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# THE SMART GRID VISION FOR INDIA'S POWER SECTOR

**March 2010**

This publication was produced for review by the United States Agency for International Development. It was prepared by PA Government Services, Inc.

# The Smart Grid Vision for India's Power Sector: A White Paper



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# Foreword

USAID/India and the Government of India's Ministry of Power provided the inspiration for this white paper for the electricity distribution sub-sector under the Distribution Reform, Upgrades and Management (DRUM) project. This paper is a by-product of the time, talent, effort and imagination that USAID, in collaboration with the Ministry of Power, invested over many years in initiatives involving energy, power sector reform, energy efficiency, and the market development of renewable energies as well as environmental and water-energy nexus issues. Collectively, these are vital to the future of India and the goal of crafting a sustainable model for high-growth, low-carbon economic development.

The smart grid vision is responsive to a need. Losses remain high and the industry continues to struggle with service quality and reliability in urban areas and electrification in rural areas. Climate change and a carbon crisis of global proportions have added to the urgency of finding a sustainable, high-growth, low carbon economic model.

One question is whether developing economies must move sequentially through the same stages as mature power sectors in order to be ready for a smart grid world? Or will the awesome challenge of providing sufficient supplies of clean energy to enable sustainable economic development inspire a breakthrough? Can the smart grid vision enable India to leapfrog into a new, different and better electricity environment?

The adaptation of the smart grid vision to the Indian context offers the potential to revolutionize electricity supply and increase the probability of achieving the Government of India's electricity sector goals sooner and more effectively. The immediate beneficiaries would be the people of India. The design of a sustainable smart grid model would also provide a blueprint for developing nations. And the reduction in carbon emissions along with potential technological innovations would benefit all nations, developed and developing alike.

Defining a smart grid vision for India's power sector is a worthy challenge. We hope this white paper advances the understanding of that vision and provides insight into the potential it offers.

# Acknowledgments

The preparation of this white paper relied on observations, comments and inputs from a consultative process that involved a cross-section of knowledgeable industry experts and stakeholders in addition to USAID/India and the project team members and technical advisors from PA Government Services, Inc. In particular, we would like to acknowledge the guidance and support we received from Dr. Gaurav Bhatiani of USAID. His assistance in framing the issues, participating in stakeholder consultations and providing insightful comments on drafts of this white paper were invaluable. We are also especially grateful for the valuable time and useful insights provided by representatives of the Government of India, including the Ministry of Power, the Central Electricity Authority, the Power Finance Corporation and the Central Power Research Institute.

Many other organizations, including energy companies (both state-owned and private), universities and training institutes, software firms, information and communications technology consultancies, metering companies and engineering firms shared their knowledge and insights generously, including at a day-long workshop on smart grids sponsored by USAID/India. They include, in alphabetic order, AREVA, Autech Automation, Bangalore Electricity Supply Company, Centre For the Study of Science, Technology and Policy, CISCO, Dhiya Consulting, GE Energy, the Government of Karnataka, Honeywell Technology Solutions Lab Private Limited, IBM, Indian Electrical & Electronics Manufacturers Association, the Indian Institute of Technology (Kanpur), Infosys, the Institute of Engineering and Technology (Lucknow), Karnataka Electricity Regulatory Commission, Kalki Communications, Karnataka Power Transmission Company Limited, Karnataka Renewable Energy Development Limited, KEMA, Larson & Tubro, Maharashtra State Electricity Distribution Company Limited, Maharashtra Electricity Regulatory Commission, Mercom Communications, North Delhi Power Limited, ORACLE, Orb Energy, Patni Computers, the Public Affairs Foundation, Power Grid Corporation of India Limited, Quanta Technologies, Quanta Services, Reliance Communications, Reliance Energy, Reliance Energy Management Institute, Reliance Infrastructure, Secure Meters, SIEMENS (India), Tata Consulting Engineers, Tata BP Solar India, The Energy Research Institute, the U.S. Department of Agriculture's Rural Utilities Service and the Uttar Pradesh Electricity Regulatory Commission.

Additionally, we are grateful to the National Regulatory Research Institute (USA), PJM, and Puget Sound Energy for their help in providing invaluable research guidance and assistance. Two others who generously offered unique insights are Ashley Brown, executive director of the Harvard Electricity Policy Group, and Leonard Hyman of B&V Management Consulting.

Without the support we received from all these organizations and the many unnamed individuals who represent them, our task would have been much more difficult.

# Executive Summary

Is electricity a commodity or a premium value-added service? The way this question is answered over the next decade will reshape, perhaps radically, the way electricity is produced, transported and used. That, in turn, will influence the way societies grow and the way people live their day-to-day lives. Recently, the concept known as “the smart grid” has been gaining momentum. The idea has captured the imagination of a widening circle of believers and — in part, due to the US Government’s stimulus spending plan<sup>1</sup> — it is finding its way into the public consciousness.

The Smart Grid cannot be reduced to a simple formula or template. It is as much a vision as a blueprint. In its broadest interpretation, the smart grid vision sees the electric industry transformed by the introduction of two-way communications and ubiquitous metering and measurement. It will enable much finer control of energy flows and the integration and efficient use of renewable forms of energy, energy efficiency methodologies and technologies, as well as many other advanced technologies, techniques and processes that wouldn’t have been practicable until now. It will also enable the creation of more reliable, more robust and more secure electrical infrastructure, and it will help optimize the enormous investments required to build and operate the physical infrastructure required.

There are some who say these ideas are not yet practicable or that the cost of implementing them will exceed the benefits. There are some thorny practical problems, too. Most notable are customer response and cost-benefit analysis (CBA). How customers will respond to time-of-use (TOU) rates — much of the potential benefit attributed to the smart grid hinges on the effectiveness of TOU rates — is a pivotal issue but difficult to estimate before the fact. If there is not wide adoption rate of TOU rates, the expected benefits could be anemic. That is also one of the issues that feeds into CBA, but not the only one. Regulators around the world have quickly honed in on both of these overlapping issues and they may become the litmus test for proposed smart grid projects around the world.

Our remit was not to take a position in this debate, but to sketch the “what is” of smart grids, including an overview of its various definitions<sup>2</sup> and comment on certain key issues, including technology and the subtleties involved in the economic analysis of this vision that is, as yet, mostly non-existent in the real world.

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<sup>1</sup> The American Reinvestment and Recovery Act (ARRA) allocated \$4.5 billion to smart grid spending projects.

<sup>2</sup> We discovered that definitional differences are caused more by where one draws a boundary than any fundamental disagreement about the essence of the smart grid vision.

In today's world of sound bites and takeaways, we would suggest the following are essential points we learned in developing this white paper:

- Electricity is morphing from a commodity into a premium form of energy
- Demand for more high-quality electricity will continue growing unabated
- The link between economic prosperity and quality electricity is tightening
- Traditional fossil fuels will be increasingly scarce, expensive and polluting
- The smart grid vision offers unique solutions to meet customers' needs and society's need for a sustainable, high-growth, low-carbon economic model.

For India, the smart grid may offer a unique opportunity to leapfrog into a vastly improved electricity environment. We encourage the development of a smart grid vision tailored to India's unique needs and circumstances. A brief review of that vision suggests there is enormous potential for gain, but also some significant risks. The best course of action is to proceed with deliberate speed with a program that emphasizes front-end analysis, planning and goal setting.

India's robust economic growth and limited reserves of oil, gas or high-quality coal have also added energy security as a national imperative. In the words of Kirin Parikh, "... we are very short of oil, very short of gas. We need to find in the next 20, at the most 30 years, an alternative to coal-based power plants."<sup>3</sup> India's national interest could be directly affected — for better or for worse — by its success in defining and implementing a smart grid vision for the power sector and the nation. Thus, the specific conclusions for India are:

- One or more smart grid pilot projects would be a logical next step to build on the accomplishments of USAID's successful collaboration with the Government of India's Ministry of Power.
- The realities of India's power sector should determine the kind of pilot projects that are taken up, including high aggregate technical and commercial losses, reliability issues, and rural electrification and agricultural irrigation. Most of these suggest a focus on improving the distribution system or, especially in rural areas, of implementing micro-grids.
- Pilot projects should also consider the need for more renewable energy and energy efficiency measures and the need to confirm the commercial viability of new techniques, technologies and/or methodologies that would contribute to a sustainable, high-growth, low-carbon model for the power sector.

Some knowledgeable observers believe the smart grid will revolutionize the electricity business and forever change the business model that has been in place for the past 75 years and more. Although the extent of the coming transformation is difficult to predict,

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<sup>3</sup> Kirin Parikh, the head of a Government of India panel tasked with developing India's low-carbon strategy, as quoted in *The Economic Times*, 22 March 2010.

there is little question that much will have to change. That may well require changes in the boundary conditions and rules of the game to ensure there is a level playing field for all participants and to provide the incentives for market participants to get the best possible results.

Existing energy laws and regulations that address technical (e.g., reliability, service standards), economic (reasonable and economically efficient tariffs) and customer service issues were developed for a closed system that is now changing. Thus, regulations may have to be expanded and augmented to encourage innovation and provide incentives to adapt to a new paradigm and new market rules.

The economic model for the electric industry is still (mostly) based on maximizing revenue by maximizing the volume of electricity sales. As with demand-side management (DSM) initiatives several decades ago, this may put the increased emphasis on energy efficiency to be accomplished through a smarter grid, in conflict with a utility's bottom line. Of course, that assumes discoms are successful in reducing the extraordinary loss levels that are a more immediate and more potent threat to the financial viability of India's discoms.

New policies will also be needed to encourage innovation, to provide incentives for utilities to pursue energy efficiency, load management and conservation initiatives, to provide incentives to attract private players — with appropriate rewards and the assurance of a level playing field — and to empower consumers to manage energy usage more effectively. If the promotion of private investment in smart grid investments is deemed to be in the national interest, then a study of innovative financing techniques (e.g., tax incentives, accelerated depreciation,) would be warranted.

Evaluating the costs and benefits of proposed smart grid investments warrants a broad-gauged approach that incorporates societal benefits and externalities as well as the costs and benefits of more conventional utility investment proposals. This will require a delicate balance, but the transformational potential of the smart grid vision warrants it. A reduction in carbon emissions will contribute to improved public health. Some smart grid projects may create employment, enhance agricultural security, stimulate economic growth or provide other benefits that are outside the strict boundaries of traditional power sector projects. These should be taken into account.

The fact that such benefits are difficult to measure should not deter policy makers and regulators from developing a methodology to do it. India is uniquely well equipped to add to the conceptual foundation that has already been established and develop a workable cost-benefit methodology that encompasses the full range of potential benefits as well as the known and more easily quantifiable costs and risks.

It is difficult to explore the smart grid vision without thinking of the phrase “inflection point.” The electric utility business is like a centenarian being reborn and there is a realistic possibility that the traditional business model could be changed radically, and quickly too. Although it is too early to predict how the smart grid vision will reshape the production, transportation and use of electricity, the potential is extraordinary.



Despite the appeal — and, admittedly, the glitter — attached to the smart grid vision, one serious practical problem is that it is difficult for customers to judge the value of something they can't envision. That has always been the case. This is equally true for policy makers, regulators and utility managers. Thus, education and capacity building will be essential enabling preconditions.

Fortunately, computing and telecommunications — key drivers of the smart grid — are the archetypes for a transformational technology. Nonetheless, it would be a mistake to underestimate the importance of communicating with and educating consumers, policy makers, regulators and utility managers. The electric industry is different. It is a slow-moving behemoth, steeped in an insular culture that is resistant to change. For their part, customers in India have been conditioned to expect the worst and to view electricity as a cheap public good.

The enlightenment of all stakeholders will be a vital first step.

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# Acronyms

AMI	Advanced metering infrastructure
APDRP	Accelerated Power Development and Reform Programme
ARRA	American Recovery and Investment Act
AT&C	Aggregate technical and commercial
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
CBA	Cost-benefit analysis
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CER	Certified emission reduction
CERC	Central Electricity Regulatory Commission
CIP	Competitiveness and Innovation Framework Programme
CIS	Customer information system
CO <sub>2</sub>	Carbon dioxide
CPP	Critical peak pricing
CPRI	Central Power Research Institute
CPUC	California Public Utilities Commission
CPUC	Colorado Public Utilities Commission
CRM	Customer relations management
DCA	Development Credit Authority (US)
DFID	Department for International Development (UK)
DMS	Distribution management systems
DNO	Distribution network operator
DOE	Department of Energy (US)
DR	Demand response
DSM	Demand-side management
EE	Energy efficiency
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
ESCO	Energy service company
EU ETS	European Union's Emission Trading Scheme
EV	Electric vehicle
FERC	Federal Energy Regulatory Commission (US)
GIS	Geographic information system

GOI	Government of India
GPRS	General packet radio service
GWAC	GridWise Architecture Council
ICT	Information and communications technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IED	Intelligent electronic device
ISO	Independent system operator
IVVC	Integrated Vol/VAR control
IPP	Independent power producer
JI	Joint Implementation
JUCCCE	Joint US-China Cooperation on Clean Energy
KPI	Key performance indicator
LEED	Leadership in Energy and Environmental Design
MoP	Ministry of Power
NERC	North American Electricity Reliability Council
O&M	Operations and maintenance
OE	Office of Electricity Delivery and Energy Reliability, DOE
NARUC	National Association of Regulatory Utility Commissioners (US)
NERC	North American Electric Reliability Corporation
NIST	National Institute of Standards and Technology (US)
PEV	Plug-in electric vehicle
PFC	Power Finance Corporation
PG&E	Pacific Gas and Electric Company
PHEV	Plug-in hybrid electric vehicle
PLC	Power line carrier
PLC	Programmable logic controller
PMU	Phasor measurement unit
PNNL	Pacific Northwest National Laboratory
PTR	Peak time rebate
PUCO	Public Utilities Commission of Ohio
R-APDRP	Restructured Accelerated Power Development and Reform Programme
RE	Renewable energy
ROI	Return on investment
RTU	Remote terminal unit
SCADA	Supervisory control and data acquisition
SCE	Southern California Edison Company
SEB	State Electricity Board
SERC	State Electricity Regulatory Commissions

SPC	State Power Corporation (China)
T&D	Transmission and distribution
TERI	The Energy Research Institute
TOU	Time of use
USAID	US Agency for International Development
V2G	Vehicle to grid



# Chapter I

## Overview and Background

Utilities around the world are rapidly making the “smart grid” the centerpiece of their infrastructure development plans. But the term “smart grid” seems to have many different meanings. In its *Position Paper on Smart Grids*, the European (Union) Regulators’ Group for Electricity and Gas noted: “There is as yet no internationally unified definition of a smart grid.”<sup>4</sup>

This chapter begins with an overview of the key forces driving the smart grid’s development. It also touches on the role of smart grids in enabling sustainable, low-carbon/high-growth economies.

In the United States, the electric industry emerged as a grid-connected, central station network during the 1920s and 1930s. The shape of the industry had been set decades earlier when George Westinghouse won the battle with Thomas Edison over AC vs. DC power and large central station grid-connected vs. small-scale distributed generation networks. In the following fifty years, technological advances enabled ever-larger power plants to be built at ever lower unit costs. As the industry expanded, the enormous fixed costs of the grid-connected central station network could be spread over many more units of production, further reducing unit costs.

But that has changed.

Nobel laureate Lester Thurow made an interesting comparison between the technological revolution in computing and telecommunications that has been underway since the 1950s and an earlier technological upheaval that revolutionized the world. He was referring to the development of electricity in the late 19<sup>th</sup> century, or “the second industrial revolution,” as he called it.<sup>5</sup>

The new electricity technology turned night into day by providing a better source of illumination and made it possible to locate power sources — and work that needed it — at great distances from rivers that for most of human existence had served as the

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<sup>4</sup> *Position Paper on Smart Grids*, An ERGEG Public Consultation Paper, Ref: E09-EQS-30-04, December 10, 2009, p. 11.

<sup>5</sup> “Building Wealth,” *Atlantic Monthly*, June 1999, p. 57.

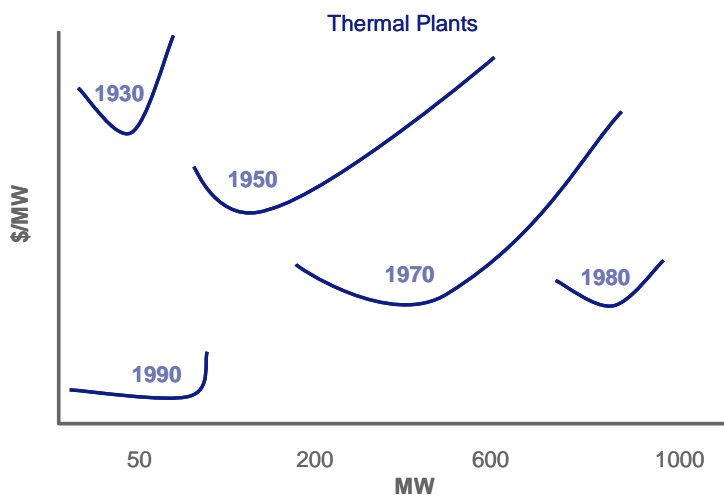
most important source of motive power. This miraculous new technology changed the nature of work radically:

In the steam era, a giant engine powered a central rotating shaft, and machine tools ran off pulleys in long linear factories. In the new electric model of production, small motors could be arranged on the factory floor. It was an early industrial version of what is known today in the computer industry as distributive processing.<sup>6</sup>

After its financing needs were resolved either through the advent of regulated monopolies or direct government ownership, the electric supply industry enjoyed decades of almost uninterrupted growth.

This was the best of all worlds. Economies of scale, spurred by a string of technological breakthroughs, produced step-function improvements in productivity and continuous reductions in unit cost. The result was a string of ever-lower costs per megawatt to build ever-larger power plants, as Figure 1 shows.

**Figure 1. Cost curves for optimal plant size per MW**



Hunt, Sally and Graham Shuttleworth. *Competition and Choice in Electricity*. Chichester: John Wiley & Sons, 1999.

Each reduction in the price of electricity opened up new uses for it, which led to further reductions in unit prices because the high fixed costs of plant investment could be spread over greater sales volumes. This led to a continuing expansion in the application of electricity that resulted in historic growth in customers and sales. The parallels with today's growth in IT are compelling.

It is Lester Thurow (again) who pointed out that — after adjusting for such things as inflation, lumens emitted and bulb life, etc. — a 100-watt bulb has dropped from the equivalent of almost \$1,500 in 1883 to about \$1.50 today. In its infancy, electricity was a luxury. Today, it's a commodity.

<sup>6</sup> Ibid., p. 59.

In the mid-1960s, the first northeast blackout hit New York City and much of the northeastern part of the country, stunning the public. This led to a Congressional study and the formation of the North American Electricity Reliability Council (NERC) to coordinate the industry's planning efforts. It's easier to see in the rear view mirror of history that this event signaled the end of the longstanding trend of declining unit costs.

Next, the joint and reinforcing results of the OPEC cartel, coupled with high inflation and high interest rates, rocked the capital-intensive electricity business. The industry's then-latest technological development (nuclear power) failed to produce lower unit costs. Nuclear power was the largest failure of a technological innovation in electricity production since the earliest days of the industry.

The sharp run up in prices triggered by the OPEC oil embargo but compounded by the failure of nuclear power combined to reduce the average rate of sales growth to a fraction of what it had been. Sales growth plunged from roughly 7% to 9% a year to 2% or less. This led to a severe over capacity situation and, thus, upward pressure on unit costs.

What followed was a massive breakdown in pricing. Regulators and politicians found it difficult to raise prices to cover sharply higher costs. Keeping prices below economic levels contributed to the uneconomic consumption of electricity, the wasteful deployment of high-cost assets, and mounting economic losses.

Those companies operating as regulated monopolies discovered that regulation works better in declining cost environments than when conditions require successive and substantial price increases. Where governmental ownership was the norm, the industry discovered that governmental ownership and financing may have been a good at stimulating the development of early-stage growth but, here too, there was a massive failure in the pricing mechanism. If regulators had difficulty in imposing the necessary increases in tariffs, government-owned utilities found it almost impossible.

The OPEC oil embargo also signaled the finite nature of oil and gas, and unleashed a frenzy of inventiveness aimed at conservation and load management, as energy efficiency and demand-side management (DSM) were then known. Initially, in the face of industry resistance, DSM programs were mandated by regulators. Likewise, energy efficiency (EE) had a tumultuous beginning and many electric industry executives resisted it because it would reduce corporate revenues. As Upton Sinclair famously said, "It is difficult to get a man to understand something when his salary depends on his not understanding it." Ultimately, this too changed.

During the murky transition to liberalized markets after the mid-1980s, something else happened. There was another technological inflection point in power technology. This time, there was a major trend reversal in the link between greater plant size and lower cost per MW. Until then, the bigger the plant, the lower was the cost per MW to build it. Usually, this also meant the lower the cost per MW to operate. Instead of lower unit costs being associated with ever large plants, the optimal plant size (in terms of cost per MW) had dropped to a fraction of what it had been before.

Today, these revolutionizing technologies — electricity and information and communications technology (ICT) — are converging with the descendants of DSM (now considered a sophisticated marketing tool known as “demand response” or DR) and energy efficiency know-how. Collectively, cost-effective, small-scale distributed generation monitored by sophisticated electronic sensors and managed by advanced metering and control systems (all enabled by advances in ICT) are spurring more innovative and cost-effective applications of DR and EE to radically transform the way electricity is produced, delivered and used.

And just in time.

## **1.1 Key Drivers of the Smart Grid**

Today, the electricity supply industry is wrestling with an unprecedented array of challenges, ranging from a supply-demand gap to rising costs and global warming. These and other forces are driving the need to reinvent the business. That, in turn, is driving the need for a smart grid.

There is an emerging consensus on the principal forces driving the transformation of the electricity network worldwide; these are discussed first in this section, followed by an examination of additional factors that spurred the smart grid in OECD countries. Here, the emphasis is on the United States where the smart grid experience has ramped up due to the government's \$787 billion dollar stimulus plan, which includes a specific tranche of grant funding for smart grids.

India has limited experience with smart grid deployments and advanced metering, especially for small consumers and farmers. The factors that will drive India's adoption of smart grids include the need to reduce technical and commercial losses, resolve its chronic supply-demand gap, and find a way to “leapfrog” into a more advanced electricity supply solution to satisfy its sustainable, low-carbon, high-growth economic development goals. The drivers for India are also discussed in this section.

## Global drivers

Three main factors are driving utility deployments of the smart grid:

**Unrelenting increases in electricity demand.** Rising world population, the growing affluence of emerging nations, and escalating demand for goods and services that require ever more electricity, and the growing need for the unique properties of electricity in an increasingly digital world are all driving the demand for power to unprecedented levels. In India's high-growth economy, for example, the demand for electricity is forecast to grow by an estimated 10% per year until the existing supply-demand gap is closed. In the United States, the growth in peak demand for electricity has exceeded transmission growth by almost 25% per annum. As noted on the main page of the Edison Electric Institute's website, there has been serious under-investment in transmission networks for several decades.<sup>7</sup>

### Electricity is the fastest growing form of end use energy

In the USA, power generation will increase by 77% between 2006 and 2030: from 18.0 to 31.8 trillion kilowatt hours. The fraction of US energy needs met by electricity increased from 20% in 1960 to 40% in 2000 and demand continues to outstrip the growth in production. Globally, non-OECD countries will account for 58% of world energy use by 2030.

US Energy Information Administration, *International Energy Outlook, 2009*.

While many nations struggle to supply enough power to meet their peoples' basic needs, electricity has also emerged as a premium energy source, enabling the proliferation of electronic end-use devices, particularly for computing and communications. This spurred demand for more (and more reliable) electricity.

**Global warming.** There is broad consensus that global warming has already begun to cause serious and lasting damage to the world's ecology. Because electricity production is a major source of carbon emissions, "early adapters" around the world — both governments and corporations — have begun exploring ways to create sustainable, low-carbon, high-growth economies. The smart grid offers the potential to conserve energy, both through reducing demand at peak times and by its ability to deploy renewable energy sources, thus lessening the industry's contribution to climate change.

**An upturn in the trend in unit costs of electricity.** It is becoming more apparent that the long-term trend of rising unit costs of electricity began as long ago as the late 1960s, after nearly a half century of declining unit costs.

Many factors will continue to put upward pressure on costs, including increased commodity prices, especially for oil and gas, plus "dispatchability" and thus lower plant load factors for renewable energy sources, among others. At the same time, a construction cycle of historic proportions is unfolding for utilities to replace and renew

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<sup>7</sup> The Edison Electric Institute is a trade organization representing the investor-owned utilities that provide 80% of the electricity sold in the United States.

the aging transmission and distribution infrastructure, and just as India, China and other high-growth developing economies are aggressively expanding their own power generation.

As a result of the construction boom, the competition for resources — from raw materials to capital and know-how — will continue to intensify, especially as economies emerge from the current downturn. If economies are to flourish, they must maximize output with a minimum of resources. The pressure to use assets wisely will only increase as the cost of capital rises, which is expected to occur when the current recession ends.

In the United States this is taking place against an ominous backdrop. The industry's aggregate credit rating is hovering one notch above junk bond status and the current worldwide recession has brought resistance by regulators, consumer advocates and the general public to rate increases.

## INDIA

### Infrastructure spending is growing

Between 2005 and the end of 2010, China will have spent \$494 billion on infrastructure. India estimates \$250 billion spending for the power sector alone over the next eight years and total spending on infrastructure of \$447 billion for 2006 through 2012. In the US, Southern California Edison has started a \$30 billion, ten-year construction program to replace almost half

## Drivers in OECD countries

In addition to the universal factors above, certain changed realities and problems are setting the stage for smart grids in the mature economies of more developed nations.

**Reliability.** The electric utility industry is facing a decline in quality at the same time unit costs are rising. The United States, for example, has experienced 5 massive blackouts in the last 40 years (3 of them in the last 10 years) that have left a deep scar on the industry and, perhaps more so, society, as well as government and regulators. In the United States, these blackouts led to the codification of reliability standards<sup>8</sup> and the imposition of regulations with stiff penalties<sup>9</sup> to govern the reliability of bulk power supply networks. An important goal of the smart grid vision is a network that can improve outage management performance by responding faster to repair equipment before it fails unexpectedly.

**Efficiency.** The smart grid can improve load factors and reduce system losses. According to the US Department of Energy's (DOE) estimates, if the US electricity

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<sup>8</sup> The US Energy Policy Act of 2005 authorized the FERC to approve and enforce mandatory reliability standards for the bulk power system. Section 215 of the Federal Power Act makes compliance with national and regional reliability standards mandatory and enforceable. In July 2006, FERC certified NERC as the authority to oversee development and enforcement these standards.

<sup>9</sup> In 2009 Florida Power & Light paid a \$25 million fine (out of shareholders' equity) for a breach of NERC's Reliability Standards that caused a blackout for three million of its customers.

system were just 5% more efficient, the energy savings would be equivalent to eliminating the fuel and greenhouse gas emissions produced by 53 million cars.

**Environment.** Emerging and more stringent greenhouse gases limitations, renewable portfolio standards, and energy conservation requirements have become one of the key issues for utilities and are increasingly more ingrained in the environmental corporate responsibility commitments of vendors and industries.

Renewable energy use has been growing rapidly, driven in part by renewable portfolio standards. Much of the recent thrust has been on larger-scale renewable systems, and owing to their variability and intermittency, require increased grid flexibility. Consumer-scale renewables such as rooftop photovoltaics are also expected to take off. On a distributed scale, these energy sources require “smarter” grids to meet safety, reliability, and control requirements.

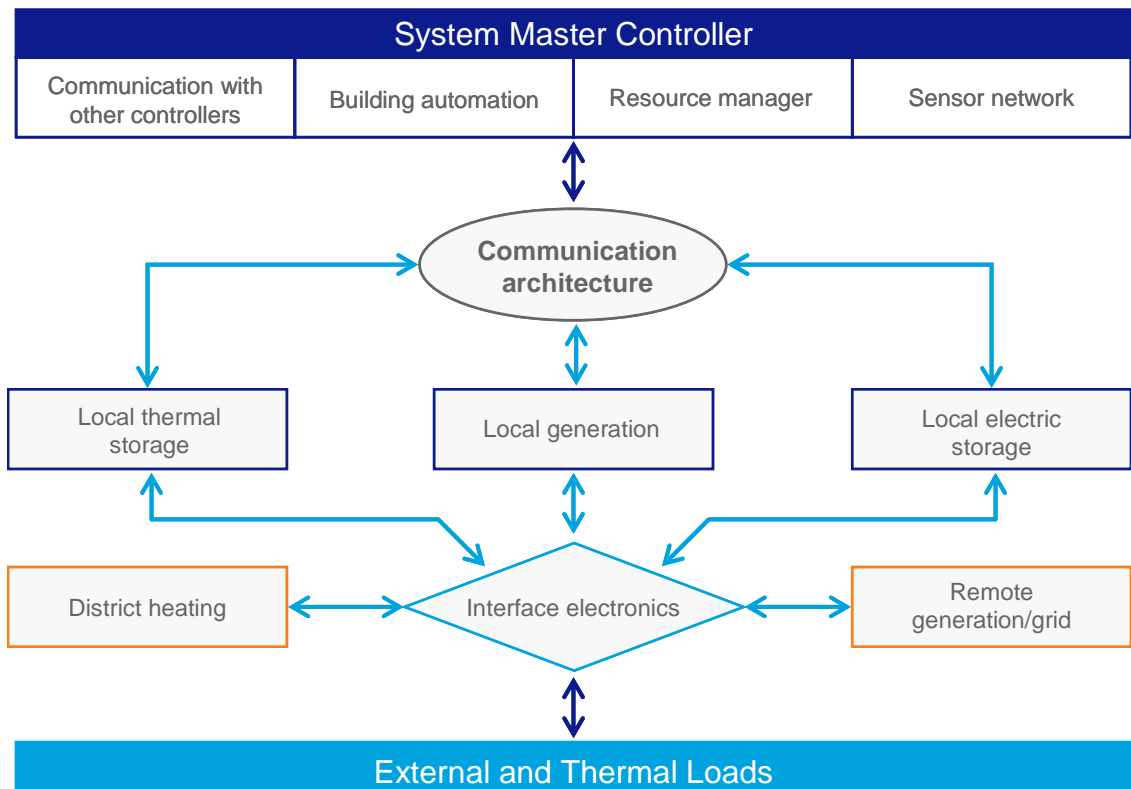
As noted in a book jointly authored by the retired CEOs of Motorola and the Electric Power Research Institute, a smart grid should ideally consist of clusters of micro-grids that exist in a symbiotic relationship with the traditional large-scale grid.<sup>10</sup> These micro-grids could be — and, the authors argue, should be — based on small-scale renewable energy sources. Figure 2 depicts this concept.

The enabling ingredient consists of sensors and an electronic control system that would provide the communications and control capability for the smart micro-grid and that also would enable it to interact with the larger (host) grid. The two grid networks would work in concert to achieve maximum reliability and serve the unique needs of different customers at minimum cost.

**Renewable energy use is becoming a necessity, but ...**

Using more renewable energy will put upward pressure on unit costs. Renewable energy doesn't have the same operating characteristics, load factors, cost-volume drivers, or “dispatchability” of conventional energy, especially base load plants. Renewable energy will stress transmission grids differently and significant investment will be needed to reconfigure bulk power networks.

<sup>10</sup> Galvin, Robert and Yeager, Kurt, *Perfect Power*, McGraw Hill, 2009.

**Figure 2. Distributed micro-grid power system**

**Cost savings.** Meter reading is a non-trivial component of a distribution utility's fixed monthly costs; typically, the costs of reading a meter are between US \$0.50 and \$3.00. Many US utilities do not read meters monthly. A common practice is to read bi-monthly and estimate usage in the interim month. If there is what is known as a CGI ("can't get in") problem because the meter is located inside the premises and nobody is home (a frequent occurrence in recent decades), the "estimating" could continue (legally) for up to a year. In addition to making meter reading nearly instantaneous, smart metering can synergize with gas and water meter readings, creating additional cost savings and, more important, greater convenience for customers.

With electricity prices set to continue rising sharply, the smart grid will also offer consumers choices that could reduce their bills. It can offer time-of-use and possibly even real-time pricing, as opposed to the flat rate retail tariffs most consumers now pay. When consumers respond to such tariffs through a smart grid, peak load would be reduced, which will improve asset utilization and in turn lower per-unit generating costs.

**Grid improvement.** Electricity demand in the United States is growing much faster than the transmission system. Deregulation has also increased the long-distance transmission of power, which is increasingly sourced from greater distances, driven by economics, rather than security and performance needs as in the past. In the words of one retired utility CEO: "The U.S. transmission system is under tremendous strain and only marginally stable. It was designed as a regional system and has been forced to



function as a national system, a function for which it was not designed and does not handle very well.”<sup>11</sup> The smart grid will improve the grid’s resilience and robustness.

**Technological advances.** The advances in computing and telecommunications during the last half century have affected almost every facet of life. One reason the smart grid is taken seriously is because advanced computing and telecommunications have made it possible. As a network, the electricity industry has always required measurement, making it an ideal candidate for such advanced technology.

In a fundamental sense, the industry needs a breakthrough to enable it to rebalance the value equation it presents to customers. Costs are headed up while reliability is slipping. The recent advances in computing, telecommunications and metering have not arrived too soon. The smart grid also presents an opportunity to bundle “in-home intelligence” offerings, such as healthcare and home monitoring.

**Improved customer satisfaction.** If its costs cannot be driven down, the utility industry will need to improve the quality of service. As former Harvard Business School Professor Ted Levitt noted, it is possible to augment the commodity value of a utility service.<sup>12</sup> If done successfully, this will result in an increase in the “perceived” value of the product or service. The electric industry needs an increase in perceived value to improve its value offering. Because the smart grid promises to give customers more control over their use of electricity, it offers a way to increase perceived value. It could enable customers to minimize the total amount of their bills. So even though unit prices may not go down, the total size of a customer’s bill could be minimized if not absolutely reduced. And the total amount of a bill, surveys show, has a much bigger impact on customer satisfaction than unit price.

**Electric vehicles.** According to the DOE, the smart grid’s single biggest potential for delivering carbon savings is in providing cost-effective and increasingly clean energy for plug-in electric vehicles (PEVs) and their hybrids. PEVs can be plugged into a standard household electrical outlet to recharge their batteries. Capable of traveling up to 40 miles in electric-only mode, the majority of PEVs operating on battery power would meet the daily needs of most drivers.

Compared with a current hybrid, a PEV with an electric-only range of 20 miles could reduce fuel use by about one-third according to a report by the American Council for an Energy-Efficient Economy.<sup>13</sup> The Electric Power Research Institute estimates that the same PEVs could reduce fuel consumption by about 60% compared with non-hybrid vehicles.<sup>14</sup>

Although electric vehicles are not yet available on a large scale, a number of grid-connectible vehicles are anticipated to join the US fleet in the next five years. The

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<sup>11</sup> Wayne Brunetti, former CEO, Xcel Energy, 2002, quoted in Warren Causey, “Transmission Strains,” *EnergyBiz Insider*, Feb. 8, 2010.

<sup>12</sup> Theodore Levitt, *The Marketing Imagination*, The Free Press, 1983.

<sup>13</sup> <http://www.eei.org/ourissues/EnergyEfficiency/Pages/Technologies.aspx>.

<sup>14</sup> *Ibid.*

technology is still expensive, mainly due to the cost of batteries, but the US Government is supporting the development of storage technology. An increase in production volumes would also help lower unit costs.

An intriguing addition to the potential of PEVs is that, while most of the discussion up to now has centered on “plugging the (electric) car into the house,” there is a nascent but growing discussion about “plugging the house into the car.” In other words, the collective storage capacity of PEVs could serve as reserve storage capacity for a micro-grid to help balance an unanticipated outage or shortfall in supply.

As ZigBee Alliance<sup>15</sup> chairman Bob Heile said, “American consumers are going to have to live with the interactive nature of the smart grid and the overwhelming fact that power generation will never keep up with future demand...Even if utilities pursued new power generation by every means, American attitudes towards nuclear power, not-in-my-backyard sentiments and demands of the Clean Air Act will constrain new generation to lag behind demand ... We can't build new power plants fast enough, even without the transportation sector going electric. With EVs in the mix, demand will be huge.”<sup>16</sup>

## Drivers in India

Six factors will drive the adoption of the smart grid in India:

**Supply shortfalls.** Demand, especially peak demand, continues to outpace India's power supply. The increasing affordability of household appliances is adding to the burden on the grid. Official estimates of India's demand shortfall are 12% for total energy and 16% for peak demand. Managing growth and ensuring supply is a major driver for all programs of the Indian power sector.

**Loss reduction.** India's aggregate technical and commercial losses are thought to be about 25-30%, but could be higher given the substantial fraction of the population that is not metered and the lack of transparency. While a smart grid is not the only means of reducing losses, it could make a substantial contribution.

**Managing the “human element” in system operations.** Labor savings are not a prime driver for the smart grid in India, as contracts for outsourcing are inexpensive. However, automated meter reading would lower recording and other errors — including what are known elsewhere as “curbstone readings” or “shade tree” readings — or even deliberate errors, which are thought to be significant reasons for losses.

**Peak load management.** India's supply shortfalls are expected to persist for many years. A smart grid would allow more “intelligent” load control, either through direct

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<sup>15</sup> ZigBee is an open, global standard for low-power, wireless networks for monitoring and control products.

<sup>16</sup> As quoted in *intelligentutility*, February 12, 2010.

control or economic pricing incentives that are communicated to customers in a dynamic manner. Such measures would help mitigate the supply-demand gap.

