customers, in the first and second years, respectively.[10] Using interval consumption data from advanced meters, these reports also could be used to identify actions consumers can take to reduce peak demand.

An often-cited report on the impact of in-home displays estimates savings in the range of 5 percent to 15 percent.[11] A more recent review of in-home displays found savings of 7 percent on average for customers who pay for electricity use after the fact (typical monthly billing) and twice that for customers on pre-payment plans.[12] However, the incremental value of real-time feedback through in-premise devices such as in-home displays is not a settled issue, including persistence of savings over time.[13]

The Pacific Northwest National Laboratory (PNNL) estimates the *technical* potential for electricity savings for homes and small and medium commercial buildings from improved feedback *enabled by the smart grid* at 6 percent. PNNL indicates a wide range of uncertainty for potential savings in this area – 1 percent to 10 percent. That's due to a number of limitations of studies to date: self-selection bias, small and homogeneous samples, lack of research into persistence of savings over time, and shortcomings in evaluation to determine *how* savings were actually achieved.[14] For perspective, it's useful to compare overall savings found in the randomized, large-scale feedback tests described above (approaching 3 percent).

Unless verified savings from behavior-based programs are qualifying measures for meeting state energy efficiency goals, and included in any utility shareholder incentive mechanisms, these programs will not make significant inroads – with or without smart grid. Also needed is an agreed-upon framework for measuring energy savings from behavior-based programs. Energy savings from home energy reports using standardized EM&V procedures already count toward energy efficiency goals in California, Massachusetts, Minnesota and Texas, and several other states have taken the preliminary step of approving filings for such programs.[15] Incorporating smart meter data into these programs will help meet state goals to reduce peak demand.

Commissioning and Continuous Building Diagnostics

"Commissioning" is a systematic process of ensuring that building equipment and systems are designed, installed and initially functioning as the owner intended, and building staff are prepared to operate and maintain them.[16] Existing building commissioning (also called retro-commissioning or recommissioning) is used to improve operations and maintenance of buildings that were not commissioned during design and construction.

The commissioning process covers heating, ventilating, and air conditioning (HVAC) systems and controls, lighting and life safety systems. It ensures that equipment and systems are sized, specified and tested for a particular pattern of operation based on expected occupancy, weather and other factors that determine how they are used.

Using a large database of commissioning results in nonresidential buildings in the U.S. of various sizes and types, Lawrence Berkeley National Laboratory[17] found median energy savings of 16 percent for existing buildings and 13 percent for new construction.[18] The costs of commissioning paid back in energy savings in 1.1 years and 4.2 years, respectively, with median benefit/cost ratios of 4.5 for existing buildings and 1.1 for new construction. According to the study, energy savings persist for at least three to five years.[19] Many measures undertaken during commissioning, such as properly sizing HVAC equipment, are very durable.

Because energy savings exceed the costs of commissioning, the analysis estimates negative costs for associated reductions in greenhouse gas emissions, with median values of -$110 per tonne[20] for existing buildings and -$25 per tonne for new construction. Benefits beyond energy savings include occupant comfort and improved indoor air quality.

The report concludes that commissioning may be the most cost-effective strategy for reducing energy use and greenhouse gas emissions in buildings. Applying median energy savings from the study to the stock of U.S. nonresidential buildings, the researchers estimated that commissioning could save $30 billion in energy costs annually by 2030, with a corresponding reduction of about 340 megatons[21] of carbon dioxide each year. In addition, commissioning ensures that building owners get what they pay for when constructing or retrofitting buildings, detects and corrects problems early and in a less costly manner, and helps verify that energy efficiency programs are meeting their savings targets.

Despite its benefits, commissioning is not widely practiced. The smart grid has the potential to considerably reduce the cost and time involved for commissioning, further tipping the scales in its favor and accelerating its adoption, and to facilitate monitoring-based, ongoing commissioning.

Smart grid's interval meter data and two-way communication, together with building energy management systems and automated diagnostic tools, could constantly monitor equipment and performance for some parameters and update settings to optimize performance and efficiency. That would avoid the time-consuming process of manual inspection and testing of end-use devices. In addition, facility energy managers could receive immediate alerts when equipment is not performing to efficiency specifications. Such proactive maintenance would improve building operation, reducing energy use and costs and greenhouse gas emissions. Utilities could use automated diagnostics to screen buildings for energy efficiency programs.

The Electric Power Research Institute estimates an incremental market penetration for ongoing commissioning due to smart grid ranging from 5 percent to 20 percent of large commercial buildings, translating into an annual energy savings potential of 0.14 percent to 0.18 percent in retail sales of electricity in 2030.[22]

Only a fraction of buildings are using automated diagnostic tools today because of complexity, cost and other issues. The smart grid is not a requirement for automated diagnostics, but such investments can potentially make the practice available to all consumers, particularly if a common data platform is developed and historical interval data are stored for future use.[23]

Using whole-building, interval meter data, some types of energy waste can be detected by identifying base load and peak operation patterns, off-hours usage, relative cooling/heating efficiency, and periods when outside air is not used for free cooling. With thermostat information on the status of heating, cooling and water heating, end-use loads can be disaggregated from whole building energy use to provide better quality information for diagnostics. Residential and small commercial applications are most amenable to this approach.[24]

While commissioning today is focused on large commercial buildings, PNNL estimates that using smart grid technologies for ongoing diagnostics could reduce electricity used for home heating and cooling by 10 percent to 20 percent, and reduce consumption for HVAC and lighting for small and medium commercial buildings by 10 percent to 30 percent.[25] Homeowners, for example, could receive alerts immediately when heating equipment is operating abnormally. Incorporated into ratepayer-funded energy efficiency programs, homeowners could receive recommendations for correcting the problem, including potential costs, savings, and rebates for relevant energy efficiency measures and high-efficiency replacement equipment, if needed. Alerts also could be provided for routine maintenance schedules.

