Growth and Decarbonization: How Smart Utilities Contribute

by Xavier Moreau and Edward Jarvis

Executive summary

Although there is still some debate on the causal relationship between energy and GDP, energy clearly has the power to propel communities out of poverty, improve economic conditions, and provide a better quality of life for billions of people. This paper demonstrates how electric utilities can leverage technological advancements and reach beyond traditional operational boundaries to address the increasing worldwide demand for energy and reduced CO_2 emissions.

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Introduction

The world maintains a seemingly insatiable appetite for energy. In fact, global energy consumption is expected to double by the year 2050[1]. Yet at the same time, scientists warn that greenhouse gas emissions, responsible for driving climate change, must be reduced by half over that same period[2]. The ultimate challenge is for the global community to learn how to drive economic growth while reducing overall energy consumption. Until recently, increased economic growth was accompanied by increased energy consumption. How can society break through this barrier? The answer is increased efficiency. This implies the ability to produce more work while consuming fewer resources.

One key to successfully addressing this challenge is the development of new technologies that leverage data and information to simplify processes within the energy production, delivery, and consumption cycle. The energy waste and consumption problem is not impossible to solve. With over 42% of CO_2 emissions coming from the power sector[3], electric utilities worldwide, along with governments, concerned citizens and global providers of energy-related technologies, have an important role to play.

This paper reviews current progress toward balancing the growth, energy consumption, and sustainability needs of our planet. Important energy trends and topics such as renewables, smart grids, prosumers, regulation, and individual energy consumption are discussed. The role of new technologies is also reviewed.

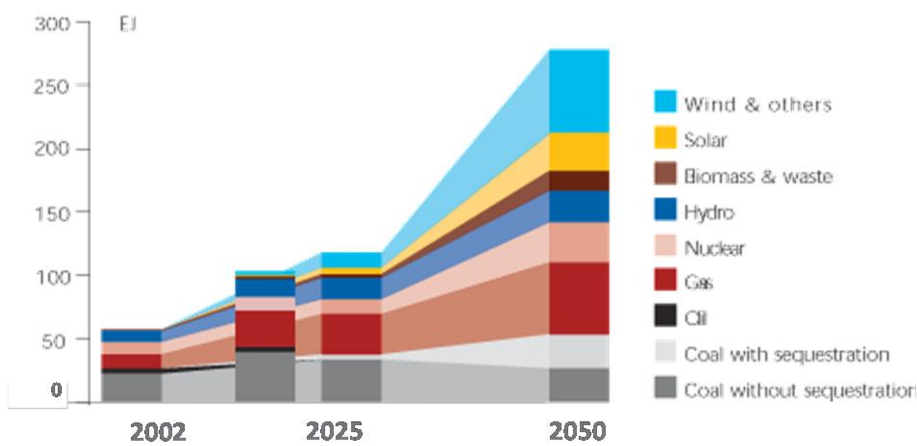

Figure 1
Projected energy generation through 2050 (courtesy of World Business Council for Sustainable Energy)

Powering an always-on world

Our devices are getting smarter. Our vehicles are getting smarter. Computing and advanced communicating capabilities are becoming more embedded into the fabric of the home and workplace. So it’s only natural that the energy that powers our world should follow suit.

These changes can be recognized in subtle ways. The monthly utility bill, for example, is one logical place to begin the conversation. Once today’s homeowner receives his bill, he may see a bar graph that displays his year-to-date energy usage. He may notice that his consumption either went up, down, or stayed the same. However, he generally has no idea why the bill went up or down—and worse, he has no clear idea of what steps to take to better control his energy consumption in the future. The homeowner might speculate that a harsh winter caused the bill to go up, or that his old refrigerator is inefficient, or that his teenage son has been leaving lights on in the basement. But he has no data to justify any actions.

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[1] International Energy Agency, *World Energy Outlook*, 2007

[2] Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report* 2007

3 International Energy Agency, World Energy Outlook, 2012, OECD/IEA, Paris, 2012

Enter smart energy. The smart energy consumer today is empowered by data. Through detailed information and controls provided by the utility, he now understands why the energy bill is going up. He also knows how to control his bill to the extent that he might even receive rebates from the utility for using less energy or for using energy at specific times during the day when there is low demand.