**Renewable energy.** India has supported the implementation of renewable energy. Historically, much of its support was for wind power, but the newly announced National Solar Mission and its goal to add 20,000 MW of solar energy by 2020 should be an accelerant. Spurred by environmental concerns and the desire to tap into all available sources of power, this move can also be a smart grid driver.

**Technological leapfrogging.** Perhaps the most intriguing driver for India is the potential to “leapfrog” into a new future for electricity, as it did with telecommunications. Also, the “smart” in a smart grid is ICT — an area of unique capability in India.

## 1.2 What, Exactly, is a Smart Grid?

Simply put, a smart grid is the integration of information and communications technology into electric transmission and distribution networks. The smart grid delivers electricity to consumers using two-way digital technology to enable the more efficient management of consumers’ end uses of electricity as well as the more efficient use of the grid to identify and correct supply demand-imbances instantaneously and detect faults in a “self-healing” process that improves service quality, enhances reliability, and reduces costs. Thus, the smart grid concept is not confined to utilities only; it involves every stage of the electricity cycle, from the utility through electricity markets to customers’ applications.

### Key characteristics of the smart grid

- *Self-healing:* The grid rapidly detects, analyzes, responds, and restores
- *Empowers and incorporates the consumer:* Ability to incorporate consumer equipment and behavior in grid design and operation
- *Tolerant of attack:* The grid mitigates and is resilient to physical/cyber-attacks
- *Provides power quality needed by 21<sup>st</sup>-century users:* The grid provides quality power consistent with consumer and industry needs
- *Accommodates a wide variety of supply and demand:* The grid accommodates a variety of resources, including demand response, combined heat and power, wind, photovoltaics, and end-use efficiency
- *Fully enables and is supported by competitive electricity markets.*

Perfect Power, McGraw Hill, 2009, p. 82.

The emerging vision of the smart grid encompasses a broad set of applications, including software, hardware, and technologies that enable utilities to integrate, interface with, and intelligently control innovations.<sup>17</sup> Some of the enabling technologies that make smart grid deployments possible include:

- Meters
- Storage devices

<sup>17</sup> US Department of Energy, *The Smart Grid: An Introduction*, 2009.

- Distributed generation
- Renewable energy
- Energy efficiency
- Home area networks
- Demand response
- IT and back office computing
- Security
- Integrated communications systems
- Superconductive transmission lines.

### **1.3 Potential Benefits of the Smart Grid**

The smart grid presents a wide range of potential benefits, including:

- Optimizing the value of existing production and transmission capacity
- Incorporating more renewable energy
- Enabling step-function improvements in energy efficiency
- Enabling broader penetration and use of energy storage options
- Reducing carbon emissions by increasing system, load and delivery efficiencies
- Improving power quality
- Improving a utility's power reliability, operational performance, asset management and overall productivity
- Enabling informed participation by consumers by empowering them to manage their energy usage
- Promoting energy independence.

## 1.4 Smart Grid and the Environment

There is a broad consensus that smart grid deployments will provide environmental benefits, including significant reductions in greenhouse gas emissions. EPRI has projected that by 2030, the implementation of a smart grid across the United States would reduce annual greenhouse gas emissions by 60-211 metric tons of carbon dioxide equivalent compared to “business as usual.” This is equal to 2.5 to 9% of the greenhouse gas emissions of the US in 2006.<sup>18</sup>

More than half of the potential emission reductions can be achieved through improvements in end-use efficiency and increased energy conservation enabled by the smart grid, as well as the integration of large-scale renewable energy projects into the grid. Smart grids can bring about environmental improvements by:

- **Managing peak load** through demand response rather than spinning reserves.
- **Reducing transmission losses** through better management of transmission and distribution networks. A recent study shows that a smart grid could reduce transmission and distribution losses by 30% from the business-as-usual case in 2020, the equivalent of \$10.5 billion in energy savings and \$2.9 billion in carbon costs.<sup>19</sup>
- **Monitoring equipment in real time**, which will enable the redirection of power flows in response to early warnings of system problems, detect and remedy faults in a “self-healing” mode and keep important system components operating at high efficiency.
- **Increasing transparency in electricity prices** to help consumers understand the true cost of electricity by time of day. Giving continuous feedback on electricity use could reduce annual CO<sub>2</sub> emissions by 31-114 million metric tons of CO<sub>2</sub> equivalent in 2030 as consumers adjust their usage in response to pricing and consumption information.<sup>20</sup>

### Energy savings and carbon emission reductions enabled by a smart grid

An EPRI analysis indicates that the US energy sector will need to rely on a portfolio of technologies to meet future carbon reduction goals, including energy efficiency, renewables, nuclear, advanced coal, carbon capture and storage, plug-in hybrid vehicles, and distributed energy sources.

The results show what most industry experts agree: energy efficiency is the most technically and economically viable near-term option for the electric power industry to reduce its carbon footprint.

Electric Power Research Institute, *Prism Analysis*, 2008.

<sup>18</sup> <http://www.pewclimate.org/technology/factsheet/SmartGrid>.

<sup>19</sup> The Climate Group, *Smart 2020: Enabling the Low Carbon Economy in the Information Age*, 2009.

<sup>20</sup> <http://www.pewclimate.org/technology/factsheet/SmartGrid>.

- **Reducing new infrastructure construction** by helping optimize the use of existing generation and transmission and distribution capacity. Together with energy efficiency and conservation savings, this will reduce the pace at which new supply and delivery infrastructure must be built to satisfy increasing demand.
- **Integrating more renewable energy sources and energy storage**, to support system operators by providing more real-time information to make decisions on selecting generation from clean energy sources, thus substituting renewable energy when possible. EPRI estimates increased renewable generation enabled by a smart grid could reduce US greenhouse gas emissions by 19-37 million metric tons of CO<sub>2</sub> equivalent per year in 2030.<sup>21</sup>

Based on the rapid growth of renewable generation in a number of countries in Europe, Asia and the Americas, it is clear that the role of smart grid enabling technologies will facilitate the integration of additional renewable energy resources at a faster pace than during the past decade. Figure 3 provides an indication of the significant growth rate of renewable generation.

#### Southern California Edison's plan for a clean energy future

- SCE is doing its part to reduce greenhouse gas emissions by providing customers with energy from renewable resources
- Smart power delivery is needed to manage greater diversity of supply and to optimize existing capacity
- Smart metering enables customers to increase energy conservation and reduce peaks while improving customer service and operational efficiency
- Plug-in electric vehicles will achieve transportation stability and enable distributed energy storage.

A study by the DOE's Pacific Northwest National Laboratory concluded that if 100% penetration of smart grid technologies could be achieved by 2030, a smart grid could reduce energy and CO<sub>2</sub> emissions from America's power sector by at least 12%. It identified nine mechanisms by which smart grids can lower energy use and carbon impacts, and quantified their effects. These mechanisms can be direct or indirect (Table I):

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<sup>21</sup> EPRI, *The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid*. I016905. Palo Alto, CA: 2008.

- Direct mechanisms include adding more plug-in hybrid vehicles and incorporating smart grid-enabled diagnostics in residential and commercial buildings.
- Indirect mechanisms are realized when smart grid capabilities are used to reduce the costs of energy efficiency and renewable energy. An example would be the use of demand-response methodologies and energy storage devices.

Figure 3

### Growth in Renewable Generation



Source: GE T&D Marketing, The smart grid, May 2009.

Table I: Smart grid mechanisms for reducing CO<sub>2</sub>

Mechanism	Reductions in Electricity Sector Energy and CO <sub>2</sub> Emissions (%)*	
	Direct	Indirect
Conservation effect of consumer information and feedback systems	3	--
Joint marketing of energy efficiency and demand-response programs	--	0
Deployment of diagnostics in residential and small/medium commercial buildings	3	--
Measurement and verification for energy efficiency programs	1	0.5
Shifting load to more efficient generation	<0.1	--
Support for additional electric vehicles and plug-in hybrid electric vehicles	3	--
Conservation voltage reduction and advanced voltage control	2	--
Support the penetration of renewable wind and solar generation (25% renewable portfolio standard)	<0.1	5
<b>Total reduction</b>	<b>12</b>	<b>6</b>

Mechanism	Reductions in Electricity Sector Energy and CO <sub>2</sub> Emissions (%)*	
	Direct	Indirect
Assumes 100% penetration of smart grid technologies		
Source: R.G. Pratt et al., <i>Smart Grid; An Estimation of the Energy and CO<sub>2</sub> Benefits</i> , Pacific Northwest National Laboratory, January 2010.		

Also, smart grid deployments could provide added value for the utility industry due to the prospects of the costly emission control measures that many governments are now discussing.

**Challenges to quantifying smart grid benefits.** Environmental benefits will be difficult to quantify due to the complex dimensions of the smart grid and the fact that benefits are often dispersed and therefore not readily identifiable or easily quantifiable. Some other reasons for this concern include:

- Environmental benefits tend to occur due to avoided emissions or offset impacts, which are often difficult to quantify
- The benefits cannot always (or easily) be traced to a single organization
- Benefits will occur outside the boundary of the firm implementing the program
- Environmental benefits accrue over very long time periods.

**The Indian context.** Even with a population of over a billion, India is a relatively low carbon economy — ranking 63<sup>rd</sup> worldwide in per capita emissions and 48<sup>th</sup> in CO<sub>2</sub> emissions per unit of GDP. Furthermore, recent studies commissioned by the Ministry of Environment and

India's nearly 100 GW of thermal power generation currently accounts for nearly 60% of its net power generation and 57% of its total greenhouse gas emissions. Based on current expansion plans, this scenario is expected to persist until 2020.

Forests have found evidence that India is improving the energy intensity of its GDP: in 1980, it used 0.30 kilograms of oil equivalent per \$ of GDP in purchasing power parity terms; today, the comparable figure is 0.16. Most independent projections indicate that India's CO<sub>2</sub> intensity is likely to continue to decline over the 2030-2050 timeframe.<sup>22</sup>

Nonetheless, the potential for offsetting CO<sub>2</sub> emissions in India is high owing to the large opportunities to both lower energy intensity and improve the carbon intensity of its fuel mix. India's commitment to a low-carbon economy will involve major changes to the way it supplies and uses energy. Modernizing and improving the operational efficiency and increasing the proportion of renewable energy in its fuel mix while

<sup>22</sup> Ghosh, Pradit, Ph.D. Distinguished Fellow, The Energy & Resource Institute, *India's GHG Emissions Profile: Results of Five Climate Modeling Studies*. Ministry of Environment and Forests, Government of India, 2009. Also, see *Climate Change Negotiations; India's Submissions to the United Nations Framework Convention on Climate Change*, August 2009.



reducing peak demand (especially for electricity created from fossil fuels) will remain central to achieving the objective of a lower carbon footprint.

Meeting this objective will require a development strategy to design smart grids at the outset, spur more consumer-driven energy efficiency, optimize the sector's fuel mix, and speed the deployment of grid-connected renewable energy sources.

The ideal outcome would be a plan to enable India to "leapfrog" into an advanced electricity supply system without going through the life cycle of the power sectors in mature industrial and post-industrial economies.

# Chapter 2

## The Technology of Smart Grids

A variety of computing and telecommunications technologies can make many of the smart grid's envisioned benefits a reality. A few of these include detecting and quickly responding to power outages, providing consumers with near real-time information on the amount and cost of the power they use, improving the security of the system, and linking all elements of the grid to enable better decision making on resource use. As these technologies advance, they will produce more and better-quality data, which will give utilities new opportunities to improve their analyses of, for example, customer load patterns and tariffs, and thus offer better services to their customers.

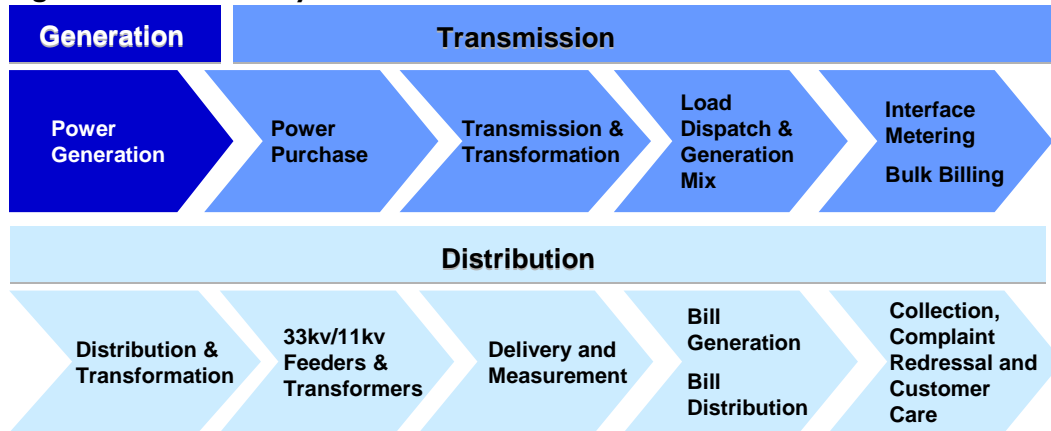
After a brief overview of the electricity value chain and a review of the evolving role of the independent system operator (ISO), this chapter's discussion of smart grid technologies follows the path data will take within the utility system's architecture: from the field device to the computer system at a central location (e.g., the data management system at the utility's headquarters, the customer information and billing system, the dispatch center). For some applications, such as control, data also flow in the opposite direction, from the head of the system to the field device.

### 2.1 The Electricity Value Chain

The process for generating electricity and transporting it through the bulk power supply network (the transmission grid) has been in place for many decades. A critical early step was the adoption of AC power to enable the cost-effective transportation of bulk power over long distances.

This enabled the technical structure of the electric industry that was set almost 100 years ago, namely, large, central-station power plants connected to a transmission grid (the superhighway of the electric system) to move power to load centers where transformers reduced voltage levels to distribution levels for use by customers.

The core process remained largely unchanged, except for technical advances that allowed for ever-larger plants producing power at ever-lower unit costs as well as the continuous enhancement of transmission technology. Figure 4 shows the major elements of the value chain.

**Figure 4: The Electricity Value Chain**

For more than a half century, the vertical integration of all elements of the value chain was under the ownership and control of individual, vertically-integrated companies. This enabled the industry to optimize the economies of scale inherent in the capital-intensive electric supply industry.

Once this began to change, in the 1970s and 1980s, the dynamics of the business began to change as well. Market liberalization, functional unbundling and competition are common features of the changes that are taking place in the power sector in most countries around the world.

Today, the convergence of several major forces is changing the historical structure of the industry. These include: technological advances in ICT, the growing scarcity and increasing price of fuel, and the advent of cost-effective, small-scale distributed generation. The increasing technical efficiency and cost-effectiveness of renewable energy sources, coupled with growing public concern about the effects of climate change, have also brought about change. These are the underpinnings of what is known as the smart grid.

The heart of the smart grid vision relates to metering (and the technical enhancements that have been a work-in-progress for the past 35 years and more) and the distribution sub-sector. Thus, this white paper will focus on them. However, that is not the entire story. As discussed elsewhere in this report, the array of generation options, in terms of fuel sources and sizes, is greater than ever before. The consensus view seems to be that the smart grid will not replace the “legacy” grid, but rather will augment it with micro-grids, with the traditional grid serving as the host.

Nonetheless, the way an integrated smart grid will operate will be different — radically different in the view of many — from the way the industry operated historically. One feature that will change but remain central to the smooth functioning of the electricity supply industry is network operations, or system operations and dispatch, as it was commonly known in the past.

## Network Operations

The most visible differences between today's power networks and the smart grid of tomorrow will be in the distribution area at the customer/network interfaces. However, in the generation and transmission areas, the role of the system operator (which today is already complex) will become even more complex and critical as it will have to ensure the reliable, efficient, and more integrated operation of many additional energy resources.

These additional energy resources include increasing amounts of intermittent solar and wind generation, distributed generation, and demand response options (DR) that are expected to become an integral part of the power system of tomorrow, thanks to the smart grid enabling technologies currently under development and implementation.

System operators will play a crucial role in tomorrow's smart grid. They will need to be supported by even more advanced and sophisticated energy management systems to oversee and manage all available energy resources and transmission constraints in every part of the system under a broad variety of operating and market conditions and possible future scenarios.

## Evolutionary changes in network operations

The traditional system network operation model has evolved from the cost-based, supply-side system dispatch paradigm when companies operated as vertically-integrated utilities. Electric utilities operated large, remote power stations, long transmission lines, and a distribution system primarily designed to deliver power to a fairly static load.

This will change to a more sophisticated market-driven system dispatch with multiple-asset owners with a wide range of commercial interests. This evolution has been underway for several decades and will continue; the pace of change may accelerate. The new approach will have to accommodate more demand-side resources, generation and storage resources on the distribution system, and considerably higher levels of wind, solar and other types of renewable generation.

The traditional or classical system dispatch focused mainly on:

- Unit commitment scheduling
- Economic dispatch
- Automatic generation control
- Grid security
- Local dispatch with some regional implications.

The more sophisticated market-based system dispatch has additional focus areas including:

- Formal day-ahead and real-time tasks

- Unit commitment/economic dispatch with more explicit transmission security constraints
- Checks and balances to ensure transparency and consistency
- Large-scale system dispatch that is regional and multiregional in scope.

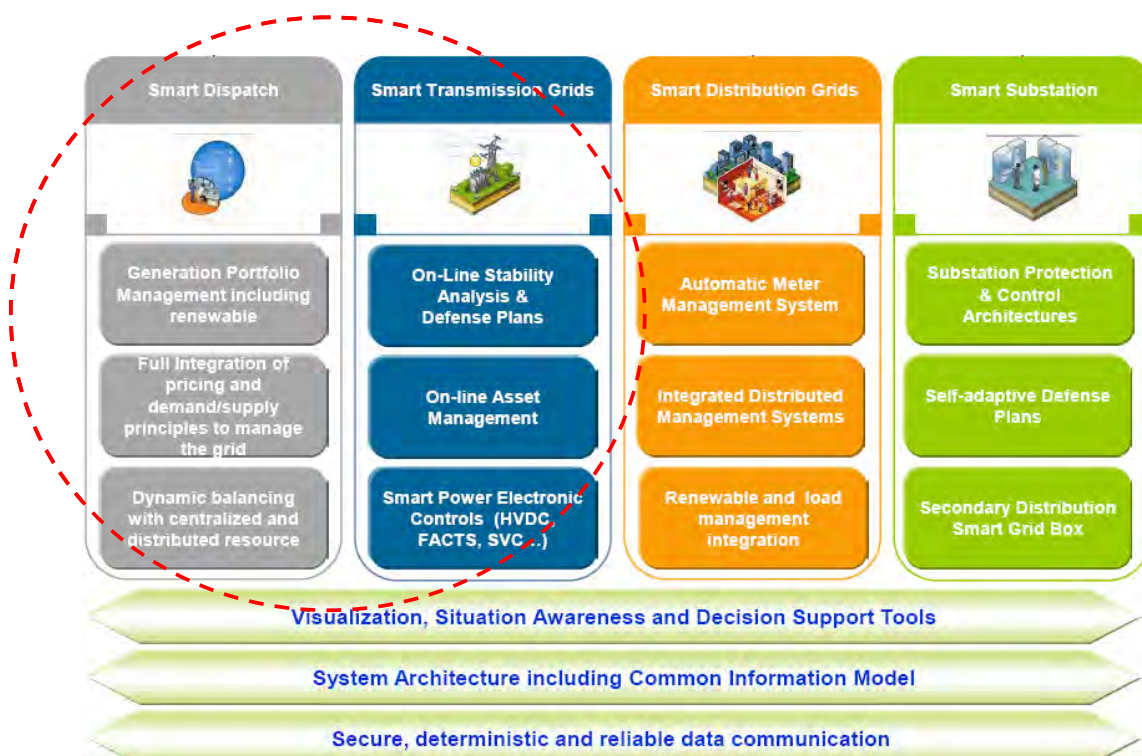
The evolution into a smart grid system dispatch environment will add even more dimensions, which include the following:

- Dynamic balancing of centralized and distributed resources.
- Integration of distributed energy resources and demand response resources.
- Integrating large-scale intermittent renewable generation.
- Increased coordination of renewable generation and storage resources. Given the variability of some renewable generation (e.g., wind, solar), more real-time control will be needed to instantaneously balance supply and demand. New forms of storage resources, such as plug-in electric vehicles, could provide a critical buffer.
- Shifting loads to more efficient generation using demand response and distributed generation and storage with the aim of saving energy and reducing carbon emissions, depending upon the mix of base, intermediate, and peak load generating resources in use at any given time.
- Integrating technological advances in transmission to control power flows (FACTS, SVC, etc.).

Figure 5 illustrates the smart grid environment in which transmission and generation operations are evolving. It provides a view of the supply chain from generation, through transmission and distribution without getting into the purely customer end of the smart grid spectrum.

These changes may require changes to the power system capacity and capabilities. They will also have a significant impact on systems operators and the IT needed to monitor and control the reliable operation of the power system in an optimal economic manner.

In the future, the range of possible scenarios that system operators face will increase dramatically. Electrical variables such as current and voltage will need to be monitored extensively across the network, even at the lowest voltages, and on-line network analysis will have to be included so that automatic or manual actions can be taken to ensure that circuit capacities are not exceeded. These network data will be used locally or regionally to balance generators and demand response resources in real-time.

**Figure 5: The smart grid environment**

Source: Generation Dispatch, AREVA – IEEE Smart Grid Conference January 2010.

Smart grid technologies will allow better management of network flows. Specific network operation solutions include:<sup>23</sup>

- More accurate monitoring of the network and analysis of the operational state of the network, including lower voltage levels
- Increasingly efficient allocation of cross-border interconnection capacity
- Power flow control (e.g., by phase shifting transformers, FACTS and HVDC devices)
- Improved coordination of operations across countries
- Exploitation of real-time thermal monitoring for power cables and/or critical overhead lines
- Increasingly intelligent post-contingency corrective actions and defense schemes
- Activation of pre-contingency preventive actions after exceeding pre-defined stability limits and thresholds
- Improved automation in distribution grids and optimal use of grid reconfiguration after faults.

Table 2 summarizes how smart grid could affect some of the generation and transmission functions of systems operators to ensure reliable and efficient performance of the network.

<sup>23</sup> Source: "Position Paper on Smart Grids," An ERGEG Public Consultation Paper, December 2009

**Table 2: How the smart grid can affect generation and transmission**

<b>Primary Function</b>	<b>Description of Functions</b>	<b>How the smart grid affects these functions</b>	<b>How an intelligent communications infrastructure enables and amplifies the smart grid impact</b>
<b>Generation</b>			
Load control and dispatch	Economical load dispatch scheduling and optimization help to select the right dispatch for the right load at the right time, reducing the cost of generation (startup, operations, and wind down)	The smart grid helps with the scheduling of committed generating units so as to meet the required load demand at minimum operating cost while satisfying all units and system equality and inequality constraints	Economic load dispatch during unforeseen events warrants robust real-time communication infrastructure between the demand and generation functions
Load shaping	Shaping the load during peak demand times reduces the idle and standby generating capacity	Demand-side management helps to manage and accurately estimate demand to as to meet demand without extra generation	Load shaping with DSM involves reliable communication between AMI and CIS (customer information systems) and generation functions
Distributed, renewable generation	The integration of micro-grids as well as customer premises with the utility infrastructure	The smart grid enables distributed generation and automated adjustment of feed-in tariff regulation to receive premiums in the case of forced switch-off of distributed-generation asset for balancing	Infrastructure is needed to confirm, analyze, and dispatch available load to distribution generation sources
Generation equipment maintenance	Diagnoses and maintenance of the generation equipment reduces faults and prevents their propagation	The smart grid helps asset management and conditioning in preventive maintenance. It also helps accessing newly sensed data.	Data from utilities need to be transferred to the generation control center for better equipment conditioning and monitoring.
<b>Distribution</b>			
Transmission-grid monitoring and control	Energy management systems and transmission SCADA for data acquisition needed for the following functions: 1) outage management, 2) Volt/VAR management, 3) state estimation, 4) network sensitivity analysis, 5) automatic generation control, and 6) phasor data analysis.	Automatic regulation of load tap changer and capacitor banks for voltage regulation.  Wide-area phasor management and control for grid optimization and control.  Volt/VAR management using capacitor switches and controls.	Substation automation results in two-way communication between transmission SCADA equipment and the energy management system.  Communication between transmission and generation units is necessary for automatic generation control.
Maintenance of	The transmission control center is the	Automated operations eliminate human	Real-time communication between primary and backup

<b>Primary Function</b>	<b>Description of Functions</b>	<b>How the smart grid affects these functions</b>	<b>How an intelligent communications infrastructure enables and amplifies the smart grid impact</b>
transmission control center	first line of defense for transmission fault detection and prevention	interventions in fault prevention, detection, isolation, and correction	transmission control center, transmission, generation, and distribution units is necessary for control center operations.  Security technology deployment provides for secure data sharing between transmission and other utility functions.
Equipment maintenance	Maintenance of transmission equipment, including breakers, relays, switchers, transformers, and regulators, prevention of faults	The smart grid helps asset management and conditioning for preventive maintenance	Data from transmission equipment need to be transferred to the generation control center for better equipment conditioning and monitoring

Source: Smart Grid - Leveraging Intelligent Communications to Transform the Power Infrastructure

### **What are ISOs doing about the smart grid?**

In the USA, independent system operators (ISO) are already taking leading roles or specific steps in the coordination and or implementation of smart grid projects that would enhance their operations.

The ISO New England will receive \$3.7 million in federal funding to develop a smarter, more efficient energy grid. The U.S. Department of Energy chose ISO New England as one of 100 companies nationwide to receive federal stimulus funds as part of the American Recovery and Reinvestment Act of 2009.



The project's focus is to install 30 synchrophasors to provide enhanced real-time visibility of the electric grid. As a result of this project, systems operators in New England will be connected to increase response time to real time system events and reduce congestion by being able to collect and share synchrophasor and disturbance data with other regions for wide area monitoring.<sup>24</sup>

- Transmission owners in New England will install smart-grid devices at 30 locations across the region to enable enhanced monitoring and control by ISO system operators
- "Synchrophasor" technology will be used as a foundation for the next generation of power-grid situational awareness
- Phasor measurement units will observe system conditions 30 times per second—much faster than conventional technology.

The New England ISO is also implementing several other smart grid projects. One initiative that already is being implemented in New England is demand response. The North American Energy Standards Board is developing demand-response standards, and FERC and the North American Electric Reliability Corporation (NERC) have issued regulations that provide guidance to implement DR capabilities. An ISO New England pilot program on using demand-response resources for ancillary services (e.g., reserves) is just beginning, and the region's ongoing demand response programs continue to deliver results.

In addition, the ISO's Forward Capacity Auction for 2010 produced approximately 1,100 new "megawatts" of capacity obligations from demand resources (representing almost two-thirds of the new capacity that will come online in 2010).<sup>25</sup> Table 3 lists the ISO's current demand-response programs, as well as other types of smart grid projects. While

### Synchrophasor Monitoring

Most monitoring of the grid is based on non-simultaneous average values of measurements taken over a period of several seconds. This is valuable in assessing the steady-state condition of the grid. The monitoring of line voltage phase angles (phasors) can fill that gap, providing the instantaneous measurement of electrical magnitudes and angles that can reveal emerging instability. The deployment of phasor measurement units (PMUs) is growing, along with the development of predictive algorithms that can assess system risk. For example, the Center for Energy Advancement through Technology Innovation has initiated a project to directly input phasor data into an ultra-fast load flow to identify thermal overloads, voltage constraints, and voltage instabilities. Reliable broadband communication channels are needed to accommodate the system-wide deployment of this tool.

Source: National Energy Technology Laboratory, *The Transmission Smart Grid Imperative*, developed for the US Department of Energy Office of Electricity Delivery and Energy Reliability, September 2009.

<sup>24</sup> George, Anne, VP, Corporate Communications and External Affairs, ISO New England, Inc., "Improving Reliability and Integrating New Resources with Smart Grid Technology in New England," February 25, 2010.

<sup>25</sup> ISO New England, Inc., "Overview of the Smart Grid – Policies, Initiatives, and Needs," February 17, 2009.

some of the demand-response programs are well underway, some of the R&D projects will take time to mature.<sup>26</sup>

**Table 3: ISO New England smart grid projects**

<b>Project</b>	<b>Description</b>
Integration of demand resources within ISO/Regional Transmission Organization operations	A project to develop real-time dispatch and telemetering capabilities for demand-response resources with capacity obligations for 2010 obtained via the forward capacity market.
Demand-Response Reserves Pilot Program – Phase II	Thirty-minute real-time demand response program to provide load reduction capability of less than 5 MW.
Demand-Response Programs	Consists of reliability programs where customers respond to system reliability conditions, as determined by the ISO New England control room, and price programs where customers respond to wholesale spot prices, as determined by the market.
Rig Replacement Project	A project to replace the proprietary Qualitrol Remote Intelligent Gateway master communication equipment located at ISO New England with equipment that supports interfacing with industry standard equipment for substation automation.
Alternative Technology Regulation Pilot Program (ATR)	An 18-month program in response to FERC Order 890 that will test the impact of non-generating technologies on the regulation market and allow owners of ATR resources to evaluate the technical and economic suitability of their technologies as possible regulation-service sources. The ATR Pilot Program is limited to 13 MW of participation, and no single entity will be allowed to provide more than 5 MW of regulation service. Eligible non-generating resources include flywheel technology, battery technology, and certain demand-response resources. Resources must be commercially on line by November 1, 2009.
North America Synchrophasor Initiative (NAPSI)	A program sponsored by PNNL to improve the planning, operation, and reliability of the electric power system through wide-area measurement, monitoring, and control. The mission of the group is to create a robust, widely available and secure synchronized data measurement infrastructure for the integrated North American electric power system with associated analysis and monitoring tools. Under NAPSI, over 40 synchronized phasor measurement units (PMUs) have been disbursed across the eastern United States. A super phasor data concentrator collects real-time phasor data at the Tennessee Valley Authority which makes tools available to view and analyze the information. ISO New England has installed two PMUs and is planning to install more as part of this project. Control room operators will be able to view the accurate phasor information, which will assist in understanding system dynamics in real time. The phasor data also will be integrated with the state estimator (SE) to improve the performance of the SE.
Situational awareness (SA)/visualization	The ISO's implementation of advanced alarm management and wide-area power system visualization, for example, and new technologies such as PMUs, interactive 3D and Google Earth, help operators better assess and visualize system operation states. System operators' situational awareness and monitoring capability are important to the reliability and security of power systems. Many advanced technologies in SA and visualization exist, although they have not been used in the power industry.

<sup>26</sup> Ibid.

<b>Project</b>	<b>Description</b>
Real time stability analysis and control	A planned, day-ahead automated and real-time (voltage and transient stability) assessment to improve the accuracy of stability analysis and control options available to operators when instability conditions occur. Currently, the stability limits used in daily operations are based on off-line studies, which are conservative and have numerous uncertainties.
System Black Start and Restoration Automation	A planned on-line decision support tool to help operators to restore the system in real time. System restoration is primarily based on off-line planning and manual work by system operators. An actual blackout may have different characteristics from the off-line studied system.
Advanced Grid Simulator Project	A project to create a simulator based on the current dispatcher simulator, which will simulate the operational characteristics of the grid of the future. It is envisioned that this tool will be built using a 2020 calendar year Network model of the electric grid and will analyze the operational impacts of various alternative resources and smart grid technologies tied to the grid. The tool could also be used to conduct economic analysis at a higher level of detail than what was done in ISO's <i>2007 Scenario Analysis</i> .

ISO New England is sponsoring two smart-grid initiatives with the ISO/RTO Council:

1. Plug-In Electric Vehicles (PEV) Integration Project will:
  - Identify products and services that PEVs could provide under existing market and reliability structures within ISO/RTO markets
2. Smart Grid Standards Development Project will develop a straw standard:
  - Describing smart grid end-to-end process flows, from all service providers between customers and the ISO/RTO
  - Defining and prioritizing the applications and functions that have the most urgent need for standards
  - Developing draft architecture and standards to support information between ISO/RTOs and smart grid aggregators.

Other ISOs like the California ISO and the Electric Reliability Council of Texas (ERCOT) are also actively evaluating options to deal with the expected increased penetration of renewable generation resources, which increases the need for regulation services.

The regulation (of electricity flows) is one form of ancillary services needed to stabilize the grid during normal operations, and the need for regulation is expected to increase in order to manage the planned high penetrations of renewables. An illustrative example of this occurred in February 2008, when the ERCOT had to curtail power to many interruptible customers because wind production unexpectedly and suddenly dropped by 1700 megawatts.

The drop in output had been forecast, but occurred several hours earlier than expected, so base load power plants had not been scheduled for dispatch to provide the replacement energy and the ramping up services to manage the transition. Some generation capacity is always held back and kept "hot" to handle a sudden contingency (known as spinning reserves), but this event exceeded the capacity of the spinning

reserves and fast-start, non-spinning reserves (e.g., gas turbines) to pick up the deficit in output. The situation was made more difficult by the fact that it occurred in February. That is during the off-peak-load season in Texas and many power plants were down for scheduled maintenance.

As a result of the sudden deficit, grid frequency dropped quickly and emergency curtailment contracts, mostly with large industrial customers, were called on to drop load to prevent a potential blackout until additional power plants could be brought online.<sup>27</sup>

## 2.2 Intelligent Electronic Devices

Utilities have used electromechanical devices such as land lines and power line carriers for many years. But today, many of these devices are taking on enhanced, and even new, features and functions in the form of intelligent electronic devices (IEDs). For example, the old single-function electromechanical meters have given way to multi-function electronic meters that can communicate with a central computer. Also, the addition of electronics to the control units of reclosers has enabled them to communicate with a utility's central computers, which automatically store the outage data (e.g., number, duration) needed for reliability and availability indices (SAIDI, CAIFI, SAIFI, etc.).

Remote terminal units (RTUs) for supervisory control and data acquisition systems (SCADA) are smaller and less expensive than before. For this reason, the use of SCADA RTUs is expanding out from the transmission system to the distribution system.

Modern digital relays perform the detection and tripping algorithms that were impossible to implement with electromechanical relays. These relays have hundreds of set points and a broad range of storage history. While this can be addressed with internet protocols, relays still require ongoing operational technology to manage security, firm-ware changes, configuration changes, maintenance, health checks, version control, compatibility testing, and more. Thus, the enterprise information management system must evolve for relays.

Some of the advances India is making in the area of intelligent electronic devices include:

- The Restructured-Accelerated Power Development and Reforms Programme (R-APDRP) is stimulating progress toward 100% metering on distribution transformers and feeders.
- The conversion from electromechanical to static (electronic) metering is progressing at the low-tension level (400/220 Volts) to residential and small commercial customers.

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<sup>27</sup> Pacific Northwest National Laboratory, *The Smart Grid: An Estimation of the Energy and CO<sub>2</sub> Benefits*, January 2010.

- The Bureau of Indian Standards is scheduled to issue a standardized meter protocol in March 2010 to address meter interoperability. The Meter Inter-Operability Solution being promoted by the Indian Electrical and Electronics Manufacturers Association and Device Language Message Specification are also gaining ground.
- Although meter data acquisition and management are still within the purview of meter vendors, which is hindering the interoperability of the products of different meter suppliers, R-APDRP is working on a holistic approach to meter data management.

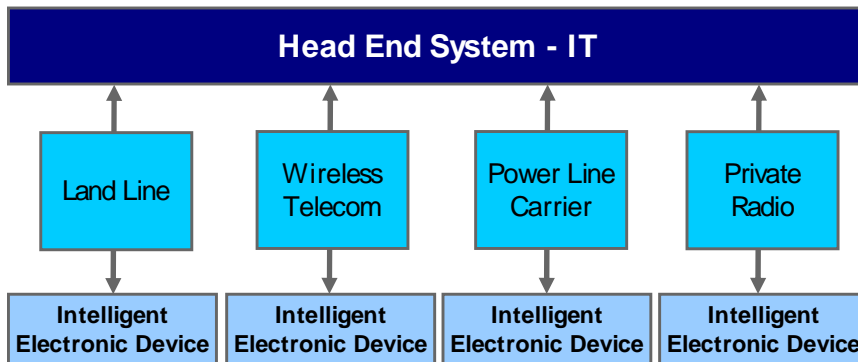
## 2.3 Telecommunications

The core of the smart grid transformation is the use of intelligent communications networks and systems as the platform that enables grid instrumentation, analysis, and control of utility operations from power generation to trading, and from transmission and distribution to retail.

Telecommunications channels can be divided into four categories:

- **Land line:** this includes analog subscriber lines, digital subscriber lines, coaxial cable, and fiber optics
- **Wireless:** this includes cell phone communications systems (both the GSM/GPRS/EDGE method and the CDMA method) and Wi-Fi
- **Private radio:** this includes trunk mobile dispatching channels and meshed meter networks
- **Power Line Carrier:** this encompasses traditional power line carriers between substations and the new technology of broadband-over-power line at the distribution voltage.

A smart grid system could be constructed from just one of these telecommunications technologies, but a utility will often use two or three in order to add more reliability to its service territory coverage.

**Figure 6. Telecommunication technologies for the smart grid**

### Considerations in selecting telecommunications technologies

Telecommunications is critical to a power system because it serves as a backbone for information exchange, which helps the utility's delivery performance and resilience. Combined with distributed intelligence, telecommunications make it possible to report and resolve grid issues in real time (self-healing). In addition, the information communicated by intelligent electronic devices alerts operators to problems. It is thus important to evaluate the system's reliability, security and availability, as well as technology cost, when choosing telecommunication methods.

