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# Introduction to Smart Grid Technology

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Exploring the imperative of revitalizing  
America's electric infrastructure.

# THE SMART GRID: AN INTRODUCTION.

How a smarter grid works as an enabling engine  
for our economy, our environment and our future.



PREPARED FOR THE U.S. DEPARTMENT OF ENERGY BY LITOS STRATEGIC COMMUNICATION UNDER CONTRACT No. DE-AC26-04NT41817, SUBTASK 560.01.04



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# PREFACE

## IT IS A COLOSSAL TASK. BUT IT IS A TASK THAT MUST BE DONE.

The Department of Energy has been charged with orchestrating the wholesale modernization of our nation's electrical grid.

*While it is running.*

*Full-tilt.*

Heading this effort is the Office of Electricity Delivery and Energy Reliability. In concert with its cutting edge research and energy policy programs, the office's newly formed, multi-agency Smart Grid Task Force is responsible for coordinating standards development, guiding research and development projects, and reconciling the agendas of a wide range of stakeholders.

Equally critical to the success of this effort is the education of all interested members of the public as to the nature, challenges and opportunities surrounding the Smart Grid and its implementation.

It is to this mission that *The Smart Grid: An Introduction* is dedicated.



### **From the Department of Energy**

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The *Smart Grid Introduction* is intended primarily to acquaint non-technical yet interested readers about:

- the existence of, and benefits accruing from, a smarter electrical grid
- what the application of such intelligence means for our country
- how DOE is involved in helping to accelerate its implementation.



# TABLE OF CONTENTS

TOC

KNOWLEDGE BROUGHT  
TO POWER



		
	<b>ONE INTRODUCTION:</b> We Don't Have Much Time. <i>Toward an orderly transition to a smarter grid...</i>	2
	<b>TWO EDISON VS. GRAHAM BELL:</b> The Case for Revitalization. <i>Presenting the argument in a timely fashion requires a trip "back to the future..."</i>	4
	<b>THREE THE GRID AS IT STANDS:</b> What's at Risk? <i>The many hazards associated with operating the 20th century grid in the 21st century. The lights may be on, but consider what we're missing...</i>	6
	<b>FOUR THE SMART GRID:</b> What It Is. What It Isn't. <i>Why it's important to know the difference...</i>	10
	<b>FIVE COMPARE AND CONTRAST:</b> A Grid Where Everything is Possible. <i>For an invigorating vision of our energy future, look forward...</i>	16
	<b>SIX FIRST THINGS FIRST:</b> Teasing Out the Complexities. <i>How various constituencies – i.e., utilities and regulators – are working toward fundamental realignment to make a smarter grid get here faster...</i>	24
	<b>SEVEN HOW THINGS WORK:</b> Creating the Platform for the Smart Grid. <i>Making it possible for consumers to participate...</i>	28
	<b>EIGHT PROGRESS NOW!:</b> A Look at Current Smart Grid Efforts and How They're Succeeding. <i>From West Virginia to California to Hawaii, a smarter grid is taking shape...</i>	32
	<b>NINE EDISON UNBOUND:</b> What's <i>Your</i> Stake in All This? <i>Benefits for everyone...</i>	36
	<b>RESOURCES AND GLOSSARY</b> <i>Coming to terms with the Smart Grid...</i>	40

# TOPICS



# WE DON'T HAVE MUCH TIME.

*Our nation's electric power infrastructure that has served us so well for so long – also known as “the grid” – is rapidly running up against its limitations. Our lights may be on, but systemically, the risks associated with relying on an often overtaxed grid grow in size, scale and complexity every day. From national challenges like power system security to those global in nature such as climate change, our near-term agenda is formidable. Some might even say history-making.*

## **Fortunately, we have a way forward.**

There is growing agreement among federal and state policymakers, business leaders, and other key stakeholders, around the idea that a Smart Grid is not only needed but well within reach. Think of the Smart Grid as the internet brought to our electric system.



## **A tale of two timelines**

There are in fact two grids to keep in mind as our future rapidly becomes the present.

**The first** – we'll call it “a smarter grid” – offers valuable technologies that can be deployed within the very near future or are already deployed today.

**The second** – the Smart Grid of our title – represents the longer-term promise of a grid remarkable in its intelligence and impressive in its scope, although it is universally considered to be a decade or more from realization. Yet given how a single “killer application” – e-mail – incited broad, deep and immediate acceptance of the internet, who is to say that a similar killer app in this space won't substantially accelerate that timetable?

In the short term, a smarter grid will function more efficiently, enabling it to deliver the level of service we've come to expect more affordably in an era of rising costs, while also offering considerable societal benefits – such as less impact on our environment.

Longer term, expect the Smart Grid to spur the kind of transformation that the internet has already brought to the way we live, work, play and learn.





***A smarter grid applies technologies, tools and techniques available now to bring knowledge to power – knowledge capable of making the grid work far more efficiently...***

- Ensuring its reliability to degrees never before possible.
- Maintaining its affordability.
- Reinforcing our global competitiveness.
- Fully accommodating renewable and traditional energy sources.
- Potentially reducing our carbon footprint.
- Introducing advancements and efficiencies yet to be envisioned.

Transforming our nation's grid has been compared in significance with building the interstate highway system or the development of the internet. These efforts, rightly regarded as revolutionary, were preceded by countless evolutionary steps. Envisioned in the 1950s, the Eisenhower Highway System was not completed until the early 1980s. Similarly, the internet's lineage can be directly traced to the Advanced Research Projects Agency Network (ARPANET) of the U.S. Department of Defense in the 60s and 70s, long before its appearance as a society-changing technology in the 80s and 90s.

In much the same way, full implementation of the Smart Grid will evolve over time. However, countless positive steps are being taken today, organizations energized and achievements realized toward reaching that goal. You will learn about some of them here.

The purpose of this book is to give readers – in plain language – a fix on the current position of the Smart Grid and its adoption. You will learn what the Smart Grid is – and what it is not. You will get a feel for the issues surrounding it, the challenges ahead, the countless opportunities it presents and the benefits we all stand to gain.

Remember life before e-mail?

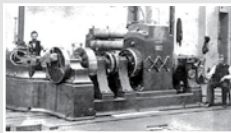
With every passing day, fewer and fewer people do.

With the appropriate application of ingenious ideas, advanced technology, entrepreneurial energy and political will, there will also come a time when you won't remember life before the Smart Grid.

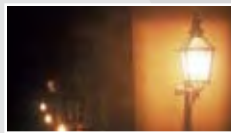




Menlo Park Workshop



Pearl Street Station



First Street Lamps



Metering



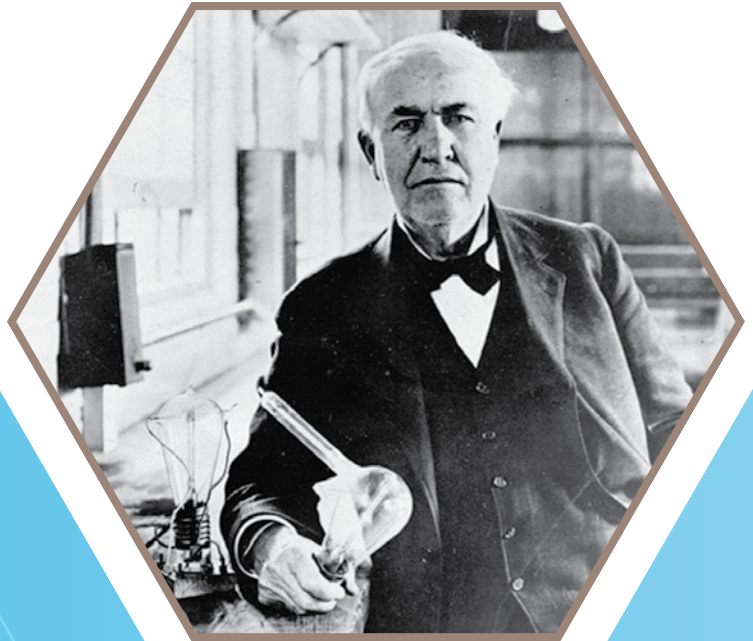
Compact Fluorescent Light

### ADVANCEMENTS IN ELECTRICITY

*There is a popular comparison that underscores the pace of change – or lack thereof – regarding our nation's grid.*

#### SECTION TWO:

## EDISON VS. GRAHAM BELL: THE CASE FOR REVITALIZATION.



#### **The story goes like this:**

If Alexander Graham Bell were somehow transported to the 21st century, he would not begin to recognize the components of modern telephony – cell phones, texting, cell towers, PDAs, etc. – while Thomas Edison, one of the grid's key early architects, would be totally familiar with the grid.

### ADVANCEMENTS IN TELECOMMUNICATIONS



First Telephone



Operator Switching Stations



Rotary Dialing



North American Numbering System



Rotary Dial with Ringer and Handset

While this thought experiment speaks volumes about appearances, it is far from the whole story. Edison would be quite familiar with the grid's basic infrastructure and perhaps even an electromechanical connection or two, but he would be just as dazzled as Graham Bell with the technology behind the scenes.

Our century-old power grid is the largest interconnected machine on Earth, so massively complex and inextricably linked to human involvement and endeavor that it has alternately (and appropriately) been called an ecosystem. It consists of more than 9,200 electric generating units with more than 1,000,000 megawatts of generating capacity connected to more than 300,000 miles of transmission lines.

Given that the growth of the nation's global economic leadership over the past century has in many ways mirrored the trajectory of the grid's development, this choice is not surprising.

In many ways, the present grid works exceptionally well for what it was designed to do – for example, keeping costs down. Because electricity has to be used the moment it is generated, the grid represents the ultimate in just-in-time product delivery. Everything must work almost perfectly at all times – and does. Whenever an outage occurs in, say, Florida, there may well be repercussions up the Atlantic seaboard; however, due to the system's robustness and resultant reliability, very few outside the industry ever know about it.

#### POWER SYSTEM FACT

*Today's electricity system is 99.97 percent reliable, yet still allows for power outages and interruptions that cost Americans at least \$150 billion each year — about \$500 for every man, woman and child.*

In celebrating the beginning of the 21st century, the National Academy of Engineering set about identifying the single most important engineering achievement of the 20th century. The Academy compiled an estimable list of twenty accomplishments which have affected virtually everyone in the developed world. The internet took thirteenth place on this list, and "highways" eleventh. Sitting at the top of the list was electrification as made possible by the grid, "the most significant engineering achievement of the 20th Century."

Engineered and operated by dedicated professionals over decades, the grid remains our national engine. It continues to offer us among the highest levels of reliability in the world for electric power. Its importance to our economy, our national security, and to the lives of the hundreds of millions it serves cannot be overstated.