Interval data from advanced metering infrastructure also could be used to improve data for benchmarking – comparing a building's current energy performance with its energy baseline or with the energy performance of similar buildings, based on use. Key metrics from interval meter data could be benchmarked against a population of similar buildings. For example, the ratio of average peak load to base load may indicate problems with off-peak energy use.[26]

With commissioning and automated diagnostics made easier and cheaper, efforts can focus on addressing the remaining barriers to their implementation, including increasing public awareness, training for the building industry, and incorporating these measures in energy efficiency potential studies and program requirements.

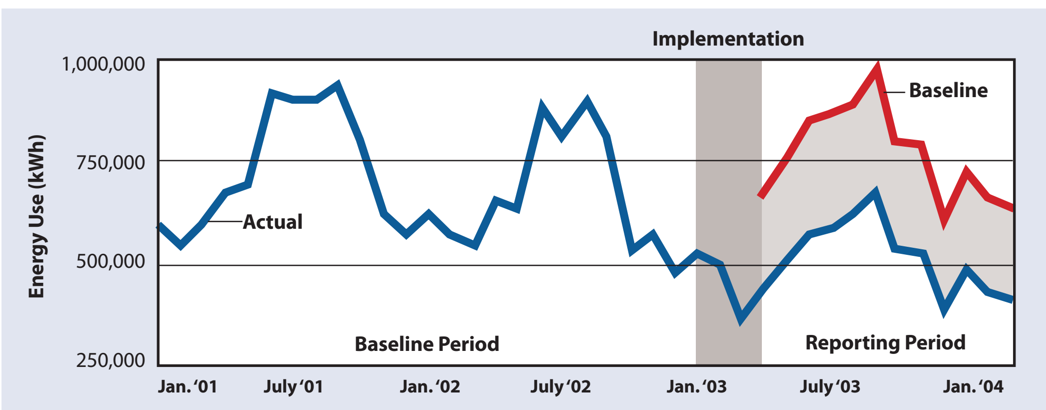


Figure 3.[27] *The basic approach to energy efficiency impact evaluation includes defining baseline energy use and projecting energy use patterns into the reporting period, with adjustments as needed for weather, occupancy, production level and other relevant factors. Smart grid's mass deployment of advanced meters plus two-way communication between the meter and the customer will allow for impact evaluations to cost effectively incorporate far more data and thus improve the quality and accuracy of savings determinations, as well as reduce data collection costs and the time required to present results and provide feedback for project improvement.*

Enhanced Evaluation, Measurement and Verification (EM&V)

Impact evaluations quantify the energy and peak demand savings of energy efficiency programs. Such evaluations also are used to help assess the cost-effectiveness of energy savings programs, set energy savings goals, identify receptive market segments, assist in cost recovery determinations, identify potential energy-saving measures in integrated resource planning, and for program planning, budgeting and design, among other uses.[28] Measurement and verification determines the energy and demand savings from individual projects and measures.

The two key objectives of EM&V are:[29]

1. To document and measure the effects of a program and determine whether it met its goals with respect to being a reliable energy resource.
2. To help understand why those effects occurred and identify ways to improve current programs and select future programs.[30]

EM&V is increasingly important as utilities, third-party service providers and organized power markets reach for advanced levels of efficiency to meet energy and capacity needs. Many states now have requirements to acquire all cost-effective energy efficiency, or they have established energy efficiency resource standards that require utilities to meet specified energy savings that ramp up over time. In addition, a number of states provide performance-based incentives that encourage utilities to achieve the highest levels of savings. Conversely, utilities and other energy efficiency providers may be subject to penalties for failure to meet minimum standards.

As system operators increase their reliance on energy efficiency to meet peak demand, they need better information on the size and timing of savings. Forward capacity markets in the ISO New England and PJM regions are increasingly relying on energy efficiency to meet reliability requirements. Capacity payments for energy efficiency measures are made only for verified savings.

In addition, air quality regulators need effective EM&V protocols in order to include energy efficiency programs in implementation plans as a mechanism for meeting air quality standards.

Generally speaking, the most rigorous and reliable EM&V approaches require a significant amount of end-use energy data collected both before and after implementation of efficiency measures. The collection of such data may require monitoring devices on isolated circuits for each end-use application studied. Because of the expense, such monitoring tends to be limited in time and a sample of the population of interest.

Smart grid's benefits for EM&V stem from interval data from mass deployment of advanced meters plus two-way communication between the meter and the customer – data collection and transfer capability for massive numbers of customers that can be turned on when needed. When such energy data are collected, for minute-by-minute energy consumption for a whole facility or for specific energy loads, the ability to analyze energy use and correlate it with external factors (such as weather and use patterns) increases and becomes affordable.