Scalability is another important consideration in choosing telecommunications technologies. With smart metering, an advanced infrastructure of interval meters and two-way communication systems serves as a gateway for distribution company-customer interaction. This integration brings with it an exponential growth in the amount of data that must be gathered, stored, and transformed in near real-time for intelligent responses and decision support. Thus, the ability to scale a communications method also becomes an important parameter.

### Telecommunications in India

The telecommunications emphasis in India is on mobile phones, which are more reliable and have good coverage in urban areas, but do not have full coverage or enjoy network reliability in rural areas. In urban areas, mobile network congestion (the spectrum for unlicensed radio bands is also becoming crowded) is a challenge because the smart grid requires voluminous data over short intervals. Although communication costs, especially those for general packet radio service (GPRS), have dropped dramatically, the overall quality of the infrastructure to support them is improving only slowly. However, it is possible to transmit smart grid and smart meter data during off-peak times in the mobile network, thus improving the load factor of the mobile telecommunications network. India's electric utilities can explore time-of-use tariffs with their mobile phone counterparts in order to shift the mobile phone load.

Programmable logic controllers<sup>28</sup> (PLCs) present their own set of challenges due to the quality of cable and joints, resulting in poor communication speeds. PLCs do, however, have an advantage when an electric utility has a good PLC network and owns these assets. Because the utility is responsible for maintaining the PLCs and the PLC signal goes everywhere the electric utility wants it to, it could use the PLC as the option to install a smart grid device or smart meter and save on recurring costs.

Wide Area Network and expanded advanced metering infrastructure implementations are also underway in India. R-APDRP will be able help demonstrate the reach, reliability and scalability of communication systems to meet these requirements. This will help define gaps and requirements for smart grid telecommunications. In addition, it will help define the migration path from legacy systems to standards based on smart infrastructure, leading to the most cost-effective hybrid model.

Both government-owned and private telecommunication service providers are taking single ownership of their telecommunications systems and will require an approach for gearing up to meet the needs of the distribution companies. This will be critical in large-scale smart grid implementations, which need integrated communications networks.

With telecom utilities learning to adapt and industry supporting them to develop end-to-end networking solutions, a fundamental platform will evolve for utilities to improve their energy efficiency, security and service innovations for electrical grids. Companies like Cisco are sharing their networking expertise with leading utility providers around the world to build standards based on interoperable platforms to provide efficient backhaul communications smart meters that will integrate proprietary solutions in the overall smart grid platform.

According to Carnegie Mellon University and other leading research centers, 49% of cyber security breaches involve physical security. Secure standards-based data center portfolios are being enabled to use sophisticated data collection techniques and storage solutions for grid analysis and subsequent optimization. Software development companies such as Accenture, Capgemini, HCL, Infosys, IBM, OATI, Oracle, and Wipro, along with power and utility integrators such as Areva, General Electric, Schneider Electric and Siemens, are working with a host of smart metering, grid automation, business and home automation technology companies in collaboration with connectivity and transport service providers such as Cable and Wireless, and Verizon, to develop solutions.

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<sup>28</sup> A power line communication or power line carrier (PLC), also known as power digital subscriber line, is a system for carrying data on a conductor that is also used for electric power transmission. Broadband over power lines use PLC by sending and receiving information-bearing signals over power lines to provide access to the Internet. Electrical power is transmitted over high-voltage transmission lines, distributed over medium voltage, and used inside buildings at lower voltages. Power line communications can be applied at each stage. Most PLC technologies limit themselves to one set of wires (for example, premises wiring), but some can cross between two levels (for example, both the distribution network and premises wiring). Typically, the transformer prevents propagating the signal so multiple PLC technologies are bridged to form very large networks.

Table 4 presents the key characteristics of the major telecommunications technologies available in India.

**Table 4: Features of major telecommunications options in India**

<b>Technology Capability</b>	<b>Land Line</b>	<b>Wireless Telecom</b>	<b>Power Line Carrier</b>	<b>Private Radio</b>
Infrastructure available in India	Remote area connectivity not available everywhere	Available also in remote areas. Connectivity improving	Not widely used in India until now	Remote area connectivity may not be available and point-to-point networks would need to be established
Cost of transferring data	Low	Low (based on transmission during off-peak time)	Low (different standards must be implemented first so initial cost may be high)	Free
Reliability	Low (due to risk of physical damage)	High	Low (due to use of newer and untested technologies)	High
Risk involved	Physical damage	High traffic during day-time	Newer, relatively untested technology	Onsite support
Scalability	High (major investment needed)	Low (bandwidth in wireless domain is limited, but with 3G near this may not be a concern)	High (major investment needed)	High (regulatory concerns and initial high costs are barriers, technology is not a barrier)

## 2.4 Information Technology

The head-end system is the apex node of the network; it consists of the telecommunication system and field devices. The role and function of the head-end system vary depending on the system's application (for example, metering for billing, SCADA, automatic generation control with economic dispatch, metering for load research, demand-side and load management, load shedding, disconnection and reconnection as part of billing, energy accounting, and SAIDI, SAIFI, and CAIDI indices).

The size of the head-end system is usually in proportion to its position within the utility hierarchy, with systems at the apex usually being the largest. System size (number of file servers, amount of storage, etc.) decreases for systems in the second and third tiers of the hierarchy.

This combination of growing technology in distribution management and operations is leading to an emerging need to support the integration of micro grids, open-access



energy systems, and the use of network-controlled devices, and hence, a need for a converged security infrastructure for all. The first priority is securing these assets of electric power delivery systems, from the control center to the substation, to the feeders and even to the customer meters. This will require an end-to-end secure infrastructure that protects the web of communication assets (control center-based SCADA, RTUs, PLCs, power meters, digital relays and bay control) used to operate, monitor and control power flow and measurement.

## Physical and cyber security

Smart grid communications will play a critical role in maintaining high levels of electric system reliability, performance and manageability. But at the same time, the grid is increasingly subject to attack, as many of the technologies being deployed to support smart grid projects (such as smart meters, sensors, and advanced communication networks) are interoperable and open.

Meeting the critical need for an integrated security infrastructure will require the establishment and implementation of a security framework for managing both physical and cyber security, as well as an accompanying security policy. In addition to reducing the system's vulnerability to physical or cyber attacks, a comprehensive approach to security will help utilities better manage their systems, keep costs lower, and improve the system's resilience against security disruptions and data privacy invasions. This framework should cover:

- Physical safety and security
- Generation plant security
- Substation security
- Utility regulatory compliance
- Identity management
- Access control
- Threat defense
- Wide Area Network security
- Security management and monitoring.

Cyber security encompasses privacy. The Government in India has yet not demonstrated superior cyber security enforcement, and its standards for security are limited.

## Business applications and services

The first priorities in smart grid development are addressing the transmission and distribution infrastructure, the telecommunications network, and data centers (computing platforms). Next, attention should turn to building the right operational systems for automated metering infrastructure, outage information, customer information, geographic information systems (GIS), meter data management, asset management and distribution management. Currently the R-APDRP does not adequately address these systems, which should be viewed from the perspective of overall business applications and workforce management so that India can evolve into transmission and distribution automation, smart meter communications, and business and home energy management applications.

As discussed above, several software companies are working to develop these infrastructures. However, in India infrastructure developments have been restricted to micro grids and pilots in which a zone is ring fenced and then preliminary analytics are done to make business cases for smart metering. Hopefully in R-APDRP, 100%

distribution transformer and feeder metering will be completed, although interoperability issues may still need to be addressed. The Ministry of Power has appointed a task force on the adoption of smart grid technology, and has charged the Central Power Research Institute with helping to finalize standards; the Ministry is conducting capacity building and awareness programs for the adoption of standards, which should be released during 2010.

Indian companies that are developing products for world markets have adopted a standards-based approach for software integration. Significant contributions towards integrated applications are also being made as a result of the focus on utility business applications in R-APDRP, such as enterprise resource planning systems, customer relations management, and meter data analysis solutions. This, in turn, will encourage standards-based provisions for backward compatibility so that it becomes easier to migrate from one technology to another and to make those technologies interoperable.

Software standardization in the distribution sector is being based on International Electrotechnical Commission standards (IEC SG / IEEE SG P 2030), which will help ensure:

- **Interoperability:** The capability of “plug and play” devices and software is important for the field devices, telecommunication channels, and IT system of the head-end equipment.
- **Open architecture:** A service-oriented architecture produces savings in both capital and life cycle costs. Adopting a non-proprietary architecture will eliminate vendor lock-in, be easier to maintain than the architectures of disparate proprietary systems, and will help in the development of uniform systems across enterprises because when vendors compete, innovations result.
- **Based on industry- accepted standards:** Architectures that conform to such standards protect the utility’s investment, reduce the risk of obsolescence, and ensure a smooth migration to future technologies.

Unfortunately, India’s utilities lack the basic hardware and software required to deploy a smart grid. India’s utilities have not adopted large-scale basic enterprise systems or followed a broad IT strategy (the few exceptions are mainly found in private distribution utilities). Most deployments are limited to a few functionalities such as computerized billings and setting up control centers. Several pilot projects have been implemented and most deployments have delivered results, but an integrated approach and road map for taking these pilots to the utility scale are still needed to enable smart grid implementations.

A major hurdle to be overcome in India is that the asset and customer repositories are not being updated. A GIS-based approach is being adopted in R-APDRP, which will require validating and migrating current data to create an integrated customer asset profile. Several aspects of a comprehensive strategy and plan have been addressed in R-APDRP, but successful implementation and a utility-wide scaling plan are absent.

R-APDRP partially addresses customer relationship management, outage management, and work management. From a smart grid perspective, however, power resource management (trading and contracts, settlement and risk) needs to be addressed on a functional level, as do network management at the operations level and home area networks for communications.

At the infrastructure level, the smart home infrastructure (smart thermostats, load control devices, gateways, etc.) has also not been addressed. Government support for these technologies, through incentives and subsidies, will help build meaningful volumes and spur adoption. In summary, India is some distance away from the time when peak power demand loads can be assessed at the customer and cluster levels.

## 2.5 Customer Relations Management

Customer management, particularly regarding increased availability and reduced commercial losses, is key driver for the smart grid. India has a long way to go in customer management because most of its distribution companies are in various stages of updating and organizing their customer information. Under R-APDRP they are investing in business applications that will help integrate the various pieces of customer information over various customer databases.

Utility customers are becoming more demanding and impatient. They expect utilities to produce such benefits as:

- Reduced outages
- Lower bills
- Increased awareness and control over energy consumption through better information on usage patterns (the telecom industry has achieved something akin to this)
- More choices for energy sources along with options to supply energy to the grid
- More green and renewable choices to increase environmental sustainability (this pressure is greater now that the price gap between peak power, solar and diesel generation alternatives is closing).

Integrating customer relations management (CRM) and advanced metering infrastructure (AMI) data will be a key enabler here, as it will help derive the benefits of optimized capacity utilization and system performance. Up-to-date load data at each feeder section are required along with customer load profiles in order to develop auto fault detection, location isolation, and service restoration. In addition such data will help evolve fault isolation and service restoration switching sequences for premium customers. This integration will also enable utilities to set up quick response teams that will improve demand response (DR) and lead to the integration of AMI/DR in systems planning and engineering. Coincident load data for optimized load balancing and the potential for using AMI for end voltage monitoring will help complete the load profile data for estimating and minimizing technical losses.

Currently meter vendors in many Indian states own the meter data. A holistic approach for meter data management will help bridge this gap and build the ability to conduct end voltage monitoring. Thus, knowledge of customers' profiles with their usage requirements and patterns is critical for utilities wishing to implement a smart grid.

Complete knowledge of customers and their needs will also allow utilities to influence consumers to shift peak demand consumption and protect customers from over-consumption. In addition, it will enable utilities to help customers comply with contract fulfillments, environmental and security regulations. This, in turn, will help utilities to manage their assets, improve customer service, and control costs.

An important aspect of CRM is customer awareness (education) and participation. Customers will be important stakeholders in the smart grid and they will need to be more aware of the risks involved. For example, unless availability-based tariff customers modify their usage patterns, they will see higher bills. Also, because smart meters will be more accurate than current electromechanical meters, customers' usage will be tracked more accurately and they may see higher bills. Last, the energy savings accrued through smart grids will need to be distributed and incentives to conserve energy will be needed. Customer participation will be important in all of these activities and will also help improve the smart grid's overall governance and utility-wide implementations.

## **Automated call centers**

The infrastructure set up for automated call centers is being developed under the R-APDRP. These centers will allow utilities to integrate customer information, address customer queries and complaints, and provide basic information about office locations, billing information, bill payment centers, modes, connection status, service levels, planned outages, and information on efficiency programs, among others. These initiatives will help utilities measure and drive customer satisfaction, and make customers more aware of opportunities for energy efficiency. They will also help utilities track consumption patterns and payments. In addition, the databases maintained by the centers would enable quick-start smart grid implementations, through targeted programs for home area networks and smart appliances projects to increase availability and reduce commercial losses.

At present, the complaint handling process in India is weak, resulting in decreased customer satisfaction. However, these centers are helping build better processes and more accountability within the utilities.

## **Utility portals**

Utility portals (interactive websites that are linked to the call center databases and help customers log directly into websites) are being enhanced under R- APDRP. Their objectives are similar to those of the automated call centers and give customers another medium for interacting with the utility. Again, private utilities are leading in this area in

India. Government-owned utilities are also implementing portals, but a few of these have failed due to a lack of training staff and integration of IT into the workflow. Because of this lack of integration, many state-owned utilities find it necessary to maintain a paper-based system as well, resulting in a duplication of effort.

### **Informing customers before and during meter change-out**

The change-out of an existing meter is often a contentious issue for customers, especially when the new electronic meter registers a higher bill. The reasons why customers' bills can be higher after a meter change-out are well known and are not repeated here. In addition, the customer may have to bear some of the costs of the change-out. For example, the customer's electrical installation may not comply with electrical safety codes, and the installation may have to be rehabilitated at the customer's expense.

A customer relations program is needed to alert customers to the upcoming meter change-out. It should spell out what the customer's rights are, explain the long-run benefits of smart meters, and describe how the change-out will be conducted.

### **Resolving bill complaints**

When a new, accurate meter replaces an old, inaccurate or tampered meter, the customer will receive a higher bill. The customer relations program of the utility needs to be ready to address this collateral effect of the re-metering program.

## 2.6 Some Illustrative Applications

This section presents some examples of the application of smart grid and smart metering, and the issues that will likely arise with their implementation in India. The extant literature provides numerous examples and offerings of the features and benefits of smart grids and smart metering. Annex A lists some of the more salient literature.

### Automatic meter reading

Automatic meter reading is often the most widely implemented smart system in a utility. Its contribution to making the grid smarter is that meter data are rapidly and accurately collected. Many countries have adopted this technology to save labor costs, but labor costs are not an important factor in India. However, in India, as in other countries, automatic meter reading facilitates the collection of data that are critical for utility planning and implementation. Such data also improve the inputs to the retail tariff structure, help with regulatory compliance, and help customers better understand their consumption and plan their usage accordingly.

### Remote disconnect and reconnect

The remote disconnection and reconnection of customers who do not pay their bills is an extension of automated meter reading. The meter contains, or controls, a large contactor (relay) that disconnects or reconnects the customer from the head-end system, most often the billing system.

### Outage monitoring and evaluation

SAIDI, SAIFI, and CAIDI are common measures of the power system network's availability and reliability. The collection of the field data to perform these measurements is time consuming, tedious, prone to arithmetic errors, and open to manipulation by personnel who collect the data. Smart devices on the distribution system (meters, reclosers, circuit breaker controllers, etc.) that are equipped with remote reading capability make the collection of field data automatic and accurate. This will help the utility improve its planning process and optimize the resources deployed in power restoration.

## **Mini-SCADA**

In the past, the high cost and large size of RTUs for SCADA limited SCADA systems to the transmission network. As the size of RTUs increases and their costs decrease, SCADA is penetrating the distribution networks.

## **Demand-side management and load management**

Like automated meter reading, demand-side management and load management have long been features of the utility system. As the cost of the field devices for demand-side and load management drops and their functionality increases, these devices will become increasingly integrated into customers' lives.

## **Renewable energy**

Wind generation, small hydro, micro hydro, bio gas generation, bio gas fuel cells, solar and similar supply-side technologies need to be integrated into the power system network. Smart control devices are needed to connect these renewable energy sources to the power grid, and exchange information and commands with the energy dispatch center.

## **Distributed, standby, mini-grids, and off-grid generation**

A large portion of India's energy comes from distributed, standby, mini-grid, and off-grid generation sources. However, as rural electrification extends farther into un-electrified areas, there is a concern that the arrival of relatively inexpensive national grid energy will lead to the abandonment of much off-grid generation. Since there may not be a corresponding increase in national generation, the sudden addition of off-grid load to the national grid will increase load shedding.

The smart grid offers a way to incorporate these sources of energy into the national grid in a rational and balanced way. For example, off-grid generation could be dispatched by the central control center and used only during peak times. Appropriate feed-in tariffs would compensate the off-grid generator for costs, and would shield the pool of customers from adverse pricing by blending the cost of off-grid generation with the average weighted price of electricity used in the tariff. The smart grid can convert this problem into an advantage for India, and changes in regulations and feed-in tariffs can manage the societal aspects.

## **Time-of-use rates**

Time-of-use (TOU) tariffs involve a sharing of some risks between the utility and the customer. During those times of the day when energy is cheap for the utility (early morning hours and weekends), the savings are passed on to the customer. When energy



is expensive for the utility (peak times) the customer experiences the high cost. The objective is for customers to shift their utilization in response to a price signal,

For over two decades electronic static meters have been available to handle TOU tariffs. In fact, they handle very complicated and very extensive tariffs (on peak, shoulder peak, and off peak; fixed and variable holidays; seasonal data capture; etc.). A difficulty that a smart grid can overcome is the effort needed to re-configure the meters on a regular basis, which will allow TOU tariffs to change as rapidly as desired by the utility and customer. The smart grid, with its telecommunication link between the customer information (billing) computer system and the meter in the field, overcomes this.

## Islanding

At the transmission level, large sections of a utility, state, or region may be cut off from other sections in order to preserve the electrical system during major system disturbances and block cascading outages. Such systems have been used for many decades, having been perfected and extensively implemented in Russia before 1990. These protection systems operate very fast, and keep generation and load in balance; when a generating unit trips, a corresponding block of load is immediately tripped. Within minutes other generators increase their output and when spinning reserve and frequency are strong, the load that was shed is reconnected, usually within minutes. The philosophy behind this is to keep most of the electric system operating so that power can be restored quickly and efficiently.

The smart grid can do the same thing at the distribution level, rapidly isolating failed portions of the network and restoring service automatically and rapidly.

## Capacitor control

Capacitor control in the distribution network has a direct and significant effect on customer satisfaction. It also improves utilities' financial performance by reducing a component of technical losses. If capacitor control is implemented poorly, there will be insufficient capacitor support during periods of high demand and low voltage (peak times), and over-compensation during periods of light load and high voltage (midnight to dawn, and weekends).

When integrated into a smart grid, advanced capacitor control by the utility (not the customer) allows the utility to provide the right amount of capacitor injection at the right time. This approach also removes a requirement on customers to install, operate, control, and maintain their own capacitors.

## Demand response

Smart grid applications allow electricity producers and customers to communicate with one another and make decisions about how and when to produce and consume. This

emerging technology will allow customers to shift from an event-based demand response where the utility requests the shedding of load, towards a more 24/7-based demand response where the customer sees incentives for controlling load at all times. Although this utility-customer dialogue increases the opportunities for demand response, customers are still largely influenced by behavioral as well as economic incentives and many have demonstrated reluctance to relinquish total control of their assets to utility companies.

One advantage of a smart grid application is time-based pricing. Customers who traditionally pay a fixed rate for kWh and kW/month can set their threshold and adjust their usage to take advantage of fluctuating prices. This may require the use of an energy management system to control appliances and equipment, and can involve economies of scale. Another advantage, mainly for large customers with generation, is being able to closely monitor, shift, and balance load in a way that allows the customer to save during times of peak load, not only kWh.

Smart grid applications increase the opportunities for demand response by providing real-time data to producers and consumers, but economic and environmental incentives remain the driving force behind this practice. The foundation for this would again be having accurate customer profiles with load, consumption pattern and asset data so as to be able to evolve customer segmentation and develop business cases for supporting each of those categories with different plans and incentives.

Table 5 summarizes the areas in which each of the technologies discussed above makes its greatest contribution.

## Phasor Measurement Units

Phasor measurement units (PMUs) are the most accurate and advanced technology available for wide area monitoring, protection and control. A well-planned, system-wide PMU deployment over optimal system architecture provides several unique advantages, including the avoidance of outages as the result of a true early warning system, congestion mitigation through better system margin management and better “state estimation” for the location marginal pricing that will be increasingly required to enable transmission grids that optimize competitive markets.

### Invisible smarts: Let's talk synchrophasors

Synchrophasors, aka synchrophasor measurement units, or PMUs, have been upgraded with the advent of the civilian use of global positioning system (GPS) to provide near real-time data on wide areas of the grid and its behavior. Before that, PMUs provided forensic data on past events such as blackouts. Today, they can provide the basis for making decisions that could prevent blackouts.

PMUs measure grid conditions about 30 times per second, a considerable improvement over the once per four seconds possible in the past. Each measurement is “time stamped” using GPS so that different utility grids in an interconnection can be compared and realigned. Those comparisons are expressed in degrees, as in a compass bearing. If two interconnected grids are

seriously out of phase, for example, there may be trouble ahead an PMUs can provide operators with timely data to suggest a correction.

PMUs can be discreet, dedicated devices installed at the substation or they can be digital fault recorders (DFRs) or relays already in place and optimized to provide analogous data. So the patchwork of grids that make up an interconnection such as the Western interconnection already have some PMUs in place. Now, more than 800 additional PMUs will be added to the North American bulk power system over three years using federal investment grants.

The transmission operator employing PMUs collects the raw data and “pushes it up” to a regional data concentrator (CAISO in the West, TVA in the East, etc.) that archives and time-aligns the data. That data is fed to applications that translate it into actionable intelligence such as the Real time Dynamics Monitoring System (RTDMS), a phasor application program.

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**Table 5: Technology contributions to the smart grid**

	Availability	Reliability	Reduce operating costs	Reduce commercial losses	Increase electricity supply	CRM applicable
Automated meter reading			■	■	■	■
Remote disconnection and reconnection			■	■		■
Outage monitoring and evaluation	■	■				
Mini-SCADA	■	■	■		■	
DSM and LM			■		■	■
Renewable energy					■	■
Distributed, standby and off-grid generation					■	■
Time-of-use tariffs			■		■	■
Islanding	■	■	■		■	
Capacitor control		■	■		■	
Demand response			■	■		■
Phasor Measurement Unit	■	■	■			

# Chapter 3

## Engineering Economics and Financing

Since the early 2000s, the Government of India's policy has been to balance the development of generation, transmission, and distribution. This policy has served as the touchstone for a number of financing innovations to deal with the power sector's large capital investment deficit: unbundling the vertically-integrated power companies to improve their performance and accountability, attracting increasing private sector participation, expanding all sources of capital market financing (bonds, listings and privatizations), and continuing public and multilateral investments in strengthening and expanding transmission and distribution, in particular. These new capital sources are expected to play a role in smart grid roll-outs in India.

A number of problems, however, will continue to hamper smart grid deployments and must be factored in during project design, including the determination of the financial feasibility of investing in projects.

The poor balance sheets of many electric utilities, coupled with the lack of an efficient procurement and project management culture at most State Electricity Boards, has resulted in inadequate investments in state transmission and distribution systems. In addition, many of the utilities that are undertaking projects under the Restructured Accelerated Power Development and Reform Programme lack management experience with R-APDRP; this lack of experience spans the full project cycle, from formulation to appraisal, procurement, construction supervision and commissioning. As a result of the lack of automation (computerization and telecommunications) in their businesses, the discoms also have a serious skills deficit in information and communications technology (ICT). Many will also be hard pressed to

In the United States, the Electric Power Research Institute developed a *Methodological Approach for Estimating Benefits and Costs of Smart Grid Demonstration Projects*, with joint funding from the US Department of Energy (DOE). The report, issued in January 2010, shows the importance EPRI and DOE place on cost-benefit analysis (CBA). Our interpretation of this action is that they (correctly) realized that CBA may well become the pivot point in the assessment of proposed smart grid projects. If too narrow an approach is taken, some otherwise worthy projects may be rejected. The comments in this engineering economics chapter are consistent with the findings of EPRI's report.

attract qualified talent to join bureaucracies that are still dominated by work cultures and practices of the past.

The barriers to implementing smart grid concepts in India are much the same as the barriers that have slowed power sector reform since market liberalization was first announced almost 20 years ago. With the government already running severe losses on its current power subsidies, the additional cost of moving to a smart grid will be problematic. If there are only limited fiscal benefits from smart grid investments in the short term, it will be a challenge to get a commitment for significant additional funds from the government. Hence, innovative financing alternatives will have to be explored.

Some possible avenues for funding include a combination of grants, self-funding, and public-private partnerships. Ultimately, however, the widespread implementation of a broad interpretation of the smart grid vision may be held back by the sector's lack of commercial viability.

In India, smart grid projects will be subject to the same issues that face conventional utility capital projects. Cost-benefit methodologies have been established for energy efficiency and renewable energy projects, and these can serve as a starting point for determining the viability of smart grid projects.

### **3.1 Engineering Economic Issues**

The smart grid is a system that enables two-way communication between consumers and electric power companies. In this system, electric power companies receive consumer's information in order to provide the most efficient electric network operations. At the same time, consumers get better access to data to help them make intelligent decisions about their consumption. Thus, project economics will need to reflect the benefits to both consumers and utilities.

A top-down review of "typical" smart grid projects reveals that a large capital outlay will usually be required to fund the various aspects of implementation. The primary costs will include automated metering infrastructure, customer systems such as in-home displays and digitally controlled appliances, and electric distribution and transmission system grid automation.

The primary benefits include lower operating and maintenance costs, lower peak demand, increased reliability and power quality, reductions in carbon emissions, expansion of access to electricity, and lower energy costs from fuel switching and home automation.

### **3.2 Traditional Cost-Benefit Analysis**

Although many countries have been discussing the concept of a smart grid for several years, projects are only now beginning to move forward. In the United States, where

many projects are in various stages of preparation, most project sponsors are using traditional cost-benefit approaches to gauge their projects' viability.<sup>29</sup>

The suggested cost-benefit analysis methodology described here has three main objectives:

- Develop a common cost-benefit methodology that can be applied across all smart grid demonstrations (approved by financing sources and regulators)
- Publish an agreed upon methodology, including underlying rules and assumptions
- Ensure that the methodology can easily accommodate changes and expansion.

In order to work out the engineering economics of smart grid projects, one needs to consider various scenarios with selected elements being implemented in a phased manner.

This section presents a high-level framework for identifying the typical costs attached to the various elements of smart grid and the potential benefits associated with its projects. This framework must be customized for each project.

While still new enough to lack a universally agreed upon definition, some typical project components of a smart grid include:

- **Smart power meters** featuring two-way communications between consumers and power providers to automate billing data collection, detect outages, and dispatch repair crews to the correct location faster. This one element — sensors and two-way communication and control equipment — is central to most definitions. Smart measurement and metering also often embrace smart substation and smart distribution (together known as distribution automation). Collectively, these elements represent the *de facto* core of most programs that are being proposed or implemented.
- **Smart substations** include the monitoring and control of critical and non-critical operational data such as power factor performance, security, and breaker, transformer and battery status.
- **Smart distribution** is self-healing, self-balancing and self-optimizing, including superconducting cables for long-distance transmission, and automated monitoring and analysis tools capable of detecting or even predicting cable and other failures based on real-time data on weather, outage history, etc.
- **Smart generation** capable of “learning” the unique behavior of power generation resources to optimize energy production, and to automatically maintain voltage, frequency and power factor standards based on feedback from

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<sup>29</sup> The American Recovery and Reinvestment Act (ARRA), known as the Stimulus Plan, provided \$4.5 billion in grant funding for smart grid investments for qualified applications that were approved by the US Department of Energy.

multiple points in the grid.

- **Universal access to affordable, low-carbon electrical power generation** (e.g., wind turbines, concentrating solar power systems, photovoltaic panels) and storage (e.g., in batteries, flywheels or super-capacitors or in plug-in hybrid electric vehicles).
- **Intelligent appliances** capable of deciding when to use power based on pre-set customer preferences. This can go a long way toward reducing peak loads, which has a major impact on electricity generation costs by alleviating the need for new power plants and cutting down on damaging greenhouse gas emissions. Early tests with smart grids show that consumers can save up to 25% on their energy usage by simply providing them with information on that usage and the tools to manage it.

## Cost analysis

The typical costs associated with the smart grid are categorized according to the elements and functions they provide. The major cost items are:

- Cost of project design and feasibility studies
- Cost of program management
- Cost of setting up infrastructure to enable two-way communications between the consumer and the utility; this will include the costs of the communications medium (e.g., fiber optic, PLC), installing sensors, monitoring equipment, and software, and an online tracking mechanism
- Cost of purchasing and installing the smart meters
- Costs for in-home devices and customer information systems
- Training and development of key staff.

It is difficult to provide a more specific sense of costs because most of the utilities in the US and Europe are still in the initial stages of implementing smart metering, so the actual costs of deployment are not available. However, from the estimated cost proposals submitted by various US utilities (such as PG&E and Allegheny Power), the total capital invested tends to vary from **\$250 to \$600 per meter installed**. It is notable that the range provided by utilities is wide and hence estimating a reasonable cost based on this range is not prudent.<sup>30</sup>

Some key variables that can have a major impact on costs are also worth noting:

- Size of the project, which is determined by the number of transmission and distribution lines in the grid, and number of buildings to be covered
- Strength and compatibility of the existing infrastructure, if the project is not a green field project

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<sup>30</sup> Furthermore, it may be possible to manufacture meters with comparable features and functionality, but at a much lower cost, in India.

- Ability to forecast the schedule of generation for that area.

## Benefits analysis

The move to a smarter grid promises to change the power 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.

The smart grid envisages providing choices to every customer and enabling them to control the timing and amount of power they consume based upon the price of the power at a particular moment of time. Some basic benefits of a smart grid are:

- **Peak load reduction.** Smart grids can use time-of-day price signals to reduce peak load – this benefit has particular importance for Indian utilities coping with urban loads.
- **AT& C loss reduction.** For Indian utilities, this is a major driver from a commercial and regulatory point of view. For distribution operations with high losses that are upgrading meters and other equipment, companies may consider smart grid components as a way to build in additional communication technology and upgrades.
- **Self-healing.** A smart grid automatically detects and responds to routine problems and quickly recovers if they occur, minimizing downtime and financial loss.
- **Consumer motivation.** A smart grid gives all consumers – industrial, commercial, and residential – visibility into real-time pricing, and affords them the opportunity to choose the volume of consumption and price that best suits their needs.
- **Attack resistance.** A smart grid has security built-in from the ground up.
- **Improved power quality.** A smart grid provides power free of sags, spikes, disturbances and interruptions. It is suitable for use by the data center, computers, electronics and robotic manufacturing that power an economy.
- **Accommodation of all generation and storage options.** A smart grid enables “plug-and-play” interconnection to multiple and distributed sources of power and storage (e.g., wind, solar, battery storage).
- **Enabled markets.** By providing consistently dependable operation, a smart grid supports energy markets that encourage both investment and innovation.
- **Optimized assets and operating efficiently.** A smart grid enables the construction of less new infrastructure and the transmittal of more power



through existing systems, thereby requiring less spending to operate and maintain the grid.

These benefits can be combined under three broad categories:

**Economic benefits.** Five types of economic benefits can be derived from the smart grid.

- **Cost savings from peak load reduction.** Smart grids bring about a reduction in per-unit production costs due to demand response / load management programs.
- **Reductions in capacity costs.** These can be attributed to residential customer reductions in demand during the 50 to 100 hours of highest system demand each year (critical peak periods) in response to some form of dynamic pricing, either peak time rebates or critical peak pricing.
- **Deferred capital spending for generation, transmission, and distribution investments.** By reducing peak demand, a smart grid can reduce the need for additional transmission lines and power plants that would otherwise be needed to meet that demand.
- **Reduced operations and maintenance costs.** Smart grid technologies allow for remote and automated disconnections and reconnections, which eliminate unneeded field trips, reduce consumer outage and high-bill calls, and ultimately reduce O&M costs. Reduced costs can also result from near real-time remote asset monitoring, enabling utilities to move from time-based maintenance practices to equipment condition-based maintenance.
- **Reduced industrial consumer costs.** Industrial and commercial consumers could benefit significantly from a smart grid. Electric motors account for about 65% of industrial electricity usage because they power virtually every moving process necessary for process industries, including power generation, oil and mining extraction, and pharmaceuticals, as well as for the compression and pumping needed for heating and cooling buildings. Motors are also essential to India's growing manufacturing sector for automobiles and other products. Small improvements in motor efficiency can generate significant savings in energy costs, but more sophisticated motors require higher-quality power.

**Service benefits.** The smart grid will bring benefits to residential, commercial, and industrial consumers alike:

- **Improved reliability.** A smart grid enables significant improvements in power quality and reliability. Smart meters will allow utilities to confirm more easily that meters are working properly. Two-way communications all across the grid will let utilities remotely identify, locate, isolate, and restore power outages more quickly without having to send field crews on trouble calls. A smart grid

could eliminate up to 50% of trouble calls in a mature power sector.

- **Increased efficiency of power delivery.** Up to a 30% reduction in distribution losses is possible from optimal power factor performance and system balancing. Today, this problem is managed to some extent by controlled or automated capacitor banks on distribution circuits and in substations. But the control of these devices can be greatly improved with better real-time information through a smart grid.
- **Consumption management.** Smart grid technologies offer consumers the knowledge and ability to manage their own consumption habits through in-home or building automation. Advanced meters tell consumers how energy is used within their home or business, what that usage costs them, and what kind of impact that usage has on the environment. They can manage their usage interactively or set preferences that tell the utility to automatically make adjustments based on those choices.
- **Improved system security.** Utilities are increasingly employing digital devices in substations to improve protection, enable substation automation, and increase reliability and control.
- **Enhanced business and residential consumer service.** The smart grid will allow automatic monitoring and proactive maintenance of end-use equipment, which can be an avenue for energy savings and reduced carbon emissions. Equipment is sometimes not properly commissioned when it is first installed or replaced. With the two-way communications of a smart grid infrastructure in place, a utility could monitor the performance of major consumer equipment through advanced interval metering and on-premise energy management control systems. The utility would thus be able to advise the consumer on the condition of specific facilities.

**Environmental benefits.** According to recent studies, the smart grid can reduce emissions at a lower cost than many of the newest clean energy technologies. The smart grid will reduce emissions in four ways:

- Enabling the integration of clean, renewable generation sources
- Reducing electrical losses
- Increasing the penetration of distributed energy resources
- Increasing energy conservation through feedback to consumers.

More specifically, emission reductions will come from:

- Expanded renewable resource integration, enabled by a smart grid through its “plug and play” capability.
- Reduced transmission and distribution electrical losses, as generation is placed closer to the load, load curves are flattened, flow patterns are optimized, more efficient components are deployed, and as power quality (e.g., harmonics and

phase balance) are improved. Reduced losses translate to a corresponding reduction in gross generation, and hence, less emissions.

- Improved central generation efficiency, as units face flatter load curves.
- Increased penetration of distributed energy resources, including combined heat and power, and plug-in hybrid electric vehicles. These resources could provide fine-tuned support for the grid and ancillary services to increase efficiency and reduce energy-consuming spinning reserves.
- Increased conservation, as software provides feedback information about emissions to the marketplace and customers. This will also encourage consumers to invest in energy efficiency and demand response options to save money.
- Reductions in other major pollutants (e.g., nitrous and sulfur oxides, particulate matter, ozone) due to conservation and the use of cleaner energy sources.

## Calculating project costs and benefits

The methodological approach for calculating smart grid project costs and benefits has several steps:

- Identify the assets/elements that are deployed for the smart grid's systems
- Assess the principal characteristics of the smart grid; each will have one or more metrics that are reflected in the project
- Identify, from a standardized set, the smart grid functions that each project element/asset could provide and what will be demonstrated
- Estimate benefits
- Map each function onto a standardized set of benefit categories
- Define the project baseline and how it is to be estimated
- Identify and obtain the baseline and project data needed to calculate each type of benefit
- Quantify the benefits
- Monetize the benefits
- Estimate the relevant, annualized costs
- Compare costs to benefits.

An insightful point noted in EPRI's Cost Methodology is that there is third dimension to cost-benefit analysis (CBA) in the form of the level of precision. Since the biggest risk with CBA relates to the accuracy of the assumptions made, it makes sense to attempt to measure the precision of estimates. For smart grid projects, an ongoing data base of projects and project studies could be maintained to enable users to hone their estimates on the basis of experience. The importance of accurate estimates may also warrant a focused study of early implementers and/or a review of earlier studies of the experience of other "first time" implementations.

### 3.3 Estimating Technology Costs for a “First Time” Implementation

Five major types of technology costs will be incurred for a first-time implementation of a typical smart grid project:

- **Integrated communications** include data acquisition, protection, and control, and enable users to interact with intelligent electronic devices in an integrated system.
- **Sensing and measurement technologies** support acquiring data to evaluate the health and integrity of the grid. They support automatic meter reading, eliminate billing estimates, and prevent energy theft.
- **Advanced components** are used to determine the electrical behavior of the grid and can be applied in either standalone applications or connected together to create complex systems such as microgrids. The success, availability, and affordability of these components will be based on fundamental research and development gains in power electronics, superconductivity, materials, chemistry, and microelectronics.
- **Advanced control methods** are the devices and algorithms that will analyze, diagnose, and predict grid conditions, and autonomously take appropriate corrective actions to eliminate, mitigate, and prevent outages and power quality disturbances.
- **Improved interfaces and decision support** convert complex power-system data into information that can be easily understood by grid operators.