The workplace is also ripe for smart energy management practices to take hold. In electro-intensive industries, such as steel making, stakeholders could view patterns in energy usage and isolate areas where efficiencies could be applied. The same holds true for corporate office buildings, where the individuals who consume the most energy never see the bill. Smarter energy management practices place knowledge into the hands of these individuals so they can actively participate in curbing costly usage.

Those who do somehow manage to get a copy of the building's utility bill are often at a loss to understand it and how they can best cut their energy costs. However, once these business consumers learn the language of utility bills, they quickly realize that powerful financial incentives exist for consuming energy in flexible patterns.

From the control room of a power utility to the electrical outlets in the homes of consumers, technology is making our use of energy smarter and more efficient. A multitude of existing operating equipment is being enhanced through the integration of sensors, information technology (IT), and communications subsystems, making power generation, delivery, and consumption more adaptive, dynamic, and energy efficient.

Figure 2
Workplace technology is quickly evolving to become more powerful and more affordable

By enhancing operational technologies with a layer of intelligence, connected solutions are energizing workspaces and living spaces. The efficiency of businesses and homes is improving while power consumption is radically reduced.

Utilities must adopt a system-thinking approach because a change to one variable in the system might have serious consequences elsewhere. The traditional priority of local system optimization must give way to the higher priority of system-wide optimization. The new network of widely connected intelligence is of critical importance to the modern utility's viability.

For utilities, the transition to the new energy evolution begins with learning how to leverage the exponential growth of data. Almost 90% of all the data in the world have been generated over the past two years alone. People and machines are gaining easier access to more and more intelligence. Energy consumers expect solutions that connect to that intelligence and help them make sense (and good use) of this ocean of data.

Business and operating model transformation

A revolution is taking place within the walls of utility corporate boardrooms. The centrally managed, fossil-fuel dominated approach of our recent past is being challenged as new energy technologies emerge, demanding prosumers and regulatory agencies push for a greater proportion of decentralized power sources. That same drive for change is being reflected in the way power networks are designed and upgraded, for example to enable two-way power flows. However, as in all industries, changes have a financial cost.

This is especially true in Europe, where the popularity of feed-in tariffs has placed an additional burden on operations. At first these tariffs rewarded the generation of electricity from renewable energy sources (such as solar panels and wind turbines). However, over time, these tariffs have penalized the centralized production of electricity, discouraged investment in gas-burning generation, and, some argue, have somewhat given a respite to the burning of dirty coal. As a result, the lack of economical coordination of renewable integration with centralized generation has led to the undesired effect of sparing coal plants while squeezing gas plants out of business in some countries in Europe.

"The Smart Grid is not a start-from-scratch process. It requires a reconfiguration — a reimagining — of the existing network."

In other parts of the world, legacy equipment and aging infrastructure are also delaying the move away from a centralized power structure. In a perfect world, outdated equipment, substations, and transmission networks could simply be ripped out and replaced to accommodate modernized infrastructure capable of controlling wind, solar, and other renewables. But the Smart Grid is not a start-from-scratch process. It requires a reconfiguration and reimagining of existing networks, which in most cases work reliably and in which capital investment has not been fully depreciated. This experience could be compared to changing the (not-so-old) tires on a car without stopping. For this reason, investors and stakeholders are realizing that much greater cost control gains can be had within the operations realm by improving the efficiency of the grid and lowering the operating expenses of utility business processes, despite the existing legacy infrastructure.

The intelligent use of data and the rapid expansion of connected technologies are an important key to reducing operational expenditures in a decentralized Smart Grid era. This great expansion in the access to and affordability of technology is sometimes referred to as the Internet of Things (IoT). This has emerged as a critical tool for managing increased grid complexity, automating electricity distribution, and enhancing customer satisfaction.

These capabilities will become critical as residences, businesses, data centers, hospitals, transportation, and advanced manufacturing facilities grow more dependent on reliable power of high quality. Automated systems and greater visibility of both the network and the consumer will empower grid operators to reconfigure the grid and adjust both generation and consumption faster than ever before while limiting manual intervention. Utilities will also be able to use data to help customers better understand their energy consumption patterns and identify areas where they can save money on their bills.