But we – all of us – have taken this marvelous machine for granted for far too long. As a result, our overburdened grid has begun to fail us more frequently and presents us with substantial risks.



Long Distance Calling



First Telecom Satellite



Touch-Tone Telephones



Cellular Communications



Phone Over the Internet

Since 1982, growth in peak demand for electricity – driven by population growth, bigger houses, bigger TVs, more air conditioners and more computers – has exceeded transmission growth by almost 25% every year. Yet spending on research and development – the first step toward innovation and renewal – is among the lowest of all industries.



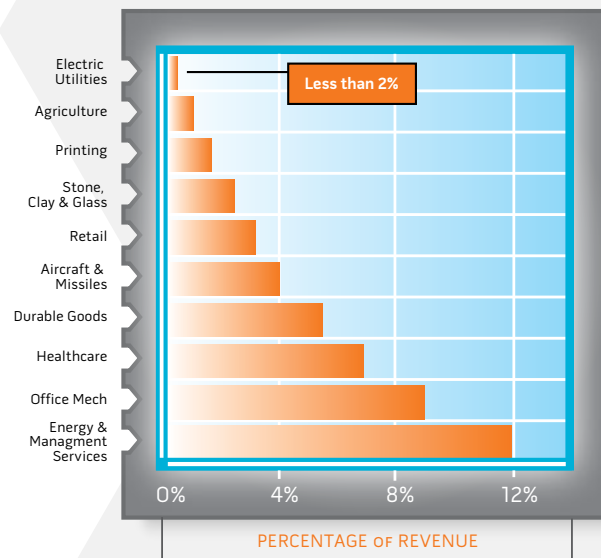
SECTION THREE:

# THE GRID AS IT STANDS: WHAT'S AT RISK?

Even as demand has skyrocketed, there has been chronic underinvestment in getting energy where it needs to go through transmission and distribution, further limiting grid efficiency and reliability. While hundreds of thousands of high-voltage transmission lines course throughout the United States, only 668 additional miles of interstate transmission have been built since 2000. As a result, system constraints worsen at a time when outages and power quality issues are estimated to cost American business more than \$100 billion on average each year.

***In short, the grid is struggling to keep up.***

R&D as a % of Revenue



Based on 20<sup>TH</sup> century design requirements and having matured in an era when expanding the grid was the only option and visibility within the system was limited, the grid has historically had a single mission, i.e., keeping the lights on. As for other modern concerns...

*Energy efficiency?* A marginal consideration at best when energy was – as the saying went – “too cheap to meter.”

*Environmental impacts?* Simply not a primary concern when the existing grid was designed.

*Customer choice?* What was that?

**RELIABILITY:** There have been five massive blackouts over the past 40 years, three of which have occurred in the past nine years. More blackouts and brownouts are occurring due to the slow response times of mechanical switches, a lack of automated analytics, and “poor visibility” – a “lack of situational awareness” on the part of grid operators. This issue of blackouts has far broader implications than simply waiting for the lights to come on. Imagine plant production stopped, perishable food spoiling, traffic lights dark, and credit card transactions rendered inoperable. Such are the effects of even a short regional blackout.



#### **DID YOU KNOW**

In many areas of the United States, the only way a utility knows there's an outage is when a customer calls to report it.

Today, the irony is profound: In a society where technology reigns supreme, America is relying on a centrally planned and controlled infrastructure created largely before the age of microprocessors that limits our flexibility and puts us at risk on several critical fronts:

**EFFICIENCY:** If the grid were just 5% more efficient, the energy savings would equate to permanently eliminating the fuel and greenhouse gas emissions from 53 million cars. Consider this, too: If every American household replaced just one incandescent bulb (Edison's pride and joy) with a compact fluorescent bulb, the country would conserve enough energy to light 3 million homes and save more than \$600 million annually. Clearly, there are terrific opportunities for improvement.

#### **POWER SYSTEM FACT**

41% more outages affected 50,000 or more consumers in the second half of the 1990s than in the first half of the decade. The “average” outage affected 15 percent more consumers from 1996 to 2000 than from 1991 to 1995 (409,854 versus 355,204).



**NATIONAL ECONOMY:** The numbers are staggering and speak for themselves:

- A rolling blackout across Silicon Valley totaled \$75 million in losses.
- In 2000, the one-hour outage that hit the Chicago Board of Trade resulted in \$20 trillion in trades delayed.
- Sun Microsystems estimates that a blackout costs the company \$1 million every minute.
- The Northeast blackout of 2003 resulted in a \$6 billion economic loss to the region.



**RESOURCE RECOVERY**

Dollars that remain in the economy rather than "paying the freight" for system inefficiency are dollars that society can put to good use for job creation, healthcare, and homeland security.

Compounding the problem is an economy relentlessly grown digital. In the 1980s, electrical load from sensitive electronic equipment, such as chips (computerized systems, appliances and equipment) and automated manufacturing was limited. In the 1990s, chip share grew to roughly 10%. Today, load from chip technologies and automated manufacturing has risen to 40%, and the load is expected to increase to more than 60% by 2015.



**AFFORDABILITY:** As rate caps come off in state after state, the cost of electricity has doubled or more in real terms. Less visible but just as harmful, the costs associated with an underperforming grid are borne by every citizen, yet these hundreds of billions of dollars are buried in the economy and largely unreported. Rising fuel costs – made more acute by utilities' expiring long-term coal contracts – are certain to raise their visibility.

◆ Decrease in Transmission Investment (Dollar Amount In Billions)



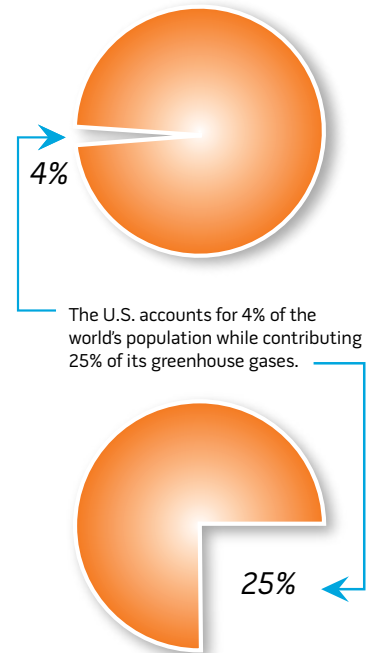
**SECURITY:** When the blackout of 2003 occurred – the largest in US history – those citizens not startled by being stuck in darkened, suffocating elevators turned their thoughts toward terrorism. And not without cause. The grid's centralized structure leaves us open to attack. In fact, the interdependencies of various grid components can bring about a domino effect – a cascading series of failures that could bring our nation's banking, communications, traffic, and security systems among others to a complete standstill.

**ENVIRONMENT/CLIMATE CHANGE:** From food safety to personal health, a compromised environment threatens us all. The United States accounts for only 4% of the world's population and produces 25% of its greenhouse gases. Half of our country's electricity is still produced by burning coal, a rich domestic resource but a major contributor to global warming. If we are to reduce our carbon footprint and stake a claim to global environmental leadership, clean, renewable sources of energy like solar, wind and geothermal must be integrated into the nation's grid. However, without appropriate enabling technologies linking them to the grid, their potential will not be fully realized.

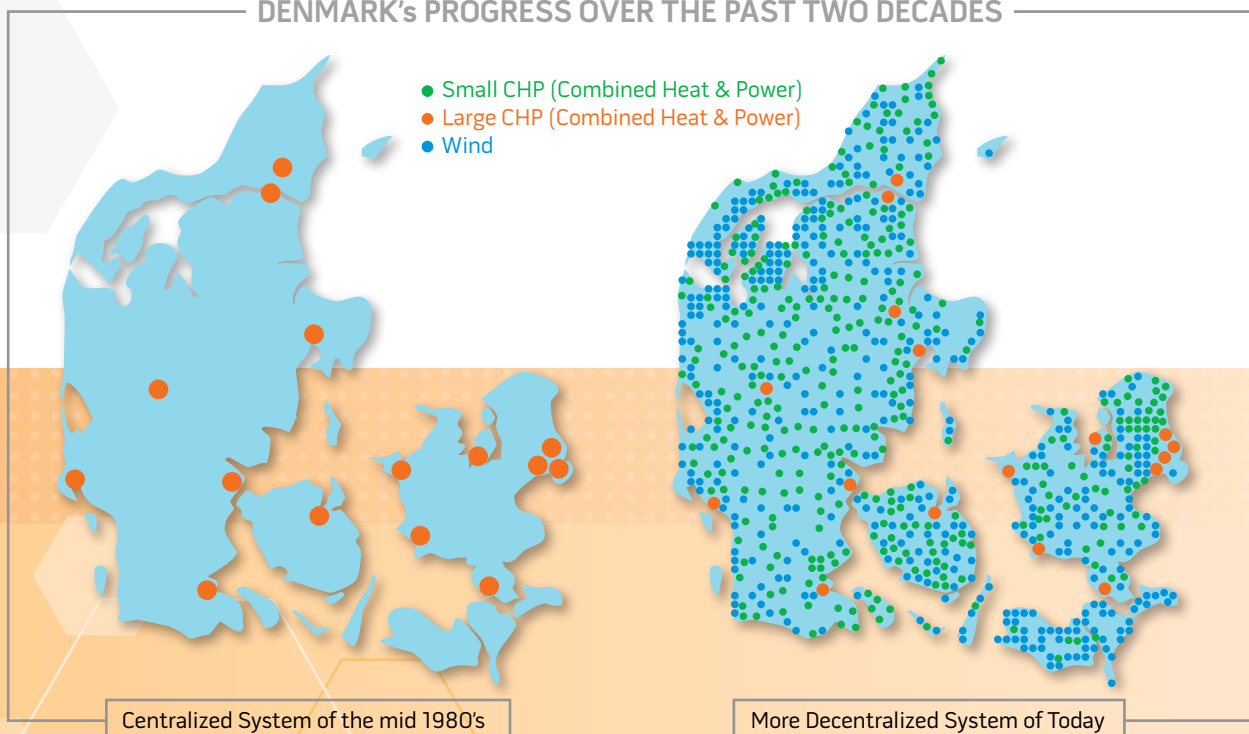
**GLOBAL COMPETITIVENESS:** Germany is leading the world in the development and implementation of photo-voltaic solar power. Japan has similarly moved to the forefront of distribution automation through its use of advanced battery-storage technology. The European Union has an even more aggressive "Smart Grids" agenda, a major component of which has buildings functioning as power plants. Generally, however, these countries don't have a "legacy system" on the order of the grid to consider or grapple with.