The categories of costs associated with these technologies are listed in Table 6.

**Table 6: Typical cost categories for a smart grid implementation**

<b>Smart Grid Elements and Functionality</b>	<b>Prerequisites</b>	<b>Attached costs</b>
<b>Program design and appraisal</b>		
Project feasibility and management	Need for project design team, feasibility studies, pilot projects and reporting requirements	Initial concept and pilot studies Feasibility studies Program management Measurement and verification
<b>Demand-side management an energy efficiency</b>		
Smart metering	Smart meter capable of two-way communication with control facility	Cost of smart meter and installation
	Automated meter infrastructure, including software	Cost of actual software and installation

<b>Smart Grid Elements and Functionality</b>	<b>Prerequisites</b>	<b>Attached costs</b>
	Display at consumer premises	Cost of display equipment
	Operational readiness	Cost of preparing the existing infrastructure compatible with the new metering
Load research	Meter having load survey capability for every category of consumers	Cost of smart meter or cost of upgrading a meter to provide this functionality
	Software capable of storing and processing data, and producing results in different scenarios	Software cost
	Facilitation through which load curve can be flattened including peak curtailment	Cost of man hours and training
Load control	Remote equipment control	Cost of equipment
	Adequate advance technological communication infrastructure	Cost of infrastructure including wiring, etc.
	Energy efficient appliances with remote control facility	Appliance costs
<b>Integration of renewable energy sources</b>		
Technically strong	Integration of renewable sources at any voltage	Cost of integrating the renewable source to the new grid
	Promotion of energy storage devices	Cost of running workshops to build consumer awareness for purchasing energy storage devices
	Adequate and robust protection system	Cost of installing the protection system
Plug-in hybrid electric vehicles	Market development of electrical vehicles	Cost of electrical vehicles and cost associated with bringing these to market
	Charging stations	Cost of building charging stations
	Advance information on charging price as per time-of-use pricing	Cost of monitoring equipment required to record time of use
Net metering	Regulatory insight and passage of tariff order	Regulatory intervention
	Promotion of solar roof top and other models	Promotion costs
Energy storage	Energy storage devices	Cost of energy storage devices and installation costs
	Batteries	Cost of batteries

<b>Smart Grid Elements and Functionality</b>	<b>Prerequisites</b>	<b>Attached costs</b>
<b>Self-healing power quality</b>		
Safety	Network sensors	Cost of network sensors
	Closed loop control system to detect and take appropriate preventive measures	Cost of loop control systems
	Automatic adjustment and curtailing of load through smart grid software	Cost of installing smart grid software
Online monitoring of network health vis-à-vis improving reliability indices	Network sensors	Cost of network sensors
	Preventive maintenance	Cost of monitoring and maintaining the system
<b>Loss minimization</b>		
Available transfer capability loss reduction	Online monitoring of energy audit	Cost of online systems
	Smart meter having control and bidirectional control facility	Cost of smart meter and installation
	Smart grid software integration with billing and other software	Cost of software
<b>Asset optimization</b>		
Increase power throughput on transmission and distribution assets	Online monitoring of asset utilization	Cost of installing an online monitoring system
	Network reconfiguration as per informed decision	Cost of reconfiguring the network
<b>Workforce management</b>		
Workforce effectiveness	Advance visualization and control system to support and automate decision making	Cost of visualization and control system
	Usage of emerging field technologies to improve crew safety and efficiency	Cost of using new field technologies
<b>Consumer web portal</b>		
Consumer awareness and control	Repository of consumer information (not data)	Cost of designing and running a consumer web portal

### 3.4 Risks Associated with Smart Grid Projects

Because of the lack of experience with the full-scale deployment of advanced metering infrastructure (AMI) and dynamic pricing, there are a number of uncertainties associated with certain of a smart grid's projected benefits and costs.

## **Assessing the Impact of a Project's Scale and Complexity, and the Impact of Resources Constraints**

These uncertainties create a financial risk that the actual benefits from a smart meter plan may prove to be even less than the stated projections.

A number of AMI projects have not been approved in US and Europe due to the unclear projections and the lack of a contingency plan in case the utility becomes cash strapped. A recent example from US is the smart grid project by Xcel Energy in Colorado, where projected capital expenditures for the SmartGridCity went up from an initial estimate of \$15.3 million in March 2008 to \$27.9 million in May 2009. As of February 2010, the company believes the total bill will reach \$42.1 million, not including the costs of operating and maintaining the new grid.

A large part of the increased price tag is associated with the unanticipated difficulty of the scale and resources required in constructing the system's fiber network. (See Annex B for a description of this program.)

Hence, it is important to plan in advance for unanticipated resource constraints while budgeting for a smart grid project.

## **The Effect of "Fast Tracking" on Project Schedules and Cost**

The rapid development of both the technologies and rate designs and related AMI functionalities makes the job of the system planner complicated and challenging. Best practices require that the designers of the hardware, software and communications networks engineer the system to a well-defined end-state of functionalities. When evaluating project costs, they must determine exactly what the information will do, and who needs it for what purpose, at what time.

Utilities such as PG&E and Oncor in US have experienced difficulties because when they were attempting to fast track a project, they chose technologies that turned out not to have certain desired functionalities (in these cases, desired by the regulators). PG&E customers are paying incremental costs for functions that conceivably could have been integrated less expensively had the utility started with those specifications in mind before designing and bidding out its metering project. Oncor finds itself trying to recover the costs of a metering choice that was rendered obsolete when the state of Texas determined that utilities must provide different functionalities in their smart meters. Inasmuch as proponents of the smart grid point to the possibility of benefits not yet imagined, the continuing evolution of the smart grid presents challenges to system planners, especially at this early stage in its development.

## **"Systems Integration" Effect**

The costs of information technology integration and software are the largest component in a smart grid project. A utility attempts to recover this cost through smart pricing

techniques, which help in peak load management, thus reducing the utility's cost of generation and service. Response programs and rate offerings are provided to all ratepayers in the form of lower generation service costs due to the impacts of reductions in peak load wholesale capacity and energy prices.

However, the cost recovery aspects of a company's proposed smart grid plan include the level of annual revenue requirements to be recovered, the allocation of those revenue requirements among rate classes, and the design of the specific rates by rate class to recover those allocated revenue requirements. There is a minimum level of revenue requirements the utility banks on for this recovery. This is where the "systems integration" effect kicks in, when partial and isolated smart grid projects are planned. Such standalone projects typically cannot meet the minimum required level of revenue requirements because of their smaller scale, which leads to a more complex, more complicated and, sometimes, somewhat convoluted cost-benefit ratio.

### **Accelerated depreciation of technology**

For many decades, once a utility plant was constructed or equipment installed, it could be reliably expected to remain in service for its estimated useful life. Many of these ranged from 10 to 40 years. Meters, for example, had useful lives of 10 to 15 years. However, advanced meters and metering systems employ computing technology.

The technological and cost curves for computers may be very different from the equipment historically used in the electric utility industry. If advanced metering systems exhibit technological and cost behaviors that are similar to those of computers, then their useful lives may turn out to be shorter than estimated.

Smart grid technology is classified among the high-technology systems and hence requires faster depreciation than traditional meters. For tax purposes, the use of accelerated depreciation would be an incentive for utilities to promote the technology.

Utilities with advanced meter and related programs already underway would benefit from the acceleration of depreciation, as their cash flows would increase as a result. But it may not be a powerful enough incentive to spur utilities that have not yet launched a smart grid initiative to undertake a smart grid program.

Accelerated depreciation could increase regulatory and political difficulties if it means higher expenses and, thus, a higher revenue requirement and increased upward pressure on tariffs. Governments could find that this adds to the difficulty of approving smart grid capital requests.

Although that could heighten resistance to smart grids, it should be evaluated in a larger context that considers externalities, e.g. carbon reduction, and the long-term benefits, including societal benefits. In India, this might be best done as part of a holistic assessment of the costs and benefits of smart grids. That could, and probably should, include an examination of innovative financing techniques and ways to provide incentives to spur smart grid development.



## Risk of stranded assets

This could, as an example, involve equipment that was, at the point of installation, the state-of-the-art, but (before it reached the end of its useful life) it was eclipsed by a newer technology that might cost significantly less. As (formerly) staid electric utilities take on some of the characteristics of high-tech industries, utility managers and regulators may have to deal with the unique challenge of cost recovery of significant asset values where the actual experience differs greatly from the assumed technological and economically useful life.

This is an example of a “known unknown.” The more utilities take on the characteristics of a high-tech business, the greater will be the probability that the industry — as well as policy makers and regulators — will have to balance the competing needs of stability (i.e., allowing companies to recover investments over a long time to minimize rates) vs. the volatility (and potential write downs) associated with companies in competitive markets.

Deployment of smart grid technology will be piecemeal and utilities that do not install smart meters will still need to install conventional meters. This clearly establishes the risk of creating stranded assets, as the smart roll-out could make them redundant before the end of their asset life.

## 3.5 Examples of Recent Smart Grid Analyses

The experience with smart grids is recent in the United States and Europe; most of the projects have been implemented only within the last two years or so. In Asia (China and India), full smart grid projects are not underway, but there are a number of efforts toward a smart grid.

### United States and Europe

In the US, most recent smart grid projects (e.g., smart metering) are driven by utility operational needs. In order to fund these upgrades, regulators and utilities propose to use the value of demand response programs such as load control and pricing-responsive rates to bridge the gap between operational savings and project cost. A complexity in this approach is that operational savings are difficult to pass on to consumers and utility regulators are more comfortable using traditional project valuation methodologies. Thus, these efficiency benefits might not garner the same weight as do operational

The *Boulder Daily Camera* recently reported that the costs of Xcel's high-visibility smart grid pilot project in Boulder had increased to about \$42 million, or almost three times the original estimate of two years ago. By itself, this is not a matter of grave concern, but it has attracted the attention of the state regulator because it raises the possibility that additional ratepayer funds may be required to for the introduction of the new technology.

benefits. Utilities are also beginning to attempt to value carbon reduction.

Benefits can also include emission reductions from the particular utility's generation mix taken against the price of carbon credits. While sometimes significant, these costs are not likely to bridge the gap that can run upwards of hundreds of millions of dollars on large smart metering projects. Carbon reduction may represent a growth opportunity, but current prices are at historic lows, although they are predicted to rise. Some examples of smart grid initiatives include:

**Xcel Energy, USA.** In May 2008, Xcel began implementing a smart grid network in Boulder, Colorado. SmartGridCity™ is a multi-phase project that will run through 2011. It is expected to provide customers with a portfolio of smart grid technologies designed to provide environmental, financial and operational benefits.

**Centerpoint Energy, USA.** In May 2008, CenterPoint Energy filed its advanced metering system initial deployment plan with the Texas Public Utilities Commission. The company anticipates that it will begin deploying up to 250,000 interactive meters and related infrastructure over a three-year period.

**Oncor, USA.** In March 2007, Oncor became the world's first utility to install S&C Electric Company's new TripSaver Dropout Recloser™ as a part of a smart grid initiative in which the electric grid will monitor, think, act, repair and prepare itself to respond quickly to consumer needs. The smart grid will heal itself, sense outages as they occur, monitor equipment performance, report back on needed maintenance, and more, all of which will result in an increase in reliability and service quality.

**Southern California Edison, USA.** Between 2009 and 2012, SCE plans to replace more than 5 million traditional electric meters with next-generation smart devices, making possible money-saving time-differentiated rates and demand response options as well as home area connectivity with appliances of the future. The new meter system will allow customers to set smart, communicating thermostats and appliances to respond automatically to periods of peak pricing and grid emergencies, potentially reducing overall peak demand on SCE's grid by as much as 1,000 MW – the output of a major power plant. The company also has a joint program with the Ford Motor Company to explore plug-in hybrid vehicles and vehicle-to-grid technology.

**Pacific Gas & Electric, USA.** PG&E is partnering with Tesla Motors to further evolve vehicle-to-grid (V2G) technology by researching smart charging (a form of V2G designed to allow remote control charging of electric vehicles connected to the power grid).

**American Electric Power, USA.** AEP is deploying advanced metering and an enhanced infrastructure. Initially, the systems are expected to be in place by 2010, and to be fully deployed by 2015 for more than 5 million customers. The company is also collaborating with General Electric to address the full energy pathway from the power plant to the customer's home.

**San Agustin del Guadalix, Spain.** This pilot includes both residential and commercial consumers. It consists of power supplied to building loads as well as to an experimental

grid that supports the installation and re-configuration of a number of distributed components, and incorporates a variety of different power generating units such as photovoltaic panels, wind turbines and diesel generators. The energy management system enables power quality to be monitored and tested with varying configurations of distributed generators, storage systems and loads.

**Supply Centre East, Germany.** This pilot incorporates both commercial and industrial loads in six different buildings. Power sources include a battery system with a bi-directional inverter and a 5.5 kW co-generation plant. It also includes a high-bit-rate communication system that supports messaging between units solely via their power line connections. The utility can readily check to see how much it saves by managing the battery operation, and it can thereby benchmark future pricing to a privately owned combined heat and power facility.

## Asia

**Rabirashmi Abasan, Kolkata, India.** In July 2008, Rabirashmi Abasan became the first housing project in India where residents have the option of generating power from rooftop solar photovoltaic panels, and selling it to the power grid utility. From now on, their electricity bills will reflect the difference between the energy consumed from the utility and how much they send to the grid.

**BESCOM, Bangalore, India.** The Karnataka Government will soon deliberate on the State's 2009 Renewable Energy Policy, whose aim is to "enhance the contribution of Renewable Energy in the total installed capacity of the state from 2400 MW to about 6600 MW by 2014." BESCOM is in talks with information companies to start a pilot project for a smart grid that could be replicated in other parts of the State.

**SA Habitat and Valence Energy, India.** In January 2009, a partnership project between property developer SA Habitat, and solar company Valence Energy, located on the outskirts of Hyderabad, incorporated renewable, decentralized energy production, smart grids, and home automation. Under this scheme, 18 of the 330 houses that make up this residential complex are equipped with a 4.2 kW solar photovoltaic system (it comes equipped with solar water heaters) on their roof, which will provide 40% of the complex's electricity needs. All of the equipment for this project is fully automated ("smart").

**China:** In April 2007, the MIT Forum on the Future of Energy in China took place in Shanghai. This led to the formation of the Joint US-China Cooperation on Clean Energy (JUCCCE), a non-government organization dedicated to bringing together international expertise and technologies to accelerate the use of clean and efficient energy in China. Since a third of particulate matter pollution in California comes from China, one of JUCCCE's primary goals is to identify and catalyze a regional pilot for a smart grid in China. In addition, JUCCCE will be giving away 10 million light bulbs at no cost to households in Shanghai, the pilot city for a clean lighting conversion program. This project alone will result in the reduction of over 2 million tons of CO<sub>2</sub> emissions over the five-year lifespan of the bulbs.

### 3.6 Challenges for the Smart Grid

Several challenges present themselves for smart grid development, and may affect the results of a cost-benefit analysis.

**Financial resources.** The business case for a self-healing grid is good, particularly if it includes societal benefits. But regulators will require extensive proof before authorizing major investments based heavily on societal benefits.

**Government support.** The industry may not have the financial capacity to fund new technologies without the aid of government programs to provide incentives for investment. The utility industry is capital-intensive, but has been sustaining exorbitant losses due to thefts and subsidization.

**Compatible equipment.** Some older equipment must be replaced as it cannot be retrofitted to be compatible with smart grid technologies. This may present a problem for utilities and regulators since keeping equipment beyond its depreciated life minimizes the capital cost to consumers. The early retirement of equipment may become an issue.

**Speed of technology development.** The solar shingle, the basement fuel cell, and the chimney wind generator were predicted 50 years ago as an integral part of the home of the future. This modest historical progress will need to accelerate.

**Lack of policy and regulation.** No defined standards and guidelines exist for the regulation of smart grid initiatives in India.

**Capacity to absorb advanced technology.** Most discoms have limited experience with even basic information and communications technology and, as a result, they have weak internal skills to manage this critical component of smart grids. R-APDRP aims to provide some redress, but it is relatively recent and has not yet had a major impact on the industry. The industry's reluctance to implement ICT appears to have been a by-product of a desire to avoid transparency, especially in meter-billing-collection processes. Now, the lack of automation and the heavy dependence on outsiders for ICT know-how is an unavoidable penalty for any effort to implement a smart grid vision. This suggests that 1) policy makers actively discourage the organizational culture that fostered a lack of transparency, 2) recruiting and capacity building in these areas should be accelerated, and 3) partnerships with leading Indian ICT organizations should be considered as a means to accelerate implementation of smart grid concepts.

**Consumer education.** "Customer response" is the phrase used to describe the reaction of customers to the new features and functionality enabled by the smart grid. If, for example, a company installs advanced metering and two-way communication along with time-of-use rates, the question is "Will customers use it?" If there aren't enough customers who use the features, the benefits of a smart grid will not be achieved. Thus, two critical and often overlooked components of a smart grid implementations are 1) sufficient marketing analysis and product design to optimize the likelihood that

customers will use the new technology, and 2) an education, communication and public relations program aimed at creating an understanding of smart grids, the associated benefits and the potential implementation issues. The program should be aimed at customers but also policy makers, opinion leaders, regulators and financial institutions.

**Cooperation.** The challenge for diverse State utilities will be the cooperation needed to install critical circuit ties and freely exchange information to implement smart grid concepts.

**Cost assessment.** Costs could ultimately be higher than projected because the standards and protocols needed to design and operate an advanced metering infrastructure are still in a state of flux. Thus, investments made now, before the standards are settled, have a higher risk of obsolescence. Failure to include estimates of the costs for the control equipment customers will install to automate their response to time-differentiated pricing could put smart grid investments at risk. Other risks include 1) no demonstration that the proposed project is more cost-effective than alternative approaches that will achieve the same major energy cost reduction objectives at less cost and 2) exclusion of incremental costs of “stranded” existing meters (i.e., accelerated depreciation).

According to Anil Razdan, Secretary of Union Power Ministry, India's power demand is increasing at 8-10% per year. In October 2008, the Smart Grids India Conference was held to discuss the infrastructure needed to modernize the grid and to turn a “dumb grid” into a “smart grid.” Indian utilities have been challenged to achieve the ambitious target set by the MOP to provide “power to all by 2012.” According to California-based Echelon, this will take roughly an investment of \$100 billion in technologies for generation, distribution, transmission, and monitoring.

**Rate design.** Many utilities are proposing to recover these costs via a customer surcharge. This is not reasonable, based on the view of cost causation, and will have disproportionate adverse impacts on low-usage customers.

**Consumer protection.** Privacy concerns about customer usage data and other personal data are real, but it is not clear how such data will be protected. Also, the installation of smart meters will open the door to remote involuntary disconnection and the use of service limiters, all of which limit customer access to and control over electricity service. Even unfounded concerns about a “spy in the house” may affect consumer attitudes. Thus, issues related to consumer privacy will likely be submitted to regulators and consumer protection agencies as soon as new technologies are planned.

**Lack of empirical evidence.** Utilities have done a number of pilot projects to test AMI and dynamic pricing on a limited basis, but it is only recently that several US utilities received regulatory approval to deploy AMI and dynamic pricing tariffs on a wide scale. In fact, most of those utilities are still in the process of completing deployment. The absence of robust empirical evidence regarding the performance and economics of AMI and dynamic pricing on a system-wide basis over time is a source of uncertainty over

both long-term technical performance and the magnitude of peak load reductions that will actually be sustained in the long term in response to dynamic pricing.

## **Funding issues for India**

Historically, building the grid through transmission and distribution lines has been undertaken by PowerGrid Corp. and various state-regulated distribution companies. Central programs such as APDRP and R-APDRP provided some support in modernizing and rationalizing the billing and metering systems, but there have been relatively few such programs.

While no one has estimated with any level of detail the costs required for India to upgrade to a smart grid, estimates range widely depending on the utilities involved and the timing.

Given the large investment required to build out the current set of plans, Indian utilities will need to experiment with how best to fund such projects. Based on a survey by the authors, most utilities are proposing to recover all of these costs via a fully reconcilable surcharge. Many are proposing to allocate these costs among rate classes according to the number of customers in each class. Some utilities are also proposing to recover these costs via a monthly customer surcharge.

With the introduction of smart grid technology at the distribution level, consumers will have more incentive to switch to a new tariff. The existing tariff structure will have to be rationalized and time-of-day tariffs must be introduced to provide incentives to consumers. Similarly, for new renewable generation, more system integration will be required to ensure system security.

Some possible alternatives for funding are presented below. However, these are only illustrative in nature. Detailed rounds of talks with government, banks and the private sector will need to be undertaken to rationalize and validate the plausibility of these alternatives.

***For central sector lending, develop a new appraisal process for smart grid projects.*** Grant and loan funding for the smart grid can come through traditional sources (e.g., PFC), but a revised project appraisal process that incorporates operational benefits will be needed to evaluate project submittals.

***Reach self-funding.*** Following the lead of on-going loss reduction projects, many smart grid projects will become self-funded by exceeding the stipulated payback periods.

***Attract new players and bring in vendor financing.*** Information and communication technology companies such as IBM, Infosys, and Wipro have started smart grid programs and are developing commercial models. Some examples of pilot projects include those with real estate developers to implement small-scale smart grid projects for residential and commercial complexes.

**Expand bank understanding of the smart grid.** Banks that are already lending to the power sector will see the business case for the smart grid quickly and can act to increase funding directly to projects, or indirectly to companies and utilities.

The most prudent route is however, a combination of these sources through public-private partnerships. State utilities can take the lead on developing the business case for pilot implementations of smart grids and then invite private players to participate by providing both technical know-how and funding. Private players can further approach the banks to fund their investment.

## Regulatory issues

India's electric power delivery system is much like the telecommunications network of the past – dated and increasingly costly for consumers. Like the telecommunications revolution, which created new technologies, choices and improved service levels, there is a need for a similar revolution in the power sector.

Being a highly regulated sector, regulatory intervention is imperative for successful smart grid implementation across the following key areas:

- Funding
- Consumer awareness
- Establishing common standards
- Playing the role of a “watchdog”
- Cyber-security
- Interoperability.

The Government of India is keen to prepare the power sector for the introduction of the smart grid. Indian utilities are showing initial interest and starting to explore the subject. The private sector, especially companies with global experience in smart grid technology, is helping the Indian market understand the concept of the smart grid.

Based on technical presentations and discussions held during a recent seminar on the subject of “Smart Power Grid,” the following recommendations are being considered by the Government of India.

- India's Ministry of Power may appoint a task force consisting of various stakeholder representatives to study the status of smart grid implementations in other countries. It will consider various issues relevant to India in examining the introduction of smart grid technology and make suitable recommendations for introducing smart grids in the country at different levels.
- The Central Power Research Institute (CPRI), Bangalore, could be appointed as a nodal agency for the collection of data / information from other countries and assist the task force in its study and finalization of recommendations. CPRI could even coordinate with other agencies on the development of smart grid

technologies.

- Institutions such as CPRI, IITs, technological universities like JNTU, IT industries etc., may be identified to conduct further research on the “smart grid” technology for implementation suitable for the Indian environment.
- Since the IT sector in distribution companies is being developed under R-APDRP, the scope of funding could be increased to introduce smart grid technology in distribution wherever distribution control centers are already in operation. One distribution company in each region may be selected to implement pilot projects, as recommended by the task force.
- A small region in a central location like Bangalore or Hyderabad could be selected to implement the concepts of the smart grid as a pilot project in order to update the status of the smart grid's design and implementation in a phased manner.

### Other considerations

The potential benefits of the smart grid vision extend well beyond the power sector value chain. Thus, a utility-centric approach is too narrow and too parochial, and it probably won't produce the best results for customers and society. The only reason a state-owned utility deserves to exist is to benefit customers and the commonweal. Shaping a smart grid vision should begin with customers and customer solutions. The utility will play an important role in achieving these benefits – at least, it could play an important role – but the beneficiaries are the customers and commonweal of India.

It is difficult to monetize some of the gains or benefits of a smart grid. An improvement in the health of citizens due to a reduction in carbon emissions is one such benefit. Given the wide impact of smart grids, an innovative methodology for guiding CBA and project appraisals will be needed. In the United States, EPRI and DOE have recognized this need. They organized a high-level group for this purpose, but even with the very substantial work accomplished to date, their efforts are ongoing.

Certain of the benefits of smart grids can be monetized, but for others, the current regulatory framework or accounting rules may not be supportive. For example, utilities benefit from the increased sale of electricity, so there is no incentive to reduce sales by implementing DSM<sup>31</sup> – even though that would help reduce the supply-demand gap and benefit customers and society. Another example is the incentive utilities have to increase the absolute value of their earnings by expanding their asset base.<sup>32</sup> Perversely,

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<sup>31</sup> Decoupling or, more specifically, revenue decoupling, has been proposed as an alternative. A decoupling mechanism seeks to provide an opportunity for a regulated power company to earn a fair return but in a way that “decouples” its earnings ability from sales volume.

<sup>32</sup> The phenomenon known as the Averch-Johnson Theorem is that utilities that are regulated under a “rate base, rate-of-return” approach demonstrate an observable tendency to over-invest in assets that can be included in rate base.



there is no incentive to deliver a high volume of electricity with existing assets. These issues suggest that some modifications to India's regulatory framework or accounting rules may be warranted.

Communications infrastructure is costly, yet is at the heart of the smart grid vision. As we move deeper into a smart grid world, communication will play an ever-larger role in the power sector. Often, utilities will argue that they should build their own communication infrastructure owing to reliability and security concerns. This could result in the duplication of infrastructure, and as noted earlier, the electricity sector may not have the bandwidth in term of ICT skills to engineer, procure and implement this technology. This suggests that it might be advantageous to encourage close coordination between the telecommunication and power sectors, with the participation of policy makers and regulators.

## Chapter 4

# Recommendations

**T**he still-evolving concept of the smart grid is a vision of an industry transformed. The electric industry's historic business model will be changed, perhaps as much as the long-successful business model of the telephone industry was. For the electric industry, technology is the key enabling factor, but the situation is more complicated.

Whatever else might be said, the ultimate reality is that the electric industry desperately needs a new business model. Companies must learn how to prosper in an era of increasing unit costs, when their primary measures of service quality are either high but declining (as in the United States) or low and stagnant (as in India). As one industry observer recently put it:

The electric industry is unique. Its real "customer"<sup>33</sup>... (has been the) regulator ... An industry facing increasing costs per unit for the foreseeable future ... (but without any) ... obvious productivity gains to offset them and (that also) must ask permission to raise prices ... (is not in) an enviable position.<sup>34</sup>

The smart grid concept results from the convergence of a number of trends that have been evolving for up to a half century, including:

- **Information and communications technology (ICT)** – Moore's Law continues in effect and ever-cheaper computer chips, sensors and controllers, coupled with increasingly sophisticated mobile and WiFi capabilities, have already begun to radically transform the data-intensive electric business.
- **Advances in metering technology** – Likewise, digital meters are increasingly affordable and rugged, and they have begun to replace electro-mechanical meters on a wholesale basis, even in some developing countries.
- **Costs** – The trend in the unit cost of electricity turned upward several decades ago, although that wasn't clear until more recently. The reality is that electric companies need to learn how to prosper during an era of increasing costs and

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<sup>33</sup> In India, the state politician might be the "real" customer.

<sup>34</sup> Judith Warrick, in a speech at a clean technology conference in Palm Springs, California, on January 10, 2010 and as published in Morgan Stanley's *Energy Insight, January 25, 2010*

declining service quality. That may well require a “next new thing.” If the smart grid is not the answer, the industry’s future could be unpleasant as well as unprofitable.

- **The dawning of the digital age** – The automation of almost everything is occurring at a breathtaking pace. Likewise, the expansion of high-tech electronic manufacturing has spread in response to mushrooming demand. One side effect of the digital age is the increased demand for electricity as the premium form of energy (as the authors of *Perfect Power* put it, “Try running your laptop on a lump of coal”) and the need for higher-quality power to run everything from delicate precision machinery to advanced household appliances.<sup>35</sup>
- **Growing prosperity** – It is difficult to acknowledge in the midst of the most serious recession in 75 years, but the world is becoming more affluent. There are significant risks attached to recent economic developments but, with the exception of a worst-case scenario, the long-term trend is still up. And customer expectations are rising in tandem with individual affluence.
- **Climate Change** – Mounting evidence is reinforcing the consensus of leading scientists that global warming is real, that it is a function of historic amounts of carbon that have been released to the environment as the result of human behavior. The reality of global warming and the increasing public concern it has triggered — and the close link between electricity production and carbon emissions — add an accelerant to the technological, utility cost and behavioral economic influences that are converging.

In the West, the smart grid vision is compelling, even though it may sound a bit like science fiction to some today. Of course, the early days of mobile telephones were characterized by “mobile” phones that were bigger than many laptop computers today. Despite the reality of the “convergence” of the historic forces discussed above, there are also some daunting hurdles, including:

- **Initial cost** – The utility sector is steeped in the concepts of return on investment (ROI) and cost-benefit analysis (CBA). The American Recovery and Reinvestment Act of 2009 (ARRA), also known as the stimulus package, set aside \$4.5 billion for qualifying smart grid projects. This resulted in the telescoping forward of projects that otherwise would have been pursued over a longer time frame.

Our study of smart grids, including discussions with knowledgeable experts on the cost of implementing smart grid technology, suggests that the initial stage may experience a significant increase in costs but without a commensurate near-term reduction in O&M costs from savings. Unknowns surrounding actual vs. projected costs and the nature and value of benefits may be difficult to quantify (fully) and assign a value. The engineering-economics chapter discusses several factors that

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<sup>35</sup> Robert Galvin and Kurt Yeager, *Perfect Power: How the Microgrid Revolution Will Unleash Cleaner, Greener, More Abundant Energy*, McGraw-Hill Companies, 2008.

will complicate CBA. The significance of this issue is reflected in the fact that EPRI has been developing a CBA methodology tailored to smart grid projects.<sup>36</sup>

If the full benefits of the smart grid vision will not be realized until the full “system integration” effect kicks in, the debate may gravitate towards a battle between believers (i.e., in the potential of the smart grid vision) vs. skeptics. Unfortunately, regulators have an institutional responsibility to be skeptics.

- **Policy and regulatory** – The power sector is composed of an institutional complex that includes companies, regulators, governmental agencies, politicians and more. The laws, policies and regulations governing the behaviors of various actors are elaborate and detailed, and were developed over very long periods. The further the industry must move away from the traditional model in order to deploy a smart grid vision, the more it will require changes to existing policies and regulations. When policy, law and regulation must be changed as a precondition, the time frame to accomplish the desired result will be lengthened.

One of the challenges for regulators and policymakers will be dealing with the societal benefits of smart grids. This will influence the cost-benefit analyses that must be done and it could become a difficult issue. For example, a reduction in utility O&M costs would offset the higher cost of installing advanced meters. However, discoms in India will not have a net gain from the reduction in labor-intensive meter reading activities, as will utilities in the West. But one benefit would be the increased transparency in consumption, billing and payment, and a reduction in aggregate technical and commercial losses.

Other societal benefits will accrue once a more robust smart grid comes into existence, including micro-grids powered by renewable energy sources and more advanced variations of energy efficiency. Some of these will be quantifiable, but others will be more difficult, and there are some that may not materialize until the “system integration” effect comes into play.

Costs will probably be easier to quantify. The full range of benefits, including some elusive societal benefits, will need to be properly valued too.

- **Technology** – How will the smart grid work? Within living memory, the electric industry was in the throes of an earlier transforming technology that was lauded by advocates as having the potential to produce energy that was “too cheap to meter.” Alas, nuclear power is not the only or even the most recent “next new thing” that didn’t deliver on its initial promise. Even though nuclear power has since become a vital part of a sustainable energy solution, the hype surrounding its introduction is not dissimilar to that surrounding the smart grid vision today. One question about the implementation of smart grid technology is whether a robust foundation must first be built before jumping into the new world of smart grids?

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<sup>36</sup> US Department of Energy and the Electric Power Research Institute, *Methodological Approach for Estimating Benefits and Costs of Smart Grid Demonstration Projects*, January 2010.

For India, a critical question is: “How can you implement a smart grid when the existing grid isn’t yet capable of providing reliable service to half the population?”

While this over-simplifies the issue, it does help frame an important question about the “how to” of adopting smart grid concepts. Pondering this issue can help develop an understanding of how the smart grid vision could be used to leapfrog into an entirely different future than the conventional path would lead to.

- **Customer response** – The most unique “human factor” in business is customer response. The electric industry’s historic term for a customer (“ratepayer”) says something about how they are still perceived in what has long been a centralized, bureaucratic, supply-side business. In competitive retail industries, marketing — developing customer solutions — is where strategy begins. Not so in the electricity business. Not yet.

That may change even with powerful institutional forces aligned against it.

In a business-as-usual case, India’s state-owned monopolies may be evolving in a “Swiss cheese” pattern where high-profit customers with the ability to solve their own problems (e.g., industrials) are abandoning the SEBs for SEZs with captive power. Market liberalizations in other countries saw industrials become “first movers,” but it didn’t stop there. It probably won’t in India either.

For smart grid expenditures, proposed projects will have to pass rigorous CBA tests. However, even for those who are persuaded that the benefits of the smart grid vision will ultimately justify the costs incurred, there is still a question of the transition. Another question is who will bear the risks and costs relative to potential benefits. Customer response — specifically whether customers will pay extra for early smart grid features — has become a much-discussed issue for smart grids. The answer for some customers is “no,” but it’s difficult to judge consumer response to a service they have never experienced. Nonetheless, it’s clear that cost will be important in shaping customer sentiment.

- **AT&C losses** – In India, the issue of aggregate technical and commercial (AT&C) losses must be added. A reduction in AT&C losses is central to reducing cost, improving cash flow and, thus, enhancing the financial viability of discoms so they can pursue measurable service quality improvements. Loss levels of 32% of total electricity produced are ruinous.

Any effort to capitalize on the smart grid vision should build on India’s continuing program to reduce AT&C losses. A smart grid initiative should begin with an enlargement of the R-APDRP program to link R-APDRP to the achievement of specific service quality improvements as measured by key performance indicators (KPIs) such as those developed by four discoms<sup>37</sup> under the MOP’s distribution reform initiatives.

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<sup>37</sup> Bangalore Electricity Supply Company (BESCO) in Karnataka, MGVDC in Gujarat, MSEDCL in Maharashtra, and North Delhi Power, Ltd. in New Delhi.

**Electrification** – Another key driver in India is electrification. Urban areas are expanding access to electricity, although considerable unevenness and significant power quality issues remain. In rural areas, access to electricity is lagging seriously. About 50% of rural households lack electricity and even where service is available, the rationing of supply with daily outages lasting for hours is the norm. The GOI is committed to an ambitious plan to make electric service universally available to all. The smart grid vision can help achieve that goal.

## **4.1 How Should India Respond to the Smart Grid Vision?**

Does the smart grid vision make sense for India? We believe the answer is, “Absolutely.” Nonetheless, an across-the-board implementation should not be attempted right away. While India’s power sector needs a “next new thing” more than the power sectors in mature economies need a new business model, a selective and flexible approach will yield a better result than a “one size fits all” approach. Generally, the following are basic preconditions for the successful implementation of the smart grid:

- Commercially viable and self-sufficient discoms
- Public awareness and acceptance of the smart grid
- A national smart grid vision and a flexible plan
- Appropriate smart grid standards.

Optimally, these should all be in place before smart grid implementation is launched. These preconditions do not yet exist in India and it is likely that their achievement will be uneven going forward. In 2007-08, AT&C losses averaged 32% of total generation and, in 6 of 30 states, discom AT&C losses were above 50%.

Some might conclude that India should defer pursuing a smart grid vision. However, the same elements that are regarded as preconditions to the smart grid are also the ones that benefit most from the adoption of smart grid elements and principles. For instance, improved metering through the deployment of remote measurement and monitoring of energy use will help utilities better monitor energy use across the grid and allow them to trace the source of energy losses. The resulting improvement in transparency will lead to reduced losses and improved financial health of the sector. Smart grid technologies can enable improvement in meter-billing-collection systems and help reduce line losses.

### ARRA's fast track approach in the USA

The American Recovery and Reinvestment Act of 2009 allocated \$4.5 billion in grants for smart grids. A recent survey showed that 70% of utility managers said their companies would apply for a grant even though less than 45% felt the projects would achieve the desired results cost-effectively. It appears that ARRA has caused spending on smart grid projects to be telescoped forward. That is quite understandable (and a more reasonable risk in the US), but it has also resulted in a "fast track" situation that brings certain risks. The fast tracking of complex, large-scale projects brings a higher risk of cost and schedule overruns. By moving slowly, India will be able to learn from the experience of others, and possibly avoid some costly missteps.

Furthermore, investment in a smart grid today may enable India to leapfrog into a vastly improved electricity scenario. Even under a business-as-usual case, the GOI will have to invest heavily in the power sector over the next two decades and beyond. Smart grid technologies could enable India to leapfrog into a much more advanced grid infrastructure and electricity market, and more quickly achieve parity with developed economies.