Advanced metering infrastructure, if combined with communicating thermostats, energy management systems, demographic data, appliance and equipment surveys, weather data and hourly (or finer-grained) avoided costs, offers the following opportunities to improve EM&V at lower cost:[31]

- Better understanding of how and when energy is consumed
  - Higher quality estimates of savings for existing energy efficiency programs
  - Better information for designing new programs
- Disaggregation of heating and cooling loads from other loads – using whole-premise interval data and other information to break down consumption into end uses
- Reduced data collection costs through remote monitoring, leaving more money for actual efficiency measures
- Rapid feedback on new or expanded energy efficiency programs
- More refined load-shape characteristics of individual energy efficiency measures, by season and time of day
- Better information for targeting programs to diverse customers
- More accurate, individual baselines and estimated savings – and how and why they happened
- More detailed data for analyzing the effects of weather, day type, occupancy and other variables affecting savings
- Many data points for better calibration of energy savings models
- Better analysis by subgroup – customer type or

location – by matching interval meter data for survey respondents with premise and occupant characteristics

To get these benefits, however, utilities must make arrangements for meter data to be collected at the required interval (e.g., hourly), safely stored and easily retrievable. Also, unless the data are being used routinely for another purpose, such as designing rates and allocating revenue requirements to customer classes, data clean-up will be required. In addition, time stamps for meters by various manufacturers may not be aligned.[32]

Policies Needed to Take Advantage of Smart Grid Capabilities for Energy Efficiency

If increasing energy efficiency is an objective of smart grid deployments, utilities and stakeholders will need to consider how to harness smart grid capabilities for ratepayer-funded energy efficiency programs. Policies for states to consider include the following:

Broad Strategies, With or Without Smart Grid

- Treat energy efficiency at least on a par with supply-side alternatives in resource planning and acquisition, transmission and distribution planning, and organized markets
  - Acquire all energy efficiency resources that represent the best combination of cost and risk (or set aggressive but achievable goals through energy efficiency resource standards)
  - Provide adequate program funding to achieve targets
  - Fully value energy efficiency by including all relevant benefits in the applied cost test, such as avoided costs associated with line losses, avoided costs for transmission and distribution systems, and reduced fossil fuel use and water consumption
- Adopt regulatory and ratemaking mechanisms that align utility and consumer interests[33]
  - Use alternative regulation (e.g., decoupling), shareholder incentives or both
  - Move away from average rates to deployment of inclining block or time-varying rates
- Engage consumers – enable, motivate and educate
  - Provide information, evaluation tools, and targeted advice coupled with incentives
  - Use multiple channels to get and keep customers' attention
- Include verified savings from behavior-based programs as qualifying measures for meeting energy efficiency goals

Policies Specific to Smart Grid Deployments

- Require smart grid transition plans and updates
  - Explain how the plan meets the state's energy efficiency and other goals, estimate costs and benefits, forecast phased deployments and establish an evaluation plan
- Specify minimum technology functional requirements, staging utility cost recovery with availability of these services
- Adopt interoperability[34] standards
- Address information access, privacy and security
  - Give consumers easy access to their own interval usage data in a helpful format
  - Allow third parties authorized by the customer to receive the data for customized energy efficiency products and services
  - Ensure data security
- Incorporate interval meter data in EM&V plans and requirements
- Integrate rate design with smart grid technologies and applications to optimize consumer behavior and system operations

The Smart Grid and Distributed Generation

The U.S. electric power system was designed to produce electricity at large power plants in remote locations, send it over high-voltage transmission lines, and deliver it on lower-voltage utility distribution systems to passive end-use customers. Increasingly, electricity is produced by smaller, cleaner distributed generation units at or near customer sites and connected to the utility distribution system.

The traditional one-way power flow – from power plants to customers – is turning into a two-way street. Customers are becoming active partners in meeting energy and environmental goals through clean distributed generation, peak load response and energy efficiency. Smart grid's intelligent sensors, two-way communications and advanced controls can facilitate this partnership.

Many forms of distributed generation are growing in their use and potential impact on distribution systems. Costs are continuing to decline for solar photovoltaic (PV) and other small-scale renewable energy systems. Federal, state and local governments are encouraging these systems through grants, tax credits, net metering, PURPA[35] policies, set-asides in Renewable Portfolio Standards (RPS), feed-in tariffs and other programs. Some states also provide incentives for combined heat and power (CHP) facilities.[36] As penetration levels of distributed generation increase, concerns about the stability and operation of the electricity system could create barriers to further development. The evolution of distribution systems to smart grids is expected to reduce many of these barriers and help reach clean energy goals at a faster pace.

Initiatives underway are demonstrating how smart grids can support distributed generation to provide safe, clean and reliable power.[37] But not all potential benefits of the smart grid are unequivocally proven. And benefits vs. costs for smart grid components must be considered, as well as costs for related, conventional distribution system upgrades. For example, transformers may need to be replaced with larger units to accommodate higher levels of distributed generation. In addition, utility protection schemes will need to be modified to realize the advantages of smart grids.

