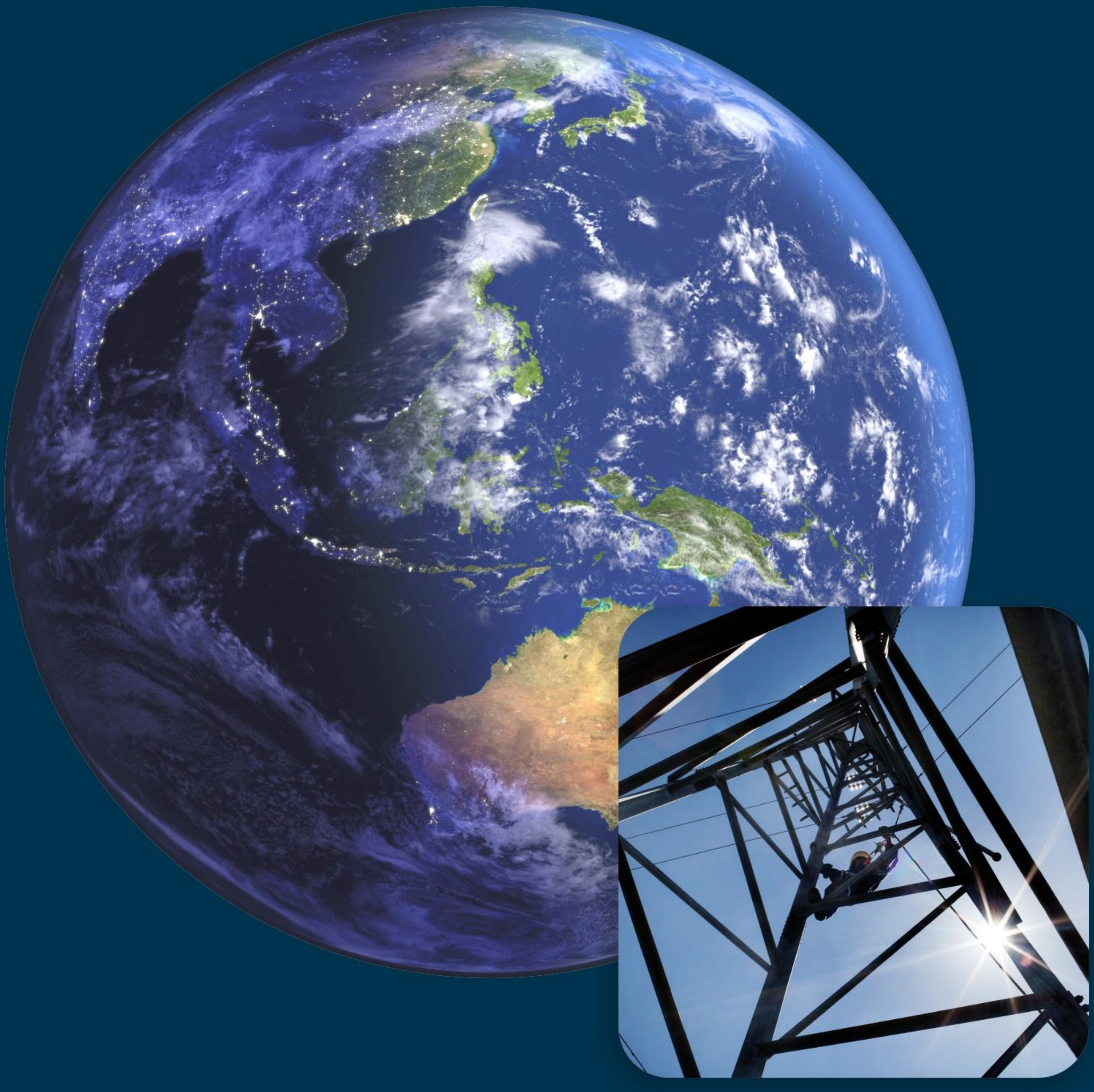
Technology Action Plan

SMART GRIDS



MAJOR ECONOMIES FORUM
ON ENERGY AND CLIMATE

DECEMBER 2009

Technology Action Plan: Smart Grids

Report to the Major Economies Forum on Energy and Climate

Prepared by Italy and Korea
in consultation with MEF Partners

December 2009

PREFACE

The Leaders of the 17 partners[1] of the Major Economies Forum on Energy and Climate (MEF) agreed on 9 July 2009 that moving to a low-carbon economy provides an opportunity to promote continued economic growth and sustainable development as part of a vigorous response to the danger posed by climate change. They identified an urgent need for development and deployment of transformational clean energy technologies, and established the Global Partnership to drive such low-carbon, climate friendly technologies.