Nonetheless, there is much unfinished business to be taken care of before adopting the more advanced features of smart grids on a broad scale. A strong follow through on earlier programs will be necessary to build the foundation needed for more advanced features of the smart grid vision. But that doesn't mean action should be deferred until a foundation is fully in place. Transitioning to a smart grid vision tailored to India's unique circumstances would have a number of dimensions:

- Develop a national vision and frame a flexible plan for pursuing smart grid benefits.
  - Build on the R-APDRP program and link it to improvements in service quality as defined by measurable KPIs.
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- Identify and implement smart grid concepts that reinforce the operational efficiency of discoms.
  - Conduct customer and marketing surveys to develop a more refined understanding of what drives customer satisfaction, and analyses to develop a better understanding of demand and consumption (e.g., an analysis of the actual cost of "free" power and a profile of who receives agricultural power and how much, among other analyses).
  - Develop policies and regulations to create a more receptive environment for smart grids, by encouraging innovation, establishing standards for interoperability, and allowing more market-oriented and entrepreneurial solutions.
  - Implement techno-commercial "proof of concept" pilot projects for initiatives that have potentially high impacts and that can be implemented independently of the grid.

As part of its approach to adopting smart grid concepts, India should give priority to customers and customer solutions over the creation of another high-level commission.

The need for a commission is unavoidable given the structure of the power sector, but its convenors should make a conscious effort to limit the temptation to develop a top-down, “one size fits all” solution.

## 4.2 What are the Barriers to Smart Grid Implementation in India?

The barriers to implementing the so-called smart grid in India are much the same as those that have stymied power sector reform ever since market liberalization was first announced nearly 20 years ago. The problems that afflict India's power sector are many and serious, and are very well known to policy makers, industry experts and, indeed, the general public.

The loss of 32% of total electricity generated, the sector's legendary voltage fluctuations, chronic blackouts in rural areas, the lack of electricity connections for almost half the population, and so-called “free” power to the 25-30% of farmers with irrigation pumps are not simply unfortunate happenstance.

All these outcomes persist despite the GOI's Rs. 25,000 crore annual subsidy to the sector and what must now be the equivalent of many billions of dollars in time, effort and capital that have been invested in power sector reforms since the early 1990s. There are causes for these effects and, if left unaddressed, they could dampen the impact of any smart grid scheme as they did in the past for other initiatives.

The power sector's chronic problems must be acknowledged, but not accepted. Despite the troubled state of the industry, there have been some notable successes, including the Delhi public-private partnership, under which discoms operated by Tata Power's NDPL and two Reliance-owned discoms are revitalizing one of the most intractable electricity distribution systems in the country, and the franchise concept that offers intriguing potential<sup>38</sup> as does an early trial of an agricultural demand-side management (DSM)<sup>39</sup> project currently under contract with an electricity service company (ESCO) with BESCO in Karnataka. In addition to BESCO, several other state-owned discoms are moving forward with impressive accomplishments, including MSEDCL in Maharashtra, MGVDC in Gujarat and APCPDCL in Andhra Pradesh.

But even with these successes, the pace of change is too slow. The world is moving faster and one insightful report on smart grids repeated a finding of other studies done in recent years: “... in India ... the network's inefficiencies are severely impeding economic growth.”<sup>40</sup> Globally, the trend in unit prices of electricity has turned upward

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<sup>38</sup> Early experiences with electricity franchising suggest that contractual terms and pricing must be revised to make the concept commercially viable.

<sup>39</sup> Designed under USAID's WENEXA II Project to reduce 22-30% of the electricity provided “free” for irrigation pumping.

<sup>40</sup> The Climate Group and the Global e-Sustainability Group, *SMART 2000*, with analytic support provided by McKinsey & Company.



and, in India, the penalty for delaying the step-function improvements needed to achieve the country's growth potential will continue to rise.

To add perspective, we note that the pay gap between India and the West seems to be shrinking as fast as the polar ice cap. On a fundamental level, this is a very positive development, but one that could expose India's soaring knowledge economy to a "productivity penalty" that won't be offset as easily as in the past by global labor rate differentials.

As experienced by other economies, electricity is an ever-more prized form of energy, especially for high-tech industries but, increasingly in manufacturing and other old-line industries too. It would be dangerous for India to be complacent about the importance of world-class electricity as an enabler of world-beating growth.

These conclusions are echoed by other reports, including The Climate Group's report, which includes a section on India's power sector as an example of how ICT as the enabling technology for a smart grid can help accomplish major reductions in carbon emissions. As the report states, the major hurdles are:

- No proven commercial viability for large-scale smart grid roll outs
- Poor financial health of most state-owned T&D companies
- Low awareness of technological developments in the utility sector
- No coordinated national road map for smart grid deployment
- A fragmented industry.<sup>41</sup>

These are daunting hurdles and the report's assessment reinforces the fact that the first step toward achieving the smart grid vision is to follow through on what has already been started. That doesn't mean the smart grid vision should not be pursued, but it would be equally dangerous to lose sight of the need to follow through on fundamental initiatives.

### 4.3 A Needs-Based Methodology<sup>42</sup>

Even for an individual electric company, setting a comprehensive smart grid strategy involves a complex mix of internal and external challenges:

- The technical challenges of new systems, new devices, new communications technologies, and a deluge of new data can be overwhelming
- The impact on existing business processes needs to be identified, with new business processes defined. The organization has to make itself ready for the significant and perhaps radical changes that will take place.

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<sup>41</sup> Ibid., p. 49.

<sup>42</sup> This section draws on PA Consulting Group's *Smart Grid Executive Insights* and its "Connecting the Smart Grid Dots™" approach to developing a smart grid strategy.

- Customers, regulators and investors need to understand the change and be convinced that it is beneficial. A successful migration to a smart grid environment will require that all of them embrace the vision, not merely accept it.

Practically speaking, the organization has to assess how its end-to-end delivery and operational value chains will be affected and determine how smart grid enhancements can add value to the customer and other stakeholders. Given sufficient time and effort, all of these challenges are manageable. The test for corporate leaders is to create a shared vision and engage internal and external stakeholders in a common focus to collaborate and ensure that smart grid benefits are delivered cost effectively.

Accomplishing these aims for the entire power sector in India will be a much more daunting challenge than for any single entity.

The development and clear communication of a credible strategy is the single-most important thing to “get right” early. PA’s “Connecting the Smart Grid Dots™” provides a framework to help define and communicate why the strategy is essential, how it can be achieved, and that it represents a well-designed program of change. The approach is shown in Figure 7.

The “takeaway” from this exhibit is that the complexity involved in migrating to a smart grid environment warrants a careful approach. “Connecting the Smart Grid Dots” can provide a framework to evaluate the needs and priorities of the sector, but achieving it will require a coordinated effort among a broad range of stakeholders.

Before proceeding with the detailed implementation, some questions must be answered. These relate to basic efficiency as well as the need to reduce carbon emissions.

“Electricity generation currently accounts for 57% of India’s total emissions and will continue to do so until 2020. India’s power network is highly inefficient and much of the generated electricity is wasted. The lack of transparency in the grid makes losses difficult to measure, but it is estimated that in 2007 India lost 32% of total generation.”<sup>43</sup>

Thus, anything that reduces the need for power production and, in particular, anything that reduces AT&C losses, will have a large potential impact on reducing emissions.

Based on analysis by McKinsey & Company, the *SMART 2020* report identifies four high-impact activities for carbon emissions that can be achieved in India’s power sector:

- Reduction in T&D losses
- Integration of renewable energy sources
- Reduction in consumption through user information
- Demand-side management.

Although *SMART 2020* is focused on carbon emissions and how the ICT industry can reduce its carbon footprint, the observations about India’s power sector are pertinent

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<sup>43</sup> The Climate Group, *SMART 2020*, op. cit., p. 47.

to the industry's migration to a smart grid vision since the underlying analysis focused on how ICT could help the ultimate users reduce their carbon footprint. Furthermore, there is a high correlation between generation and carbon emissions in the power sector. For those reasons, we use this framework as a starting point to identify the high-need/high-impact areas for potential pilot projects, as shown in Table 7. Certain institutional and policy matters will be critical to success, as will the need to improve service quality.

One-page summaries of the possible pilot projects are included at the end of this chapter. In addition to a basic requirement that each possible pilot mitigate carbon emissions, the first priority in developing them was to identify ways to contribute to the reduction in AT&C losses. Other priorities were to support demand response/energy efficiency and to enhance customer value/ease the demand for electricity on discoms (to facilitate improvement in their commercial/financial position). Another consideration went to possible pilot projects that could help accelerate the pace of reform.



**Table 7: Smart grid focus areas in India**

Possible Pilot Project/Study	Reduce AT&C Losses / Improve Efficiency	Reduce / Mitigate Carbon Emissions	Improve Service Quality / Enhance Transparency	Facilitate Demand Response and Energy Efficiency	Reduce Demand on Discoms	Transform the Biz Model / Accelerate Reform
1. Link R-APDRP to measurable service-quality KPIs	■	■				■
2. Smart green apartment complex		■	■	■	■	■
3. PHEVs		■		■		■
4. Replacement of small-scale gensets with renewable energy		■				■
5. Off-grid renewable energy for irrigation pumping	■	■	■		■	■
6. Smart grid pilot in BESCOM	■	■		■		■
7. Wastewater methane generation	■	■			■	■
8. Distributed RE generation in remote rural villages			■		■	■
9. TOU rate pilot project		■	■	□	□	□
10. Advanced Volt/VAR support	■	■	■			
11. Direct debit delivery of subsidies coupled with cost-based tariffs	□		■	■	□	■

■ High potential impact    ■ Contributing impact    □ Enabling precondition

### 4.4 Moving Forward

Techno-commercial pilot projects offer interesting potential demonstrations of ways to improve results for customers and utilities alike. However, achieving a smart grid vision goes well beyond any individual pilot and, in fact, all of them collectively. Overall, the major elements include:

- Developing a smart grid vision
- Conducting appropriate communication to educate and develop consensus
- Identifying viable funding options
- Implementing appropriate policy and regulatory actions to set common standards and encourage innovation.

In tandem with these actions, certain techno-commercial pilot projects could be implemented to demonstrate their commercial viability. A high-level view of the next steps is presented in Table 8.

**Table 8: Summary of suggested smart grid elements and components for India (2010-2020)**

Element	Components	Timing	Adoption Level		
			National	Utility	Customer
1. Develop National Smart Grid Vision	Set up a smart grid task force (multidisciplinary, with major ICT focus)	1	■		
	Confirm target loss reduction curve for AT&C losses at discoms	1	■		
	Confirm impact estimates for renewable energy, carbon emissions, cost reduction and service quality improvement	1	■	■	
	Conduct customer and market surveys to confirm objectives and get feedback from key reform participants	1		■	■
	Draft proposed vision and indicative plan identifying roles and responsibilities	1	■		■
2. Develop Flexible Smart Grid Approach for India	Link R-APDRP to service quality improvements to service quality & operational improvements demonstrated by KPIs	2	■	■	
	Identify smart grid elements for introduction to the discom business model and internal operations program using KPIs	2	■	■	
	Foster partnerships between ICT and power sector players	2		■	■
3. Develop Legal and Regulatory Framework	Amendments in Electricity Act 2003, National Tariff Policy and National Electricity Policy	1	■	■	■
	Regulatory approach for energy security and societal value	2	■	■	
	Higher return to utilities for higher risk and use of cutting-edge technology efficiency and better service delivery	1	■	■	
4. Support Development of Smart Grid Infrastructure	Develop a policy approach for cost recovery	2	■	■	■
	Identify funding source for ICT backbone infrastructure for qualified projects	2	■	■	
	Identify funding source for electric grid infrastructure for qualified projects	2	■	■	
	Develop standards and protocols for interoperability	2,3	■	■	
5. Conduct Techno-commercial Pilot Projects	Confirm and rank order commercial viability and environmental impacts and launch projects with strong monitoring and verification protocols	2	■	■	
	Develop case studies, customer education and outreach to all major stakeholders to build commitment	3	■	■	■

Timing/Phases: 1 – Immediate / as soon as feasible; 2 – As soon as preconditions are met; 3 – Continuous

## The role of USAID/India

USAID/India is uniquely well equipped to assist the GOI through the Ministry of Power (MOP) and the Bureau of Energy Efficiency (BEE) to develop and successfully implement a smart grid vision appropriate to India's circumstances. Such a vision would optimize the benefits achieved in terms of mitigating carbon emissions and optimizing the value equation for electricity customers by creating a framework for sustainable, low-carbon, high-growth economic development. USAID/India's role could include:

- Evaluate ways to integrate results-based KPIs into the R-APDRP program
- Help develop target loss-reduction curves and AT&C loss reduction programs for discoms
- Explore the potential impact of and prospects for implementing micro grids
- Conduct studies of market needs and customer behavior
- Assess the potential impact of renewable energy and energy efficiency on electricity demand
- Organize US-India collaborations and studies on technical issues and legal, regulatory and financial policies
- Help develop retail electricity tariff designs to promote DSM, tap renewable energy potential, and flatten the load curve
- Assist in developing/adapting an appropriate cost-benefit analysis methodology for the Indian context
- Help develop a methodology to estimate the cost of externalities tailored to the Indian context for use in conducting cost-benefit analyses
- Implement techno-commercial pilot projects, as agreed with the MOP, and provide feedback as appropriate
- Conduct other studies to assist with the development/implementation of a smart grid vision adapted to the Indian context
- Develop and implement consumer outreach and education programs
- Implement capacity building initiatives with regulators and policymakers on time-of-use tariffs, feed-in tariffs and other issues related to the implementation of pilots or the smart grid
- Build the capacity of discoms to absorb new smart grid technologies.

## **Opportunities for US-India collaboration**

There are some interesting possible opportunities for the exchange of knowledge, including:

- Electric Power Research Institute – seminars and/or a joint task force to adapt EPRI's Smart Grid CBA methodology to the Indian context
- National Association of Regulatory Utility Commissioners and/or National Regulatory Research Institute – collaborations on studies and workshops on policy and regulatory issues related to the smart grid
- US and Indian electric companies – information exchanges on pilot projects, e.g., Southern California Edison's smart grid pilot and/or PJM's program with the University of Delaware to purchase backup EV energy for system stabilization
- Exchange programs organized by US Energy Association
- Exchange programs with the US Department of Agriculture's Rural Utility Service
- NIST collaboration with Government of India agencies, e.g., BIS.

## **A flexible implementation approach is required**

A national-level task force will be required, but it should focus not only on policy issues as outlined above but also on customers. Table 8 presented a high-level assessment of the next steps for developing a smart grid vision and implementing it. It should be emphasized that any plan must be adaptable to the unique needs, cultural and political realities, and resource constraints of different regions, states and localities. Perhaps the gravest error at this early stage of smart grid development would be to adopt a rigid, top-down and "one size fits all" approach to achieving a smart grid vision.

## **4.5 Eleven Potential Pilot Projects for India**



## Link R-APDRP to Service Quality KPIs

Business Case	
<p>The GOI's Revised Accelerated Power Development and Reforms Programme (R-APDRP) can be viewed as a forerunner to the implementation of a smart grid vision. It encompasses the introduction of ICT into the distribution business and, as such, should be linked with improvements in service quality as measured by KPIs. The measurement and continuous reporting of the universal KPIs for service quality in the electricity business (e.g., SAIDI, SIAFI, CAIFI) and also some logically linked KPIs (e.g., transformer failure rates, percent of energy metered, percent of metered energy that is billed and collected) would help to emphasize the linkage between inputs, activities and results</p>	
Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>• Survey global practice and practice in India, including CERC, State Electricity Regulatory Commissions, State Electricity Boards and Discoms to identify the state of reporting of KPIs for service quality.</li> <li>• Develop a best practice set of KPIs</li> <li>• Present the results in a white paper and at a national conference</li> <li>• Establish an industry benchmarking forum to report results and to conduct joint studies to improve KPI results.</li> </ul>	<ul style="list-style-type: none"> <li>• The cause and effect link between the implementation of ICT in the electricity distribution business and the achievement of results as measured by KPIs (see the list above) is often influenced by other factors, especially management actions or inactions. Thus, management's commitment to achieving the results defined by the KPIs will be critical.</li> </ul>
Benefits	Costs
<ul style="list-style-type: none"> <li>• A better platform for smart grid initiatives.</li> <li>• Improved metering, billing and collection</li> <li>• Reduced AT&amp;C losses</li> <li>• Reduced carbon emissions.</li> </ul>	<ul style="list-style-type: none"> <li>• The additional cost of defining the KPIs, developing consensus and establishing an industry benchmarking forum should be modest since they can build on existing programs.</li> </ul>

## Smart Green Apartment Complex

### Business Case

The value of a Leadership in Energy and Environmental Design (LEED)-certified green building is well established and growing in popularity around the world.<sup>44</sup> Although the construction cost of a green building is about 15-20% higher than conventional construction, the higher first cost is more than offset by the reduction in annual operating costs. This project would explore using smart grid automation to optimize the LEED green building concept. It could include tasks to focus on the potential in residential apartments.

The growth in apartment housing in Indian urban pockets is creating an increasing number of “city within a city” developments. For example, Dwarka township in Delhi and Lavasa city near Pune are nearly self-contained developments but with good infrastructure for rapid mass transport, educational and public facilities. The Dwarka mini-city covers more than 5,000 hectares and is estimated to house half a million families.<sup>45</sup> Similarly, Lavasa city, when completed, will cover 10,000 hectares, almost one fourth the size of Mumbai<sup>46</sup> and Gurgaon is a separate high-growth, high-tech “new city” on the outskirts of Delhi. The discoms serving these areas cannot provide adequate supplies of reliable electricity to satisfy the expectations of the more affluent people moving into these areas. Some community organizations have organized backup generators to provide power when adequate power is not available from the discom. More can be expected to be built even though power from a diesel genset is very expensive.

A developer could improve the marketability of apartments by offering a secure source of backup power that, when blended with local discom prices, will lower total bills. Adding established energy efficiency concepts to minimize electricity usage would further minimize energy costs. Another option would be to include renewable energy and storage capacity to provide clean backup power. Another intriguing possibility – especially in view of the number of mini-cities to be developed over the next 20 years *and* the number of new cars to be sold – is integrating houses and cars in a holistic approach to optimizing energy use.

### Implementation Approach

### Key Challenges and Questions

<sup>44</sup> World Economic Forum, *Accelerating Smart Grid Investments*, Geneva, 2009.

<sup>45</sup> <http://www.dwarkaparichay.com> and [http://en.wikipedia.org/wiki/Dwarka\\_Sub\\_City](http://en.wikipedia.org/wiki/Dwarka_Sub_City)

<sup>46</sup> <http://www.lavasahillcity.com>

<ul style="list-style-type: none"> <li>• Analysis of EA03 and state regulations to identify preconditions for success</li> <li>• Develop a detailed business case, including a solution to the higher funding needs</li> <li>• Identify a developer interested in participating in a pilot project</li> <li>• Develop a cost hierarchy of smart-grid technologies to install on a least-cost basis.</li> </ul>	<ul style="list-style-type: none"> <li>• Conduct a detailed cost / benefit analysis demonstrating the business case</li> <li>• Educate developers on smart grid benefits</li> <li>• Develop a compelling marketing plan for prospective buyers</li> <li>• Develop smart-banks to finance smart grid solutions, perhaps with a DCA loan guarantee / mortgage buy-down</li> </ul>
<p><b>Benefits</b></p>	<p><b>Costs</b></p>
<ul style="list-style-type: none"> <li>• Lower electricity use and carbon emissions</li> <li>• Better value-for-money for smart housing</li> </ul>	<ul style="list-style-type: none"> <li>• Long-term O&amp;M costs for smart apartments need to be determined.</li> </ul>

## Plug-in Hybrid Electric Vehicles

### Business Case

Because of the number of new mini-cities that will be developed in India over the next 20 years *and* the number of new cars to be sold, one intriguing possibility is the idea of integrating “smart” houses and plug-in hybrid electric cars (PHEVs) in a holistic approach to optimize energy use and storage.

In the words<sup>47</sup> of Willett Kempton, director of the Center for Carbon-free Power Integration and a professor at the University of Delaware: “The long-term vision is to charge electric vehicles at night, off-peak, when intermittent but huge amounts of wind power are available. More valuable in the short term is frequency regulation, involving short bursts of charging and discharging on command by PJM.”<sup>48</sup> The net draw on the battery over time is close to zero, according to Kempton. “Electric drive vehicles cost roughly one-quarter as much as gasoline-driven vehicles per mile. Their operating pollution is negligible.” PJM is paying the University of Delaware because the cars offer cheap control of electricity that PJM needs for frequency regulation, to balance shifts between generation and demand. The technology currently is also suitable for spinning reserves. In both applications, PJM ordinarily would use power plants, with significant capital and operating costs that V2G could replace.

"What's new," according to Kempton is that "money is changing hands."

The question for India is what might be made of the potential for similar applications?

Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>Integrate the smart-grid concept at the urban planning stage.</li> </ul>	<ul style="list-style-type: none"> <li>Developing a smart bank to subsidize smart grid solutions.</li> </ul>

<sup>47</sup> As reported by Phil Carson, editor-in-chief, *Intelligent Utility Daily*, February 25, 2009.

<sup>48</sup> PJM coordinates the generation and transmission of wholesale electricity in all or parts of 13 states in the US, from the Mid-Atlantic to Chicago, and the District of Columbia.

Benefits	Costs
<ul style="list-style-type: none"><li>• Competing developers would embrace smart-grid concepts and hence trigger a cascading effect on smart apartment housing development</li><li>• Enables a low-carbon pathway consistent with national goals.</li></ul>	<ul style="list-style-type: none"><li>• Energy efficiency measures with 2-5 year paybacks and distributed renewable energy technologies with 7-10 year paybacks could be financed</li><li>• The operation and maintenance costs of smart apartment housing are not fully established and long-term O&amp;M costs need to be identified.</li></ul>

## Replacement of Small-scale Gensets with Renewable Energy and Connect them to the Grid

### Business Case

India has about 20,000 MW of captive capacity that is not connected to grid; most is stand-by generation for mostly small industrial companies. These units range from 100 kW to 500 kW with, we estimate, an average size of 200 kW. The plant load factors are low (approximately 33% at maximum). Industrial firms, shopping malls, large-scale apartment complexes and some “vest pocket” IPP operators in affluent residential enclaves represent an enormous untapped potential. Finding a way connect even a portion of this captive capacity to the grid would help close India’s supply-demand gap. The problem is that most of this capacity uses diesel for fuel and, as such, is a high carbon emitter.

The goal would be to determine whether and to what extent these distributed generators could 1) be replaced with renewable energy-fueled generation, perhaps in conjunction with storage and 2) connected to the grid. The initial capital cost would likely be significant and obtaining the appropriate policy support and regulatory approval might be a test case for evaluating the societal benefits of the conversion. A pilot project could and probably should be funded at least partly by a GOI grant, but ongoing operating costs would have to be paid on a commercial basis. Another dimension to this project could be the study of so-called “feed in” tariffs to mobilize private investment to fund the conversion of these small-scale generators to RE. How to share, if at all, the cost of linking these small gensets to the grid would have to be determined and sanctioned by policy and approved by regulation.

Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>• Study the potential and segment the existing stock of distributed gensets by location, size, age, fuel type and customer group (e.g., industrial, shopping malls, apartments). Assess the potential for 1) converting generation to RE, and 2) connecting supply to the grid. Map the potential geographically</li> <li>• Develop an economic model, evaluate costs and benefits, and assess funding options</li> <li>• Evaluate the need for / potential of a feed-in tariff to attract private investment</li> <li>• Assess the potential to package storage with the conversion to RE</li> </ul>	<ul style="list-style-type: none"> <li>• Involvement of private owners</li> <li>• Getting buy-in from discoms, political support and regulatory approval</li> <li>• Sustainability of model</li> <li>• Are feed-in tariffs workable? Needed?</li> <li>• Who will bear the cost of connecting to the grid?</li> <li>• Roll out on larger scale after successful pilots.</li> </ul>

<ul style="list-style-type: none"> <li>Plan demonstration pilots for different regions with good solar / wind potential.</li> </ul>	
<p><b>Benefits</b></p>	<p><b>Costs</b></p>
<ul style="list-style-type: none"> <li>Links to the grid capacity for which there is demand and need</li> <li>Reduces carbon emissions</li> <li>Creates entrepreneurial opportunities and generates employment.</li> </ul>	<ul style="list-style-type: none"> <li>The initial capital cost could be significant</li> <li>Installation and O&amp;M costs are unknown.</li> </ul>

## Off-Grid Renewable Energy for Irrigation Pumping

### Business Case

Many of India's 10,000,000 irrigation pumps are powered by electricity that is provided free or at a nominal tariff. These dysfunctional but politically correct tariffs have caused the wasteful use of water and electricity. Underground aquifers are being depleted at an ever-increasing rate and estimates of electricity used for irrigation pumping range from 20 to 30% of total.

Distributed renewable energy (e.g., wind, solar) could be used to provide power to operate pumps that could irrigate fields directly or pump water to storage tanks for later use or, alternatively, energize batteries. A one-time capital grant to offset the installation cost of such a system might be justified in terms of the value of subsidies to the power sector that could be discontinued. This could be integrated as part of an ESCO Agricultural DSM solution as is being tested at Doddaballapur, Karnataka or with other models considered (e.g., farmer cooperative), including the franchise model to improve the economic viability of franchises with significant agricultural demand.

#### Implementation Approach

- Analyze EA03 and state regulations, etc. to identify the preconditions for successful implementation
- Survey RE and high-efficiency pump manufacturers to identify the technology options and estimated costs
- Study the results of Ag DSM pumping pilots and franchising experiments
- Develop an economic model, evaluate costs and benefits, and assess funding options
- Plan demonstration pilots for several regions (e.g., those with good solar potential, good wind).

#### Key Challenges and Questions

- A intensive program to educate farmers will likely be required
- Regulatory approval and assent by a discom may be required if an ESCO (with a contract with the local discom) will own the RE source
- Vested interests who get free electricity under Ag tariffs may oppose something that reduces the known benefit they now receive
- The economic viability of the program might require metering and possibly a cost-recover mechanism, e.g., tariff.



Benefits	Costs
<ul style="list-style-type: none"><li>• Reliable electricity for irrigation pumping</li><li>• Enhanced control of ability to irrigate crops for farmers</li><li>• Improved agricultural outcomes, i.e., quality of crops, farmer incomes</li><li>• Reduction in power sector subsidies</li><li>• May justify the implementation of (transformer) metering if farmers are assured of adequate electricity for pumping.</li></ul>	<ul style="list-style-type: none"><li>• The initial capital cost could be significant</li><li>• Installation and O&amp;M costs are unknown.</li></ul>

## Smart Grid Pilot in BESCO

Business Case	
<p>Bangalore Electricity Supply Company (BESCOM) is one of India's leading distribution companies. It has been a pioneer in many fields of technological implementation, especially distribution automation. With a vision to continue its leadership in the electricity distribution sector, BESCOM is keen to develop a smart grid pilot project. BESCOM's smart grid pilot will be implemented in the Electronic City area. A hub for large IT companies, the pilot area comprises 17,409 consumers of all types with a relatively sophisticated consumer profile.</p> <p>A workshop on the smart grid was organized on 5 January 2010, with leading technology providers participating. IT companies expressed their willingness to support BESCOM in its venture by providing the right mix of technology free of cost as well as the support needed to integrate renewable energy and captive generation with the grid. As per workshop the smart grid pilot in electronic city area will cost about 100 corer.</p> <p>The Ministry of Power (MoP) has already approved the creation of a smart grid task force. It has set aside approximately Rs 200 crores for pilot projects. Fifty percent will be contributed by the MoP and the remainder must be arranged by a distribution company. BESCOM has already submitted an application requesting their support for this activity.</p>	
Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>• Evaluate costs and benefits, and assess funding options</li> <li>• Develop a public-private partnership model</li> <li>• Quantify robust baseline data prior to implementation so that benefits can be verified and documented</li> <li>• Focus on urban areas during first phase of implementation</li> <li>• BESCOM to solicit support from the Ministry of Power and private sector vendors and service providers for the installation of a communication network, hardware and software.</li> </ul>	<ul style="list-style-type: none"> <li>• Selecting the right technological partner and consultants</li> <li>• Regulatory approval for a variable-rate tariff based on BESCOM's power purchase price</li> <li>• Upgrading the existing network</li> <li>• Consumer education on participating in this pilot</li> <li>• BESCOM employee knowledge and skills development</li> <li>• Detailed cost/benefit analysis demonstrating the business case</li> <li>• Rolling the project out on a larger scale after the pilots have proven successful.</li> </ul>
Benefits	Costs

- Peak curtailment/levelling and time-of-use pricing – load adjustment
- Power quality improvement and grid self-healing
- Integration of renewable/captive generation
- Tariff options to consumers – monthly reduction in consumer bill
- Better and advanced customer services
- Reduced technical and commercial losses to a level of international standard.

- Network upgrade costs would be significant
- While the cost side equation is well known and focused within the utility, the benefits are often unclear and societal in nature.

## Wastewater Treatment Plant Methane Capture

### Business Case

Electricity is one of the largest factor inputs for wastewater treatment plants, which must operate 24 hours a day, 365 days a year. Methane, a by-product of wastewater treatment, can be used to produce electricity. In India, municipal treatment plants are among the largest non-payers of electricity. It is difficult to force them to pay due to the essential nature of the service.

If a cost-effective way can be found to build new wastewater facilities using methane capture to fuel an on-site generator, it could reduce the amount of electricity the local discom would have to provide and lessen the financial impact of non-payment by the municipal treatment plant. The retrofit of a power generation facility at an existing wastewater treatment plant could achieve similar results. Also, the facility could be operated under a management contract by a private operator. If suitable payment guarantees could be arranged (e.g., a contract with a power trader who could sell the output on power trading markets and pay the proceeds to the plant operator and the wastewater municipality), it might be possible to create a viable private investment.

Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>• Assess construction and O&amp;M costs of suitable plant sizes from manufacturers of on-site generation equipment</li> <li>• Survey overseas wastewater treatment plants with methane on-site generation to identify the characteristics required for a viable plant, e.g., processing volumes, off-take prices, construction costs, O&amp;M expenses</li> <li>• Analyze the power trading potential of India's power markets and transmission grids to identify high-potential areas</li> <li>• Develop an economic model, evaluate costs and benefits (including the value of carbon credits) and assess funding options (including possible loans from multilateral banks)</li> <li>• Plan and implement a demonstration.</li> </ul>	<ul style="list-style-type: none"> <li>• A municipal authority with the ability to assure backing of a payment guarantee mechanism</li> <li>• Financing, especially if a private owner / operator is desired</li> <li>• An enforceable contractual arrangement regarding delivery of electricity to a power trader, perhaps including a take-or-pay provision to ensure that the power trader would be receive power (or payment in lieu) to enable payment to the private operator.</li> <li>• Regulatory approval and assent by a discom may be required</li> <li>• A government guarantee may be necessary.</li> </ul>

Benefits	Costs
<ul style="list-style-type: none"><li>• Reliable source of electricity for wastewater treatment plants</li><li>• Increased ability to build wastewater treatment plants in urban areas</li><li>• Reduction in power sector subsidies</li><li>• Methane's high carbon credit value could defray capital cost.</li></ul>	<ul style="list-style-type: none"><li>• The initial capital cost could be significant</li><li>• Installation and O&amp;M costs are unknown.</li></ul>

## Distributed RE Generation in Remote Rural Villages

### Business Case

One of the most incorrigible problems in India's power sector is the rural-urban divide. The low customer density in rural areas, and more so in remote rural areas, creates an inherent disincentive to expand the grid. And when the grid is extended, this phenomenon (coupled with low income levels) creates a disincentive for utilities to "extensify" electricity access to more people.

The purpose of this pilot would be to identify low-cost energy solutions that do not require grid access and promote them in rural areas. Applications could include existing technologies (e.g., solar water heating, but also other limited techniques to provide high-impact access to electricity, such as community internet access for medical and educational purposes) to enable farmers to check commodity prices, etc. The concept would be to install an RE source (e.g., a solar panel) that would provide sufficient power to operate a laptop. The initial capital cost could be funded at least partly by a GOI grant program, but ongoing operating costs would have to be paid on a commercial basis.

Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>• Create a micro grid</li> <li>• Use 90% capital subsidy from GOI in RGGVY scheme</li> <li>• Develop an economic model, evaluate costs and benefits, and assess funding options</li> <li>• Plan demonstration pilots for several different regions, e.g., those with good solar potential, good wind, etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Involvement of local community</li> <li>• Sustainability of model</li> <li>• Roll out on larger scale after successful pilots.</li> </ul>
<b>Benefits</b>	<b>Costs</b>

- Basic source of electricity for remote rural villages
- Access to basic health care knowledge
- Remote learning capability (e.g., farming techniques, health care)
- Mobile phone recharging
- TV use for communication, entertainment and education
- Creates entrepreneurial opportunities and generates employment.

- The initial capital cost could be significant
- Installation and O&M costs are unknown.

## Time-of-Use (TOU) Rate Pilot Project

Business Case	
<p>The implementation of smart meters is central to the smart grid vision. The two-way communication capability that is implicit in what seems to be a universal assumption only makes sense in an operating environment where TOU rates are in effect. Without a means to signal the changing cost (and, thus, price) by time of day, it will not be possible to achieve the most basic of benefits of the smart grid vision. TOU rates make good sense from an economic and business perspective, but the process of developing them, getting them approved by regulators and accepted by customers has been fraught with difficulties, and progress has been slow. This has also been the case in India. Getting results from a valid TOU pilot is essential for the power sector – including companies, regulators and customers – to understand this concept and learn about the benefits TOU can enable.</p>	
Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>• Develop a concept note and plan, including costs and the approach to measuring results</li> <li>• Identify potential pilot sites with the discom and ERC support</li> <li>• Conduct cost-of-service study to determine costs by time of use and obtain ERC approval</li> <li>• Conduct a customer survey and a consumer education program</li> <li>• Compile baseline data</li> <li>• Implement and test meters and implement the demonstration pilot</li> <li>• Collect data from the pilot, make course corrections as needed, and analyze results</li> <li>• Conduct a follow-up customer survey.</li> </ul>	<ul style="list-style-type: none"> <li>• Customer acceptance</li> <li>• Political support</li> <li>• Regulatory approval.</li> </ul>
Benefits	Costs
<ul style="list-style-type: none"> <li>• A successful TOU pilot will enable an assessment of the potential to</li> </ul>	<ul style="list-style-type: none"> <li>• The initial capital cost could be estimated on the basis of prior</li> </ul>



<p>flatten the load curve and reduce the total amount of customer bills from a demand response program using time-of-use price signals</p> <ul style="list-style-type: none"><li>• Flattening of the peak</li><li>• Reduction in the size of customer bills.</li></ul>	<p>attempted TOU pilot projects.</p>
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## Increase the Efficiency of Electricity Delivery through Advanced Volt/VAR Control

### Business Case

Distribution management systems (DMS) have varying degrees of sophistication. Some companies handle their distribution system operations using manual and paper-based systems using static data and prevailing conditions of the network and customers. Others manage their operations using more sophisticated systems that provide operators with more real-time circuit and customer data by adopting DMS applications including distribution power flow, fault detection and restoration, voltage/VAR control, and contingency analysis.

The use of advanced DMS systems can increase efficiency in electricity delivery by reducing distribution system losses and end-user energy consumption through advanced voltage/VAR control. Distribution losses increase as voltage levels in feeders drop because motors and other types of connected loads draw more current to compensate for a drop in voltage. Since electricity losses are a function of the square of the current, they increase. Today, distribution operators try to maintain customers' voltage levels by adjusting transformers at substations and perhaps voltage regulators at the beginning of the feeders. Many utilities also need to add capacitors to provide the VAR support required to avoid excessive voltage drops along the feeders. Such capacitors are often constantly connected and manually switched on/off.

Smart grid technologies, by continuous monitoring, controlling and acquiring data, can be used to dynamically optimize the required VAR support needed on distribution feeders according to their changing load conditions. Integrated Vol/VAR control (IVVC) can provide coordinated and dynamic control of substation transformer tap changers, feeder voltage regulators and capacitor banks to ensure appropriate voltage profiles in distribution feeders.

Implementation Approach	Key Challenges and Questions
<ul style="list-style-type: none"> <li>• Analyze discos' current conditions to identify preconditions for success</li> <li>• Develop a detailed business case, identifying loss reduction potential and peak load reduction resulting in lower fuel generation costs, and deferral of generation capacity</li> <li>• Identify a developer interested in participating in a pilot project</li> <li>• Develop cost hierarchy of DMS and smart-grid technologies to implement on a least-cost basis.</li> </ul>	<ul style="list-style-type: none"> <li>• Detailed cost / benefit analysis demonstrating the business case</li> <li>• Educate discos on the benefits of DMS and value of IVVC using smart-grid applications and technologies</li> <li>• DMS requires detailed electric system modeling including connectivity, impedance, equipment, load distribution, and often geographic coordinates for all elements. Getting such data requires access to GIS/AM-FM, CIS/billing, and system load flow packages, which may not be in place.</li> </ul>

Benefits	Costs
<ul style="list-style-type: none"><li>• Reduced electricity distribution losses</li><li>• No need to manually control and inspect capacitor banks</li><li>• Real-time monitoring of voltage on circuits</li><li>• Lower electricity use and carbon emissions.</li></ul>	<ul style="list-style-type: none"><li>• The operation and maintenance of DMS and IVVC extended from the network to the pole-mounted transformer. The individual customer may not be identified and long-term O&amp;M costs need to be established.</li></ul>

## Direct Debit Delivery of Subsidies

### Business Case

One of the continuing challenges for India's power sector relates to subsidies and how to ensure that 1) they are delivered to the intended customer groups – mostly small consumers and farmers – and also that 2) a high proportion of the subsidy fund is delivered to the target customers. These phenomena are known as “targeting” and “penetration.” A related problem is the effect on customer behavior when subsidies are delivered through tariffs. These issues cause distortions in consumption and potentially significant misdirection of subsidies.