Figure 4. *Potential smart grid benefits for distributed generation in the future, compared to operations today*

Distributed Generation (DG) as Smart Grid Evolves

Today

- Low penetration of DG
- Little or no communications between DG and the grid
- Detailed system impact studies needed for many applications
- DG meets IEEE Standard 1547
- Microgrid demonstrations

Mid-Term

- Increased penetration of DG
- Some interaction between DG and the grid – to respond to price signals, for example
- Interconnection standards and rules are updated
- More microgrids develop

Long-Term

- High penetration of DG
- DG can be monitored, controlled and dispatched by utility
- Easier interconnection
- DG rides-through some grid disturbances
- DG provides local voltage regulation and other ancillary services
- Microgrids are commonplace

Potential Benefits of the Smart Grid for Distributed Generation

The smart grid will enable additional benefits of distributed generation and energy storage (distributed resources) for owners, utilities and system operators, including:

- **Better handling of two-way electrical flows –** Distributed generators "export" power to the utility system when generation output exceeds any on-site load demand. That makes it more difficult for the utility to provide voltage regulation and protective functions. Smart grid's monitoring and communication functions will make these tasks easier for utilities.

- **Easier deployment –** With real-time information provided by the smart grid, the utility system operator will have detailed reports on the current conditions of individual feeders and loads. That should allow for simpler interconnection studies – or no study at all if certain screens are passed – for some applications. Increasingly, distributed generators may apply for power export if costs and complexity of interconnection associated with power export are reduced.

- **Higher penetration levels –** With real-time knowledge of conditions on feeders, and communication between the utility system and distributed resources and loads, some utility operating practices could be modified to facilitate higher concentrations of distributed generation.

- **Dynamic integration of variable energy generation –** Smart grids will remotely monitor and report generation from distributed resources so automated systems and system operators can dispatch other resources to meet net loads.

- **Reduced distributed generation downtime –** New inverter designs integrated with smart grids will allow distributed generation to detect operational problems on the utility system, such as faults, and continue operating during some of these grid disturbances.

- **Maintaining power to local "microgrids" during utility system outages –** Smart grids could facilitate the formation of intentional islands of distributed resources and loads that disconnect automatically when the local utility system is down and automatically resynchronize to the system when conditions return to normal. Distributed resources within the microgrid continue to serve customer loads in the island.

- **Valuing distributed generation output by time of day –** Advanced metering infrastructure – a fundamental part of the smart grid – enables time-varying rate designs for retail customers that better support solar PV systems, which generate power primarily during on-peak hours[38] when it is typically more valuable.

- **Providing ancillary services –** Smart grid's built-in communications infrastructure will enable the system operator to manage distributed resources to provide reactive power, voltage support and other ancillary services under some circumstances. The system operator would need to have operational control over distributed resources in order to provide these services.

Some of these benefits are described in more detail below.

Allowing Inverter-Based Systems to Stay On-Line

With smart grid communications, utility system operators could more readily control inverter-based distributed resources to optimize utility operations by providing the following services:

- Variable voltage output for local voltage regulation
- Variable reactive power support
- Variable ramp rate
- Ride-through of voltage disturbances

Absent smart grids, inverter-based systems could provide a limited set of these functions at a reduced level.[39]

Most utilities today do not allow distributed resources to continue to provide power to the utility system during

How Distributed Resources Interact With the Utility System

The interaction of distributed resources with the utility distribution system is influenced by the type of power conversion device used:

- **Inverter-based systems**, such as solar PV and small wind turbines, use power electronics to convert electricity from direct current (DC) or non-synchronous alternating current (AC) to AC power synchronized with the utility system. They can provide reactive power and, by varying the output between real and reactive power,[40] provide voltage regulation as well. Most inverter-based systems have software-based protective relaying[41] and coordination and communication functions. That gives them two advantages over other systems: 1) they are easier to interconnect with the utility system and 2) they provide more functionality, potentially for both the distributed resource owner and the utility system.
- **Synchronous generators** can operate independently or in parallel with the utility system. They can produce reactive power and regulate voltage. They need equipment to synchronize with the utility system and protective equipment to isolate from the system during faults.[42]
- **Induction generators** receive their excitation[43] from the utility system and cannot operate independently; the utility system governs the frequency and voltage produced by the generator. Most induction generators absorb reactive power and cannot control voltage or power factor.[44] The reactive power requirements of induction generators can adversely affect the utility system.

Generators that use biogas from landfills, farms and wastewater treatment plants generally use synchronous or induction generators. CHP and waste energy recovery facilities also typically use one of these two conversion devices, although most microturbines use inverters. Distributed energy storage technologies such as advanced batteries and electric vehicle-to-grid systems use inverter-based designs. On-site diesel or natural gas-fired distributed generators typically use synchronous or induction designs.

minor voltage and frequency disturbances. As a result, the widely accepted Institute of Electrical and Electronics Engineers (IEEE) Standard 1547 requires that during abnormal voltage and frequency conditions on the utility system, the distributed resource will not energize the utility system. Thus, distributed resources are not allowed to support the operation of distribution systems.