Plans were created to stimulate efforts among interested countries to advance actions on technologies including advanced vehicles; bioenergy; carbon capture, use, and storage; buildings sector energy efficiency; industrial sector energy efficiency; high-efficiency, low-emissions coal; marine energy; smart grids; solar energy; and wind energy. These plans include a menu of opportunities for individual and collective action that may be undertaken voluntarily by interested countries, in accordance with national circumstances. Further actions may be identified in support of these plans in the future.

[1] Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom, and the United States

OVERVIEW

In today's highly technological world, the generation and delivery of electricity is vital to all global economic sectors. Today's electricity generation and transmission infrastructures largely require fossil fuels and are relatively inefficient. As a result, electricity accounts for a significant share of the carbon emissions generated by energy consumption. Smart grids—in which computers and other technologies are used to intelligently integrate the generation, transmission, and consumption of electricity—have the potential to greatly improve the efficiency of this vital energy source.

For example, smart grids technologies could enable load leveling of the electrical grid, allowing a power company to run cleaner power sources—such as hydroelectric, wind, or solar—reducing the need to use carbon-emitting gas, coal, or oil plants to meet peak demand. Reducing variability in demand could also reduce the number of new power plants that need to be constructed.

Implementing smart grids technologies does not allow a "one size fits all" approach. Each smart grid encompasses a diverse spectrum of technologies, applications, and solutions that can vary by country, regional characteristics, and stakeholder drivers. While individual countries will face unique challenges in deploying smart grids technologies, common challenges can be overcome through global coordination and cooperation.

This plan reviews the opportunities for smart grids technologies and considers the actions needed to ensure implementation and achieve reductions in related greenhouse gas (GHG) emissions. It covers the most critical areas directly relating to the effective acceleration of smart grids deployment—namely policy and regulations; financing; technology and standards; cyber security and data privacy; and skills and knowledge.

HIGHLIGHTS OF THE SMART GRIDS TECHNOLOGY ACTION PLAN

1. GHG Emissions and Mitigation Potential

- **Electricity accounts for 38% of global GHG emissions in the energy sector**, though it only represents 17% of total world fuel consumption , because of high dependence on fossil fuels and continuing grid inefficiencies.
- **Smart grids technologies are needed to help reduce these emissions.** Smart grids technologies will enable integration of renewable energies into electricity supply, increased use of electricity for transportation, and reduced end-use electricity use through energy efficiency—all resulting in reduced GHG emissions.

2. Development and Deployment: Barriers and Best Practice Policies

- **Barriers** to the development and deployment of smart grids technologies include policy and regulation, financing, consumer engagement, technology, standards, skills and knowledge, cyber security, and data privacy.
- **Best practice policies** encouraging the development and deployment of smart grids technologies include setting out the legislative and market framework to

provide the right market environment, implementing full-scale projects that develop business cases and test financing arrangements, promoting the development of technology standards, and investing in skills and knowledge.

3. Opportunities to Accelerate Development and Deployment

- **Supporting innovation:**
  - Develop a global smart grids technology strategy to work with current research initiatives to integrate and align current development efforts across the globe.
  - Develop and refine methodologies and simulation/analysis tools able to manage an integrated view of complex smart grids systems.
  - Promote international access to global test-beds to verify the coordination, interaction, and interoperability of the overall smart grids solution.
- **Accelerating deployment:**
  - Foster the development of skills relevant to the roll out of smart grids technologies by supporting new education programs at universities and institutions, smart grids apprenticeship programs, and skills exchanges among ongoing smart grids programs.
  - Establish a platform to enable international and cross-regional smart grids standards development and coordination.
  - Define smart grids cyber security and privacy requirements.
  - Establish a “Smart Grids Working Group” with associated “Engagement Groups” and a clear mandate to foster measures that accelerate smart grids deployment.
- **Facilitating information sharing:**
  - Develop and manage a central global repository with past and ongoing smart grids R&D, pilot, and full-scale deployment efforts by different entities.
  - Establish a program of workshops and communication sessions on best practices in smart grids financing, coordination, and regulation, targeting those in public sector decision-making positions.