If discoms and SEBs set tariffs based on economically efficient cost-of-service principles – and if subsidies were delivered directly to customers – they (customers) would have an incentive to respond to price signals while also receiving the intended value of their subsidy. In fact, these customers would have an incentive to minimize their electricity consumption if the system allowed them to keep any unused portion of the subsidy (i.e., beyond what was needed to pay their electricity bill) and apply it to other economic goods. Given the sophisticated ICT available in India and its robust financial system, it may be possible to provide debit cards to some, most, or even all customers who receive an electricity subsidy and allow payment to be made by that card. If that card could also be used for other purchases (up to the available balance), it would create an incentive to use electricity more carefully while also creating funds that could provide some measure of financial flexibility for small, mostly rural, customers.

### Implementation Approach

- Analyze subsidy flows and recipients by geography, occupation, age and income
- Discuss the potential for issuing debit cards with financial institutions and mobile phone operators. Assess implementation steps, costs, barriers and risks, and evaluate potential impacts of a successful roll-out
- Conduct a road show to review the idea with government policy makers and regulators at the State and Centre as well as the MOP and other stakeholders
- Enlist the participation of a financial institution and/or mobile operator
- Obtain funding, if and as required

### Key Challenges and Questions

- The data on the size of subsidies and the data subsidy flows are murky and may be difficult to obtain as well as sensitive
- Financial institutions and/or mobile telephone operators would need a high degree of confidence that the program would not be subverted; thus, a thorough risk analysis would be important
- A viable transition plan would have to be developed
- The potential that cash subsidy requirements might exceed the notional value of subsidies embodied in tariffs would have to be analyzed and a mitigation / transition plan developed.

<ul style="list-style-type: none"> <li>• Plan and implement a pilot project</li> <li>• Measure results and make a recommendation for moving forward.</li> </ul>	
Benefits	Costs
<ul style="list-style-type: none"> <li>• Price signals based on economically efficient tariffs would be introduced to the electricity market.</li> </ul>	<ul style="list-style-type: none"> <li>• The financial institution / mobile operator would pay the debit card system costs</li> <li>• Other costs should be transition costs for discoms / regulators.</li> </ul>

# Annex A

## Selected Readings

### Cost-Benefit Analysis

Before the Maryland Public Service Commission Case No. 9208 In the Matter of Baltimore Gas and Electric Company for Authorization to deploy a smart grid Initiative and to establish a surcharge mechanism for the Recovery of Cost. Direct Testimony of Nancy Brockway on behalf of The Maryland Office of People's Counsel, October 13, 2009.

*Provides an example of large cost over-runs as well as a detailed business case for installing smart meters.*

DIRECT TESTIMONY of J. RICHARD HORNBY On behalf of: PENNSYLVANIA OFFICE OF CONSUMER ADVOCATE FOR giving testimony on West Penn Power Company d/b/a Allegheny Power's petition dated August 14, 2009 requesting approval of the Smart Meter Technology Procurement and Installation Plan, October 16, 2009.

*A detailed analysis of the business case for the installation of smart meters, including the impact on rates.*

SmartGridnews.com. Demand Response Cost-Saving Potential (Case Study). Bonneville Power Administration pilot smart grid case study for Ashland, Kentucky, May 2006.

*Illustrates the business case for demand-response.*

Synapse Energy Economics, *Ratemaking Issues from Recent Smart Meter Cases in Maryland and Pennsylvania*, November 2009.

*Shows the calculation of costs for smart meters that need to be passed down in tariffs.*

U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI), "Methodological Approach for Estimating Benefits and Costs of Smart Grid Demonstration Projects, January 2010.

*Provides a proposed approach for conducting cost-benefit analyses for Smart Grid projects.*

### Regulatory Issues

European Regulators Group for Electricity & Gas, "Position Paper on Smart Grids," Ref: E09-EQS-30-04, December 10, 2009.

*Outlines a number of views and proposals regarding the regulatory aspects of electricity networks and seeks to further the discussion on the development of electricity grids and of their regulation in the future.*

## Carbon Reduction

The Climate Group and the Global eSustainability Initiative, *SMART 2020: Enabling the Low Carbon Economy in the Information Age*, 2009.

*Analyzes how the ICT industry can reduce its carbon footprint globally by enabling carbon-reducing initiatives in the end-user industries of ICT. The report includes a section devoted to India's power sector that is enlightening and useful.*

Pratt, R.G. et al., *Smart Grid; An Estimation of the Energy and CO<sub>2</sub> Benefits*, Pacific Northwest National Laboratory, January 2010.

*Articulates nine mechanisms by which the smart grid can reduce energy use and carbon impacts associated with electricity generation and delivery. The report attempts to quantify only the additional energy and CO<sub>2</sub> emission benefits inherent in the smart grid's potential contribution to the USA's goal of mitigating climate change by reducing the carbon footprint of the electric power system.*

## Smart Grids

In addition to many articles published in trade journals and internal sources on PA's KnowledgeNet, the following sources were particularly helpful:

Galvin, Robert and Yeager, Kurt, *Perfect Power*, McGraw Hill, 2009.

*Presents a cogent argument for a micro-grid based approach to smart grids that could create a revolution and unleash cleaner, greener and abundant electricity.*

Korean Agency for Technology and Standards (KATS) of the Ministry of Knowledge Economy (MKE), "Standardization on Smart Grid", January 2010.

*Provides a helpful overview of how the Korean Government intends to implement smart grid technology, including as an enabler of additional export revenues.*

U.S. Department of Energy, "Smart Grid System Report", July 2009.

*An overview of the Smart Grid, its meaning and key findings.*

Warrick, Judith, Morgan Stanley. *Navigating Technological Change: A Conversation on the Smart Grid*, speech at a clean technology conference in Palm Springs, California, January 10, 2010.

*This brief speech argues that the formerly staid electric utility sector is facing the most transformative era in its history.*

World Economic Forum, in connection with Accenture, "Accelerating Smart Grid Investments," 2009.

*Presents a thorough, detailed and well organized overview of smart grids.*

## **Information and Communications Technology**

In addition to many presentations by a host of ICT companies, including GE, IBM and others at a smart grid conference conducted by BESCO in Bangalore, the following were especially helpful:

Feisst, Christian, Dirk Schlesinger, and Wes Frye, Cisco Internet Business Solutions Group, "Smart Grid: The Role of Electricity Infrastructure in Reducing Greenhouse Gas Emissions," October 2008.

*Presents an approach to implementing smart grids from the perspective of a leading ICT company.*

IEI, *Recommendations of the All-India Seminar on "Smart Power Grids,"* Andhra Pradesh State Centre, Hyderabad, on 15-16 July 2009.

*Provides an overview of the potential for smart grids in India and a technology review.*



# Annex B

## Selected Smart Grid Pilot Programs

**D**uring the last several years, particularly in the United States, utilities and regulators have implemented a number of pilot programs to try to quantify the benefits and costs of smart grid initiatives. Six programs, some of which used stimulus funds provided under the American Recovery and Reinvestment Act, are described here.

### **B.1 Southern California Edison's SmartConnect Program<sup>1</sup>**

Southern California Edison (SCE) is one of the largest electric utilities in the United States, serving a population of nearly 14 million. Its SmartConnect is a \$1.6 billion program authorized by the California Public Utilities Commission (CPUC) to install 5 million smart meters.

The new digital, secure, two-way communicating smart meters will measure electricity usage up-to-the minute and will enable customers to track how much they use and how much it costs them. Once the smart meters' advanced features are fully activated, the meters will be enabled to communicate with the next generation of smart thermostats, appliances and other devices. In addition to installing the smart meters, SCE is rolling out new pricing plans, programs and services that will empower customers to make informed decisions about their energy use.

SCE began the application process with the CPUC for its smart metering program in 2005. In July 2007, it filed the Application for Edison SmartConnect™ Deployment Funding and Cost Recovery Proposal with the CPUC. Between January and March 2008, SCE and The Utility Reform Network (California's utility watchdog), negotiated and adjusted the costs and benefits forecasts contained in the proposal. In September 2008, CPUC finalized and approved \$1.63 billion in funding for Edison SmartConnect. In September 2009, SCE began installing the first smart meters.

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<sup>1</sup> Source: [www.sce.com/smartconnect](http://www.sce.com/smartconnect)

Figure 8

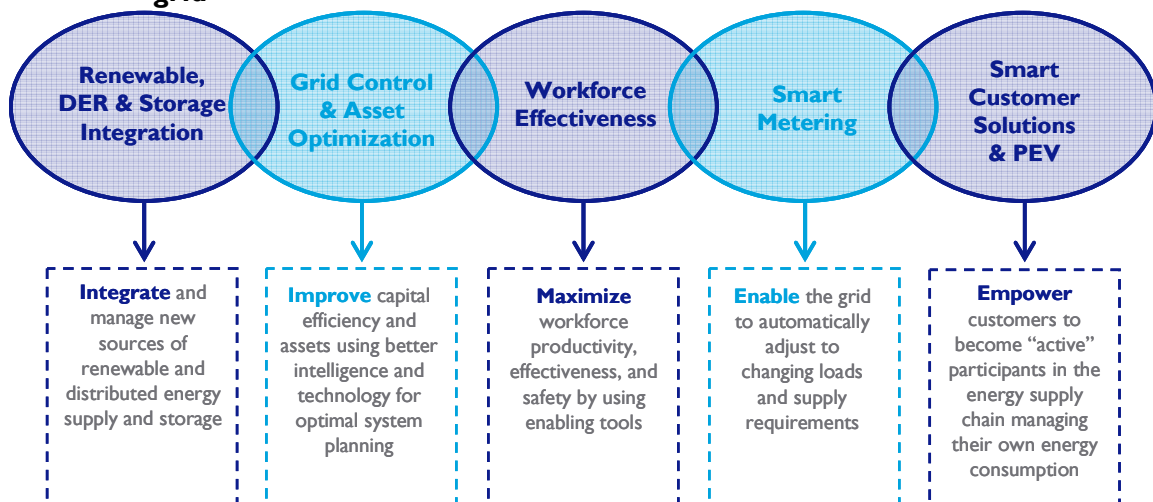
## Edison SmartConnect™ Empowering Customers



- Choice to Manage Cost & Peak Demand
  - Rates
    - Time of Use and Tiered Rates
    - Critical Peak Pricing (CPP)
    - Peak Time Rebate (PTR)
  - Programs
    - Smart Communicating Thermostats
  - Outcome
    - Reduce Peak Load by 1,000 MWs
  
- Energy Information Drives Conservation
  - Reduce Residential Energy Consumption by 1% (minimum)
  - Reduce GHG by 365,000 tons/yr
  
- Automated Self-Service
  - Remote Service Switch
  - Payment and Billing Options

SCE anticipates customers' use of the new meters will reduce demand on the electricity grid by about 1,000 megawatts, the amount of energy produced at an average power plant. Sustained energy conservation resulting from customer response to their energy use information is also expected to reduce emissions of greenhouse gases and smog-forming pollutants by a minimum of 365,000 metric tons per year — the equivalent of removing 79,000 cars from the road. SCE expects to recover the cost for SmartConnect by the end of 2013.

Figure 9: Smart metering is one of five components in SCE's vision for a smart grid



## B.2 Xcel Energy SmartGridCity Pilot Program

Xcel serves 3.4 million electricity customers across 8 US states. In October 2009 it filed for an electricity pilot pricing program with the Colorado Public Utilities Commission (CPUC) to coincide with the implementation of its SmartGridCity™ in Boulder, Colorado. The pilot will include no more than 2,000 customers and is designed to provide better price signals so customers can make informed decisions about their energy use. The program is expected to produce reductions in consumption during on-peak periods or to shift some consumption to off-peak periods. Residential customers who have a smart meter can choose to participate in the pilot, which will run until December 31, 2011.

The program allows participants to opt into a time-of-use (TOU) rate, a critical peak pricing (CPP) rate, or a peak time rebate (PTR) rate. The TOU rate divides the day into on-peak periods, when energy costs more and off-peak periods, when it costs less. The CPP rate builds on the TOU rate. If needed, the CPP rate can be invoked for capacity or economic reasons and increase the price significantly above the on-peak price. The PTR encourages customers to reduce their usage below what they would normally use at a critical peak time. Customers receive a credit for the energy saved on their bill, based on the CPP pricing. Customers will be notified of a critical peak day on the day before it is to take effect.

“We hope that the differing rates will help customers understand the true cost of electric service on the greatest energy use days of the year. We believe that this is one of the critical pieces of our overall SmartGridCity project. By informing customers of the cost of service for these various programs, we think customers will reduce their use accordingly.”

Jay Herrmann, regional vice president for Xcel Energy.

The rate structure was filed with the CPUC, along with a request to put it in place by June 2010. The table below provides the proposed rates, in cents per kilowatt-hour, which would be charged or credited (net metering), to customers within the pilot program:

**Table 9: Proposed rates under the SmartGridCity pilot**

Pricing Pilot	Time of Use	Critical Peak Pricing	Peak Time Rebate
Summer off-peak charge	\$0.04081	\$0.04081	
Winter off-peak charge	\$0.04081	\$0.04081	
Summer on-peak charge	\$0.17921	\$0.12122	
Winter on-peak charge	\$0.06202	\$0.05179	
Summer critical peak charge		\$0.53713	
Winter critical peak charge		\$0.34924	
Summer peak time credit			\$0.48612
Winter peak time credit			\$0.29823

Xcel Energy's overall smart grid implementation strategy involves a two-phased approach:

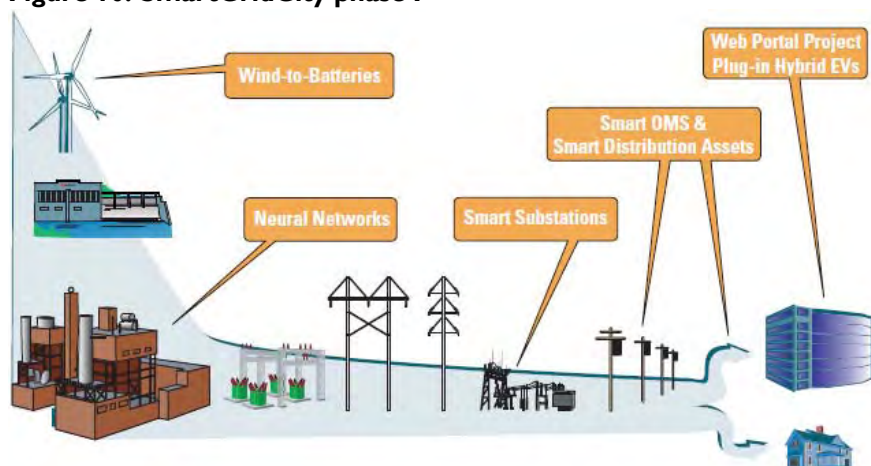
### Phase I – Quick-hit projects

In order to quickly demonstrate smart grid concepts and engage partners with tangible investment opportunities, Xcel identified seven quick-hit projects to test various technologies that could be used to build intelligence into the power grid.

**Wind power storage.** This project tests a one-megawatt battery energy storage system connected directly to a wind turbine at the MinnWind wind farm in southwest Minnesota in an effort to store wind energy and return it to the grid. It is expected to demonstrate long-term emission reductions from increased wind availability, help reduce the impacts of wind variability, and allow Xcel to meet Renewable Portfolio Standard legislation requirements. It will also help Xcel test the technology to make wind power dispatchable on a utility scale.

**Neural networks.** This project creates a state-of-the-art system that helps reduce coal slagging and fouling (the build up of hard mineral in the boiler). Slagging results in several million dollars in lost revenue each year. Boiler sensors plug directly into the distribution control. Neural networks will model the slagging/fouling by using historical data to “learn” boiler behavior. The system also captures and incorporates knowledge directly from the plant engineers and operators – effectively capturing, modeling, and using hundreds of years of collective experience.

**Figure 10: SmartGridCity phase I**



**Smart substation.** This project is retrofitting a substation with cutting-edge technology for the remote monitoring of critical and non-critical operating data. It includes developing an analytics engine that processes massive amounts of data for near real-time decision-making and automated actions. The utility will monitor breakers, transformers, batteries and substation environmental factors (such as ambient temperatures, variable wind speeds, and security cameras). This project will help optimize power factor performance and obtain a significant reduction in distribution losses, leading to a reduced carbon footprint. Expected operational benefits include reduced maintenance and installation costs, improved employee safety and equipment life, faster restoration times, and increased system reliability.

**Smart distribution assets.** This project tests existing meter communication equipment that can automatically notify Xcel Energy of outages in advance of customer calls and help the utility restore outages more quickly.

**Smart outage management.** This project tests diagnostic software that uses statistics on eight factors, including equipment maintenance, real-time weather and history, to predict

problems in the power distribution system. A substation feeder analysis system can detect cable and device failures on monitored substation banks (a cable fail predictor.) Success means responding to outages faster, with properly equipped crews – and possibly even preventing the problem – and detecting outages well before a customer's first call.

**Plug-in hybrid electric vehicles (PHEVs).** This project tests PHEVs in the field. Xcel is equipping six Ford Escape Hybrids with vehicle-to-grid technology, which will allow them to charge from and discharge energy to the grid, in one of the nation's first field tests of this emerging technology. This project will help demonstrate the significant environmental benefits associated with the dual value (transportation and electric energy storage) inherent in PHEVs by showing the degree to which the variable nature of renewable sources can be eliminated by utilizing massive amounts of storage devices connected to the grid and available to be dispatched. It will also help quantify the percentage of the vehicle fuel market that potentially can be moved to domestic electric energy sources. In addition, it serves as a testing and validation opportunity for other types of distributed generation: how they can be managed and how the energy from distributed generation can be put back onto the grid when needed.

**Consumer web portal.** This project will allow customers to program or pre-set their own energy use and automatically control power consumption based on personal preferences on both energy costs and environmental factors. The Web interface will give customers an opportunity to automatically control their energy. Customers will be able to choose to turn devices on or off from pre-selected preferences (for example, hourly price points or green energy signals sent from the Web).

Each of these projects is at various stages of development/deployment ranging from requirements definition, through the final testing and analysis stages. Partners, each of which is willing to co-invest, have been identified for all of the projects.

## **Phase II – SmartGridCity**

SmartGridCity's technology will consist of converting existing metering infrastructure to true two-way architecture integrated with outage management and customer information systems. In addition, substations will be converted to "smart" substations; 10,000 in-home control devices and the necessary infrastructure to fully automate home energy use will be installed; 1,000 dispatchable distributed generation technologies (PHEVs, battery systems, vertical wind turbines, and solar panels) will also be installed.

## **B.3 NSTAR Electric & Gas's Smart Grid Program**

NSTAR is the largest investor-owned electric and gas utility in Massachusetts. The company transmits and delivers electricity and to over 1 million customers in 81 communities. NSTAR's smart grid program includes real-time measurement and communication of energy consumption, automated load management, and remote status detection and operation of distribution system equipment. NSTAR is also including a pilot time-of-use or hourly pricing program for a portion of its customers.

This pilot program will test several pricing and technology combinations, and leverage existing automated meter reading infrastructure and customer broadband connections to support dynamic pricing and the communication of meter data and load control signals.

A full regulatory filing was developed, as well as multiple DOE grant applications for the pricing pilot and three related distribution system smart grid projects addressing: automated grid self-healing, monitoring of urban grid systems for outage restoration and renewable integration, and enhanced smart grid communications infrastructure.

The pilot program complies with statutory requirements for smart grid functionality while leveraging NSTAR's existing automatic meter reading assets, thus minimizing the investment required. The company has been able to test alternative pricing and technology options to determine which are most attractive to customers and which produce the greatest reductions in peak load and energy consumption.

This program has regulatory approval and receives supplemental funding from the federal government's Smart Grid Investment Grant Program. NSTAR receives matching federal stimulus funds from the DOE for 50% of the total costs of its two smart metering programs, and renewable energy interconnections in an urban network system.

#### **B.4 Duke Energy Smart Grid for the Greater Cincinnati Area (Ohio)**

Duke Energy is a Fortune 500 company and one of the largest US electric utilities, delivering electricity to 4 million customers. Since 2008, when the Public Utilities Commission of Ohio (PUCO) approved Duke's smart grid program, the utility has installed approximately 60,000 smart electric meters and 40,000 smart gas meters in Ohio, and will install about 80,000 more smart electric meters and 58,000 more smart gas meters in 2010.

The smart meters will enable remote meter reading, remote service connections and disconnections, faster service and fewer problems for customers. Daily energy usage data will be available online to customers, helping them make wiser energy decisions and avoid billing surprises at the end of the month. The meter would also sense and immediately report an event such as a power outage, allowing faster response times to restore service.

Duke is also installing communication boxes alongside its transformers, which serve as the "brains" of the smart grid system. They create a virtual energy Internet – collecting data from the smart meters and other digital equipment on the power lines, and sending them over a wireless network back to Duke and then back to the customer. Over 10,000 communication boxes will be installed in Ohio in 2010.

Distribution automation equipment like smart sensors and automated switching devices installed on the lines and poles will allow Duke Energy to automatically reroute power in the event of a problem, giving the grid "self-healing" ability. Electricity can continue to flow to most customers, while the automated equipment isolates the power lines in the problem area. When the equipment activates, a crew is automatically dispatched to repair the problem. In 2010, Duke plans to install 88 electronic reclosers (which work like breakers or

fuses) and 9 groups of smart sensors and automated switching devices, which will prevent or shorten power outages for customers.

To cover the cost of smart grid modernization, customers in Ohio will see incremental increases in their monthly electric bills each year, depending on the actual cost of deploying the new technology. The PUCO has capped annual spending on the program, so increases in residential customers' monthly bills will not exceed \$0.50 in 2009, \$1.50 in 2010, \$3.25 in 2011, \$5.25 in 2012, and \$5.50 in 2013 and thereafter.

## **B.5 PG&E SmartMeter Program**

Pacific Gas and Electric Company serves over 5 million electric customer accounts and 4 million natural gas accounts. Its \$2.2 billion rollout of smart meters in California was beset by a number of problems. When the program began in Bakersfield, residents believed their new smart meters were malfunctioning because their bills were much higher than before. PG&E claimed that the higher bills were due to rate hikes, an unusually warm summer, and that customers were not shifting demand to off-peak times when rates were lower. A class-action lawsuit was filed representing thousands of customers demanding damages from the utility and third-parties involved in the project.

There were a number of areas of implementation in which PG&E made mistakes, mainly relating to transparency and communication. One was the company's failure to clearly communicate to its customers the value of shifting demand to a time when rates were lower.

One of the advantages of a smart grid is that the two-way flow of information will allow utilities to alert customers to real-time electricity pricing via an in-home display. PG&E had not rolled out in-home displays with its smart meters, presumably for cost reasons. Even worse, initially PG&E was not posting daily usage numbers and some customers had to wait a month to see their electricity usage information, although this has since been corrected.

PG&E's smart grid rollout was under-resourced as well. There was a perceived lack of open standards around the smart meters and this caused mistrust when the meter installations were followed by higher bills. The negative press will likely prove to be a setback not just for PG&E's own SmartMeter rollout but also for other utilities deploying smart meters. However, valuable lessons for future smart meter rollouts can be gained from this example, particularly on the importance of transparency and clear communication with the customer.

## **B.6 Pepco Holdings Inc.**

Pepco Holdings, Inc. (PHI) is one of the largest energy delivery companies in the Mid-Atlantic region, serving about 1.9 million customers in Delaware, the District of Columbia (DC), Maryland and New Jersey. PHI subsidiaries Pepco, Delmarva Power and Atlantic City Electric provide regulated electricity service; Delmarva Power also provides natural gas service.

PHI completed a smart grid pilot program in DC late 2009 and received \$168 million in federal stimulus funds to accelerate its smart grid implementation programs in all of its service territories.



## PowerCentsDC

PowerCentsDC was a “smart” meter pilot program for approximately 800 to 900 Pepco customers in the District of Columbia. Participants received a smart meter, a smart thermostat (if desired and the residence qualified), and new energy price plans that allow savings for customers who reduce consumption during hours when wholesale electricity prices are high. It is sponsored by Smart Meter Pilot Program, Inc., a non-profit organization comprising the Consumer Utility Board, the District of Columbia Office of the People's Counsel, the District of Columbia Public Service Commission, the International Brotherhood of Electrical Workers, and Pepco. The pilot began in July 2008 and ended in October 2009 after operating for two summers and one winter. The results are expected to establish baselines for the District's energy pricing policy going forward, as Pepco deploys smart meters throughout its District service area.

PowerCentsDC received a national award for Best Pricing and Demand Response Program in 2010, presented by the Association for Energy Services Professionals (AESP). It was selected for the AESP Energy Awards specifically for:

- Contributing to the advancement of the energy services field
- Raising awareness of an energy services program or need
- Representing the “best in class” in designing, implementing, or evaluating an energy services program
- Demonstrating an outstanding commitment to advancing the energy services field.

## PHI Smart Grid Programs

PHI is implementing smart grid programs in all of its service territories, and has recently accelerated some of its smart grid programs due to the recent federal stimulus award of \$168.1million. This money will offset the cost to customers for installing meters and modernizing the electric grid. The smart grid will create new green jobs, boost the economy and lay the technological groundwork for customers to better manage their energy use and reduce carbon emissions generated by fossil-fueled power plants.

PHI's integrated smart grid is composed of advanced metering infrastructure, distribution automation, and demand response technologies.

**Advanced Metering Infrastructure (AMI).** Advanced metering is a system that measures and records customer consumption and other parameters on a set frequency. The system regularly transmits usage and other information over a communications network to a central data collection point where it is analyzed. AMI improves reliability by letting the utility know when a customer is out of service, and is also the key to providing customers with greater usage data, which will enable them to make more informed choices regarding their energy use.

**Distribution Automation.** DA consists of automated switches, controllers, smart sensors, and substation electronic relays that are connected to certain components of the physical distribution system, allowing for continuous visibility and remote control of the system. These devices work together to identify faults, automatically isolate identified

problem areas on the distribution system, reconfigure the controlled feeders, and reduce the impact on customers. This reduces the number and length of electric system outages, resulting in increased reliability and customer satisfaction.

**Demand Response (DR).** PHI's DR program consists of direct load control (DLC) devices and dynamic pricing. These will combine to drive energy efficiency by providing customers with more choices and the ability to better manage or personalize their energy use. The DLC programs allow PHI to remotely control air conditioning (A/C) units during peak demand periods. Dynamic pricing rewards customers for lowering their energy usage during peak energy demand periods with rates that reflect actual hourly supply pricing. This helps to reduce overall usage, keep energy costs down, and preserve the integrity of the electric system during critical load consumption periods.

**Communications Infrastructure.** The communications project consists of a wireless mesh network and a point-to-multipoint broadband wireless network, enabling efficient and near real-time data exchange and operational functionality across all components – AMI, DA, and DR – of the Smart Grid Program. This project includes the configuration, monitoring and control of the expanded communications networks.

The AMI field deployment has already begun in Delaware. Over the next three years, PHI will install over 850,000 smart meters and over 200,000 smart thermostats, along with automated sectionalizing and restoration schemes, capacitor bank controls, network protectors and other intelligent devices in their service territories. These intelligent grid sensors, two-way communications and DR programs will enhance grid reliability, optimize asset operation and maintenance, empower customers to better control their energy usage, and enable wide-scale renewable generation and electric vehicle adoption.

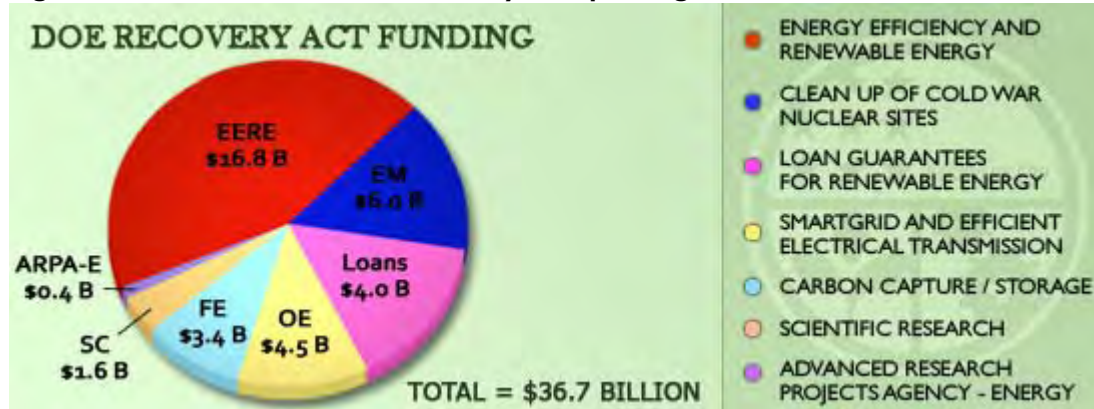
## **B.7 Stimulus Funding to Encourage Investment in the Smart Grid in the USA<sup>2</sup>**

In 2009, \$36.7 billion of the American Recovery and Reinvestment Act (ARRA) stimulus spending was committed to the US Department of Energy (DOE). Of this, \$4.5 billion was set aside for modernizing the electric grid.

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<sup>2</sup> Source: US Department of Energy.

Figure 11: Breakdown of DOE Recovery Act spending



Of this \$4.5 billion, at least \$3.5 billion is for investments in smart grids:

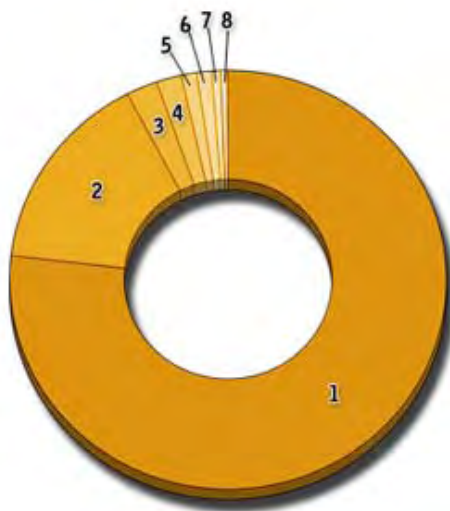
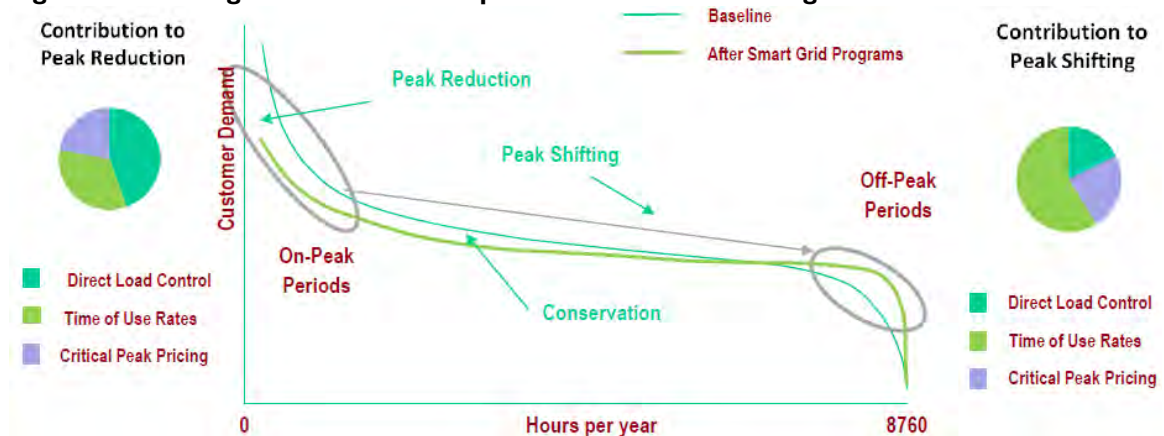


Figure 12: ARRA smart grid spending

1. \$3.5 billion for smart grid investment grant programs
2. \$700 million for energy storage demonstrations
3. \$100 million for workforce development
4. \$80 million for interconnection transmission planning and analysis
5. \$55 million for enhancing state / local governments' energy assurance
6. \$50 million for state assistance on electricity policies
7. \$29 million for program direction
8. \$10 million for interoperability standards and framework.

Over 130 smart grid programs are now being implemented using ARRA funding. The most common programs involve advanced metering infrastructure and pricing programs designed to reduce peak demand and electricity consumption and modify the load curve.

Figure 13: Smart grid contribution to peak reduction and shifting



In the United States, 10% of all generation assets and 25% of distribution infrastructure assets are required less than 400 hours per year (roughly 5% of the time). While peak reduction and peak shifting can't completely displace the need to build new infrastructure, the smart grid will enable new, more persistent forms of demand response that will succeed in deferring or avoiding some of it.

**Table 10: ARRA smart grid investments by category**

Advanced Metering Infrastructure	31 projects benefiting 29 states
Customer Systems	5 projects benefiting 4 states
Electric Distribution Systems	13 projects benefiting 15 states
Electric Transmission Systems	10 projects benefiting 33 states
Equipment Manufacturing	2 projects benefiting 2 states
Integrated and/or Crosscutting Systems	39 projects benefiting 27 states

In addition to the above projects, \$620 million has been awarded for demonstration projects in the US along with \$1 billion in private sector support, totaling \$1.6 billion support for smart grid demonstration/pilot projects.

**Table 11: Summary of the 16 existing smart grid demonstration projects in the US**

State	Sponsoring Utility	Project Title	Project Value (US millions)
California	Los Angeles Department of Water and Power	Smart Grid Regional Demonstration	120.56
California	Southern California Edison Company	Irvine Smart Grid Demonstration	80.27
Massachusetts	NSTAR	Automated Meter Reading-Based Dynamic Pricing	4.72
Massachusetts	NSTAR	Urban Grid Monitoring and Renewables Integration	10.54
Missouri	Kansas City Power and Light Company	Green Impact Zone Smart Grid Demonstration	48.13
Missouri	The Boeing Company	Demonstrating a Cyber Secure, Scalable, Interoperable, and Cost-Effective Smart Selection for Optimizing Regional Transmission System Operation	17.17
New York	Consolidated Edison Co. of NY, Inc.	Secure, Interoperable Open Smart Grid Demonstration in New York and New Jersey	92.39
New York	Long Island Power Authority	Long Island Smart Energy Corridor	25.29
New York	Power Authority of the State of NY	Evaluation of Instrumentation and Dynamic Thermal Ratings for Overhead Lines	1.44
Ohio	Columbus Southern Power Company	AEP Ohio gridSMART Demonstration Project	150.32
Texas	Center for the Commercialization of Electric Technologies	Technology Solutions for Wind Integration in ERCOT (Electric Reliability Council of Texas)	27.42
Texas	Pecan Street Project, Inc.	The Pecan Street Project Energy Internet Demonstration	24.66
Texas	Oncor Electric Delivery Co., LLC	Dynamic Line Rating Project	7.28
Virginia	National Rural Electric Cooperative Association	Enhanced Demand and Distribution Management Regional Demonstration	67.86
Washington State	Battelle Memorial Institute, Pacific NW	Pacific Northwest Smart Grid Demonstration Project	177.64
Wisconsin	Waukesha Electric Systems	Fault Current Limiting Superconducting Transformer	21.55

# Annex C

## Smart Grids and the Carbon Market

### C.1 The Role of Carbon Markets

**E**missions trading is an important mechanism for reducing CO<sub>2</sub> and other pollutant emissions. Under this mechanism, a government sets a limit on the amount of a pollutant that can be emitted (called a “cap”). Industries and other companies are then issued credits that give each of them the right to emit a specific amount of a pollutant. When that amount exceeds a cap, the company must go to the market and buy credits from another company that emits less of that pollutant (called a “trade”).

Under of these “cap and trade” schemes, companies that can reduce their emissions most cheaply will do so by buying credits, rather than paying a charge for polluting. One way for utilities to avoid purchasing credits is through investing in new technologies or processes that reduce pollution, like the smart grid.

The three largest markets for carbon that are applicable to utilities are:

- **Project-based transactions.** These are markets supplied by credits derived primarily from Clean Development Mechanism (CDM) projects, Joint Implementation (JI) projects,<sup>3</sup> and voluntary mechanism projects. These markets are governed by international rules of project development and monitoring and verification.
- **Secondary CDM.** These markets are served through sales by emission credit holders to secondary players. In this case, a bank, fund, or other rated entity guarantees the delivery of emission credits and bears the risk. Thus, these credits are often more costly than project-based transactions.
- **Allowances markets.** These are national or regional markets where credits are sold via an exchange. One example is the European Union’s Emission Trading Scheme (EU ETS).

The success of all of these schemes relies on strong and rising carbon prices: the more it costs to emit carbon, the more firms will be encouraged to develop low-carbon

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<sup>3</sup> Under the Kyoto Protocol, “Annex 1” countries can invest in emission reduction projects (Joint Implementation projects) in other Annex 1 countries. This gives them an opportunity to avoid reducing their domestic emissions. India is not on the list of Annex 1 countries.

technologies. Point Carbon estimates that a steady carbon price of at least US \$28 per tonne is needed before firms will begin to make meaningful moves away from using fossil fuels.<sup>4</sup>

The EU ETS is the world's largest emissions trading scheme. Together, the over 10,000 energy and industrial sector installations the EU ETS covers account for nearly half of the EU's CO<sub>2</sub> emissions and 40% of its greenhouse gas emissions.