Most inverters cannot differentiate between a utility outage, when the generator must disconnect from the utility system, and a minor disturbance, where remaining on-line would help stabilize the system. New inverter designs and the smart grid's sensors, communication and control systems could allow distributed resources to remain connected to the utility system during some types of abnormal conditions. Close cooperation among utility owners, inverter designers and smart grid developers is required to achieve successful development and integration of new inverters with utility facilities and operations. Work is underway to develop standard protocols.

Smart grids plus new inverter technology for distributed resources could help address problems on distribution feeders, such as outages and periods of instability. And utilities could control inverter-based systems to supply reactive power and regulate voltage in a more cost-effective manner than installing traditional utility-owned equipment.

Simplifying Interconnection Studies

Smart grids should make it easier to interconnect distributed generation to utility systems by simplifying studies required prior to commissioning the generator, saving time and money.

Utility impact studies investigate the potential adverse effects on operation, safety and reliability of interconnecting a proposed distributed resource to the utility system, absent modifications to the system. After that, the utility conducts a facilities study to identify equipment and operational changes that address the negative impacts identified.

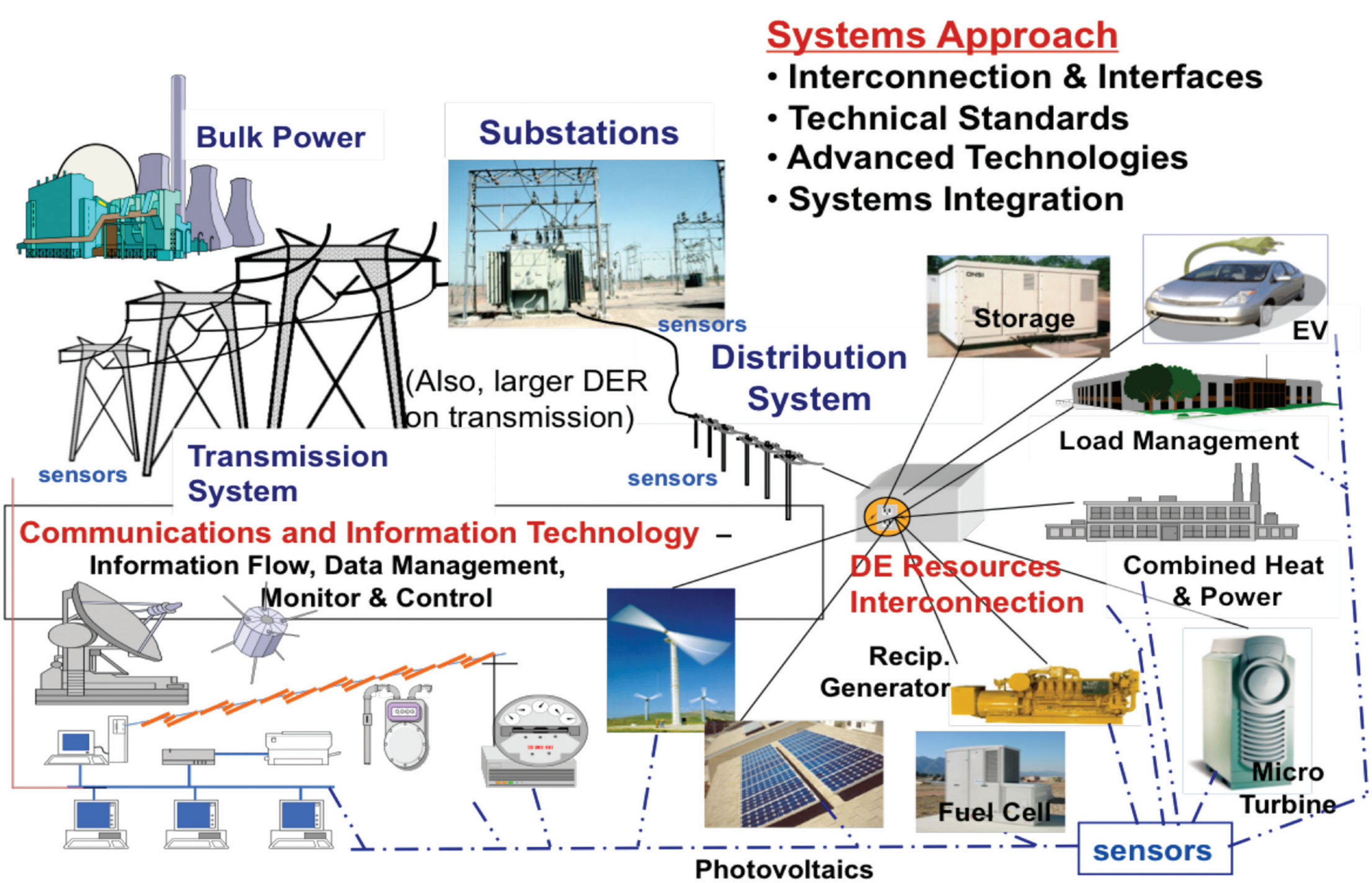
In some cases, a smart grid would not make any difference in this process. For example, a large distributed resource on a feeder circuit would likely still require impact and facilities studies and additional utility equipment to accommodate the generator. In other cases, the historical and real-time information on feeder operation that smart grids can provide could reduce the need and scope of an impact study. And because smart grids could allow utilities to control distributed resources on a feeder, including their voltage, reactive power and ramp rate, some of the potential grid problems distributed resources can cause today could be alleviated.