**How will a smarter grid address these risks and others? Read on.**

U.S. Share of World Population Compared to its Production of Greenhouse Gases



**DENMARK'S PROGRESS OVER THE PAST TWO DECADES**



*Prepare for an electric system that is cleaner and more efficient, reliable, resilient and responsive – a smarter grid.*

SECTION FOUR :

## THE SMART GRID: WHAT IT IS. WHAT IT ISN'T.



### **PART 1: WHAT IT IS.**

The electric industry is poised to make the transformation from a centralized, producer-controlled network to one that is less centralized and more consumer-interactive. The move to a smarter grid promises to change the industry's entire business model and its relationship with all stakeholders, involving and affecting utilities, regulators, energy service providers, technology and automation vendors and all consumers of electric power.

A smarter grid makes this transformation possible by bringing the philosophies, concepts and technologies that enabled the internet to the utility and the electric grid. More importantly, it enables the industry's best ideas for grid modernization to achieve their full potential.

**Concepts in action.**

It may surprise you to know that many of these ideas are already in operation. Yet it is only when they are empowered by means of the two-way digital communication and plug-and-play capabilities that exemplify a smarter grid that genuine breakthroughs begin to multiply.

Because this interaction occurs largely "in the background," with minimal human intervention, there's a dramatic savings on energy that would otherwise be consumed.

This type of program has been tried in the past, but without Smart Grid tools such as enabling technologies, interoperability based on standards, and low-cost communication and electronics, it possessed none of the potential that it does today.

**Visualization technology.** Consider grid visualization and the tools associated with it. Already used for real-time load monitoring and load-growth planning at the utility level, such tools generally lack the ability to integrate information from a variety of sources or display different views to different users. The result: Limited

**POWER SYSTEM FACT**

**AVERAGE COST FOR 1 HOUR OF POWER INTERRUPTION**

INDUSTRY	AMOUNT
Cellular communications	\$41,000
Telephone ticket sales	\$72,000
Airline reservation system	\$90,000
Semiconductor manufacturer	\$2,000,000
Credit card operation	\$2,580,000
Brokerage operation	\$6,480,000

**Advanced Metering Infrastructure (AMI)** is an approach to integrating consumers based upon the development of open standards. It provides consumers with the ability to use electricity more efficiently and provides utilities with the ability to detect problems on their systems and operate them more efficiently.

AMI enables consumer-friendly efficiency concepts like "Prices to Devices" to work like this: Assuming that energy is priced on what it costs in near real-time – a Smart Grid imperative – price signals are relayed to "smart" home controllers or end-consumer devices like thermostats, washer/dryers and refrigerators – the home's major energy-users. The devices, in turn, process the information based on consumers' learned wishes and power accordingly. The house or office responds to the occupants, rather than vice-versa.

situational awareness. This condition will grow even more acute as customer-focused efficiency and demand-response programs increase, requiring significantly more data as well as the ability to understand and act on that data.

Next-generation visualization is on its way. Of particular note is VERDE, a project in development for DOE at the Oak Ridge National Laboratory. VERDE (Visualizing Energy Resources Dynamically on Earth) will provide wide-area grid awareness, integrating real-time sensor data, weather information and grid modeling with geographical information. Potentially, it will be able to explore the state of the grid at the national level and switch within seconds to explore specific details at the street level. It will provide rapid information about blackouts and power quality as well as insights into system operation for utilities. With a platform built on Google Earth, it can also take advantage of content generated by Google Earth's user community.





### **Phasor Measurement Units.**

Popularly referred to as the power system's "health meter," Phasor Measurement Units (PMU) sample voltage and current many times a second at a given location, providing an "MRI" of the power system compared to the "X-Ray" quality available from earlier Supervisory Control and Data Acquisition (SCADA) technology. Offering wide-area situational awareness, phasors work to ease congestion and bottlenecks and mitigate – or even prevent – blackouts.

Typically, measurements are taken once every 2 or 4 seconds offering a steady state view into the power system behavior. Equipped with Smart Grid communications technologies, measurements taken are precisely time-synchronized and taken many times a second (i.e., 30 samples/second) offering dynamic visibility into the power system.

Adoption of the Smart Grid will enhance every facet of the electric delivery system, including generation, transmission, distribution and consumption. It will energize those utility initiatives that encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. It will increase the possibilities of distributed generation, bringing generation closer to those it serves (think: solar panels on your roof rather than some distant power station). The shorter the distance from generation to consumption, the more efficient, economical and "green" it may be. It will empower consumers to become active participants in their energy choices to a degree never before possible. And it will offer a two-way visibility and control of energy usage.

### **Just who's running the grid?**

Formed at the recommendation of the Federal Energy Regulatory Commission (FERC), an Independent System Operator (ISO) or Regional Transmission Organization (RTO) is a profit-neutral organization in charge of reconciling supply and demand as it coordinates, controls and monitors the operation of the power system. The ISO's control area can encompass one state or several.

The role of these organizations is significant in making the Smart Grid real. ISOs and RTOs will use the smart distribution system as another resource for managing a secure and most economic transmission system. "Lessons learned" from their experiences in building processes and technologies, etc., will be directly applicable to efforts in grid transformation, both short-term and long-term.



### **SMART DEFINITION: DISTRIBUTED GENERATION**

Distributed generation is the use of small-scale power generation technologies located close to the load being served, capable of lowering costs, improving reliability, reducing emissions and expanding energy options.



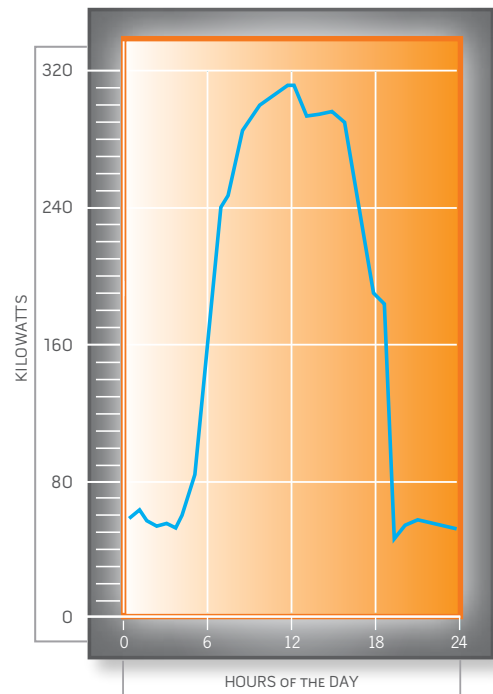
An automated, widely distributed energy delivery network, the Smart Grid will be characterized by a two-way flow of electricity and information and will be capable of monitoring everything from power plants to customer preferences to individual appliances. It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level.

***The problem with peak.***

While supply and demand is a bedrock concept in virtually all other industries, it is one with which the current grid struggles mightily because, as noted, electricity must be consumed the moment it's generated.

Without being able to ascertain demand precisely, at a given time, having the 'right' supply available to deal with every contingency is problematic at best. This is particularly true during episodes of peak demand, those times of greatest need for electricity during a particular period.

◆ Demand Profile



Imagine that it is a blisteringly hot summer afternoon. With countless commercial and residential air conditioners cycling up to maximum, demand for electricity is being driven substantially higher, to its "peak." Without a greater ability to anticipate, without knowing *precisely* when demand will peak or how high it will go, grid operators and utilities must bring generation assets called peaker plants online to ensure reliability and meet peak demand. Sometimes older and always difficult to site, peakers are expensive to operate – requiring fuel bought on the more volatile "spot" market. But old or not, additional peakers generate additional greenhouse gases, degrading the region's air quality. Compounding the inefficiency of this scenario is the fact that peaker plants are generation assets that typically sit idle for most of the year without generating revenue but must be paid for nevertheless.

In making real-time grid response a reality, a smarter grid makes it possible to reduce the high cost of meeting peak demand. It gives grid operators far greater visibility into the system at a finer "granularity," enabling them to control loads in a way that minimizes the need for traditional peak capacity. In addition to driving down costs, it may even eliminate the need to use existing peaker plants or build new ones – to save everyone money and give our planet a breather.



## **PART 2: WHAT THE SMART GRID ISN'T.**

People are often confused by the terms Smart Grid and smart meters. Are they not the same thing? Not exactly. Metering is just one of hundreds of possible applications that constitute the Smart Grid; a smart meter is a good example of an enabling technology that makes it possible to extract value from two-way communication in support of distributed technologies and consumer participation.



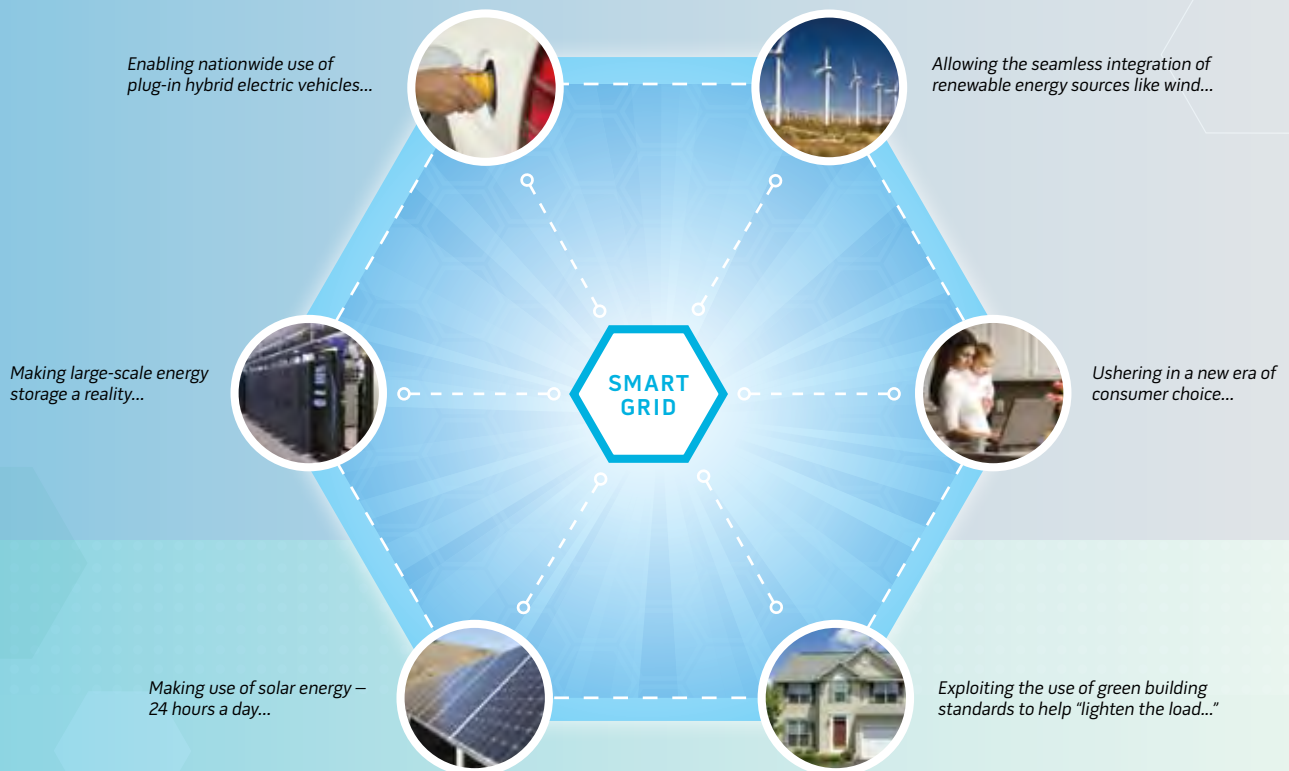
*As much as "smart technologies" can enhance this familiar device, it's not the same thing as the Smart Grid.*

As one industry expert explains it, there is no silver bullet when it comes to enabling technologies for a smarter grid; there is instead “silver buckshot,” an array of technological approaches that will make it work.