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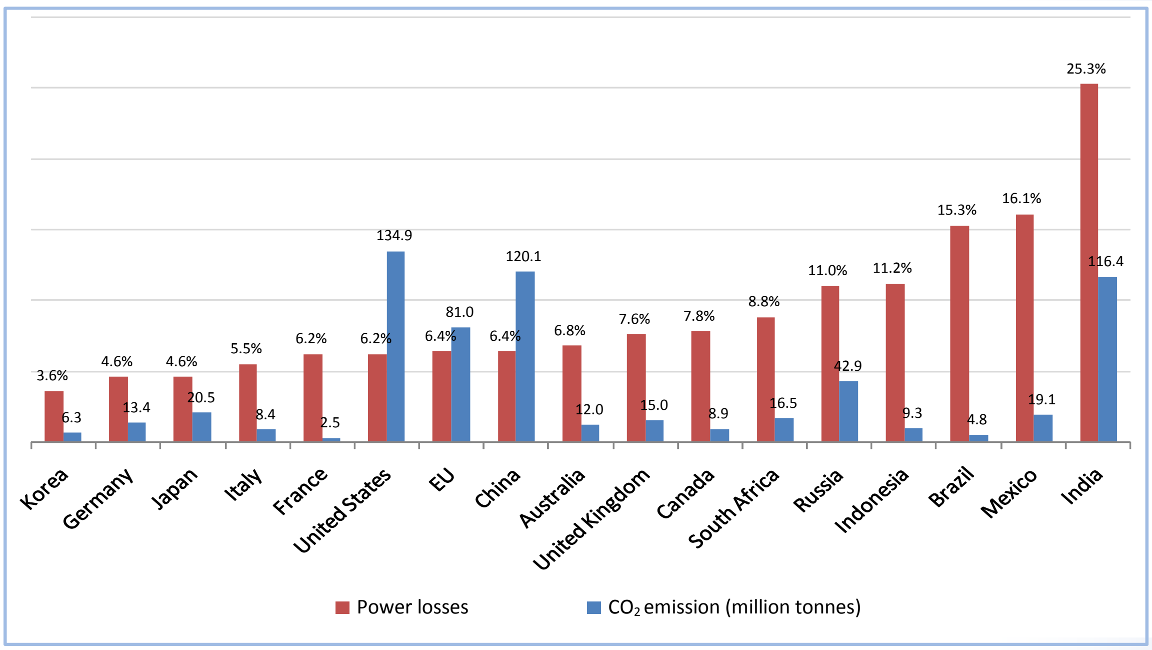
1. Smart Grids Technologies: GHG Emissions Production and Mitigation Potential

GHG Emissions Production from Electricity Generation

Electricity generation around the globe depends heavily on the combustion of fossil fuels (coal, natural gas, and oil). The systems used to produce electricity have improved through technology advances, use of cleaner fuels, and other strategies; however, significant inefficiencies remain. A recent report estimated the global average efficiencies of electricity production to be at 34% for coal, 40% for natural gas, and 37% for oil. With an average global efficiency of 36% for all fossil fuels, nearly two-thirds of the energy used to generate electricity is currently being lost (IEA 2008a). Accenture estimates that the total carbon dioxide (CO_2) emitted due to power losses at the grid amounted to 608 million tonnes among Major Economies Forum (MEF) countries (Figure 1) in 2006 (IEA 2009). The infrastructure used to transmit and deliver electricity to consumers is also relatively inefficient.