Forward-looking utilities should view these changes as an opportunity for rebirth and a chance to rebuild trust with their customers. However, transition is never easy. Skills gaps and technology adoption within an existing grid and entrenched culture require that utilities manage this transition carefully with the support of trusted partners. In addition to achieving operational excellence through a managed transition, utilities will seek new revenues by offering new services.

Utilities will need to focus on their customers' new requirements for services and technologies to support safe and reliable decentralized power sources on the grid, lower demand, and manage new energy assets (storage, microgrids) to retain large industrial customers and promote the electrification of other industrial sectors, such as transportation.

Regulation and politics

While providing an essential service, the utility industry has had its fair share of controversy, sometimes mislabeled as a 'dirty industry' managed by 'fat cats' by outspoken environmentalists, some consumer associations, and the media. Fossil fuels are synonymous with air pollution and global warming; and nuclear power evokes the notorious environmental disasters of Three Mile Island, Chernobyl, and Fukushima. In the same vein, customers in many parts of the world are seeing higher energy bills and fewer choices for purchasing energy. They are also unsure of whether that power is generated from cleaner energy sources. Regulators at the local, national, and international levels are attempting to address these issues and are catering to the concerns of their constituents through policy reform, penalties, and an increased hand in the market—all of which impact the way utilities operate.

For example, in 2005, a US-based utility was required to pay a $530,070 fine for exceeding the permitted sulfur dioxide emission limit. In another incident, as a result of a series of storm-related outages in 2011, several utilities were fined $22 million for a less-than-stellar performance in getting the lights back on after storms passed through. And just recently, the British regulator Ofgem required new rules to compel the six largest UK utilities to make billing information easier for customers to interpret.

Figure 3
Emissions are now under constant scrutiny from regulatory authorities and concerned citizens

From national governments to the local level, regulators are demanding that utilities comply with ever-changing requirements regarding reliability, renewable portfolio size, and time-of-use or critical-peak pricing. On the other hand, governments are also providing grants, acts, and initiatives to encourage the research and development of clean and efficient energy, while also fielding calls for energy independence and the need to secure domestic infrastructure from foreign security threats. In fact, multiple national and international agencies are now applying pressure for utilities to comply with standards around the growing challenge of cyber security.

Utilities have to take into account both regulatory risks and consumer trends when they make important decisions that pertain to site location, technology interoperability, regulatory approval, and financing. Otherwise they risk making costly missteps that will result in stranded assets as the energy market evolves.

"One of the most important side benefits of Smart Grid evolution is how government and industry groups are collaborating to develop industry standards."

While there is a competitive rush to launch Smart Grid initiatives, care must be taken in mapping each utility's individual journey. The regulatory and operational landscape of migration to a smarter utility is highly complex.

Fortunately, utilities are not alone in the struggle to modernize their grids. One of the most important side benefits of Smart Grid evolution is how government and industry groups are collaborating to develop industry standards. Interoperability standards play a key role in supporting grid modernization, giving utilities more choice and enabling smooth integration of equipment that can operate with the legacy grid.

The work of the National Institute of Standards and Technology (NIST), industry associations such as the International Electrotechnical Commission (IEC), the Electric Power Research Institute, the Smart Grid Interoperability Panel, and trade groups like the GridWise Alliance and GridWise Architecture Council all contribute to establishing definitions and specifications for connecting networks and devices. These groups have enabled a rapid movement forward in the development of the Smart Grid.

Processes are already in place to close the gaps in current standards. Most grid-focused interoperability projects that adhere to current standards can now move forward with a higher degree of confidence.

Asset management and operation

Once upon a time, utilities could guarantee the safety and reliability of the grid with limited asset information coming from substations, remote terminal units, relays, transformers, meters, and lines. The operation of the grid relied on an overdesigned system that allowed a large margin of error and strong redundancy.

But this came with a price, that today's limits on investment (capex) and growing pressure on operating cost (opex) has forced utilities to embrace more efficient IT- related approaches to better manage their assets. The result is that the industry is undergoing a substantial shift in asset management and operation—a shift to maintain these assets, and possibly prolong their lifespans, as the grid infrastructure faces increased disruption.

The ultimate goal is to maximize investments by operating physical assets as closely as possible to their physical limits, thanks to streamlined operations and dynamically fine-tuned settings. That requires information. But utilities often struggle to gather data and process it into information involving the wide variety of assets that support operations with engineering, accounting, maintenance and other business processes.