Further clarification: Devices such as wind turbines, plug-in hybrid electric vehicles and solar arrays are not part of the Smart Grid. Rather, the Smart Grid encompasses the technology that enables us to integrate, interface with and intelligently control these innovations and others.

The ultimate success of the Smart Grid depends on the effectiveness of these devices in attracting and motivating large numbers of consumers.

**ILLUSTRATING THE OPPORTUNITIES: THE SMART GRID AS ENABLING ENGINE.**



*The Smart Grid transforms the current grid to one that functions more cooperatively, responsively and organically.*

SECTION FIVE:

## COMPARE AND CONTRAST: A GRID WHERE EVERYTHING IS POSSIBLE.



### SMART GRID FACT

*Made possible by a smarter grid, DOE's Solar Energy Grid Integration Systems (SEGIS) is a suite of tools, techniques and technologies designed to achieve a high penetration of photovoltaic (PV) systems into homes and businesses.*

# IN TERMS OF OVERALL VISION, THE SMART GRID IS:

**Intelligent** – capable of sensing system overloads and rerouting power to prevent or minimize a potential outage; of working autonomously when conditions require resolution faster than humans can respond...and cooperatively in aligning the goals of utilities, consumers and regulators

**Efficient** – capable of meeting increased consumer demand without adding infrastructure

**Accommodating** – accepting energy from virtually any fuel source including solar and wind as easily and transparently as coal and natural gas; capable of integrating any and all better ideas and technologies – energy storage technologies, for example – as they are market-proven and ready to come online

**Motivating** – enabling real-time communication between the consumer and utility so consumers can tailor their energy consumption based on individual preferences, like price and/or environmental concerns

**Opportunistic** – creating new opportunities and markets by means of its ability to capitalize on plug-and-play innovation wherever and whenever appropriate

**Quality-focused** – capable of delivering the power quality necessary – free of sags, spikes, disturbances and interruptions – to power our increasingly digital economy and the data centers, computers and electronics necessary to make it run

**Resilient** – increasingly resistant to attack and natural disasters as it becomes more decentralized and reinforced with Smart Grid security protocols

**“Green”** – slowing the advance of global climate change and offering a genuine path toward significant environmental improvement

**Applied across various key constituencies, the benefits of creating a smarter grid are drawn in even sharper relief.**

## **The Smart Grid as it applies to utilities.**

Whether they're investor-owned, cooperatively owned or public, utilities are dedicated to providing for the public good – i.e., taking care of society's electricity needs – by operating, maintaining and building additional electric infrastructure. The costs associated with such tasks can run to billions of dollars annually and the challenges associated with them are enormous.

For a smarter grid to benefit society, it must reduce utilities' capital and/or operating expenses today – or reduce costs in the future. It is estimated that Smart Grid enhancements will ease congestion and increase utilization (of full capacity), sending 50% to 300% more electricity through existing energy corridors.

**The more efficient their systems, the less utilities need to spend.**

Given our nation's population growth and the exponential increase in the number of power-hungry digital components in our digital economy, additional infrastructure must be built – Smart or not. According to The Brattle Group, investment totaling approximately \$1.5 trillion will be required between 2010 and 2030 to pay for this infrastructure. The Smart Grid holds the potential to be the most affordable alternative to “building out” by building less, and saving more energy. It will clearly require investments that are not typical for utilities. But the overall benefits of such efforts will outweigh the costs, as some utilities are already discovering.



***One afternoon in early 2008, the wind stopped blowing in Texas.***

A leader in this renewable energy, the state experienced a sudden, unanticipated and dramatic drop in wind power – 1300 Mw in just three hours. An emergency demand response program was initiated in which large industrial and commercial users restored most of the lost generation within ten minutes, acting as a buffer for fluctuations in this intermittent resource. Smart Grid principles in action.

***The Smart Grid as it applies to consumers.***

For most consumers, energy has long been considered a passive purchase. After all, what choice have they been given? The typical electric bill is largely unintelligible to consumers and delivered days after the consumption actually occurs – giving consumers no visibility into decisions they could be making regarding their energy consumption.

However, it pays to look at electric bills closely if for no other reason than this; they also typically include a hefty “mortgage payment” to pay for the infrastructure needed to generate and deliver power to consumers.

A surprisingly substantial portion of your electric bill – between 33% – 50% – is currently assigned to funding our “infrastructure mortgage,” our current electric infrastructure. This item is non-negotiable because that infrastructure – power plants, transmission lines, and everything else that connects them – must be maintained to keep the grid running as reliably as it does. In fact, the transmission and distribution charge on the electric bill is specifically for infrastructure.

With demand estimated to double by 2050 – and more power plants, transmission lines, transformers and substations to be built – the costs of this “big iron” will also show up on your bill in one way or another. (The only difference this time is that global demand for the iron, steel, and concrete required to build this infrastructure will make these commodities far more costly; in fact, the cost of many raw materials and grid components has more than tripled since 2006.)

**POWER SYSTEM FACT**

*In the United States, the average generating station was built in the 1960s using even older technology. Today, the average age of a substation transformer is 42, two years more than their expected life span.*



**SMART DEFINITION: REAL-TIME PRICING** — These are energy prices that are set for a specific time period on an advance or forward basis and which may change according to price changes in the market. Prices paid for energy consumed during these periods are typically established and known to consumers a day ahead (“day-ahead pricing”) or an hour ahead (“hour-ahead pricing”) in advance of such consumption, allowing them to vary their demand and usage in response to such prices and manage their energy costs by shifting usage to a lower cost period, or reducing consumption overall.

**Now for the good news.** The Smart Grid connects consumers to the grid in a way that is beneficial to both, because it turns out there's a lot that average consumers can do to help the grid.

Simply by connecting to consumers – by means of the right price signals and smart appliances, for example – a smarter grid can reduce the need for some of that infrastructure while keeping electricity reliable and affordable. As noted, during episodes of peak demand, stress on the grid threatens its reliability and raises the probability of widespread blackouts.

By enabling consumers to automatically reduce demand for brief periods through new technologies and motivating mechanisms like real-time pricing, the grid remains reliable – and consumers are compensated for their help.

Enabling consumer participation also provides tangible results for utilities which are experiencing difficulty in siting new transmission lines and power plants. Ultimately, tapping the collaborative power of millions of consumers to shed load will put significant brakes on the need for new infrastructure at any cost. Instead, utilities will have time to build more cost-efficiencies into their siting and building plans.

**Consumers are more willing to be engaged.**

Consumers are advocating for choice in market after market, from telecom to entertainment. Already comfortable with the concept of time-differentiated service thanks to time-dependent cell phone rates and airline fares, it follows that they just might want insight and visibility into the energy choices they are making, too. Enabled by Smart Grid technology and dynamic pricing, consumers will have the opportunity to see what price they are paying for energy before they buy – a powerful motivator toward managing their energy costs by reducing electric use during peak periods.

Currently, recognition of the time-dependent cost of energy varies by region. In areas where costs are low and specialized rates to this point non-existent, there is little interest or economic incentive on the part of the consumer to modify usage or even think about energy having an hourly cost. In California, on a hot afternoon, consumers are well aware of the possibility of a blackout driven by peak demand and familiar with adjusting their energy usage accordingly.



**Efficiency is the way.**

10% of all generation assets and 25% of distribution infrastructure are required less than 400 hours per year, roughly 5% of the time. While Smart Grid approaches can't completely displace the need to build new infrastructure, they will enable new, more persistent forms of demand response that will succeed in deferring or avoiding some of it.



**The rewards of getting involved.**

Smart Grid consumer mantra: Ask not what the grid can do for you. Ask what you can do for the grid – and prepare to get paid for it.



*Given new awareness, understanding, tools and education made possible by a smarter grid, all consumers will be able to make choices that save money, enhance personal convenience, improve the environment – or all three.*

***The message from consumers about the Smart Grid: Keep It Simple.***

Research indicates that consumers are ready to engage with the Smart Grid as long as their interface with the Smart Grid is simple, accessible and in no way interferes with how they live their lives. Consumers are not interested in sitting around for an hour a day to change how their house uses energy; what they will do is spend two hours per year to set their comfort, price and environmental preferences – enabling collaboration with the grid to occur automatically on their behalf and saving money each time.

At the residential level, Smart Grid must be simple, “set-it-and-forget-it” technology, enabling consumers to easily adjust their own energy use. Equipped with rich, useful information, consumers can help manage load on-peak to save money and energy for themselves and, ultimately, all of us.

***The Smart Grid as it applies to our environment.***

While the nation’s transportation sector emits 20% of all the carbon dioxide we produce, the generation of electricity emits 40% – clearly presenting an enormous challenge for the electric power industry in terms of global climate change. Smart Grid deployment is a key tool in addressing the challenges of climate change, ultimately and significantly reducing greenhouse gases and criteria pollutants such as NO<sub>x</sub>, SO<sub>x</sub> and particulates.

For the growing number of environmentally-aware consumers, a smarter grid finally provides a “window” for them to assess and react to their personal environmental impacts. Already, some utilities are informing consumers about their carbon footprint alongside their energy costs. In time, the Smart Grid will enable consumers to react in near real-time to lessen their impacts.

**POWER SYSTEM FACT**

*From 1988-98, U.S. electricity demand rose by nearly 30 percent, while the transmission network’s capacity grew by only 15%. Summer peak demand is expected to increase by almost 20% during the next 10 years.*



**SMART DEFINITION: CRITERIA POLLUTANTS** - Criteria pollutants are six common air pollutants that the scientific community has established as being harmful to our health and welfare when present at specified levels. They include nitrogen dioxide (NO<sub>x</sub>), carbon monoxide, ozone, lead, sulfur dioxide (SO<sub>x</sub>) and particulate matter, which includes dirt, soot, car and truck exhaust, cigarette smoke, spray paint droplets, and toxic chemical compounds.