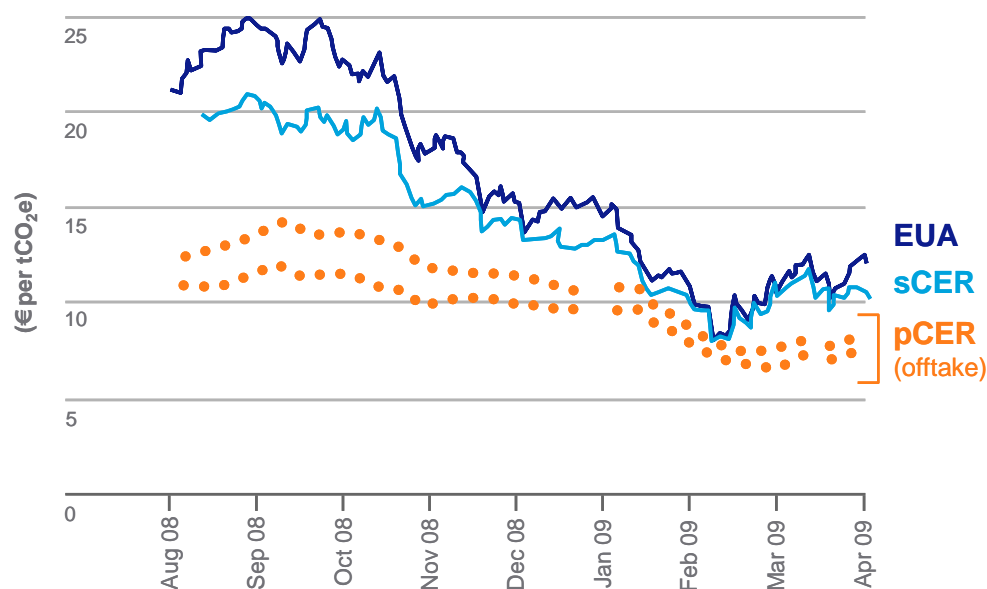
EU ETS prices had been consistently above this \$28 per tonne threshold until the world recession struck, causing a huge drop in industrial output. As a result, many firms were left with excess carbon allowances that they could sell. The price of EU allowances typically rises when gas

prices rise, as the higher cost of gas encourages energy firms to switch to cheaper but more carbon-intensive coal-fired power plants. This switch, however, increases the demand for carbon allowances because more CO<sub>2</sub> is produced. Despite the global economic crisis and declining carbon values, 2008 saw a doubling in the size of the EU's carbon market, to an estimated value of \$126 billion.<sup>5</sup> Figure 14 illustrates the decline in carbon prices.

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<sup>4</sup> <http://www.Pointcarbon.com>

<sup>5</sup> Capoor, Karan, Sustainable Development Operations and Philippe Ambrosi, Climate Change Team, the World Bank. *State and Trends in the Carbon Market 2009*, May 2009.

**Figure 14: Carbon prices respond to the recession**

EUA = European Union Allowances

sCER = secondary certified emission reduction (generated through the Kyoto Protocol's CDM mechanism)

pCER = primary certified emission reduction (can be sold directly on the market)

Source: Capoor, Karan, Sustainable Development Operations and Philippe Ambrosi, Climate Change Team, the World Bank. *State and Trends in the Carbon Market 2009*, May 2009.

In contrast, a report based on data from the trading of European Union Allowances under the EU ETs and transactions completed under the CDM and JI found that the value of carbon trading in developing countries declined by 12% in 2008, to an estimated \$6.5 billion.<sup>6</sup>

**Table 11: The carbon market in 2007-2008**

	2007		2008	
	Volume (MtCO <sub>2</sub> e)	Value (M US\$)	Volume (MtCO <sub>2</sub> e)	Value (M US\$)
<b>Project-based Transactions</b>				
Primary CDM	552	7,443	389	6,159
JI	41	499	20	294
Voluntary market	43	263	54	397
Subtotal	<b>636</b>	<b>8,195</b>	<b>463</b>	<b>7,210</b>
<b>Secondary CDM</b>				
Subtotal	<b>240</b>	<b>5,451</b>	<b>1,072</b>	<b>26,277</b>

<sup>6</sup> Capoor and Ambrosi, op. cit.



	2007		2008	
	Volume (MtCO <sub>2</sub> e)	Value (M US\$)	Volume (MtCO <sub>2</sub> e)	Value (M US\$)
<b>Allowances Markets</b>				
EU ETS	2,060	49,065	3,093	91,090
New South Wales	25	224	31	183
Chicago Climate Exchange	23	72	69	309
RGGI	n/a	n/a	65	246
AAUs	n/a	n/a	18	211
Subtotal	<b>2,108</b>	<b>49,361</b>	<b>3,276</b>	<b>92,859</b>
<b>Total</b>	<b>2,984</b>	<b>63,007</b>	<b>4,811</b>	<b>126,345</b>

MtCO<sub>2</sub>e = million tonnes carbon dioxide equivalent

RGGI = Regional Greenhouse Gas Initiative (US)

AAUs = Assigned Amount Units of the Kyoto Protocol

Source: Capoor, Karan, Sustainable Development Operations and Philippe Ambrosi, Climate Change Team, the World Bank. *State and Trends in the Carbon Market 2009*, May 2009.

## C.2 India and the Carbon Market

As a party to the United Nations Framework Convention on Climate Change, India has a National CDM Authority, which is housed in the Ministry of Environment and Forests. From 2002-2008, India held a 4% market share of the primary certified emission reductions transacted worldwide. It ranked second globally in the number of transactions, at 15.8 million CERs.

According to the Institute for Global Environmental Strategies, as of November 2009, India had 463 CDM projects operating for which over 72 million CERs have been issued. After renewable energy, energy efficiency projects are a strong component of India's CDM pipeline.

**Table 13: India's CDM pipeline**

Project Type	Number	Project Type	Number
Biomass	136	Fuel switching	11
Wind power	91	Methane avoidance	10
Waste gas/heat utilization	64	Hydrofluorocarbon reduction	5
Hydropower	57	Afforestation and reforestation	2
Energy efficiency	53	Other renewable energy	1
Cement	17	Methane recovery & utilization	1
Biogas	13	Transportation	1

Source: [http://enviroscope.iges.or.jp/modules/envirolib/upload/984/attach/india\\_final.pdf](http://enviroscope.iges.or.jp/modules/envirolib/upload/984/attach/india_final.pdf)

In 2008, most Indian project developers preferred to hold on to their CERs until issuance and then enter into spot transactions. A major Indian spot seller told the authors that this type of approach was reflective of the conservative culture of many Indian companies, which prefer to transact once they know that their supply volumes are completely secured. In February and March 2009, buyers reported a greater willingness on the part of Indian sellers to enter into forward sales with a combination of fixed and indexed pricing.

Another reason that may help explain the large gap between the potential supply of CERs and actual transaction volumes in India relates to the challenges associated with obtaining financing for projects, especially in the energy sector.

#### **India's place in the carbon market**

“As on 17 March 2009, 398 out of total 1455 projects registered by the CDM Executive Board are from India, which is next only to China with 453 projects. The National CDM Authority (NCDMA) in India has accorded Host Country Approval to 1226 projects facilitating an investment of more than Rs.151,397 crores. These projects are in the sectors of energy efficiency, fuel switching, industrial processes, municipal solid waste and renewable energy. If all these projects get registered by the CDM Executive Board, they have the potential to generate 573 million Certified Emission Reductions (CERs) by the year 2012. At a conservative price of US \$ 10 per CER, it corresponds to an overall inflow of approximately US \$ 5.73 billion in the country by the year 2012.

The National CDM Authority, in its meeting on 19.3.2009, considered more than 50 projects for Host Country Approval.”

<http://www.cdmindia.nic.in/>

# Annex D

## Institutional and Policy Issues: North America, Europe and China

**T**his chapter describes the main smart grid developments in the United States, Canada, Italy, the UK, Portugal, and China. Its focus is on the institutions that have enabled these developments and the institutional, regulatory, and policy issues that will influence smart grids.

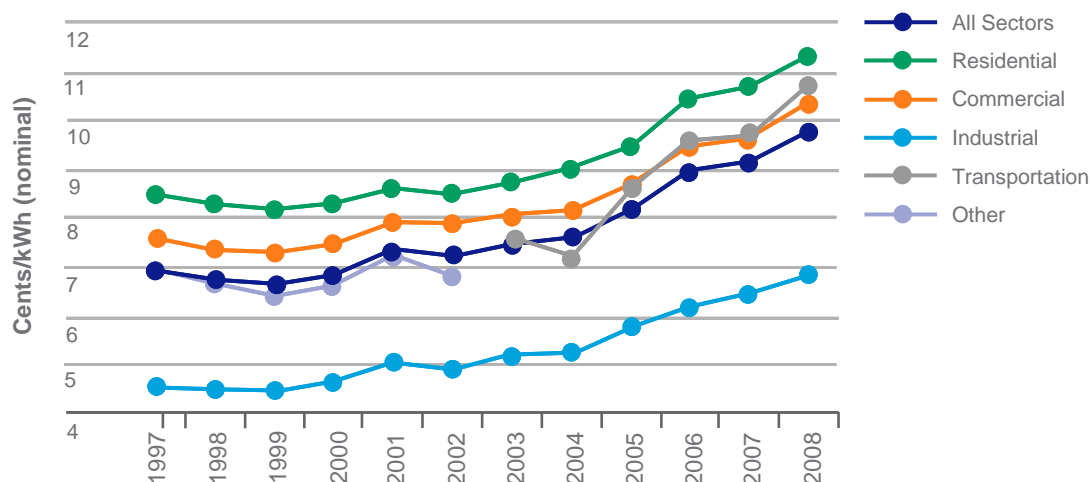
### **D.1 North America**

#### **D.1.1 United States**

The large US power sector (over 1 million MW of installed capacity) is heterogeneous, with a combined federal-state purview that is similar to India's. Its utilities, too, are diverse, with some being ahead of others in terms of smart grids, their related technologies, and degree of deregulation.

US deregulation has proceeded unevenly, with some states moving quickly in this area, and in the case of California, subsequently going back. There has been little deregulation in some regions, and some areas still have vertically integrated service providers.

Deregulation has exposed most US consumers to tariffs that are higher than under a more regulated system. As a result of this and fuel cost increases, the average price of electricity in the US has risen dramatically (Figure 15).

**Figure 15: US electricity tariffs by customer class**

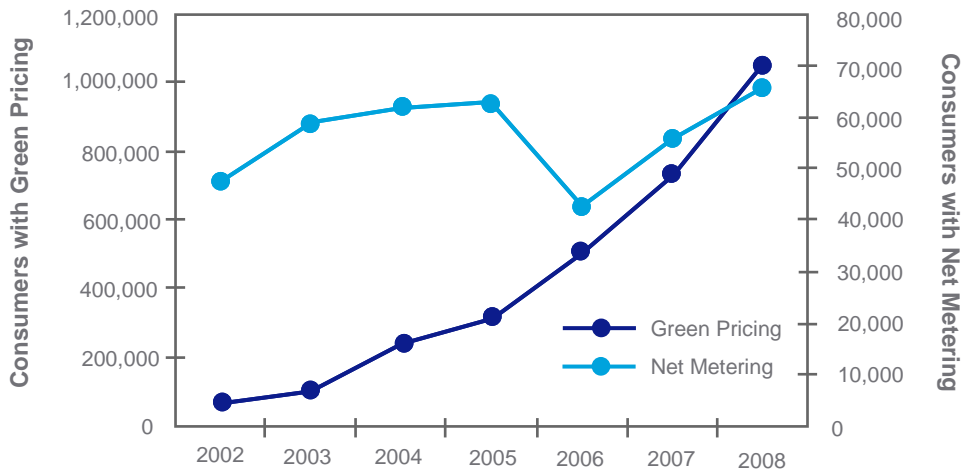
Source: US Energy Information Administration

Most electricity prices are set by state Public Utility Commissions (in some states, these are called Public Service Commissions), while the Federal Energy Regulatory Commission sets prices for some interstate activities. Policies are set at both the national and state levels, with some states (e.g., California) having a Commission that sets goals and oversees changes. The non-profit North American Reliability Council sets reliability standards. All of these actors have examined the potential of the smart grid.

## US smart grids

As a precursor to smart grid efforts, “green” pricing (e.g., for hydropower) was made available to many consumers through retail competition. However, the number of consumers (mostly residential) opting for such power has been low (see Figure 16; the large dip this figure shows has been attributed to a leading provider dropping services in two jurisdictions).

**Figure 16: Number of US consumers offered green tariffs and accepting metering**

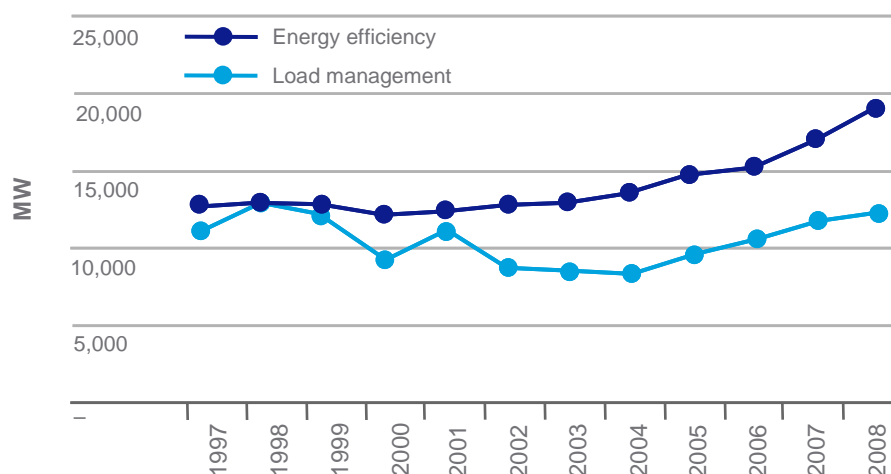


Source: US Energy Information Administration

Although net metering has been available to many US consumers, it is not common among distributed generation customers. This is partly because the incentives were mainly based on the 1978 Public Utilities Regulatory Policies Act, which called for payments based on avoided capacity for feed-in power. In addition, anecdotal evidence suggests that utilities discouraged such interconnections on commercial grounds.

A major application of the smart grid in the US may be to enable demand response, which can essentially be considered an update of the older demand-side management (DSM) model used to reduce load. Under DSM (which emphasizes energy efficiency through such actions as replacing inefficient appliances), utilities had little control over when a load reduction would occur. Demand response (DR), however, adds a time component; participants in a DR program would have to reduce their load in response to a signal or directive. To date, the issue with this type of program has been one of scale in that most DR participation has been limited to medium or large consumers (in New York State, 1 MW is the required minimum size for participation). A smart grid might allow smaller consumers, or aggregations of them, to participate.

Figure 17 shows the energy savings resulting from DSM (energy efficiency) and load management (DR) in the United States between 1997 and 2008. Although the approximately 14,000 Megawatts saved is only a few percentage points of the nation's load, the impacts on individual utilities can be high.

**Figure 17: DSM and DR response in the US**

Source: US Energy Information Administration data

## US energy policy and the US Department of Energy

The US policy framework related to modernizing the country's aging infrastructure has been a central focus of regulators and policymakers since 2003. Three major pieces of legislation have been enacted since 2005 that have increasingly encouraged the deployment of the smart grid. The main federal agency charged with carrying out this legislation is the US Department of Energy (DOE).

These three acts were prefaced by a national transmission grid study and the "Grid 2030" set of reports by the DOE, which were the initial policy movers toward smart grids. The 2002 grid study found that the country's transmission system urgently needed modernization: it had become congested owing to under-investment in new facilities, causing daily transmission constraints and increasing both costs to consumers and the prospects of blackouts. The "Grid 2030" initiative resulted in the preparation of:

- A vision report that sketched the grid in 2030 as a fully automated power delivery network that ensured a two-way flow of electricity and information between power plants and appliances, and all places in between
- An action agenda that focused on grid architecture, technologies, technology transfer and expanding education and training on new technology, market operation, and public-private partnerships
- A research plan for introducing "next generation" hardware for cables and conductors, substations and protective systems, and power electronics.

**Legislation.** The US Congress passed the **Energy Policy Act of 2005** in an effort to combat the country's growing energy problems, and it changed US energy policy by providing tax incentives and loan guarantees for various types of energy production. Some of the Act's provisions that are relevant to the smart grid include:

- DOE was required to report on the national benefits of demand-response and make recommendations on achieving specific levels of benefits
- The Act made time-based pricing (e.g., time-of-use, critical peak, real time) and other forms of demand response US policy
- Electric utilities were required to offer their customers the choice of time-based pricing
- All public utilities were required to offer net metering at their customers' request.

The ***Energy Independence and Security Act of 2007*** made achieving a smart grid national policy. It calls for utilities to invest in smart grids, provides loans and federal contributions, and authorizes funding for demonstration projects and grants to match funds from utilities investing in smart grid deployments.

The Act charged DOE with establishing a Smart Grid Advisory Commission that would advise DOE's secretary and assistant secretary, and other federal officials on the progress of a national transition to the use of smart grid technologies and services, the evolution of standards and protocols to allow interoperability and inter-communications among smart grid-capable devices, and the optimum ways to use federal incentive authority to encourage smart grid progress. As a result, DOE established a Smart Grid Subcommittee within its Electricity Advisory Committee.

"It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure infrastructure that can meet future demand growth and achieve the goals that together define a Smart Grid."

Title XIII – Sec. 1201. Statement of Policy on modernization of the Electricity Grid, Energy Independence and Security Act

The Act also required the assistant secretary of DOE's Office of Electricity Delivery and Energy Reliability (OE) to establish a Smart Grid Task Force, which includes experts from seven federal agencies:

**Table 14: The US Smart Grid Task Force**

Organization	Role
DOE	
Office of Electricity Delivery and Energy Reliability	Leadership, cyber security, state policy, transmission R&D
Office of Energy Efficiency and Renewable Energy	Energy efficiency and renewable energy
National Energy Technology Laboratory	Technology
Department of Homeland Security	Security
Environmental Protection Agency	Environmental issues
Federal Energy Regulatory Commission	Wholesale markets
National Institute of Standards and Technology	Inter-operability standards
Department of Agriculture	Rural electricity development
Department of Defense	National security

The Task Force is charged with ensuring awareness, coordinating and integrating the activities of the OE and other parts of the federal government with regard to the smart grid, and collaborating with DOE's Electricity Advisory Committee and other relevant agencies and programs.

The third major piece of legislation affecting the smart grid is the **American Recovery and Investment Act of 2009**, which is better known as the Stimulus Bill, as it was designed to stimulate the economy and to create and preserve jobs.

This Act allocated \$4.5 billion to OE for "an investment in a nationwide effort to modernize the electric grid, enhance security of energy infrastructure, and enable reliable electricity delivery to meet growing demand." These funds will support the implementation of smart grid programs authorized by the Energy Independence and Security Act of 2007. They include:

- \$615 million for regional smart grid technology research, development and demonstration programs, with the objective of verifying technology viability, quantifying costs and benefits, and validating new business models for the smart grid on a scale that could be readily adapted and replicated around the country. Of this:
  - \$435.2 million will go to utilities for regional demonstrations of water and power combined, dynamic pricing, regional integration, grid monitoring, plug-in hybrids, home area networks, battery storage, and appliance control
  - \$184.8 million will go to utilities and private companies to demonstrate various energy storage technologies such as advanced batteries, flywheel, and compressed air.
- \$3.4 billion in federal matching funds (up to 50%) for smart grid technologies that promote the Stimulus Bill's objectives, with funds distributed through a merit-based competitive grant process called the Smart Grid Investment Grant. The grant



program focuses on the manufacturing, purchase, and installation of smart grid devices and related technologies in order to demonstrate their cost-effectiveness.

- The remaining funds will support workforce training, resource assessments, an analysis of future demand and transmission requirements, and the development of inter-operability standards.

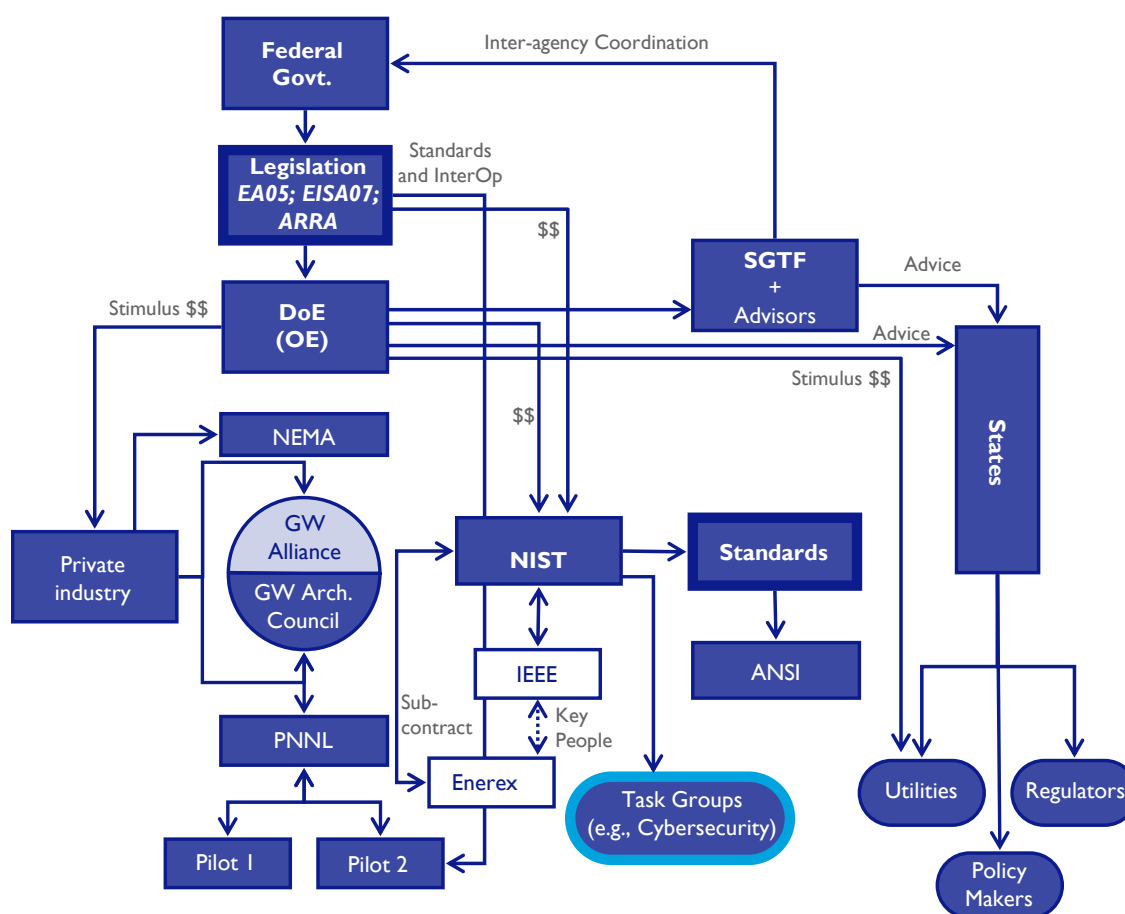
The grants process was highly competitive: roughly 25% of the applicants were awarded grants in six categories:

**Table 15: American Recovery and Investment Act smart grid investments**

Advanced metering infrastructure	31 projects benefiting 29 states
Customer systems	5 projects benefiting 4 states
Electric distribution system	13 projects benefiting 15 states
Electric transmission systems	10 projects benefiting 33 states
Equipment manufacturing	2 projects benefiting 2 states
Integrated and/or crosscutting systems	39 projects benefiting 27 states

Six utilities received grants of \$100 million or more for large rollouts of smart meters and the data processing and communications systems to support them. A large portion of the grants was awarded to organizations that manage and regulate regional transmission (independent and regional transmission operators); their grants ranged from \$3.7 to \$5.39 million. The vast majority of these grants involve rollouts of phasor measurement units to monitor and control electricity flows through the system.

**Office of Electricity Delivery and Energy Reliability.** As a lynchpin in the smart grid process, OE works with federal bodies, states, and private industry (Figure 18).

**Figure 18: Overview of US federal activities on the smart grid**

A recent OE status update report highlights a number of the Office's activities:<sup>7</sup>

- Establish a Smart Grid Advisory Committee
- Establish a Smart Grid Task Force
- Submit to Congress a report on the status of smart grid system deployments
- Submit to Congress a study assessing laws and regulations affecting the shifting of privately owned electricity distribution wires on and across public rights-of-way
- Submit to Congress a quantitative assessment of the security implications of smart grid system deployments
- Carry out a program to research, develop, and demonstrate smart grid technologies
- Establish a smart grid regional demonstration initiative showcasing advanced technologies
- Establish a federal matching funds program.

**GridWise Alliance.** Founded in 2003, the GridWise Alliance is a consortium of public and private stakeholders who represent a broad spectrum of the energy supply chain:

7

[http://www.oe.energy.gov/DocumentsandMedia/Smart\\_Grid\\_Eric\\_Lightner\\_Presentation\\_05072008.pdf](http://www.oe.energy.gov/DocumentsandMedia/Smart_Grid_Eric_Lightner_Presentation_05072008.pdf)

- Utilities (e.g., Consolidated Edison of New York)
- IT companies (e.g., Google, IBM)
- Equipment vendors (e.g., ABB)
- Academia (e.g., Purdue University)
- New technology providers
- Battelle National Laboratory (DOE).

A consensus-based organization, the Alliance advocates for change at the national and state levels. Its mission is to facilitate stakeholder collaboration, and to promote, educate, and advocate for the adoption of innovative smart grid solutions.

**GridWise Architecture Council.** Formed in 2004, the GWAC comprises industry leaders who are working to identify and shape the guiding principles of a highly intelligent and interactive electric system. Although the Council stemmed from a number of related efforts, including DOE's GridWise Program, it is independent (the DOE does, however, provide it with limited financial and logistical support). DOE and GWAC have issued a memorandum of understanding that outlines a series of collaborative activities designed to transform the nation's electric power system.

GWAC strives to create a broad industry consensus in support of the technical principles that will enable the vast scale of interoperability needed to transform electric power operations into a smart grid. This includes articulating the goal of interoperability, identifying the concepts and architectures needed to make it possible, and developing actionable steps to facilitate the inter-operation of the grid's systems, devices and institutions that encompass the nation's electric system.

**Pacific Northwest National Laboratory.** PNNL provides assistance and support to the GridWise Alliance on behalf of DOE. It actively coordinates efforts within the research community, electric power sector, and industry that affect GridWise efforts, including those of the Consortium for Electric Reliability Technology Solutions, the Electric Power Research Institute's IntelliGrid work, and Washington State University's GridStat. PPLN also develops simulations, models, and demonstration projects such as the Good Friendly Appliance Project and Olympic Peninsula Project.

**National Association of Regulatory Utility Commissioners and Federal Energy Regulatory Commission.** Founded in 1889, this non-profit organization's members include governmental agencies that are engaged in the regulation of utilities (energy, water, and telecommunications) and carriers in all 50 US states, the District of Columbia, Puerto Rico, and the Virgin Islands. It also represents the interests of State Public Utility Commissions before the federal government.

After the passage of the Energy Independence and Security Act of 2007, NARUC and the Federal Energy Regulatory Commission (FERC) launched a Smart Grid Collaborative to serve as a forum for discussing technological and other issues to facilitate the transition to a smart grid. Many companies are now promoting smart grid technologies, and this dialog is perceived as helping regulators understand what is being developed and how it will impact consumers.

In March 2009, FERC proposed a policy to prioritize the development of standards for cyber and physical security, to enable effective communications and coordination at the boundaries of utility systems, and to prioritize wide-area situational awareness, demand response, electric storage and electric transportation. DOE adopted this policy in July 2009.

**National Institute of Standards and Technology.** NIST has been assigned the “primary responsibility to coordinate the development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems.”<sup>8</sup> It was selected for this role based on its collaboration with businesses and standards organizations on guidelines and standards to protect industrial supervisory control and data acquisition (SCADA) systems and to secure their interface with the power grid.

NIST has been working with stakeholders on a broad effort toward interoperability:

- With GWAC, it created domain expert working groups that involve more than 100 organizations that focus on transmission and distribution, building to the grid, industry-to-grid, home-to-grid, and business and policy. It and GWAC have also reached out to stakeholders to communicate their plans.
- NIST formed a Cyber Security Coordination Task Group and other cross-domain groups to address overlapping challenges.
- Collaborating with power industry stakeholders, NIST is building an initial suite of business use cases to help guide the development of standards.
- NIST is developing an interoperability knowledge base to promote understanding and further consensus on standards, taxonomy, interfaces, and vocabulary for the smart grid.
- NIST created the National Coordinator for Smart Grid Interoperability Office to provide visible national-level leadership. In April 2009, this office launched a three-phase plan to expedite development and promote the widespread adoption of smart grid interoperability standards:

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<sup>8</sup> [www.nist.gov/smartgrid/](http://www.nist.gov/smartgrid/)

**Engage stakeholders in a participatory process to identify applicable standards, gaps in current standards, and priorities for new standardization activities**

The Electric Power Research Institute was contracted for this effort and in January 2010 released a document describing a high-level conceptual reference model for the smart grid and a strategy for establishing requirements and standards.

NIST is also collaborating with other standards bodies to facilitate standards coordination and is working closely with the Institute of Electrical and Electronics Engineers (IEEE), which has nearly 100 standards and standards in development that are relevant to the smart grid.

In September 2009, NIST published a draft report – *NIST Framework and Roadmap for Smart Grid Interoperability Standards* – that contains an accelerated plan for developing standards for smart grid deployments in the US. The report identifies about 80 initial standards to support the interoperability of the various elements of the system. The document reflects input from over 1500 industry and government stakeholders.

**Establish a public-private partnership to drive longer-term progress**

NIST established a new stakeholder forum to provide technical support for the development of standards (the Smart Grid Interoperability Panel); it will consult regularly with standards development organizations, user groups, and others directly involved in standardization efforts.

**Develop and implement a framework for testing and certification**

NIST will test and certify the implementation of standards in smart grid devices, systems, and processes.

**IEEE rolls out the Distributed Network Protocol (DNP3)**

In January 2010, IEEE announced that it is working for the formal recognition of DNP3. This protocol will promote interoperability across hundreds of operational systems and strengthen security protocols, while maintaining the compatibility of existing object models. It is intended for smart grid applications in the electric utility, energy, and water industries.

IEEE press release, January 11, 2010

Title XIII – Sec. 1201. Statement of Policy on Modernization of the Electricity Grid, Energy Independence and Security Act

## Annex E

# Institutional and Policy Issues: India

Two factors – India's large and looming supply-demand gap and its high electricity losses – have spurred the interest of the Government and other stakeholders in the smart grid. India's power sector is one of the largest in the world, with a capacity of 156,092.23 MW.<sup>9</sup> Globally, it ranks 4<sup>th</sup> in terms of installed capacity and 6<sup>th</sup> in terms of energy consumption. As early as 2012, India's demand for electricity is predicted to reach 157,107 MW.<sup>10</sup> Although the government plans to add 78,577 MW of capacity during the XI<sup>th</sup> Five-Year Plan (2007-2012),<sup>11</sup> its rising population and growing economy mean that demand could rise to 800,000 MW to as much as 950,000 MW by 2030, according to Prime Minister Manmohan Singh.<sup>12</sup>

In addition, India's technical and commercial losses are estimated to be over 30%. This is a rough estimate given the lack of agricultural pump set metering and high electricity theft. This means that India's losses are some four times higher than those of developed nations (or China, which reports its total transmission and distribution losses at 8%), although a large part of the difference is poor metering, faulty billing and collection systems and practices, and theft.

This annex first discusses the major stakeholders in India with a direct or indirect role to play in the smart grid. It then presents the main steps taken to date to reform the electricity sector, and overviews of tariffs and standards for power supply in India. It closes with a description of India's first initiative toward the smart grid.

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<sup>9</sup> Central Electricity Authority estimates as of 31 December 2009. <http://www.apdrp.gov.in/>

<sup>10</sup> <http://www.indiacore.com/power.html>

<sup>11</sup> <http://www.expressindia.com/latest-news/Electricity-on-demand-by-2012-says-Power-minister/285395/>

<sup>12</sup> [http://www.monstersandcritics.com/news/energywatch/news/article\\_1184013.php/India\\_envisages\\_about\\_950000\\_MW\\_power\\_requirement\\_by\\_2030](http://www.monstersandcritics.com/news/energywatch/news/article_1184013.php/India_envisages_about_950000_MW_power_requirement_by_2030)

## E.1 Government and Other Stakeholders

Electricity is a concurrent subject in the Seventh Schedule of the Constitution of India. Hence, it falls under the domain of the states and the Centre. Generation is under the purview of the Centre and state governments, which account for 58% and 32% of the country's electricity generating capacity, respectively (the remaining 10% is generated by private sources).<sup>13</sup> The bulk of the transmission and distribution functions fall under state jurisdiction.

### The Ministry of Power

Until 1992 India had a central Ministry of Energy, which was then split into the Ministries of Coal, Petroleum and Natural Gas, Non-conventional Energy Sources, and Power. The Ministry of Power oversees the development of electrical energy in the country.

The Ministry's responsibilities include planning, formulating policy, processing projects for investment decisions, monitoring the implementation of power projects, training and manpower development, and the administration and enactment of legislation in regard to thermal and hydro power generation, transmission and distribution. Several other government agencies, including the Planning Commission and Department of Atomic Energy, play a role in energy policy.

The Government of India will necessarily be a key stakeholder in any smart grid development since it owns and/or operates the bulk of the power in the country. Thus, the major push for smart grids will have to come from the government. The Ministry of Power is already looking at undertaking a smart grid initiative.

Since most of India's utilities (the bulk of which are under state government control) find it difficult to invest funds on their own for smart grid initiatives, they will have to depend on the allocation of funds from the central government for smart grid deployment. The central government will also need to take the initiatives required to ensure that central and state regulatory bodies respond proactively in terms of developing regulations suitable to enable a smart grid effort to succeed. This has been true of past reform efforts as well as the ongoing Restructured Accelerated Power Development and Reform Programme (see Section E.5 for a description of this initiative).

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<sup>13</sup> <http://www.indiacore.com/power.html>

## Electricity regulators

The Electricity Regulatory Commissions Act of 1998 provided for the establishment of the Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs).

The mission of the CERC is to promote competition, efficiency and economy in bulk power markets; improve the quality of supply; promote investments; and advise the government on the removal of institutional barriers to bridge the demand-supply gap and foster the interest of consumers in doing so. The CERC also deals with tariffs for central generating plants and regulates the inter-state transmission of electricity. It has an advisory role with respect to national electricity policy and tariff policy.

The state regulators (i.e., SERCs) are responsible for setting tariffs within the states. It does not appear that the SERCs have given much thought to smart grid questions, and although CERC (the central regulator) is aware of these issues, it may lack the direct jurisdiction to address them at the state level.

In September 2009, CERC and the US Federal Energy Regulatory Commission signed an MOU to “share regulatory experiences and practices” in areas of mutual interest. One of the areas cited in this memorandum was the development of smart grids.

<http://www.cercind.gov.in/international-co-op.html>

One area regulators should assess and respond to in preface to any smart grid development is the requirements of the state governments and utilities for the implementation of tariffs (e.g., time-of-use, real-time pricing) that would encourage consumers to participate in demand response projects. The issue of tariffs is discussed further in Section E.3.

## Central Electricity Authority

The Central Electricity Authority (CEA) is a statutory organization constituted under Section 3 of the now repealed Electricity (Supply) Act, 1948. As per the Electricity Act of 2003, the CEA is to perform such functions and duties as the central government may prescribe or direct, in particular:

- Advise the central government on national electricity policy and the coordination of planning
- Specify the technical standards and safety requirements for construction, operation and maintenance of electrical plants and electric lines
- Specify the conditions for the installation of meters for the transmission and supply of electricity
- Collect and record data on the generation, transmission, trading, distribution and utilization of electricity
- Carry out studies relating to cost, efficiency, and competitiveness, among others
- Promote research on matters affecting the generation, transmission, distribution and trading of electricity.



Thus, the CEA can play a key role in coordinating the efforts for interoperability and standards for smart grids, in addition to its major role in planning and monitoring the country's power projects.

### **Power Finance Corporation Ltd.**

The Power Finance Corporation Ltd. (PFC) was set up in July 1986 as a financial institution dedicated to power sector financing. Initially wholly owned by the Government of India, the company issued an initial public offering in January 2007. The corporation was registered as a non-banking financial company by the Reserve Bank of India and was given the status of *navratna* public service undertaking by the government on 22 June 2007 (this status empowers a company to invest up to Rs. 1000 crore or 15% of their net worth in a single project without seeking government approval).

The PFC provides a large range of financial products and services, including loans, leases, and consultancy services for many power projects in generation, transmission and distribution. Its borrowers include State Electricity Boards, state sector power utilities, central sector power utilities, and private sector companies. The PFC is also the nodal agency for the implementation of the central government's ambitious Ultra Mega Power Plants and R-APDRP programs.

### **Power Grid Corporation of India Ltd.**

Power Grid is India's central transmission utility. Its mandate is to plan, coordinate, supervise and control the interstate transmission system. A *navratna* public service undertaking, Power Grid is one of the largest transmission utilities in the world. It wheels about 45% of the total power generated in India on its transmission network.<sup>14</sup>

The mission of this corporation is to establish and operate regional and national power grids to facilitate the transfer of electric power within and across the regions of India with reliability, security and economy. Thus, Power Grid has the responsibility for the National Load Dispatch Centre as well as the Regional Load Dispatch Centres. It also provides transmission sector consultancy services nationally and internationally.