With asset management functionality commonly spread across several software applications, grid owners must manage a tedious process across multiple databases. This often leads to a decoupling from operation and planning and prevents strategic planners from capturing a holistic view and anticipating grid weaknesses.

Utilities also often try to adapt asset management systems initially intended for power stations (which are centralized) to grid management (which is geographically distributed). Within grid infrastructures, network topology changes frequently and vast amounts of asset information are added each day through meters, home automation devices, sensors, and other hardware.

From an operations management perspective, asset data must be integrated into systems and applications in a way that allows operators to deal with a single version of the truth. So how can utilities conquer these challenges? Part of the answer lies with smart tools, harvested data, and connected technologies—all of which are components within the Internet of Things (IoT).

But first let's look back. For many years, traditional IT managed information for humans. Think customer database, billing systems, call-center software, and workforce management tools. OT (operations technology), on the other hand, managed data for machines: Metering data, transformer and switch status, relay positions, and so on, all of which were coordinated in Supervisory Control and Data Acquisition (SCADA) software systems. IT and OT existed as distinct domains managed by different corporate resources, usually the IT Department on one side and the Operations Department on the other side. But this paradigm is undergoing a radical change as OT systems are now connected through Internet Protocol (IP) addresses to IT-based networks.

Convergence of IT and OT, the Internet of Things, and the proliferation of big data are essential to asset management in the digital age. This free-flowing yet structured management of data also lets utilities control energy flows with a real-time understanding of the state of their assets. This can help operators optimize their systems based on the actual capacities of their assets.

Figure 4
Intelligent devices in the outer network are providing operators with a new wealth of data to help drive efficiency

Consider advanced metering and customer relationship management (CRM). These platforms can deliver a new level of clarity to customer service representatives, who can use local data to help customers solve common problems. For example, should a customer call to report an outage, the customer service representative can ping the meter to check its status and nearby consumers' meters to confirm the kind of outage the caller is experiencing. Then he can troubleshoot. This two-way communication between the utility and the customer can also open the door to energy incentive programs, where customers are rewarded for shifting energy use to off-peak times, thus relieving the grid and its assets.

Maintenance practices are another area where IoT offers large cost-saving opportunities. While routine maintenance programs are a major part of the asset management process, they represent a huge time drain for grid managers. As updated hardware and software applications are integrated into the network, equipment performance in the field is measured remotely via a central control panel. Substation maintenance can then be adapted to the real operating conditions the equipment inside must endure.

These connected technologies also allow new predictive models, where monitoring allows weakened assets to be discovered and proactively replaced, saving hundreds of hours and tens of thousands of euros or dollars per year by avoiding failures or unplanned (thus expensive) emergency servicing.

It's clear that as the smart grid era advances, the integration of IT and OT, and the Internet of Things, will be critical to the development of efficient asset management programs.

Integration of renewable energy

One of the biggest challenges on the roadmap to the smart utility is the responsibility (and obligation, in many cases) to combine established power sources with renewable energy in order to lower the impact on the environment and secure additional energy for the future. This transformation is partly due to pressure from private and public third-party groups and government regulators. The former (e.g., conservation advocacy groups, consumers, and shareholders) view renewable energy as a means to a cleaner environment, and many are already installing energy saving systems in their own homes and buildings. The latter are interested in encouraging the use of environmentally friendly energy sources, while at the same time improving efficiencies to control cost through improved supply and demand.

However, as new sources of local production come online in the wake of these pressures, utilities are struggling to find effective ways to combine traditional power sources with renewables without compromising the way networks are managed.

Figure 5
Renewable energy is coming down in cost and its integration within traditional grid networks is ongoing

While most renewable energy sources are diffuse and scattered, energy demand is often intense, and load centers are more and more concentrated. Connecting them must be achieved with the use of accurate and highly networked sensors, actuators, and management systems. Poorly or partially instrumented networks downstream of secondary substations need to be upgraded. Network architecture designed when generation was centralized and at a time when there was little (if any) network communication and intelligence must be reinvented to accommodate dispersed production that's not necessarily close to new load centers. And the variable nature of most renewable generation, as well as the emergence of significant new loads like electric vehicles, can complicate load balances on lines, leading to voltage instability and even failures.