*For utilities, adoption of the Smart Grid clears the air on several fronts.*

**Energy efficiency:**

On the load side, consumers capable of exercising usage control are suddenly and simultaneously also able to exercise their environmental stewardship, resulting in tremendous consumer-side energy efficiencies.

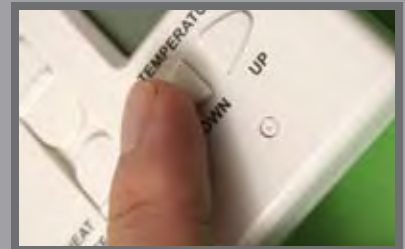
**Avoidance of new construction:**

Increased asset optimization made possible by a smarter grid means more reliance upon the most efficient power plants and less reliance upon the least efficient, more expensive-to-run peaker plants. Optimizing power plant utilization could also allow utilities to defer new generation investments or reduce dependence upon sometimes volatile and expensive wholesale markets. Utilities stand to benefit from lower costs, which increase profits.

The ability to effectively manage load with existing transmission and distribution infrastructure means that – ultimately – utilities would no longer have to build or could at least defer infrastructure to account for rapidly increasing peak demand.

**Integration of renewable energy sources:**

Given the significant concerns regarding climate change, the need for distributed solar and wind power is critical. According to the European Wind Energy Association, integrating wind or solar power into the grid at scale – at levels higher than 20% – will require advanced energy management techniques and approaches at the grid operator level. The Smart Grid's ability to dynamically manage all sources of power on the grid means that more distributed generation can be integrated within it.





**Preparation for the future:**

A smarter grid is also a necessity for plugging in the next generation of automotive vehicles – including plug-in hybrid electric vehicles (PHEVs) – to provide services supporting grid operation. Such ancillary services hold the potential for storing power and selling it back to the grid when the grid requires it.

Enabled by new technologies, plug-in hybrid vehicles – currently scheduled for showroom floors by 2010 – may dramatically reduce our nation’s foreign oil bill. According to the Pacific Northwest National Laboratory, existing U.S. power plants could meet the electricity needs of 73% of the nation’s light vehicles (i.e., cars and small trucks) if the vehicles were replaced by plug-ins that recharged at night. Such a shift would reduce oil consumption by 6.2 million barrels per day, eliminating 52% of current imports.

**However, there is a lot more to realizing this potential than simply plugging in.**

Without an integrated communications infrastructure and corresponding price signals, handling the increased load of plug-in hybrids and electric vehicles would be exceedingly difficult and inefficient. Smart Chargers, however – enabled by the Smart Grid – will help manage this new energy device on already constrained grids and avoid any unintended consequences on the infrastructure.



**To get a greener grid, you need a Smart Grid.**

Solar and wind power are necessary and desirable components of a cleaner energy future. To make the grid run cleaner, it will take a grid capable of dealing with the variable nature of these renewable resources.



**SMART DEFINITION : OFF PEAK**

A period of relatively low system demand, often occurring in daily, weekly, and seasonal patterns. Off-peak periods differ for each individual electric utility.



*With a smarter grid at work, a community "without power" is far from powerless.*

**What might the longer-term future look like?**

It is a decade from now.

An unusually destructive storm has isolated a community or region. Ten years ago, the wait for the appearance of a utility's "trouble trucks" would begin. The citizens would remain literally in the dark, their food spoiling, their security compromised and their families at risk.

Instead, with full Smart Grid deployment, this future community is not waiting. Instead, it's able immediately to take advantage of distributed resources and standards that support a Smart Grid concept known as "islanding." Islanding is the ability of distributed generation to continue to generate power even when

power from a utility is absent. Combining distributed resources of every description – rooftop PV (solar), fuel cells, electric vehicles – the community can generate sufficient electricity to keep the grocery store, the police department, traffic lights, the phone system and the community health center up and running.

While it may take a week to restore the lines, the generation potential resident in the community means that citizens still have sufficient power to meet their essential needs.

**THIS IS POWER FROM THE PEOPLE.**

*And it is coming.*

*Getting from Point A to Point B – from our present grid to the Smart Grid – requires a brief examination of the history and culture of the industry's primary custodians; namely, utilities and regulators.*

SECTION SIX:

## FIRST THINGS FIRST: TEASING OUT THE COMPLEXITIES.

When electricity's regulatory compact was first struck in the 1930s, a nation with little appetite for monopolies recognized the provision of electricity as a "natural monopoly" service, one best accomplished by a single entity, whether it was investor-owned, a municipal utility or a co-op.

Under the terms of the compact, in exchange for providing electric service to all consumers within the utility's service territory, utilities were provided a return on their investments plus a return on those investments commensurate with risks they take in ensuring service and reliability. State regulatory commissions were charged with determining whether the investments made were prudent and what a reasonable return on those investments should be.



### SMART GRID FACT

*The American Public Power Association (APPA) has launched a task force to develop a framework for deploying Smart Grid technologies in a public-power environment.*

Over the ensuing decades, much hard work was done on both sides of the compact as much of the grid as we know it was built.

Within utilities, efforts toward this objective were typically segmented or “siloed.” This division of labor worked well for utilities, providing efficiencies within the organization for quick execution and maintenance of system reliability.

Meanwhile, regulators focus on their respective states as a matter of law, an understandable circumstance given that each state must answer first and foremost to its citizens and their unique set of needs, resources and agendas.

Until relatively recently, this statutory arrangement has resulted in little regulatory action among the states and little reason to engage in collective action on a national basis, although they work at common purposes through regional associations.

Similarly, regulated utilities have traditionally been reactive, with no need or incentive to be proactive on a national level. Well aligned for utility operations, they are not necessarily well positioned for integrated strategic initiatives like the Smart Grid although they have collectively and forcefully advocated in the past on issues such as security and climate change.

## STATES TAKING ACTION:

30 states have developed and adopted renewable portfolio standards, which require a pre-determined amount of a state’s energy portfolio (up to 20%) to come exclusively from renewable sources by as early as 2010.

STATE	AMOUNT	YEAR	RPS ADMINISTRATOR	
Arizona	15%	2025	Arizona Corporation Commission	
California	20%	2010	California Energy Commission	
Colorado	20%	2020	Colorado Public Utilities Commission	
Connecticut	23%	2020	Department of Public Utility Control	
District of Columbia	11%	2022	DC Public Service Commission	
Delaware	20%	2019	Delaware Energy Office	
Hawaii	20%	2020	Hawaii Strategic Industries Division	
Iowa	105 MW		Iowa Utilities Board	
Illinois	25%	2025	Illinois Department of Commerce	
Massachusetts	4%	2009	Massachusetts Division of Energy Resources	
Maryland	9.5%	2022	Maryland Public Service Commission	
Maine	10%	2017	Maine Public Utilities Commission	
Minnesota	25%	2025	Minnesota Department of Commerce	
Missouri*	11%	2020	Missouri Public Service Commission	*Four states, Missouri, Utah, Vermont, & Virginia, have set voluntary goals for adopting renewable energy instead of portfolio standards with binding targets.
Montana	15%	2015	Montana Public Service Commission	
New Hampshire	16%	2025	New Hampshire Office of Energy and Planning	
New Jersey	22.5%	2021	New Jersey Board of Public Utilities	
New Mexico	20%	2020	New Mexico Public Regulation Commission	
Nevada	20%	2015	Public Utilities Commission of Nevada	
New York	24%	2013	New York Public Service Commission	
North Carolina	12.5%	2021	North Carolina Utilities Commission	
Oregon	25%	2025	Oregon Energy Office	
Pennsylvania	18%	2020	Pennsylvania Public Utility Commission	
Rhode Island	15%	2020	Rhode Island Public Utilities Commission	
Texas	5,880 MW	2015	Public Utility Commission of Texas	
Utah*	20%	2025	Utah Department of Environmental Quality	
Vermont*	10%	2013	Vermont Department of Public Service	
Virginia*	12%	2022	Virginia Department of Mines, Minerals, and Energy	
Washington	15%	2020	Washington Secretary of State	
Wisconsin	10%	2015	Public Service Commission of Wisconsin	



With growing consensus around the crucial need for Smart Grid deployment, the cultures of these entities are now changing dramatically.

For their part, regulators are actively sharing ideas and information with other states. Acting with an eye toward national agreement, twenty-nine states have also developed and adopted renewable portfolio standards, which require a pre-determined amount of a state's energy portfolio (up to 20%) to come exclusively from renewable sources by as early as 2010.

Regulators on both the state and federal level are stepping up their dialog. State regulators represented by the National Association of Regulatory Utility Commissions (NARUC) are exploring options for expediting Smart Grid implementation with their federal counterpart, the Federal Energy Regulatory Commission (FERC). Meanwhile, DOE is providing leadership with the passing into law of the Energy Independence and Security Act of 2007 (EISA), which codifies a research, development and demonstration program for Smart Grid technologies.

Thanks to these and other efforts, many regulators are moving toward new regulations designed to incentivize utility investment in the Smart Grid. Among these are dynamic pricing, selling energy back to the grid, and policies that guarantee utilities cost recovery and/or favorable depreciation on new Smart Grid investments and legacy systems made obsolete by the switch to "smart meters" and other Smart Grid investments.





As for utilities, an increasing number of them are taking a more integrated view of a smarter grid, particularly when there are areas of overlap that can be leveraged for cost reduction or benefit increase. There are regulatory implications here as well; if utilities are to argue for cost recovery project by project rather than by single integrated plan, some beneficial aspects of deployment of a smarter grid could be lost.

Integrated plans are being proposed and considered. In California, smart meters only became economic when the commission considered non-utility benefits – benefits to consumers from lower bills.

To an industry historically regulated for prior investment, the transformation to regulation for value delivery promises to stimulate substantial progress and alignment around the Smart Grid vision and implementation. Keep in mind, though, that regulators will continue to require a showing that the value of the investments to consumers – whatever they may be – ultimately exceeds the costs.