Power Grid is planning to deploy the country's first comprehensive synchrophasor system at the Northern Region Load Dispatch Centre for four substations. This system will allow grid operators to act proactively in contingencies, such as partial grid collapse due to disturbances. It will help operators to carry out system-wide analysis and diagnostics.

### **India's information technology and telecom industry**

India's IT industry is moving ahead with a number of solutions for the power sector, most of which are geared to the R-APDRP. These solutions, however, lack advanced functionality. It is unlikely that India's private telecom and IT service providers are geared to meet the huge

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<sup>14</sup> <http://www.powergridindia.com>.

requirements of data handling, network uptime and rural reach that are necessary to meet the needs of its electricity utilities, at least in the short term.

Twenty-one smart grid players are on the list of empanelled consultants for R-APDRP.<sup>15</sup> They are of varying skills, sizes, and backgrounds. The empanelment process used for R-APDRP has certain advantages and disadvantages when it comes to selecting firms that the government can rely on to successfully execute a project of this size.

## Electric utilities

Some states still have vertically integrated State Electricity Boards, while others have been unbundled and corporatized. Most distribution companies are still state owned, although a few are private (in Orissa, New Delhi, and Mumbai, for example).

The state-owned utilities are cash-strapped, politically guided and human resource-poor. Although the private ones are farther ahead, in the past, they have not been given governmental financial support that was available to state-owned utilities; it is unclear whether this will be the case for smart grids. In fact, because private utilities are mostly better-performing (in part due to consumer demographics rather than operations per se), they are more likely to succeed with the newer solutions that make up a smart grid.

If India's utilities are to take an active part in designing and implementing IT and smart grid projects, they must acquire the skills they need to take over their projects' operation and maintenance, as vendors assistance will only be rendered for a short period of time. Investment in developing human resources in this area will be a necessity.

## Standards organizations

In coordination with the Central Electricity Authority, the Bureau of Indian Standards is the agency best able to take the initiative to formulate or adopt international standards with modifications to suit Indian conditions. Drawing from international standards will speed up the process of developing standards to support the implementation of smart grid projects.

Industry associations, such as those for electronic meter manufacturers and other electrical equipment for distribution systems, should also be involved in standards development. This will help ensure that the equipment that goes into smart grid projects is standardized.

## Appliance and consumer equipment manufacturers

Smart loads will be a key to load management in the future. Whirlpool announced that by 2015, many of their products, worldwide, would be smart grid ready (subject to some benchmarks and standards being achieved). There are few manufacturers in India that are preparing their equipment for the smart grid (although global leader General Electric has a limited appliance presence in the country). According to the Association of Home Appliance

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<sup>15</sup>[http://www.pfcindia.com/apdrp/Detailed%20list%20of%20Empanelled%20ITC%20final\\_23042009.pdf](http://www.pfcindia.com/apdrp/Detailed%20list%20of%20Empanelled%20ITC%20final_23042009.pdf)

Manufacturers, three things are required for the success of a smart grid: 1) standards and interoperability, 2) incentives for consumers, i.e., variable tariffs, and 3) consumer privacy protection and control rights.<sup>16</sup> Most of the limited efforts in India on smart grids have focused only on the first of these.

## Other stakeholders

Consumer forums should be involved in the distribution system to encourage utilities to reduce peak demand and consumers to use power judiciously in order to reduce consumers' monthly electricity bills.

Some niche players could play an instrumental role in developing India's smart grid, especially in the initial phases where proper designs are key. These include research entities such as The Energy Research Institute (TERI), and donor organizations such as USAID and DFID. Their contributions could take the form of funding for pilots and key technology experiments to spur innovation. Funding for the development of proper baseline data and target metrics is also important and will require a fair amount of effort and time.

## E.2 Reform Efforts

In the past three decades, the Government of India has taken steps to reform and restructure the power industry. From 1975-1991, generation grew at the central level (coincident with the rise of National Thermal Power Corporation), but supplies were still inadequate. In response, the Government opened up generation to independent power producers (IPPs), which included eight "fast-track" projects. While there was much interest in the provision of private power, the actual generation from such IPPs was very low.

By the mid-late 1990s, the unbundling of the State Electricity Boards had begun, beginning with privatization in Orissa, but most states were corporatized rather than privatized. Following state efforts, the national Electricity Regulatory Commissions Act was brought into law in 1998, which helped create independent regulators at the state level and led to the formation of the Central Electricity Regulatory Commission.

The Electricity Act 2003 was enacted to consolidate the laws relating to generation, transmission, distribution, trading and the use of electricity, and to promote competition. The Act allowed the entry of private companies into generation, transmission and distribution. However, private participation in distribution remains minimal and is limited to a few states such as Orissa, Uttar Pradesh and Delhi (this excludes a handful of private distribution companies operating in cities like Ahmedabad, Kolkata and Mumbai, mostly from pre-independence days). The results of privatization have been mixed, although the Delhi privatization is considered more of a success. Delhi's bids were more performance- (loss-reduction) than financially-oriented (highest bidder), which may be an important lesson for any smart grid deployment.

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<sup>16</sup> Smart Grid White Paper: The Home Appliance Industry's Principles & Requirements for Achieving a Widely Accepted Smart Grid, December 2009.

<http://www.aham.org/ht/a/GetDocumentAction/i/44191>

### E.3 Tariffs

After independence, India's State Electricity Boards (SEBs) were created as the entities responsible for managing the delivery of power to consumers. Until 1991 the country's electricity sector remained mostly a state monopoly whose social objectives were to serve the underprivileged domestic and agricultural sectors. Thus, the SEBs set tariffs that were well below the utilities' true costs, with heavy subsidies for agricultural consumers, smaller but significant subsidies to some domestic consumers, and higher tariffs for commercial and industrial sectors.

As a result, retail tariffs in India do not align with micro-economic efficiency. The gross subsidy on the sale of electricity was estimated to be Rs 43,132.6 crores in 2007-08, of which Rs. 29,299.4 crores were for the agricultural sector.<sup>17</sup> The subsidies in the annual plan estimates for 2008-09 were Rs. 46,087.4 crores.<sup>18</sup>

The performance of the SEBs was very poor, with frequent load shedding and poor voltage regulation. Because of this, and also facing higher tariffs, most of India's industrial and commercial users switched to self-generation. This tendency further worsened the financial situation of the SEBs, since they were losing their main paying customers.

Given these problems, India introduced reforms in 1991; however, these failed to improve the financial state of the SEBs. In 1998 the Electricity Regulatory Commission Act was passed. It set up independent regulatory commissions with the objective of tariff rationalization, i.e., aligning tariffs with the costs of delivering power by reducing cross-subsidies. However, the Act did not clearly define a path or time frame for achieving this tariff alignment.

The Electricity Act, 2003 was enacted "to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, *rationalization of electricity tariff* [emphasis added], ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto."<sup>19</sup>

Further, the Electricity (Amendment) Act, 2007, which was brought into force on 15 June 2007, deleted the provision for the elimination of cross-subsidies. But the provision on reducing cross-subsidies will continue.

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<sup>17</sup> The subsidy numbers are based on aggregate, average-cost numbers, and do not necessarily reflect the true costs to serve.

<sup>18</sup> *Economic Survey of India 2007-08*. <http://indiabudget.nic.in/es2007-08/esmain.htm>.

<sup>19</sup> The Indian Electricity Act, 2003, [http://www.powermin.nic.in/acts\\_notification/electricity\\_act2003/preliminary.htm](http://www.powermin.nic.in/acts_notification/electricity_act2003/preliminary.htm)

The increase in gross subsidies is surely a cause for concern if reforms are to be sustained. Additionally, because the policy of blanket subsidies for the agricultural sector tends to benefit larger consumers, such untargeted subsidies are mostly misused since the really poor farmers operate at a subsistence level where they do not consume much power and are also less likely to have good access to electricity. The consumption of many agricultural users is un-metered and is instead based on the irrigation pump's horsepower rating, which encourages overuse and can allow theft to occur more easily.

The cost of generating and distributing electricity for agricultural use is also high compared to that of other sectors. This is because of the long distances over which electricity has to flow to deliver power to remote users, as well as the poor condition of the rural distribution grid. But attempts to raise these prices have been met with enormous political resistance.

These subsidies distort economic decisions and run counter to the spirit of the reforms. In the long term, reform could bring in a switch to renewable energy and improved efficiency, all of which could benefit the environment. However, the present subsidies lock-in fossil fuel use and make it difficult for renewable sources to compete in the market.

Another atypical feature of the retail tariffs in India is the tiered structure where consumers within a sector are categorized into different groups according to their net energy usage (for a month) and billed at a higher rate if their consumption is higher.

**Table 16: Rates for low-tension consumers in Orissa<sup>20</sup>**

Category	Consumption (kWh/month)	Energy Charge (p/kWh)	Monthly minimum fixed charge for first kW or part (Rs.)	Monthly fixed charge for any additional kW or part (Rs.)
<b>Domestic</b>				
<b>Kutir Jyoti</b>	< 30	Fixed monthly charge	30	
<b>Others</b>	<= 100	140	20	10
	>100, <=200	230	20	10
	>200	310	20	10
<b>General purpose &lt;110 kVA</b>	<=100	320	30	20
	>100, <=300	410	30	20
	>300	450	30	20
<b>Irrigation pumping and agriculture</b>		110	20	10

The weighted average cost of supply in Orissa for fiscal year 2009-10 is estimated at 263.12 paise per unit.

This tariff structure means that the poorest consumers (those who get a connection under the Kutir Jyoti Programme) have to pay the same amount of money, namely Rs. 30 per month, whether they consume 10 kWh or 20 kWh per month, which is regressive.

<sup>20</sup> Retail Supply Tariff Effective from 1 April 2009.

Three-phase consumers with static (digital) meters are allowed to use the time-of-day tariff (excluding public lighting) at 10 paise/unit for energy consumed during off-peak hours. Industry withdrawals during off-peak hours (up to 120% of contract demand) have been allowed without any penalty. For the purpose of the tariff, “peak hours” are defined as 6.00 a.m. to 10.00 a.m. and 6.00 p.m. to 10.00 p.m. “Off-peak hours” are from 10.00 p.m. to 6.00 a.m. of the next day.<sup>21</sup>

As a result of these tariff distortions, India's utilities lose some Rs. 1/kWh sold (on average), and viable tariffs are the next need for the system, with or without a smart grid.

## E.4 Standards

Any successful smart grid implementation will need to establish standards and choose a set or suite of protocols. The deployment of various smart grid elements, including smart sensors on distribution lines, smart meters, smart devices in homes, and distributed sources of renewable energy, will require an interoperability framework. Without standards, there is the potential for technologies developed or implemented with sizable public and private investments to become obsolete prematurely, fail to interoperate, or to be implemented without measures necessary to ensure security.

This interoperability framework needs to be flexible, uniform and technology neutral. If India wants to jump-start the implementation of smart grid projects, it can leverage on the work that has already been done elsewhere and adopt standards with minor modifications to suit Indian conditions. It will take at least a few years to adapt standards to the Indian context. As a member of the International Electrotechnical Commission (IEC), India already uses several IEC standards as the basis for its own standards.

The Central Electricity Authority has constituted a high-level committee to look into the issue of metering protocol compatibility. Where Indian standards are not available, it is to use British or IEC standards, with the required modifications as per Indian grid conditions. This provides a means to speed up the process for smart grid deployments.

The smart grid will ultimately require hundreds of standards, specifications, and other requirements. The priority areas could be:

- Demand response and consumer energy efficiency
- Wide-area situational awareness
- Energy storage
- Electric transportation
- Advanced metering infrastructure
- Distribution grid management
- Cyber security
- Network communications.

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<sup>21</sup> Orissa Electricity Regulatory Commission “Annual Revenue Requirement and Retail Supply Tariff for the FY 2009-10” <http://www.orierc.org/order.html>.

The Bureau of Indian Standards (BIS) is charged with developing standards. But it has not yet taken steps to refine standards in the power sector. It is now necessary that BIS, utilities, manufacturers of components/equipment, network providers, IT firms and even consumers be involved in helping the standards evolve.

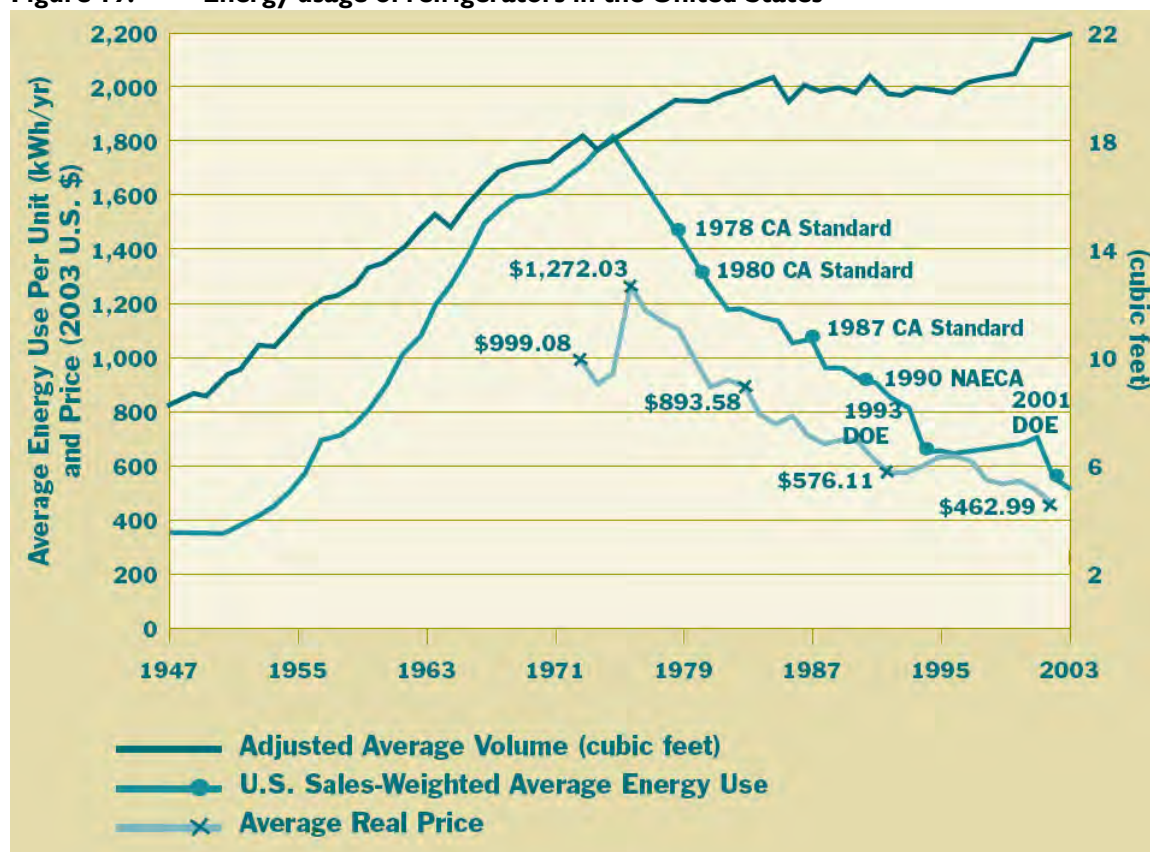
The Ministry of Power is considering a proposal to form a forum of the various stakeholders interested in smart grids in India. This forum will be useful in obtaining inputs from industry participants and making sure that all stakeholders are on board.

Even though functionality and performance are important aspects to be considered while implementing smart grid solutions, the need for standards at the basic level cannot be overlooked, as they will form the fundamental requirements to which the components of the smart grid solution will have to conform. For example, to enable the in-home display units of different manufacturers to communicate with the system put into place by the utility, they would need to be able to speak the same language. But beyond these basic requirements, the government/regulators should be fairly technology agnostic, and instead focus on functionalities that the technologies would have to enable and the performance that should be delivered.

It is worth repeating that there will not likely be a single standard or solution for any given functionality. Instead, there can be a portfolio of solutions and designs that utilities could choose from based on their needs and business case. For example, low-consumption homes may not justify a fully smart meter, but they may be ripe for a pre-paid system. Even pre-paid meters have different technology choices, each with its attendant standards, e.g., using scratch cards, smart cards, or numeric keypad entries.

One worthwhile example of standards and innovation is the use of performance-based standards instead of technology standards. The latter have usually been the norm since they are easier to comply with and verify. For example, to ensure fire safety, a building code may state “use a door of material X of thickness Y.” Instead, a performance standard would leave it to a solution provider to comply with functionality, e.g., state a “fire-safe door” must withstand a temperature of, say, 500° Celsius for two hours. This allows providers to choose the best technology on a cost basis.

In some cases, this also led to enormous innovation, as was the case for refrigerators (Figure 18). Here, California mandated a certain performance a few years in advance (pushed by the energy crisis). Manufacturers first stated it would be impossible to achieve, but they not only met the standard, they exceeded it. This then became a national standard over time. Manufacturers were given a challenge matching grant for their innovation, and one could consider such a design for components of a smart grid as well.

**Figure 19: Energy usage of refrigerators in the United States**

Source: ORNL/PEW

However, such a mechanism needs time, and there is the need for anything with network effects (like a smart grid) for the solutions to be interoperable. Thus, the performance standard may necessitate a component of technology standards as well. However, it may be preferable for Indian industry to be given the freedom to innovate instead of the government or a standards body choosing the standards up front.

## E.5 A Government Initiative toward the Smart Grid

The Government of India has identified distribution reforms as the key area in which to bring efficiency and commercial viability into the power sector. It has taken various initiatives in this direction in order to initiate a financial turnaround in the performance of the state-owned power sector. The most important of these is the Restructured-Accelerated Power Development and Reforms Programme (R-APDRP) of 2008 (an earlier version of this program, the Accelerated Power Development and Reforms Programme or APDPR, was launched in 2003), which will fund projects to upgrade sub-transmission and distribution networks.

R-APDRP has set a target of reducing 15% of the sector's aggregate technical and commercial losses combined, including collection.<sup>22</sup> This program is only applicable to urban

<sup>22</sup> It is a quirk of the aggregate technical and commercial losses definition that based on the category of the non-paying consumer and their level of cross-subsidy, a utility can reduce such losses simply by not billing such subsets of consumers!



and semi-urban areas, which account for two-thirds of India's load. In urban and semi-urban areas, technical losses are measurably lower than in rural areas owing to shorter length medium-voltage feeders, higher capacity factors of utilization (especially affecting transformer losses), and better power factors (which are heavily affected by pump sets in rural areas). Collection is also much higher in urban areas. However, even if this program is successful, India's losses will remain remarkably high.

Two preconditions for projects implemented under this program are the establishment of reliable and automated systems for the sustained collection of accurate baseline data, and the adoption of information technology in the areas of energy accounting. R-ARDRP also requires that utilities 1) achieve loss reduction targets, 2) adopt commercial measures like energy accounting and auditing, 3) take up managerial initiatives for making employees more accountable, and 4) adopt information technology for improving efficiency and enhancing consumer satisfaction.

India is behind many countries in its efforts to develop and deploy smart grids, and R-APDRP will make a contribution in this regard by focusing on information technology for utilities across India; its Part A concerns measurements and data for urban and semi-urban areas. The program offers central government funding of roughly Rs. 10,000 crore in the form of a loan convertible to a grant if the projects are completed (as verified by an independent agency appointed by the Ministry of Power) within the specified time period of three years from the date of sanction. While R-APDRP creates a reasonable starting point for further IT-based innovations, it is nowhere close to a smart grid in design or functionality.

### **A regulatory challenge for smart grids**

According to the president of the National Association of Regulatory Utility Commissioners and co-chair of the NARUC- Federal Regulatory Commission Smart Grid Collaborative, one of the most important challenges from the state regulatory perspective is for vendors and utilities to convince regulators – who are acting on behalf of consumers – that the smart grid and its related technologies are worth the investment.<sup>23</sup> This issue continues to be an important one because of the large amounts of investment required to implement smart grid deployments. Improving advanced metering capability alone will cost an estimated \$27 billion.<sup>24</sup>

Directly associated with this issue are the regulations that will allow utilities to recover these large investments. State regulators are in the business of deciding whether rate increases are needed to recover prudent investments and ensuring that rates are fair and reasonable. Smart grid deployments generally require large upfront investments, but future benefits might come only in incremental steps. Thus, regulators and utilities will have to consider full system life cycle cost and benefits in order to justify smart grid investments. It is clear that without effective cost recovery mechanisms in place, the risk associated with only partial investment recovery is high.

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<sup>23</sup> Frederic Butler, "A Call to order – A regulatory perspective on the smart grid," *IEEE Power & Energy Magazine*, April 2009.

<sup>24</sup> US Department of Energy, *Smart Grid Report*, July 2009.

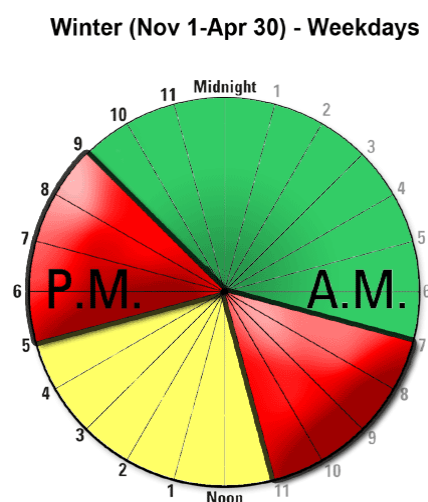
## D.1.2 Canada

Canada's power grid is very similar to that of the US, and with a few exceptions has strong provincial regulation. The country's population is very highly concentrated within 100 miles of the US border, leaving vast areas of low density that are costly to serve. The bulk of its grid is interconnected with the US grid.

One driver for smart grid adoption in Canada was the August 2003 blackout, which affected large segments of the population. Canada's smart grid efforts are not evenly distributed; there is much more activity within provinces such as Ontario where populations are dense.

A large number of smart meters have been deployed in Ontario, and the regulator, the Ontario Energy Board, has already approved time-of-use rates for consumers. Figure 20 shows a recent snapshot of the segmentation by time of day (weekends in summer and winter are both considered off-peak):

**Figure 20: Ontario Energy Board time-of-day segmentation**



The prices for off-peak, mid-peak, and peak times are 4.4 Canadian cents, 8 cents, and 9.3 cents/kWh, respectively; these are reviewed every 6 months. The system was rolled out for 10,000 consumers with smart meters in June 2009. As per government legislation, all 680,000 customers must be on time-of-use rates by 2011. By 2010, all homes in the province are expected to have smart meters.

Due to the legislative mandates for smart meters, the communications design was pushed towards WiFi for the city of Toronto to create synergy between the Internet and smart meters. However, the provider (Hydro One) chose a WiMax-based wireless communications system. Hydro One, which goes beyond the province, has many rural consumers for whom a wide area network was not available. This is reported to be one of the first licensed WiMax deployments of its kind in the world.<sup>25</sup>

<sup>25</sup> WiMax, short for Worldwide Interoperability for Microwave Access (a wide area wireless technology) is standardized (IEEE 802.16, various variants) in several spectrum bands, some licensed

Canada is also testing a broadcast (radio) signal for thermostat signaling using a radio data system. Though low-tech, it is low cost and the broadcast reaches 99% of homes. This is similar to designs proposed in the US. Such a system would be a good option for India, where more sophisticated technologies may not be viable in the near term. However, this requires differential pricing to give people incentives to participate; otherwise, a consumer may simply unplug or disable it. In addition, Indian homes rarely have a centralized thermostat (let alone centralized heating or cooling); cooling is a non-trivial load, but mostly consists of multiple individual units.

Beyond time-of-use tariffs, a promising application for smart metering and smart grids has been renewables integration. This is why modern meters have net metering capabilities, and the Canadian Government has been pushing incentives for consumer renewables (e.g., rooftop solar PV (or small/medium wind). However, the high incentives offered (30 Canadian cents per kWh for wind and 80 cents/kWh for rooftop solar) are too high for India. The growth in renewable energy has been high in Canada, not in an absolute supply percentage sense, but enough to make wind power (away from load centers, much of it at night) a viable proposition.

## D.2 Europe

The liberalization of Europe's energy markets aims to transform electric power from a utility into a commercial commodity. Given the small size of some of its utilities, a European system will help maintain balance at the continental level; the challenge, however, lies in matching regulations beyond the national level.

There is general consensus throughout Europe that long-term sustainable development will require massive investments in the generation of electricity from renewable energy sources (with the associated risks of higher marginal production costs for electricity) and that there has been a failure to add conventional generation capacity, portending future supply-side shortages. Together, these two factors have led to a growing interest in energy conservation, and smart grids as one means of delivering these savings.

**Deployments.** The adoption of smart metering in Europe is to a large extent governed and driven by regulations. Electricity reaches virtually every household and business in the whole of Europe. National concerns over the future energy situation and European initiatives such as the EU-Energy Services Directive have led to mandatory requirements or proposals for the deployment of smart meters in several countries.

**Table 17: Smart grid status in nine European countries**

Country	Smart grid status
Italy	Italy was the first to adopt the technology in the first half of this decade. By 2011, all 36 million electricity customers will be covered by smart metering.
Denmark	The main electricity distribution system operators are deploying smart meters.

(or licensable) and some unlicensed (in most countries). Many wireless ISPs have jumped on the unlicensed band due to lower costs and quicker deployment.

Country	Smart grid status
Finland	December 2008 saw the final hearing of new legislation that requires nearly full penetration of hourly metering and settlement by January 2014.
France	ERDF, the French electric network of EDF, announced the first phase of a nationwide rollout of 33 million smart meters in July 2008.
Spain	Endesa and Iberdrola plan to deploy 10 million smart meters each in order to comply with new Spanish regulations.
Ireland	A nationwide program is slated for the deployment of smart meters by 2013.
The Netherlands	In July 2008, the Dutch parliament adopted revised legislation on smart metering, introducing a two-year trial period to ensure a relaxed mandated rollout. In the meantime, Oxxio, the country's fourth-largest energy supplier, has installed over 100,000 smart meters in the residential sector.
UK	In October 2008, the government decided roll out dual-fuel smart metering for all 27 million households before 2021, introducing a two-year trial period.
Germany	In February 2008, the German utility RWE announced that it will install 100,000 smart electricity meters, making this the first project of its kind in the country.

**Policy.** Various European countries have already taken steps to develop a policy and regulatory framework for the deployment of smart grid enabling technologies. These efforts have been lunched by the European Commission through the European Strategic Energy Technology (SET) Plan.<sup>26</sup>

The SET Plan brings together the European Commission, major institutes and universities, industry and national governments, which are working to mobilize financial resources for research and related infrastructures, industrial-scale demonstrations, and market replication projects.

To engage industry, the European Commission is launching European Industrial Initiatives in wind, solar, bio-energy, electricity grids, nuclear fission, and CO<sub>2</sub> capture, transport and storage. The Initiatives are intended to strengthen energy research and innovation, and accelerate technology deployment through public-private partnerships. The grids Initiative is expected to focus on the development of the smart electricity system, including storage, and on the creation of a European Centre to implement a research program for the transmission network, with the final objective being to enable a single, smart European electricity grid able to accommodate the massive integration of renewable and decentralized energy sources.

**Standards.** European standards are those of the International Electrotechnical Commission, and are also the basis for many of the Indian standards in power and telecommunications. In contrast, the US follows those of the American National Standards Institute, which is slowly harmonizing standards for some aspects of smart meters.

In Europe, system standards for meters are determined by a number of over-arching directives and industry specifications. CEN develops standardization deliverables for heat, gas, and water meters, whereas the electricity sector is covered by CENELEC. Its Measuring Instruments Directive (MID, 2004/22/EC) aims to regulate metering products through the harmonization of technical standards based on accuracy, durability, and security. As far as smart meters are concerned, MID sets the baseline for required quality standards and

<sup>26</sup> Position Paper on Smart Grids - An ERGEG Public Consultation Paper, December 10, 2009.

regulations, but it does not mandate specific technologies or the functionality to be included within the meter.

The European Commission standardization mandate of March 2009 invites the three European Standardization Organizations (CEN, CENELEC and ETSI) to develop European Standards for an open architecture for utility meters involving communication protocols that enable interoperability.

**Funding for Research.** The European Union has three key funding instruments to support research, technological development and innovation: structural funds, the Research Framework Programme, and the Competitiveness and Innovation Framework Programme (CIP).

In 2007, information and communications technology for energy efficiency was introduced as a specific theme under the ICT priority of the 7th Framework Programme for Research, Technological Development and Demonstration Activities. It focuses on solutions for the electricity grid (smart grid), buildings and transport, and research and development on solid-state lighting. Pilot projects on the same themes are supported under the CIP. The European Commission also provides funding for energy-efficient ICTs, with over €400 million allocated to these initiatives to date.

## D.2.1 Italy

Italy is a global leader in smart metering, especially its utility Enel. Through leadership decisions and top-down designs, Enel began planning to deploy smart meters in the 1990s. These were to have bi-directional communications and a remote connect-disconnect switch. The utility began a five-year rollout of this technology in 1999-2000 for all of its 32 million consumers. Given that there was no readily available integrated solution, Enel chose Echelon's power line carrier chipsets, integrated into custom-built meters (Enel wrote the specifications for them). The power line carrier would operate in the low-voltage circuit up to an aggregator operating on GSM. The design was state of the art for its time, but today has been superseded. The payback is presumed to be four years, driven by labor savings and asset optimization.

Less traditional drivers may have led Enel to this program.<sup>27</sup> The utility was facing a meter upgrade requirement (the previous meters were generally rated at a little over 3 kW, but consumer loads were increasing). Thus, its decision for advanced technologies was based more on incremental costs than cost alone (a similar dynamic might exist in India, where even "new" digital meters are much less expensive).<sup>28</sup> The reported costs, \$100/node, were later increased when others became interested in the solution (which Enel and its subsequent partner, IBM were interested in "licensing"). Two factors contributing to this

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<sup>27</sup> R. Tongia, "What IT Can and Cannot Do for the Power Sector and Distribution in India: Link to Reforms, Incentives, and Management," Program on Energy and Sustainable Development, Working Paper 19, Stanford University, Palo Alto 2004.

<sup>28</sup> In India, more capable digital meters (which have ports for communications integration) typically cost Rs. 1100-1300; there also BIS-certified "digita", which cost around Rs. 300.

were that the Euro had appreciated significantly against the US dollar, and the embedded and R&D costs were originally not quoted.

The meters are quite advanced, but the initial design reserved in-home signaling as a future application. While the meters are time-of-use capable, their initial uptake has reportedly been low: the regulator had not mandated them, so some 10% of consumers had opted for the meters by 2009. As of the second half of 2009, the custom-built automated meter management system pulled granular data at monthly (or bi-monthly) intervals, which is low for a smart grid system. There are reports that the system now adding an in-home display unit, which was not part of the original deployment.

Enel's reach extends beyond Italy, and it is now installing smart meters for its 15 million Spanish subsidiary's consumers. This indicates a technological and business process maturity for smart meters. However, there are reports that the software is the bottleneck for increased "smart" services.

## D.2.2 United Kingdom

The UK's power capacity is about half the size of India's. Its 14 regional networks are owned by 7 distribution companies that transport electricity from the national grid to homes and businesses. Ofgem (the Office of the Gas and Electricity Markets) supports the regulator, the Gas and Electricity Markets Authority.

Ofgem has recently been exploring the potential of smart meters. Its drivers include the potential contribution to meeting the requirements of the Kyoto Protocol and the EU Energy Services Directive, rising energy prices, and international developments in smart meters.

Over the next five years UK utilities will be able to invest up to £7.2 billion to upgrade their networks. This includes a £500 million sustainability fund allowing for large-scale trials of smart grids. In addition, the UK Government announced that it will mandate smart metering for the residential sector. Starting on 1 April 2009, energy suppliers were to provide advanced metering to the commercial market whenever a meter is replaced, and provide advanced meters to all customers by 2014. The government expects that the full rollout will be completed by 2020.

A number of factors will help support generation connected directly to the UK distribution network (distributed generation), including:

- Retaining incentives for distribution network operators (DNOs) to make the investments needed to connect distributed generation
- Equalizing incentives on capital and operating expenditure to remove the previous bias towards capital investment and charging the DNOs the costs of linking to the transmission network – both of these should encourage the companies to consider using demand-side management or distributed generation as a way of addressing capacity constraints

- Introducing cost-reflective charges that benefit distributed generation, which reduces the need for network reinforcement
- Ensuring that the contracts and charging arrangements are clear and non-discriminatory.

In addition, The Electricity Networks Strategy Group, jointly chaired by the Department for Energy and Climate Change and Ofgem, has established a smart grid stakeholder group to develop a vision and route map for the development of smart grids in the UK. The development of smart grid technologies is expected to be a key enabler in meeting the UK's 2020 targets under the EU's climate-energy legislative package.

An important output from the group's work will be the identification of smart grid network solutions that could be deployed in the immediate future. Ofgem is proposing to introduce the Low Carbon Networks Fund<sup>26</sup> for electricity DNOs that will become active in April 2010. It is intended that the smart grid solutions identified by the Group could be built and trialed under this fund in the period to 2015.

A number of smart grid projects are already being pursued under an existing incentive arrangement: the Innovation Funding Incentive and Registered Power Zones. Projects employing dynamic line ratings, intelligent generator constraint management, and advanced voltage control are already operational.

### **D.2.3 Portugal**

The concept of smart grid development in Portugal was presented by the Portuguese distribution system operator, EDP Distribuição, whose first pilot demonstration is now being implemented. The concept is called INOVGRID and the pilot has the objective of connecting, during 2009, 500 customers in 4 geographic areas of Portugal and 50,000 customers during 2010. The cost of this demonstration (€15 million) was accepted by the Portuguese National Regulatory Agency and incorporated in regulatory period tariffs.

Another dimension of smart grid developments in Portugal is the Mobi-E initiative, a national structure of electric vehicle recharging stations at public spaces, promoted by the Portuguese Government to facilitate the introduction of electric vehicles. Twenty one cities are involved in Mobi-E, which will install 320 recharging stations by the end of 2010 and have 1,300 active recharging stations at the end of 2011, the planned timing of a larger electric vehicles introduction in Portugal. A consortium of Portuguese companies and research centers are taking part in this initiative.

The Portuguese intend to have renewable sources attain a 31% of market share in gross final consumption of energy by 2020. While large hydro generation represents more than 20% of its electric generation mix, the country has recently made a great effort to invest in other renewable solutions, mostly wind and solar photovoltaic. Last year, micro-generation with solar photovoltaic and wind turbines connected to the low-voltage distribution network began to be actively promoted with more than 5,000 households already being simultaneously electric consumers and producers.

This option for renewable and dispersed sources imposed some challenges to all levels of the electric network; Portugal has met them with new investments and some changes in operating procedures. Attaining a more than 40% penetration of renewable electric generation during 2008 (a wet year) is considered successful in Portugal.

### D.3 China

The importance of China's electricity sector cannot be understated. One of the world's largest producers of power, China is already the planet's largest emitter of CO<sub>2</sub>. China's capacity growth has been nothing short of phenomenal; it recently added some 100,000 MW of capacity in one year. Even such growth has been unable to keep pace with demand, and there have been periodic shortfalls. This has been one of the drivers for smart grids in China. In addition, China has often taken a long-term strategic view on technologies (e.g., their investments in solar power and clean coal), but it does not see smart grids as a short-term need per se.

China's total installed capacity is 874 GW and should reach 950 GW at the end of 2010. Conventional thermal sources are expected to remain the dominant fuel for electricity generation in the coming years (74.6% of the total), with many power projects under construction or planned that will use coal or natural gas. At the end of 2009, wind power in China accounted for 16.13 GW of electricity generating capacity. China revised its 2020 target for solar power capacity from 1.8 GW to 20 GW.

**Institutional setting.** In 2002, the Chinese Government dismantled the monopoly State Power Corporation (SPC) into separate generation, transmission, and services units. Since the reform, China's electricity generation sector has been dominated by five state-owned holding companies. Also in 2002, the State Electricity Regulatory Commission (SERC) was established, which is responsible for the overall regulation of the electricity sector.

While the generation sector has some market competition, the transmission and distribution sectors are heavily state-controlled. During the 2002 reforms, SPC divested all of its electricity transmission and distribution assets into two new companies, the Southern Power Company and the State Power Grid Company. By 2020, the government aims to merge SPC's 12 regional grids into 3 large power grid networks, namely a northern and northwestern grid operated by the State Power Grid Company, and a southern grid operated by the Southern Power Company.

**1.1.1 Smart grids.** China's largest electric transmission company, the State Grid Corporation of China, has announced an ambitious plan to develop a national smart grid by 2020. As an initiative, the City of Yangzhou is to build a smart grid demonstration center to test wireless-enabled smart meters, home energy management systems, and smart appliances set up in a 100,000 square-foot lab over the next four years.

The initiative may also include the installation and demonstration of home-based charging stations for plug-in hybrid electric vehicles (PHEVs). Teamed with dynamic pricing that encourages charging overnight, PHEVs can enable electric cars to become more commonplace, reducing China's need for oil while greatly lowering the carbon footprint of



each mile driven. China is already a leader in electric motorcycles/ scooters, as well as smaller electric cars.

Formal, accurate (and English-language) data on Chinese deployments are limited, but newspaper reports indicate China will be investing on the order of \$100 billion in smart grids and affiliated upgrades in the coming ten years. This would dwarf the expenditure of any other nation. However, China also has the track record of “going it alone” when it comes to standards for emerging technologies, such as 3G wireless, digital TV, etc., so despite the size of its market, it may not present direct sales opportunities for India or other nations.