Nevertheless, as great as these obstacles are, they are not insurmountable. New technologies, including weather forecasting software and remote management, are redefining the impact of renewable energy sources. A grid operator can now evaluate the performance of an individual wind turbine and make adjustments from a control center thousands of kilometers away. Improved forecasting, operations management, and streamlined maintenance plans are also yielding a greater return on investment.

The price of renewables is also coming down. The cost of wind or solar power has never been more competitive with fossil fuels than it is now, both in terms of its physical equipment and the actual market rate. Hydro has proven to be a highly predictable energy resource and a worthy replacement for backup diesel power plants due to its immense storage capabilities. Without question, renewable energy integration will bring more advantages than drawbacks for utilities that move toward the Smart Grid. And while the roadmap may seem unclear, experienced intermediaries such as Schneider Electric and the right technology mix can make the transition much easier.

Demand management and the role of prosumers

The energy industry's business model has remained fundamentally unaltered over the last century. It's a model that emerged out of the Edison age, where the utility was responsible for generating power and selling it to the customer. Usage meters were read and billing was based on simple bulk consumption.

Imagine that energy customers are able to proactively choose which energy source they want to consume. Or that green, renewable sources are supplying most or all of the energy needed for every purpose: lighting, heating, processes, and transportation. Consider an electricity supply that is completely reliable. As part of smart grid modernizations, new programs are being launched or expanded that encourage energy customers to adjust their consumption in response to pricing signals, penalties, or curtailment requests.

With this potential flexibility, customers' controllable energy-consuming loads and any onsite energy generation capabilities are now considered important distributed energy resources (DERs), which are critical to helping balance the grid.

"Imagine a world where a typical business or home is savvy about its energy consumption, or is actually in a position to generate revenue through the energy it does NOT consume."

At the same time, many customers have begun taking more direct control of the cost, reliability, and green mix of their energy supply. City districts, educational institutions, military bases, hospitals, commercial buildings, factories, and even residential homes are becoming proactive energy consumers, or 'prosumers', that consume energy, produce energy, and control it. They are enabled on this journey by a convergence of new, widely available technologies that can automate and fully monetize their energy resources' flexibility.

It is estimated that 3 million energy users in Europe are already generating at least some of their own power. By adding an energy management or storage system, customers are maximizing self-consumption of this energy and gaining more control over when to use it.

These prosumers are taking energy consumption and management into their own hands though a variety of activities, including purchasing smart products that turn on or off in response to changes in energy pricing and/or peak loads. For utilities, the prosumer revolution represents an opportunity to go behind the meter in order to manage assets and bring an extra layer of flexibility to modern-day grid constraints. The term "demand management" is used to describe one of the major change drivers in the industry today. "Demand" refers to everything behind the meter or any load pulling electricity from the network and "management" applies to the level of control over that load. Load here refers to net apparent load, which is subtracting any local generation or storage from the total consumption.

The goal of Demand Management is to provide utilities with an alternative to building more power plants to meet capacity needs. By having the ability to modify energy usage on the demand side through smarter technology, education, and energy-efficiency improvements, utilities can both save money and accommodate the demands of the prosumer movement. For example, a grid operator could switch off a piece of equipment at a factory for a few minutes in order to thwart the need for bringing a marginal peaking unit online. In another example, a homeowner could remotely configure a load of laundry to run during off-peak hours, based on real-time data from the utility. The trick is to do this automatically and not by only using day-ahead or hour-ahead signals for voluntary load reductions.

On the demand side, this approach can save customers money through load flexibility, either for curtailment or for consumption stimulation. On the supply side, the utility can improve the reliability, efficiency, and sustainability of modern-day energy without necessarily relying on a decrease in total energy consumption. Also, Demand Management, by matching controllable demand closer to variable generation, will enable a higher integration of variable renewable generation in the mix.

Industry knowledge and skill development

Another significant challenge is the age profile of operators and supervisors in utilities environments, creating a skills and knowledge gap. The utility industry has lost some of its shine and seems less attractive to young, highly skilled graduates as compared to high-tech and web industries, for example, making the sourcing of new skills through hiring a challenge. In addition, the increased complexity of typical utility processes, the higher speed of process changes and system upgrades, the increased frequency of new product introductions, and the amalgamation of various operations is driving demand for effective education and training.