#### **SMART GRID FACT**

*To advance the modernization of our nation's electric grid, DOE has entered into public/private partnerships with leading champions of the Smart Grid which include the GridWise Alliance, EPRI/Intelligrd, and the Galvin Electricity Initiative.*



*Open architecture. Internet protocol. Plug and play. Common technology standards. Non-proprietary. Interoperability.*

*Fine concepts all, yet one of the reasons the electric industry has been slow to take advantage of common technology standards – which would speed Smart Grid adoption – is a lack of agreement on what those standards should be and who should issue them.*

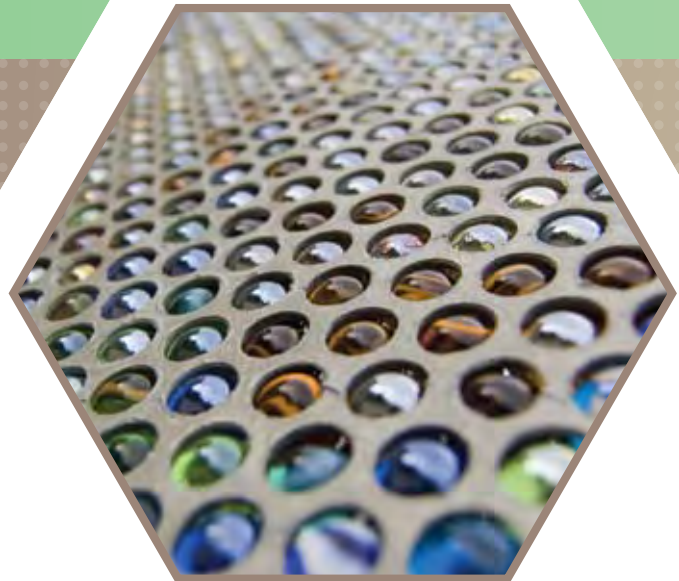
SECTION SEVEN:

## HOW THINGS WORK: CREATING THE PLATFORM FOR THE SMART GRID.

The industry is not without its role models in this regard.

**Consider the ATM.** It is available virtually anywhere. Every unit features a similar user interface, understandable whether or not you know the local language. Users don't give it a second thought. It simply works. Yet the fact that the ATM exists at all was made possible only by industry-wide agreement on a multitude of common standards, from communication to security to business rules.

Fortunately, the agendas of utilities, regulators and automation vendors are rapidly aligning and movement toward identifying and adopting Smart Grid standards is gaining velocity.



**DOE lists five fundamental technologies that will drive the Smart Grid:**

- Integrated communications, connecting components to open architecture for real-time information and control, allowing every part of the grid to both 'talk' and 'listen'
- Sensing and measurement technologies, to support faster and more accurate response such as remote monitoring, time-of-use pricing and demand-side management
- Advanced components, to apply the latest research in superconductivity, storage, power electronics and diagnostics
- Advanced control methods, to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event
- Improved interfaces and decision support, to amplify human decision-making, transforming grid operators and managers quite literally into visionaries when it come to seeing into their systems



**KILLER APP**

Will the PHEV be the Smart Grid's "killer app," the outward expression of the Smart Grid that consumers adopt en masse as they did e-mail? There are plenty of experts who think so.

The National Institute of Standards and Technology (NIST), an agency of the U.S. Department of Commerce, has been charged under EISA (Energy Independence and Security Act) with identifying and evaluating existing standards, measurement methods, technologies, and other support in service to Smart Grid adoption. Additionally, they will be preparing a report to Congress recommending areas where standards need to be developed.

The GridWise Architecture Council is an important resource for NIST. The Council, representing a wide array of utility and technology stakeholders and underwritten by DOE, has been working closely with NIST to develop common principles and an interoperability framework spanning the entire electricity delivery chain. Already, the work of the GridWise Architecture Council and other organizations such as ANSI (American National Standards Institute), IEEE (Institute of Electrical and Electronics Engineers) and the ZigBee Alliance have enabled a smarter grid to readily accept innovation across a wide spectrum of applications.



**Integration in practice.**

On Washington's Olympic Peninsula, a DOE demonstration project set in motion a sophisticated system that responded to simple instructions set in place by a consumer in his or her preference profile. Meanwhile, in the background, energy was managed on the consumer's behalf to save money and reduce the impact on the grid.

Consumers saved approximately 10% on their bills. More significantly, peak load was reduced by 15%, bringing the constrained regional grid another 3-5 years of peak load growth and enabling the installation of cleaner, more efficient technologies for supply.

Across the nation, companies are developing new Smart Grid technologies for utility-scale deployments that are progressively raising the bar on what is possible and practical.

**Steps toward a common "language."**

The independent, non-profit Electric Power Research Institute (EPRI) is also conducting research on key issues facing the electric power industry and working towards the development of open standards for the Smart Grid. The International ElectroTechnical Commission (IEC) recently published EPRI's IntelliGrid Methodology for Developing Requirements for Energy Systems as a publicly available specification.



### **Another look at the future: PHEV (Plug-in Hybrid Electric Vehicles)**

Assuming customer acceptance regarding price, performance and longevity, these vehicles offer consumers the opportunity to shift use of oil and gasoline to electricity – and to power a car for the equivalent of \$.90 per gallon. (As inefficient as the grid is today, it is cleaner on balance than oil and gasoline.) Consumers get far more affordable transportation. Relying more on electricity for transportation and less on fossil fuels increases our energy independence as well as our environmental prospects. PHEVs take advantage of lower cost and off-peak capacity and can provide grid support during the peak periods.

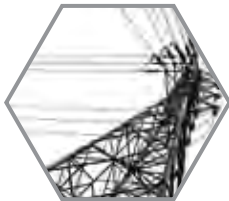


#### **ADVANCEMENTS ALSO IN DEVELOPMENT...**

##### ***Zero-net energy commercial buildings:***

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Whether measured by cost, energy, or carbon emissions, structures equipped with Smart Grid technologies capable of balancing energy generation and energy conservation.



##### ***Superconducting power cables:***

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Capable of reducing line losses and carrying 3-5 times more power in a smaller right of way than traditional copper-based cable.



##### ***Energy storage:***

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While electricity cannot be economically stored, energy can be – with the application of Smart Grid technologies. Thermal storage, sometimes called hybrid air conditioning, holds promising potential for positively affecting peak load today. Also of note is the near-term potential of lithium-ion batteries for PHEV applications.



##### ***Advanced sensors:***

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Monitoring and reporting line conditions in real time, advanced sensors enable more power to flow over existing lines.

*The Department of Energy is actively engaged in supporting a wide variety of Smart Grid projects. The role of DOE is to act as an objective facilitator, allowing the best ideas to prove themselves. Smart Grid efforts are well underway on several key fronts, from forward-thinking utilities to the 50<sup>th</sup> state.*

SECTION EIGHT:

**PROGRESS NOW!:  
A LOOK AT CURRENT  
SMART GRID EFFORTS  
AND HOW THEY'RE  
SUCCEEDING.**



**SMART GRID FACT**

*States such as Texas, California, Ohio, New Jersey, Illinois, New York and others are already actively exploring ways to increase the use of tools and technologies toward the realization of a smarter grid.*

### ***Distribution Management System (DMS) Platform by the University of Hawaii***

The integrated energy management platform will be developed, featuring advanced functions for home energy management by consumers and for improved distribution system operations by utilities. This platform will integrate AMI as a home portal for demand response; home automation for energy conservation; optimal dispatch of distributed generation, storage, and loads in the distribution system, and controls to make the distribution system a dispatchable entity to collaborate with other entities in the bulk grid.

Home energy management of this type will enable consumers to take control, automating energy conservation and demand response practices based on their personal preferences.

The home automation will be based on the SmartMeter and ecoDashboard products from General Electric. The SmartMeter with a ZigBee network will communicate with household appliances, and the dashboard will automate controls of their operations. In addition, this platform will provide ancillary services to the local utility such as spinning reserve, load-following regulation, and intermittency management for wind and solar energy. This platform will be deployed at the Maui Lani Substation in Maui, Hawaii.

### ***Perfect Power by Illinois Institute of Technology (IIT)***

A "Perfect Power" system is defined as: An electric system that cannot fail to meet the electric needs of the individual end-user. A Perfect Power system has the flexibility to supply the power required by various types of end-users and their needs without fail. The functionalities of such a system will be enabled by the Smart Grid.

This project will design a Perfect Power prototype that leverages advanced technology to create microgrids responding to grid conditions and providing increased reliability and demand reduction. This prototype model will be demonstrated at the IIT campus to showcase its operations to the industry. The model is designed to be replicable in any municipality-sized system where customers can participate in electric market opportunities.



### **West Virginia Super Circuit by Allegheny Energy**

The super circuit project is designed to demonstrate an advanced distribution circuit with improved reliability and security through integration of distributed resources and advanced monitoring, control, and protection technologies. This circuit will integrate biodiesel generation and energy storage with the AMI and a mesh-based Wi-Fi communications network for rapid fault anticipation and location and rapid fault restoration with minimized impact to customers.

Currently during a circuit fault, all customers on this circuit are being affected with power loss or with power quality issues. The super circuit will demonstrate an ability to dynamically reconfigure the circuit to allow isolation of the faulted segment, transfer uninterrupted services to “unfaulted” segments, and tap surplus capacity from adjacent feeders to optimize consumer service.



### **Beach Cities MicroGrid by San Diego Gas & Electric**

As its name implies, a microgrid resembles our current grid although on a much smaller scale. It is unique in its ability – during a major grid disturbance – to isolate from the utility seamlessly with little or no disruption to the loads within it and seamlessly reconnect later.

The Beach Cities Microgrid Project will be demonstrated at an existing substation identified as “Beach City Substation.” It is intended to offer a blueprint to all distribution utilities – proving the effectiveness of integrating multiple distributed energy resources with advanced controls and communications. It seeks to improve reliability and reduce peak loads on grid components such as distribution feeders and substations.

Both utility-owned and customer-owned generation, i.e., photovoltaic (PV) systems and biodiesel-fueled generators, and energy storage will be integrated along with advanced metering infrastructure (AMI) into the real-world substation operations with a peak load of approximately 50 MW.



Beach Cities will serve as a guide for improved asset use as well as for operating the entire distribution network in the future. Successfully “building” such capabilities will enable customer participation in reliability- and price-driven load management practices, both of which are key to the realization of a smarter grid.

### ***High Penetration of Clean Energy Technologies by The City of Fort Collins***

The city and its city-owned Fort Collins Utility support a wide variety of clean energy initiatives, including the establishment of a Zero Energy District within the city (known as FortZED).

One such initiative seeks to modernize and transform the electrical distribution system by developing and demonstrating an integrated system of mixed distributed resources to increase the penetration of renewables – such as solar and wind – while delivering improved efficiency and reliability.

These and other distributed resources will be fully integrated into the electrical distribution system to support achievement of a Zero Energy District. In fact, this DOE-supported project involves the integration of a mix of nearly 30 distributed generation, renewable energy, and demand response resources across 5 customer locations for an aggregated capacity of more than 3.5 Megawatts.