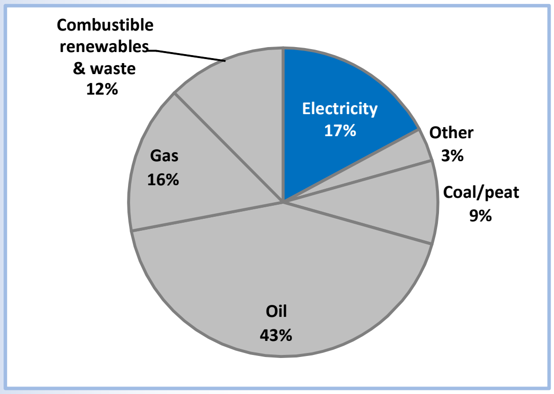
Figure 1. Power Losses at the Grid and Resulting CO_2 Emissions of MEF Countries in 2006



Source: Accenture, based on IEA 2006 statistics

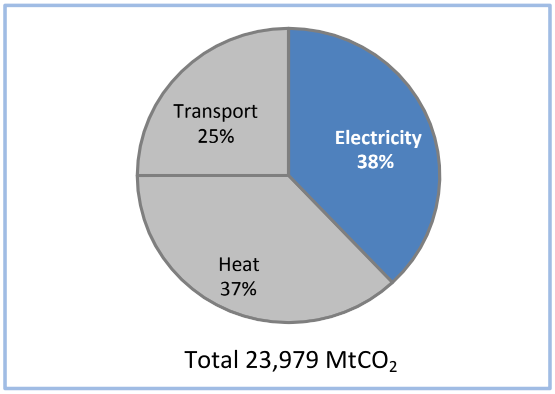
As a result, although electricity represents only 17% of world fuel consumption (Figure 2), it accounts for 38% of global greenhouse gas (GHG) emissions in the energy sector (Figure 3)—mostly due to the sector's high dependence on fossil fuels and continuing grid inefficiencies. Based on figures from the International Energy Agency (IEA), the power generation sector emitted 11.4 metric gigatonnes (Gt) of CO_2 in 2004 (accounting for 41% of global emissions) and that total is projected to increase to 18 Gt in 2030 (accounting for 45% of global emissions) (IEA 2008c).

FIGURE 2. TOTAL CONSUMPTION BY FUEL (2007)



Source: IEA 2009

FIGURE 3. CO_2 EMISSION BY ENERGY SECTOR (2002)

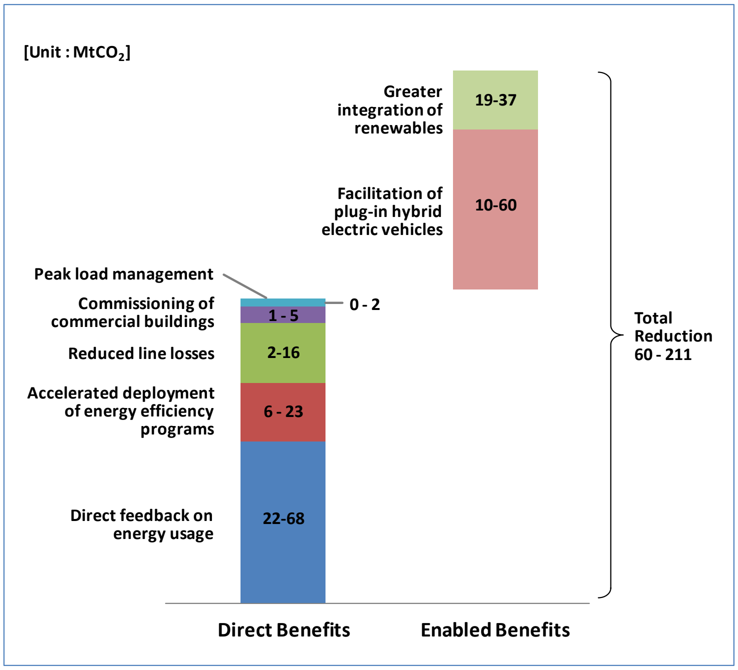


Source: IPCC 2007

Mitigation Potential from Smart Grids Technologies

The environmental benefits of smart grids technologies are often overshadowed by the economic or technical value of smart grids deployment. Merely focusing on the financial or technical benefits of smart grids systems undermines the total value of smart grids deployment, thereby creating "ceilings" on a smart grid's untapped potential. Various research activities have supported the notion that implementing smart grids technologies will significantly reduce CO_2 emissions.

FIGURE 4. ESTIMATED SMART GRIDS-RELATED CO_2 EMISSIONS REDUCTION IN THE U.S. BY 2030



Source: EPRI 2008

Under the *Energy Technology Perspectives 2008* (IEA 2008b) Blue scenario, which envisages reducing global energy-related CO_2 emissions in 2050 to 50% of 2005 emission levels, IEA predicts a reduction in power generation-related CO_2 emissions to only 2 Gt of CO_2 in 2050. This represents an 80% reduction from 2005 power generation emission levels. GHG reductions are a result of significant renewable electricity generation, a significant increase in nuclear generation, and employment of carbon capture and storage (CCS) technology. Further predicted reductions in the ETP 2008 Blue scenario are the result of increased use of electricity for transportation and reduced end-use electricity consumption through energy efficiency (IEA 2008b).