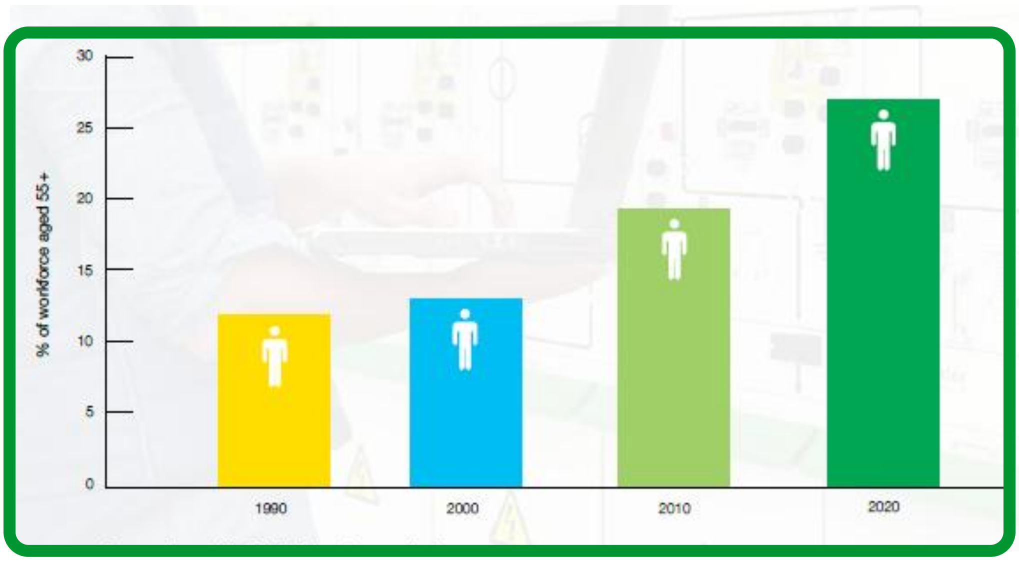

Figure 6
As an increasing number of utility industry employees approach retirement, the training of new employees becomes more critical

* Source: Toossi, M, Monthly Lab. Rev. January 2012

To that end, only solution providers with expertise in utilities and grid technology can be training collaborators for utilities and provide the right consulting and expertise. They are an important resource because they can easily transfer knowledge and enhance the utility's skill base while speaking the same language and understanding the key issues of safety, reliability, and flexibility.

The importance of education and training is increasing as we exit the baby-boomer era with many experienced staff nearing retirement. Most mature industries (e.g., mining, oil & gas, primary metal, fabricated metal, textile, chemicals, plastics, machinery, utilities) that rely on process control solutions are the same industries that undertook most of their hiring decades ago. Baby boomers therefore make up a larger share of their workforce than that of emerging industries. As experience is lost, training needs increase.

A cultural shift is taking place, one that moves from viewing training as a necessary chore to an environment where training is regarded as a must-have opportunity for productivity and profit gains. The system and technology provider's knowledge base is leveraged and considered a 'skills base' of understanding the technology and how it works so that utilities can focus on their core areas of expertise: delivering clean, stable power to consumers.

All utility employees, through training, will develop the ability to think from an 'integrated solutions' perspective so that overall utility performance can be maximized.

Conclusion

We've reached a pivotal moment. The global need for reliable power has never been greater, and the way we deliver that energy has never been more fragile. It's the power utilities' mission to balance that equation. They must now engage on a path toward decarbonization and make decisions with impacts that will be felt throughout this century and the next. The choices made now can bring the world smarter, more collaborative and common-sense energy.

We now know where the new energy journey is taking us: Through changing business models and renewable energy, through Smart Grids and prosumers, right down to homeowners' electric bills. And though that journey is beset by challenges and opportunities, utility industry stakeholders must assume a leadership role and act.

Energy has the power to propel communities out of poverty, improve economic conditions, and provide a better quality of life for billions of people. It's a basic human need. Today's utilities therefore bear a huge responsibility. New smart utilities will deliver reliable, safe, affordable, and clean energy in non-traditional ways. Consumers and prosumers demand more choices in how they purchase and use energy. Utilities that succeed in this transition will operate an efficient smart grid, de-carbonize their power generation, and provide new services to their customers.

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