*The resources being integrated include:*

- *photovoltaic (PV)*
- *microturbines (small combustion turbines that produce between 25 kW and 500 kW of power)*
- *dual-fuel combined power and heat (CHP) systems (utilizing the by-product methane generated from a water treatment plant operation)*
- *reciprocating (or internal combustion) engines*
- *backup generators*
- *wind*
- *plug-in hybrid electric vehicles (PHEV) in an ancillary-services role*
- *fuel cells*

This project will help determine the maximum degree of penetration of distributed resources based on system performance and economics.



*When Smart Grid implementation becomes reality, everyone wins – and what were once our risks become our strengths.*

SECTION NINE:

## **EDISON UNBOUND: WHAT'S YOUR STAKE IN ALL THIS?**



## LET'S REVISIT THAT LIST:

**EFFICIENCY:** It is estimated that tens of billions of dollars will be saved thanks to demand-response programs that provide measurable, persistent savings and require no human intervention or behavior change. The dramatically reduced need to build more power plants and transmission lines will help, too.

**RELIABILITY:** A Smart Grid that anticipates, detects and responds to problems rapidly reduces wide-area blackouts to

toward energy independence from foreign energy sources, which themselves may be targets for attack, outside of our protection and control.

**ENVIRONMENT/CLIMATE CHANGE:** Clean, renewable sources of energy like solar, wind, and geothermal can easily be integrated into the nation's grid. We reduce our carbon footprint and stake a claim to global environmental leadership.

*"We are being presented with unprecedented opportunity and challenge across our industry. By coming together around a shared vision of a smarter grid, we have an equally unprecedented opportunity and challenge for shaping our industry's and our nation's future."*

**STEVEN G HAUSER** PRESIDENT,  
THE GRIDWISE ALLIANCE

near zero (and will have a similarly diminishing effect on the lost productivity).

**AFFORDABILITY:** Energy prices will rise; however, the trajectory of future cost increases will be far more gradual post-Smart Grid. Smart Grid technologies, tools, and techniques will also provide customers with new options for managing their own electricity consumption and controlling their own utility bills.

**SECURITY:** The Smart Grid will be more resistant to attack and natural disasters. So fortified, it will also move us

**NATIONAL ECONOMY:** Opening the grid to innovation will enable markets to grow unfettered and innovation to flourish. For comparison's sake, consider the market-making effect of the opening of the telephone industry in the 1980s. With revenues of \$33 billion at the time, the ensuing proliferation of consumer-centric products and services transformed it into a \$117 billion market as of 2006.

**GLOBAL COMPETITIVENESS:** Regaining our early lead in solar and wind will create an enduring green-collar economy.



### TODAY'S GRID. AND TOMORROW'S.

<b>Characteristic</b>	<b>Today's Grid</b>	<b>Smart Grid</b>
<i>Enables active participation by consumers</i>	<i>Consumers are uninformed and non-participative with power system</i>	<i>Informed, involved, and active consumers - demand response and distributed energy resources.</i>
<i>Accommodates all generation and storage options</i>	<i>Dominated by central generation- many obstacles exist for distributed energy resources interconnection</i>	<i>Many distributed energy resources with plug-and-play convenience focus on renewables</i>
<i>Enables new products, services and markets</i>	<i>Limited wholesale markets, not well integrated - limited opportunities for consumers</i>	<i>Mature, well-integrated wholesale markets, growth of new electricity markets for consumers</i>
<i>Provides power quality for the digital economy</i>	<i>Focus on outages - slow response to power quality issues</i>	<i>Power quality is a priority with a variety of quality/price options - rapid resolution of issues</i>
<i>Optimizes assets &amp; operates efficiently</i>	<i>Little integration of operational data with asset management - business process silos</i>	<i>Greatly expanded data acquisition of grid parameters - focus on prevention, minimizing impact to consumers</i>
<i>Anticipates and responds to system disturbances (self-heals)</i>	<i>Responds to prevent further damage- focus is on protecting assets following fault</i>	<i>Automatically detects and responds to problems - focus on prevention, minimizing impact to consumer</i>
<i>Operates resiliently against attack and natural disaster</i>	<i>Vulnerable to malicious acts of terror and natural disasters</i>	<i>Resilient to attack and natural disasters with rapid restoration capabilities</i>

The Smart Grid creates value up and down the value chain, much like the internet has. As we've experienced with the internet, affordable, rapid and universal communication can enable sophisticated transactions, create entirely new business models and sweep across society with surprising speed.

*Consider for a moment your iPod, YouTube, internet banking...*

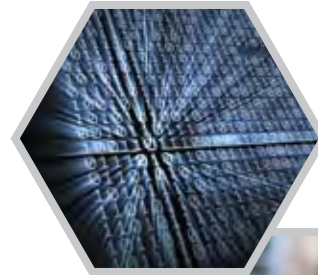
Prior to the internet's adoption, markets didn't have the ability to operate as cost-effectively and productively as they do today. Few predicted that people would engage as seriously with the internet as they have. And no one could have predicted the revolutionary advancements it has fostered.

Similarly, we had no idea that the internet would revolutionize so many aspects of our lives.

The Smart Grid represents the relatively simple extension of this movement to power consumption.

Thomas Edison, The Wizard of Menlo Park, would approve of the enterprise and innovation that drive the Smart Grid. He might even ask what took us so long. New technologies and public policies, economic incentives and regulations are aligning to bring the Smart Grid to full implementation. Its success is imperative to the economic growth and vitality of America far into the future.

We hope that ***The Smart Grid: An Introduction*** has given you a clearer understanding of the need for immediate and concerted action in the transformation of our nation's electrical grid. To learn more, please visit the websites listed on the following page.



***“If we all did the things we are capable of doing,  
we would literally astound ourselves.”***

**THOMAS A. EDISON (1847-1931)**

# RESOURCES

## 2007 INTERGRAPH ROCKET CITY GEOSPATIAL CONFERENCE:

**Presentation:** <http://www.directionsmag.com/images/RCG/Main/Damon%20Dougherty.ppt#257,3,What%20is%20Smart%20Grid>

**COLUMBIA UNIVERSITY:** <http://www.ideo.columbia.edu/res/pi/4d4/testbeds/Smart-Grid-White-Paper.pdf>

## EEI :

[http://www.eei.org/industry\\_issues/electricity\\_policy/advanced\\_metering\\_infrastructure.htm](http://www.eei.org/industry_issues/electricity_policy/advanced_metering_infrastructure.htm)

[http://www.eei.org/magazine/editorial\\_content/nonav\\_stories/2007-09-01-Smart.pdf](http://www.eei.org/magazine/editorial_content/nonav_stories/2007-09-01-Smart.pdf)

[http://www.eei.org/magazine/editorial\\_content/nonav\\_stories/2005-01-01-Smarter.pdf](http://www.eei.org/magazine/editorial_content/nonav_stories/2005-01-01-Smarter.pdf)

## ENERGY FUTURE COALITION :

**Smart Grid Working Group:** <http://www.energyfuturecoalition.org/preview.cfm?catID=13>

**Reports:** [http://www.energyfuturecoalition.org/pubs/app\\_smart\\_grid.pdf](http://www.energyfuturecoalition.org/pubs/app_smart_grid.pdf)

<http://energyfuturecoalition.org/pubs/PJMsmartgrid.pdf>

## ELSTER:

[http://www.eei.org/meetings/nonav\\_2008-02-06-ja/Gray\\_Elster.pdf](http://www.eei.org/meetings/nonav_2008-02-06-ja/Gray_Elster.pdf)

[http://www.eei.org/industry\\_issues/electricity\\_policy/federal\\_legislation/deciding\\_on\\_smart\\_meters.pdf](http://www.eei.org/industry_issues/electricity_policy/federal_legislation/deciding_on_smart_meters.pdf)

**GRIDPOINT:** [http://www.electricitydeliveryforum.org/pdfs/Gridpoint\\_SmartGrid.pdf](http://www.electricitydeliveryforum.org/pdfs/Gridpoint_SmartGrid.pdf)

## NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION:

**Presentation:** <http://www.nema.org/gov/energy/smartgrid/upload/Presentation-Smart-Grid.pdf>

## NATIONAL ENERGY TECHNOLOGIES LABORATORY:

**Presentation:** [http://www.energetics.com/supercon07/pdfs/NETL\\_Synergies\\_of\\_the\\_SmartGrid\\_and\\_Superconductivity\\_Pullins.pdf](http://www.energetics.com/supercon07/pdfs/NETL_Synergies_of_the_SmartGrid_and_Superconductivity_Pullins.pdf)

## THE PEW CENTER ON GLOBAL CLIMATE CHANGE:

**Workshop Proceedings:** [http://www.pewclimate.org/docUploads/10-50\\_Anderson\\_120604\\_120713.pdf](http://www.pewclimate.org/docUploads/10-50_Anderson_120604_120713.pdf)

**SAN DIEGO SMART GRID STUDY:** [http://www.sandiego.edu/epic/publications/documents/061017\\_SDSmartGridStudyFINAL.pdf](http://www.sandiego.edu/epic/publications/documents/061017_SDSmartGridStudyFINAL.pdf)

**SMART GRID NEWS:** <http://www.smartgridnews.com/artman/publish/index.html>

## XCEL ENERGY:

**Smart Grid City Web site:** [http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-1\\_15531\\_43141\\_46932-39884-0\\_0\\_0-0,00.html](http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-1_15531_43141_46932-39884-0_0_0-0,00.html)

**EPRI INTELLIGRID:** <http://intelligrid.epri.com/>

**PNNL GRIDWISE:** <http://gridwise.pnl.gov/>

**SMART GRID TASK FORCE:** [http://www.oe.energy.gov/smartgrid\\_taskforce.htm](http://www.oe.energy.gov/smartgrid_taskforce.htm)

**SMART GRID:** <http://www.oe.energy.gov/smartgrid.htm>

**GRIDWISE ALLIANCE:** [www.gridwise.org](http://www.gridwise.org)

**GRID WEEK:** [www.gridweek.com](http://www.gridweek.com)

# SOURCES

Sources for this book include the Department of Energy, the GridWise Alliance, the Galvin Electricity Initiative and EPRI/Intelligrid.

# GLOSSARY: COMING TO TERMS WITH THE SMART GRID

**AMI:** Advanced Metering Infrastructure is a term denoting electricity meters that measure and record usage data at a minimum, in hourly intervals, and provide usage data to both consumers and energy companies at least once daily.

**AMR:** Automated Meter Reading is a term denoting electricity meters that collect data for billing purposes only and transmit this data one way, usually from the customer to the distribution utility.

**ANCILLARY SERVICES:** Services that ensure reliability and support the transmission of electricity from generation sites to customer loads. Such services may include: load regulation, spinning reserve, non-spinning reserve, replacement reserve, and voltage support.