Research shows that smart grids technologies can enable emissions reductions. The Electric Power Research Institute (EPRI) expects smart grids to reduce up to 211 million tonnes of carbon emissions annually in the United States by 2030 (Figure 4). This represents nearly 9% of the total domestic carbon emissions generated by the U.S. power sector in 2006. In most areas, smart grids technologies can directly reduce carbon emissions by achieving better energy efficiency—avoiding an estimated 31 to 114 million tonnes of CO_2 annually. Moreover, smart grids technologies can facilitate carbon emission reductions independent of direct power savings—by enabling the deployment of such low-carbon emission technologies as renewable generation and electric vehicles, which could reduce CO_2 emissions by approximately 37 and 60 million tonnes, respectively (EPRI 2008).

The IEA projects that the world will need more than $1.8 trillion over the next two decades to upgrade the grid infrastructure (IEA 2004). Significant investments will be required to upgrade electricity systems and implement more efficient, smart technologies.

Drivers for Smart Grids Implementation

Many converging factors are driving the energy industry toward smart grids (Figure 5). Many of these drivers are country- and region-specific, based on unique governmental, economic, societal, and technical characteristics. For developed countries, the main reasons to adopt smart grids technologies are grid loss reduction; system performance and asset utilization improvement; integration of renewable energy sources; active demand response; and energy efficiency. Many developed countries are experiencing the degradation of system reliability resulting from aging grid infrastructure. Inadequate access to strong transmission and distribution grid infrastructure limits the integration of renewable energy generation and its potential benefits. Smart grids technologies can address these issues by improving grid reliability through the application of new technologies and increased capacity to absorb renewable energy generation.

FIGURE 5. SMART GRIDS DRIVERS

Environmental
- Reduce greenhouse gas emissions
- Support and lower cost of Kyoto compliance
- Increase renewable energy generation
- Improve energy efficiency

Regulatory/ Governmental
- Respond to governmental mandates (i.e. UK, Netherlands, Sweden, US, Australia, Brazil, etc.)
- Support building renewable/distributed generation
- Support performance-based rate making
- Enable national security objectives
- Facilitate wholesale and retail market efficiency

Economic
- Improve reliability (e.g. decreased outage duration and frequency, etc.)
- Reduce labor costs (e.g. meter reading and field maintenance, etc.)
- Reduce non-labor costs (e.g. field vehicle, insurance and damage, etc.)
- Reduce system losses (e.g. better systems planning and asset management, etc.)
- Provide revenue protection (e.g. better billing accuracy, prevention/detection of theft/fraud, etc.)
- Provide new revenue sources (e.g. energy management, etc.)
- Deferral of large capital projects (e.g. reduced generation requirements, etc.)

Societal
- Respond to consumer demand for sustainability and enhanced ability to manage their usage
- Respond to customer increasing demand for uninterruptible power
- Provide customer options for energy conservation

Technology & Infrastructure
- Invest significant capital for development of new technology (improvement of existing technologies)
- Replace outdated T&D infrastructure
- Decreasing workforce (50% of technical workforce are expected to reach retirement age in 5-10 years)

Source: Accenture

Smart grids technologies are also beneficial for developing countries. These countries can achieve fast and sustainable smart grids growth with “forward-thinking” design, planning, and development of a modern electricity infrastructure, using the most advanced technologies suitable for their geographic conditions. For example, large countries such as China and India, where generation facilities are physically distant from some sparse demand sites, may consider grid interconnection using Ultra High Voltage AC/DC transmission lines.

Developing countries can proactively plan for increasing future power demand by maximizing the portfolio mix of conventional and renewable energy (at the transmission level) or by increasing their use of distributed energy generation under the virtual power plant (VPP) concept—whereby a central control entity runs and manages a cluster of distributed generation installations. This arrangement enables sustainable micro-grid and island communities/grids to operate effectively based on a mix of energy generation and energy storage, supported by well-defined protection, automation, monitoring, and control design and engineering standards/principles. In addition, countries can expect the additional benefits of economic stimulation through the creation of new businesses and “green” jobs. Smart grids technologies can also help prevent power theft, power losses, and frequently planned power outages, all of which continue to pose a problem in developing countries.