Smart grids also could reduce interconnection cost and complexity for distributed generators that will export power to the utility system. Currently, in many cases modifications to a utility's protective scheme may be required when a distributed generation unit applies to export power to the grid. The generation owner typically bears the cost of these modifications. The smart grid may alleviate some of these costs by applying adaptive protection systems that can better accommodate power flows from distributed generators, without requiring extensive modifications.

The Federal Energy Regulatory Commission (FERC) and many states have adopted technical standards and procedures that simplify the process of interconnecting distributed generation. FERC and nearly all these states provide an expedited and less expensive interconnection process – including no impact study in some cases – if the application passes a set of "screens" that include criteria such as:

- The size of each distributed generation unit must not exceed 2 megawatts (MW).
- The aggregated distributed generation on a line section must not exceed 15 percent of the line's annual peak load.
- The aggregated distributed generation on the distribution circuit must not contribute more than 10 percent to the circuit's maximum fault current at the point on the primary line nearest the point of common coupling.

Figure 5. *Distributed energy resources (DER) and the smart grid* [45]



- The aggregated distributed generation on the distribution circuit must not cause any fault currents exceeding 87.5 percent of the short circuit-interrupting capability.

Smart grid capabilities could go further by allowing some of these screens to be relaxed. The additional information, communication and remote monitoring infrastructure will give the utility the operating characteristics of individual feeder circuits, allowing for higher penetration of distributed generation without performing detailed impact studies for some installations. That will lower costs and speed deployment.

Enabling Microgrids and Premium Power Parks

Microgrids include parts of the utility grid, multiple distributed generation units and multiple loads connected by circuits. The generators are distributed within a campus or among multiple buildings. The generating system can detect grid stability events that trigger disconnection from the utility system, quickly creating an electrical "island" that continues providing power to loads within. Microgrids need to be carefully planned and implemented. Microgrid loads need to be managed and, in some cases, loads need to be reduced when the microgrid is disconnected from the utility grid.

There are several types of microgrids, including the following:

- **Type 1 microgrids** are designed for continuous operation in parallel with the grid. Distributed generators feed the campus' own distribution system, generating some or all of the power required. When a fault is detected on the utility grid, the microgrid disconnects and operates independently. The transition to microgrid supply is typically accomplished through the use of paralleling switchgear. In some cases, load will need to be reduced.

- **"Premium power parks" (Critical Type 2 microgrids)** provide critical backup power systems that serve multiple facilities. These microgrids include energy storage systems and static transfer switches that can seamlessly switch over part or all load during utility outages. Storage carries the system through until emergency generators start up.[46]

- **Non-critical Type 2 microgrids** are for campuses that can tolerate a short outage. These microgrids manually or semi-automatically disconnect from the grid, start their emergency generators and continue operation. In some cases, Type 2 microgrids can be used for peak shaving or short-term baseload operation, but additional equipment is required.

Using smart grid capability, microgrids could be much larger in scale than those existing today and could be part of the utility-owned distribution system. IEEE Standard 1547.4, currently under development, will provide alternative approaches and good practices for the design, operation and integration of microgrid systems with the utility grid.

Supporting Variable Generation

Some distributed generation technologies use renewable energy resources, such as solar and wind, with power production levels dependent on forces of nature. At high penetration, these variable energy resources can create instability on the grid the way it is operated today as their power output decreases or increases within the hour. Within-hour scheduling and other operational changes under consideration to support variable generation would complement smart grid applications and new inverter designs. For example:

- Distributed generation could be controlled like utility-scale power plants to provide automatic generation control – instantaneous regulation of electricity to maintain frequency on the system within tight parameters.
- Smart grid's sensors and communications could help grid operators predict short-term generation impacts of winds and clouds as they move from one region to the next.
- Grid operators could control energy storage systems to meet peak demands when generation levels from distributed energy resources are low.
- Distributed generators could gain access to new markets for energy, capacity and ancillary services. The additional revenue streams could help overcome economic barriers to greater investment in distributed renewable resources.

Smart Grids and Combined Heat and Power

Combined heat and power (CHP) systems are typically run near their full capacity or are limited by on-site (host) thermal demands – for manufacturing processes, for example. However, some CHP systems can provide additional capacity for brief periods. Others may increase output beyond what is needed on site and reject excess thermal output, similar to conventional power plants. Some applications use condensing turbines that are operated only when thermal demands drop. These could be used more frequently to serve periods of high loads on the utility system. In addition, new CHP units could be sized larger for power export to the grid, if it became economically favorable to do so. CHP also can enable customers to participate in demand response programs and capacity markets.