**APPLIANCE:** A piece of equipment, commonly powered by electricity, used to perform a particular energy-driven function. Examples of common appliances are refrigerators, clothes washers and dishwashers, conventional ranges/ovens and microwave ovens, humidifiers and dehumidifiers, toasters, radios, and televisions. Note: Appliances are ordinarily self-contained with respect to their function. Thus, equipment such as central heating and air conditioning systems and water heaters, which are connected to distribution systems inherent to their purposes, are not considered appliances.

**CAPITAL COST:** The cost of field development and plant construction and the equipment required for industry operations.

**CARBON DIOXIDE (CO<sub>2</sub>):** A colorless, odorless, non-poisonous gas that is a normal part of Earth's atmosphere. Carbon dioxide is a product of fossil-fuel combustion as well as other processes. It is considered a greenhouse gas as it traps heat (infrared energy) radiated by the Earth into the atmosphere and thereby contributes to the potential for global warming. The global warming potential (GWP) of other greenhouse gases is measured in relation to that of carbon dioxide, which by international scientific convention is assigned a value of one (1).

**CLIMATE CHANGE:** A term used to refer to all forms of climatic inconsistency, but especially to significant change from one prevailing climatic condition to another. In some cases, "climate change" has been used synonymously with the term "global warming"; scientists, however, tend to use the term in a wider sense inclusive of natural changes in climate, including climatic cooling.

**CONGESTION:** A condition that occurs when insufficient transfer capacity is available to implement all of the preferred schedules for electricity transmission simultaneously.

**DSM:** This Demand-Side Management category represents the amount of consumer load reduction at the time of system peak due to utility programs that reduce consumer load during many hours of the year. Examples include utility rebate and shared savings activities for the installation of energy efficient appliances, lighting and electrical machinery, and weatherization materials. In addition, this category includes all other Demand-Side Management activities, such as thermal storage, time-of-use rates, fuel substitution, measurement and evaluation, and any other utility-administered Demand-Side Management activity designed to reduce demand and/or electricity use.

**DISTRIBUTED GENERATOR:** A generator that is located close to the particular load that it is intended to serve. General, but non-exclusive, characteristics of these generators include: an operating strategy that supports the served load; and interconnection to a distribution or sub-transmission system.

**DISTRIBUTION:** The delivery of energy to retail customers.

**DISTRIBUTION SYSTEM:** The portion of the transmission and facilities of an electric system that is dedicated to delivering electric energy to an end-user.

**ELECTRIC GENERATION INDUSTRY:** Stationary and mobile generating units that are connected to the electric power grid and can generate electricity. The electric generation industry includes the "electric power sector" (utility generators and independent power producers) and industrial and commercial power generators, including combined-heat-and-power producers, but excludes units at single-family dwellings.

**ELECTRIC GENERATOR:** A facility that produces only electricity, commonly expressed in kilowatthours (kWh) or megawatthours (MWh). Electric generators include electric utilities and independent power producers.

**ELECTRIC POWER:** The rate at which electric energy is transferred. Electric power is measured by capacity and is commonly expressed in megawatts (MW).

**ELECTRIC POWER GRID:** A system of synchronized power providers and consumers connected by transmission and distribution lines and operated by one or more control centers. In the continental United States, the electric power grid consists of three systems: the Eastern Interconnect, the Western Interconnect, and the Texas Interconnect. In Alaska and Hawaii, several systems encompass areas smaller than the State (e.g., the interconnect serving Anchorage, Fairbanks, and the Kenai Peninsula; individual islands).

**ELECTRIC SYSTEM RELIABILITY:** The degree to which the performance of the elements of the electrical system results in power being delivered to consumers within accepted standards and in the amount desired. Reliability encompasses two concepts, adequacy and security. Adequacy implies that there are sufficient generation and transmission resources installed and available to meet projected electrical demand plus reserves for contingencies. Security implies that the system will remain intact operationally (i.e., will have sufficient available operating capacity) even after outages or other equipment failure. The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on consumer service.

# GLOSSARY (CONT'D)

**ELECTRIC UTILITY:** Any entity that generates, transmits, or distributes electricity and recovers the cost of its generation, transmission or distribution assets and operations, either directly or indirectly, through cost-based rates set by a separate regulatory authority (e.g., State Public Service Commission), or is owned by a governmental unit or the consumers that the entity serves. Examples of these entities include: investor-owned entities, public power districts, public utility districts, municipalities, rural electric cooperatives, and State and Federal agencies.

**ELECTRICITY CONGESTION:** A condition that occurs when insufficient transmission capacity is available to implement all of the desired transactions simultaneously.

**ELECTRICITY DEMAND:** The rate at which energy is delivered to loads and scheduling points by generation, transmission, and distribution facilities.

**ENERGY EFFICIENCY, ELECTRICITY:** Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption (reported in megawatthours), often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technologically more advanced equipment to produce the same level of end-use services (e.g. lighting, heating, motor drive) with less electricity. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

**ENERGY SAVINGS:** A reduction in the amount of electricity used by end users as a result of participation in energy efficiency programs and load management programs.

**ENERGY SERVICE PROVIDER:** An energy entity that provides service to a retail or end-use customer.

**FEDERAL ENERGY REGULATORY COMMISSION (FERC):** The Federal agency with jurisdiction over interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification. FERC is an independent regulatory agency within the Department of Energy and is the successor to the Federal Power Commission.

**FUEL CELL:** A device capable of generating an electrical current by converting the chemical energy of a fuel (e.g., hydrogen) directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside. It does not contain an intermediate heat cycle, as do most other electrical generation techniques.

**GENERATION:** The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in kilowatthours.

**GLOBAL WARMING:** An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is today most often used to refer to the warming some scientists predict will occur as a result of increased anthropogenic emissions of greenhouse gases.

**GREENHOUSE GASES:** Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface.

**INTERMITTENT ELECTRIC GENERATOR OR INTERMITTENT RESOURCE:** An electric generating plant with output controlled by the natural variability of the energy resource rather than dispatched based on system requirements. Intermittent output usually results from the direct, non-stored conversion of naturally occurring energy fluxes such as solar energy, wind energy, or the energy of free-flowing rivers (that is, run-of-river hydroelectricity).

**INTERRUPTIBLE LOAD:** This Demand-Side Management category represents the consumer load that, in accordance with contractual arrangements, can be interrupted at the time of annual peak load by the action of the consumer at the direct request of the system operator. This type of control usually involves large-volume commercial and industrial consumers. Interruptible Load does not include Direct Load Control.

**LINE LOSS:** Electric energy lost because of the transmission of electricity. Much of the loss is thermal in nature.

**LOAD (ELECTRIC):** The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.

**LOAD CONTROL PROGRAM:** A program in which the utility company offers a lower rate in return for having permission to turn off the air conditioner or water heater for short periods of time by remote control. This control allows the utility to reduce peak demand.

**OFF PEAK:** Period of relatively low system demand. These periods often occur in daily, weekly, and seasonal patterns; these off-peak periods differ for each individual electric utility.

**ON PEAK:** Periods of relatively high system demand. These periods often occur in daily, weekly, and seasonal patterns; these on-peak periods differ for each individual electric utility.

**OUTAGE:** The period during which a generating unit, transmission line, or other facility is out of service.

**PEAK DEMAND OR PEAK LOAD:** The maximum load during a specified period of time.

**PEAKER PLANT OR PEAK LOAD PLANT:** A plant usually housing old, low-efficiency steam units, gas turbines, diesels, or pumped-storage hydroelectric equipment normally used during the peak-load periods.

**PEAKING CAPACITY:** Capacity of generating equipment normally reserved for operation during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on an around-the-clock basis.

**RATE BASE:** The value of property upon which a utility is permitted to earn a specified rate of return as established by a regulatory authority. The rate base generally represents the value of property used by the utility in providing service and may be calculated by any one or a combination of the following accounting methods: fair value, prudent investment, reproduction cost, or original cost. Depending on which method is used, the rate base includes cash, working capital, materials and supplies, deductions for accumulated provisions for depreciation, contributions in aid of construction, customer advances for construction, accumulated deferred income taxes, and accumulated deferred investment tax credits.

**RATE CASE:** A proceeding, usually before a regulatory commission, involving the rates to be charged for a public utility service.

**RATE FEATURES:** Special rate schedules or tariffs offered to customers by electric and/or natural gas utilities.

**RATE OF RETURN:** The ratio of net operating income earned by a utility is calculated as a percentage of its rate base.

**RATE OF RETURN ON RATE BASE:** The ratio of net operating income earned by a utility, calculated as a percentage of its rate base.

**RATE SCHEDULE (ELECTRIC):** A statement of the financial terms and conditions governing a class or classes of utility services provided to a customer. Approval of the schedule is given by the appropriate rate-making authority.

**RATEMAKING AUTHORITY:** A utility commission's legal authority to fix, modify, approve, or disapprove rates as determined by the powers given the commission by a State or Federal legislature.

**RATES:** The authorized charges per unit or level of consumption for a specified time period for any of the classes of utility services provided to a customer.

**RELIABILITY (ELECTRIC SYSTEM):** A measure of the ability of the system to continue operation while some lines or generators are out of service. Reliability deals with the performance of the system under stress.

**RENEWABLE ENERGY RESOURCES:** Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include: biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

**SOLAR ENERGY:** The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

**TARIFF:** A published volume of rate schedules and general terms and conditions under which a product or service will be supplied.

**THERMAL ENERGY STORAGE:** The storage of heat energy during utility off-peak times at night, for use during the next day without incurring daytime peak electric rates.

**THERMAL LIMIT:** The maximum amount of power a transmission line can carry without suffering heat-related deterioration of line equipment, particularly conductors.

**TIME-OF-DAY PRICING:** A special electric rate feature under which the price per kilowatthour depends on the time of day.

**TIME-OF-DAY RATE:** The rate charged by an electric utility for service to various classes of customers. The rate reflects the different costs of providing the service at different times of the day.

**TRANSMISSION AND DISTRIBUTION LOSS:** Electric energy lost due to the transmission and distribution of electricity. Much of the loss is thermal in nature.

**TRANSMISSION (ELECTRIC) (VERB):** The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

**UTILITY GENERATION:** Generation by electric systems engaged in selling electric energy to the public.

**UTILITY-SPONSORED CONSERVATION PROGRAM:** Any program sponsored by an electric and/or natural gas utility to review equipment and construction features in buildings and advise on ways to increase the energy efficiency of buildings. Also included are utility-sponsored programs to encourage the use of more energy-efficient equipment. Included are programs to improve the energy efficiency in the lighting system or building equipment or the thermal efficiency of the building shell.

**WIND ENERGY:** Kinetic energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators.



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