Overview of Technology

The term “smart grids” has many definitions and interpretations, depending on the specific country, drivers, and desirable outcomes or benefits (summarized in Appendix A). Beyond a specific, stakeholder-driven definition, smart grids refers to the entire power grid, including the generation, transmission, and distribution infrastructure, as well as electricity consumers (Figure 6).

Factors such as legacy systems and assets, social conditions, political and consumer choices, and so forth will drive the selection of technologies and functionality in smart grids. European smart grids stakeholders have recently proposed a holistic approach to smart grids functionality (Figure 6). This approach outlines a set of smart grids technologies and capabilities for various levels of grid infrastructure, with the view that the deployment of increasingly sophisticated smart grids will require commensurately more advanced technologies.

Table 1 summarizes key smart grids technologies and capabilities. The technologies and capabilities detailed below apply to the entire grid spectrum—from consumers to the transmission network. Detailed descriptions of each of these technologies and capabilities, including maturity level, technological barriers, deployment trends, and R&D needs, are presented in Appendix B.

Table 2 indicates where each key technology or capability stands in terms of relative maturity, penetration, and rate of deployment. As Table 2 shows, the majority of technologies are emergent or developing at the present time. A rapid pace of deployment is predicted for some developing technologies that currently face minimal barriers.

FIGURE 6. THE SMART GRID CONCEPT

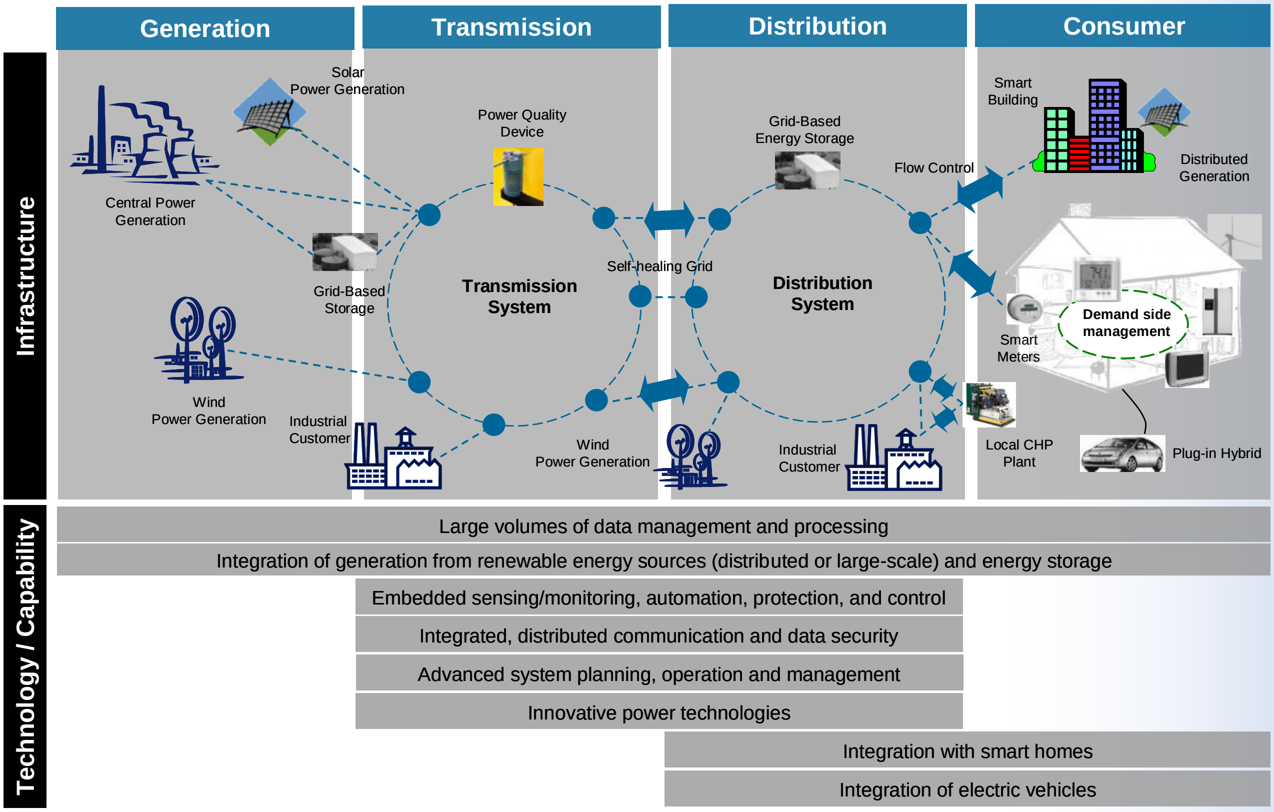


TABLE 1. KEY TECHNOLOGIES AND CAPABILITIES ENABLING SMART GRIDS DEPLOYMENT

	Technology / Capabilities	Functionality	Technology / Capabilities Enablement
1	Active demand response and integration with smart homes	• Demand-side user participation and response to the market • Time-based energy consumption management based on the market's various price signals and the grid's critical and emergency performance requirements	• Real-time, bi-directional information flow • Smart metering • Smart home (e.g., smart appliances, energy portal) • Consumer programs and user interface • Electricity price diversity
2	Smart metering infrastructure and data processing	• Reading remote energy consumption • Real-time, bi-directional information exchange between consumer and utility/retailer	• Real-time, bi-directional information flow • Smart metering • Interoperability and standardization • Data security measures

	Technology / Capabilities	Functionality	Technology / Capabilities Enablement