Following are two examples of CHP systems providing grid support in a smart grid concept:

- At Princeton University, facility planners incorporated a number of smart grid attributes when they changed production strategies involving the campus CHP system as well as steam and electric chillers to take advantage of high-priced electric periods. The system increases electricity production and reduces electric loads during periods of high grid demand and reduces electricity production during low-demand periods.[47]

- The City of Stamford, Connecticut, is developing an Energy Improvement District that embodies many smart grid concepts, such as reducing demand on the grid and deploying advanced generation in a microgrid structure. The district will deploy CHP, distributed generation using renewable resources, and advanced controls that will allow it to operate independently or in conjunction with the utility grid, connecting or disconnecting itself seamlessly as needed without disrupting service.[48]

Standards and Rules Will Need to Change

Technical standards and interconnection procedures for distributed resources must build upon the current IEEE Standard 1547, which was designed for low penetration of distributed generation and does not address impacts on the grid or grid operations. Standards will need to be updated to address higher penetration levels and improved utility operations made possible by smart grids, and to take advantage of smart grid-enabled capabilities such as riding through some types of utility disturbances, regulating voltage, reclosing and automating utility reliability schemes.

IEEE P2030[49] provides guidelines to define interoperability[50] between the smart grid and end-use applications and loads. The draft guide addresses terminology, characteristics, functional performance and evaluation criteria, and application of engineering principles for interoperability. It also discusses other best practices for the smart grid.

IEEE P1547.8[51] recommends practices to expand strategies for interconnecting distributed generation with electric power systems and will include guidance on generators beyond 10 MW, extending its reach beyond the stated scope of IEEE Standard 1547. The new standard also identifies innovative designs, processes and operational procedures that may be used to realize extended use beyond IEEE Standard 1547 requirements.

The Electric Power Research Institute, the U.S. Department of Energy, Sandia National Laboratories and the Solar Electric Power Association have launched a collaborative to develop common methods for communication between inverter-based distributed resources and other grid components.

Federal and state regulators can modify their interconnection rules to incorporate these new standards as they become available.

Smart Distributed Generation Policies for Smart Grids

Smart grids are expected to enable higher levels of distributed generation. But supportive policies are needed to achieve this goal. The following table highlights potential smart grid benefits for distributed generation and policies needed to take advantage of these capabilities.

Distributed Generation Policies to Take Advantage of Smart Grids

Smart Capabilities	Smart Policies
Enable higher penetration levels of clean distributed generation	Provide incentives for clean distributed resources, adopt best practices for net metering, require advanced metering infrastructure to support net metering,[52] and enable excess power sales through RPS set-asides, state PURPA policies or feed-in tariffs
Accelerate deployment and allow interconnected distributed generators to operate during utility outages	Update interconnection standards and utility operations to reflect smart grid capabilities and provide incentives to distributed resources to provide new services for the utility system
Dynamically integrate distributed wind and solar resources	Improve utility planning for renewable resources and support mechanisms to reduce integration costs – for example, intra-hour scheduling
Optimize voltage and reactive power on distribution systems	Remove barriers to utility investments that improve distribution system efficiency – for example, through decoupling, where retail customer rates for recovering fixed utility costs are adjusted periodically to keep utility revenue at the allowed level
Increase demand response to allow loads to follow variable renewable energy resources	Offer customers dynamic pricing options and incentives for other types of demand response programs; provide customers with easy access to useful energy consumption data, evaluation tools and targeted advice; foster innovation in the marketplace for controls that automate the customer's response; and incorporate demand response in integrated resource planning
Provide physical connection and communication with wholesale and retail markets	Provide access to new markets and revenue streams for customer-owned distributed generation
Provide timely information on each distributed generator, including type and availability; allow tracking for RPS compliance and reduce tracking costs	Better incorporate distributed generation into energy forecasting and RPS compliance
Easier and timely interconnection of distributed generation for exporting power to the grid	Provide transparent cost information and fair cost allocation for interconnection; streamline and update interconnection study requirements for exporting power to the grid

Conclusion

The smart grid offers the potential to increase energy savings and improve customer control of bills through information and automation. In addition, widespread availability of interval meter data and two-way communication between the utility and the meter should significantly improve EM&V for energy efficiency programs.

To support these outcomes, state regulatory utility commissions can specify functional requirements for smart grid technology and applications to support energy efficiency programs, ensure consumers and authorized third-party service providers have secure access to energy usage information, require utilities to develop and periodically update a smart grid transition plan that explains how all the components phased in over time will fit together and address state goals for energy efficiency, and adopt rate designs that encourage energy-efficient consumer behavior.[53]

Clean, distributed generation also can flourish with the support of smart grid's advanced monitoring, communication and controls. To take advantage of this opportunity, states can adopt best practices in areas such as distributed generator interconnection,[54] net metering, accounting for distributed generation in resource planning and distribution system planning, distributed generation procurement, and removing utility disincentives to non-utility-owned generation.

With an understanding of the potential benefits of smart grids for energy efficiency and clean distributed generation, state regulators can use their broad authority to put in place a regulatory framework to tap smart grid's full potential.

Endnotes

1 Thanks to our reviewers: Thomas Basso, National Renewable Energy Laboratory (distributed generation), Chris King, eMeter, and Ogi Kavazovic, OPOWER (information feedback); Hannah Friedman, PECI (building diagnostics); Steven Schiller, Schiller Consulting, and Miriam Goldberg, KEMA, Inc. (EM&V).

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4 Going even further, device monitors can show instantaneous usage for individual appliances.

5 Inclining block rates, also called inverted block or tiered rates, charge a higher rate per kilowatt-hour at higher levels of energy usage (and a lower rate at lower usage levels). Pacific Gas & Electric, for example, allows customers to sign up for "tier alerts" to help them avoid more expensive energy use.