3	Integration of small- and large-scale renewable energy sources and storage	• "Green" energy production through renewable energy sources, to reduce high CO_2 emissions	• Renewable generation technology and grid integration: performance, lifespan, and cost • Energy storage to mitigate technical challenges related to dispatch and control issues • Reinforcement of the transmission and distribution (T&D) networks • Safety and protection schemes • Grid operation and control guidelines • Engineering, maintenance, safety standards, and guidelines
4	Infrastructure to host electric vehicles	• Central or local charging and discharging of electric vehicles • Billing for charging electric vehicles (grid-to-vehicle) • Crediting for supply of ancillary services to the grid (vehicle-to-grid)	• New and reinforced T&D infrastructure • Charging station technology • Specific ICT schemes • Billing technologies • Solutions/technology standardization • Business model definition • Engineering and maintenance standards and guidelines
5	Embedded sensing automation, protection, and control	• Intelligent fault and outage detection based on the sensing system combined with advanced analytics • Self-healing grid • State estimation enabling real-time dynamic and static system stability analysis • Grid risk and margin evaluation • Power system optimization • Failure probability • Predictability of possible severe grid disturbances leading to major power system outages and blackouts • Power system reliability improvement	• Advanced sensors • Advanced technology • Interoperability and standardization • Knowledge rules • Engineering and maintenance standards and guidelines
6	Integrated distributed communication and data security	• Real-time data transfer between grid assets between generation, transmission, distribution, and end user • Secure access and data management for all smart grids stakeholders	• Technology developments (PLC, IP, etc.) • Standardization between various smart grids communication technology solutions • Interdependence between electric and communication infrastructure • Cyber security/data/information standards and rules
7	Advanced system operation	• Dynamic security assessment • Wide-area grid reliability improvements	• Advanced simulation/estimation methods and tools

	Technology / Capabilities	Functionality	Technology / Capabilities Enablement
8	Advanced system management	• Optimum equipment performance (effective asset utilization) • Condition and performance-based maintenance	• Advanced sensing equipment • Dynamic engine, methods, and tools
9	Advanced system planning	• System planning considering real-time system impacts from large-scale integration of renewable energy resources, high penetration of distributed generation, and chargeable electric vehicles	• Advanced planning/ simulation/ estimation methods and tools • New and reinforced T&D infrastructure • Grid codes, standards, and regulations
10	Innovative power technologies	• Grid reliability improvements • Grid efficiency and asset utilization improvements • Effective integration of distributed and renewable energy technologies	• Advanced technology • Interoperability and standardization • Construction and engineering standards and guidelines • Regulation and finance