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15 Communication with Ogi Kavazovic, OPOWER, February 2011.

16 Buildings should be "re-commissioned" periodically to address changes in functional requirements over time that reduce energy efficiency and compromise efficient operations.

17 Evan Mills, Lawrence Berkeley National Laboratory, *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions*, prepared for California Energy Commission Public Interest Energy Research Program, July 2009, http://cx.lbl.gov/2009-assessment.html.

18 More typical applications may see lower savings, in the range of 8 percent to 10 percent (communication with Hannah Friedman).

19 Data over longer time horizons were not available.

20 A tonne, or metric ton, is equal to 1,000 kilograms (roughly 2,205 pounds).

21 Millions of metric tons.

22 EPRI, *The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid,* Technical Update, June 2008, www.epri.com.

23 Hannah Friedman, PECI Inc., *Wiring the Smart Grid for Energy Savings: Integrating Buildings to Maximize Investment,* 2009, http://www.peci.org/documents/white-paper/smartgrid_whitepaper_031010.pdf.

24 Hannah Friedman, PECI, and Priya Sreedharan, EPA, "Wiring the Smart Grid for Energy Savings: Mechanisms and Policy Considerations," 2010 ACEEE Summer Study on Energy Efficiency in Buildings, August 2010.

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26 Interval meter data also could be used to help identify opportunities for customers to offer demand response resources to the utility or market.

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31 See Lisa Schwartz, "Smart Policies Before Smart Grids: How State Regulators Can Steer Investments Toward Customer-Side Solutions," 2010 ACEEE Summer Study on Energy Efficiency in Buildings, http://raponline.org/docs/RAP_Schwartz_SmartGrid_ACEEE_paper_2010_08_23.pdf. Also see Miriam Goldberg, KEMA Inc., "Improved Analysis of Savings Potential and Achievement via Smart Grid/Meters," presentation for EPA-DOE Webinar, Dec. 2, 2010, http://www.emvwebinar.org/Meeting%20Materials/2010-2011/index.html.

32 Goldberg.

33 See National Action Plan for Energy Efficiency, *Aligning Utility Incentives With Investment in Energy Efficiency,* November 2007, at http://www.epa.gov/cleanenergy/energyprograms/napee/resources/guides.html; additional resources from the Regulatory Assistance Project at http://raponline.org/.

34 The ability of systems or products to work with other systems or products without special effort by the customer.

35 The Public Utility Regulatory Policies Act of 1978 requires utilities to buy all energy and capacity made available by Qualifying Facilities (QFs) – renewable resources up to 80 MW and energy-efficient cogeneration of any size – at avoided cost rates. States have broad discretion over implementation. While a 2005 amendment provides for termination of a utility's obligation to enter into new contracts with QFs if the Federal Energy Regulatory Commission makes specific findings about their access to competitive markets, termination is typically limited to organized markets and QFs larger than 20 MW.

36 CHP systems sequentially produce both electric power and thermal energy. Related, waste energy recovery recycles heat from industrial processes to generate electricity. Some states offer incentives for efficient CHP systems.

37 Initiatives include projects funded by the U.S. Department of Energy and demonstration projects by the Electric Power Research Institute.

38 Sundays are off-peak all-day in U.S. energy markets. Thus, some power from solar PV systems will be produced during off-peak hours.

39 Induction and synchronous generators cannot provide these functions as easily – or at all.

40 Reactive power establishes and sustains the electric and magnetic fields of alternating-current equipment and directly influences electric system voltage. Reactive power must be supplied to most types of magnetic (non-resistive) equipment and to compensate for the reactive losses in distribution and transmission systems. Reactive power is provided by generators, synchronous condensers, and electrostatic equipment such as capacitors. Real power is the component of electric power that performs work, typically measured in kilowatts or megawatts.

41 Protective functions address issues such as under/over current, under/over voltage and ground fault detection. Most inverter units provide automatic, built-in overload and short-circuit protection.

42 A fault is an abnormal connection causing current to flow from one conductor to ground or to another conductor. A fault may be corrected automatically or may lead to a voltage sag or power outage.

43 A generator consists of a rotor spinning in a magnetic field. The magnetic field may be produced by permanent magnets or by field coils, where a current must flow to generate the field. "Excitation" is the process of generating a magnetic field by means of an electric current.

44 Power factor is the ratio of real power flow to a piece of equipment to the apparent power flow. The difference is determined by the reactive power required by certain types of loads, such as motors and transformers. The power factor is less than one if there is a reactive power requirement.

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49 *IEEE P2030 Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System, and End-Use Applications and Loads.* This guide is among the smart grid interoperability standards under development by the National Institute of Standards and Technology, for consideration by FERC. For more information on the standards, see Smart Grid Interoperability Panel Standards Update, Nov. 5, 2010, http://www.smartgridlistserv.org/presentations/naruc/index.html (or http://vimeo.com/16831719 for a simplified version that works on all computer operating systems).

50 Interoperability is the ability of systems or products to work with other systems or products without special effort by the customer.

51 IEEE P1547.8, Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547.

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54 A new RAP publication on best practices for interconnection of distributed generators will be available soon at www.raponline.org.

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