TABLE 2. KEY TECHNOLOGIES AND CAPABILITIES ENABLING SMART GRIDS DEPLOYMENT

	Technology/Capabilities	Maturity	Penetration	Trend
1	Active demand response and integration with smart homes	developing	limited	slow
2	Smart metering infrastructure and data processing	mature	moderate	rapid
3	Integration of small- and large-scale renewable energy sources and storage	developing	moderate	rapid
4	Infrastructure to host electric vehicles	developing	limited	slow
5	Embedded sensing automation, protection, and control	developing	moderate	rapid
6	Integrated distributed communication and data security	developing	moderate	rapid
7	Advanced system operation	emergent	limited	slow
8	Advanced system management	mature	moderate	rapid
9	Advanced system planning	emergent	limited	slow
10	Innovative power technologies	developing	limited	slow

***Maturity:* commercial availability**

- *Emergent:* Under active research and development
- *Developing:* Prototype stage (demonstration scale in an operational environment)
- *Mature:* Commercial stage (technology is commercially available)

***Penetration:* deployment scale**

- *Limited:* Very few examples of the demonstration deployment
- *Moderate:* Stakeholder examples of the demonstration and "at-scale" deployment
- *Widespread:* Industry-wide examples of the demonstration and "at-scale" deployment

***Trend:* deployment velocity**

- *Slow:* Limited deployment growth due to a number of barriers
- *Rapid:* High deployment growth due to a limited number of barriers

Smart Grids as Enabler of Low-Carbon Technologies

The electricity network is of central importance to a carbon-constrained energy system. Wide and effective deployment of most advanced energy technologies that reduce CO_2 emissions will be limited without a suitable electrical network. For example, integrating large amounts of wind power into the energy system requires specific preparation of the electricity grid, including sufficient current carrying capacity, power flow control, and, possibly, energy storage capabilities. Additionally, typical smart grid concept features (i.e., smart meters) must be suitably developed and deployed before load leveling and active demand response can be used to conserve energy in buildings. Thus, smart grids are not only a means to reduce carbon footprints by themselves—they are a key enabler for other CO_2-reduction technologies and solutions.

Figure 7 illustrates the interrelationships between smart grid capabilities and the wide range of energy technologies selected by the MEF partners. For each energy technology considered, it shows the importance of having already deployed the various components of a smart grid. For example, to allow deployment of energy efficiency measures in buildings, it is vital to have previously deployed the smart grids technologies related to demand response and smart metering, etc. In the case of large-scale renewable generation integration and electric vehicle deployment, the smart grid concept refers more to the electricity grid reinforcement requirements (physical grid infrastructure) than to the advanced intelligence, functionalities, solutions, and technologies.

Worldwide Smart Grids Implementation Initiatives

A large number of projects are being developed worldwide under the smart grids umbrella. Each of these projects is driven by a different set of objectives and benefits, use various types of technologies (e.g., AMI, automation, distributed generation, electric vehicles, renewable energy generation, etc.), and exhibit differences in the complexity of solutions and integration architecture (demonstration project vs. full-scale deployment). Appendix C provides details of key smart grids initiatives around the globe.

FIGURE 7. SMART GRIDS ENABLE OTHER TECHNOLOGIES SELECTED BY MEF

LEGEND

- Vital - enabling (red)
- Facilitating (yellow)
- Useful (but not vital) (green)
- Not relevant (blue)

	Transformational Low-Carbon Technologies Considered by MEF							
	WIND-SOLAR 1: Integration of bulk variable renewables - connected on the transmission network	WIND-SOLAR-BIOENERGY 2: Integration of distributed variable renewables - connected on the distribution network	ADVANCED VEHICLES (with particular reference to electric vehicles)	EFFICIENT BUILDINGS	ENERGY EFFICIENCY IN INDUSTRY	CARBON CAPTURE, USE AND STORAGE	CLEAN COAL TECHNOLOGIES	BIO-ENERGY
Active demand response and integration with smart homes	Not relevant	Useful (but not vital)	Facilitating	Vital - enabling	Not relevant	Not relevant	Not relevant	Not relevant
Smart metering infrastructure and large volume of data management and processing	Not relevant	Useful (but not vital)	Vital - enabling	Vital - enabling	Vital - enabling	Not relevant	Not relevant	Not relevant
Integration of small and large scale renewable energy sources and storage	Vital - enabling	Vital - enabling	Useful (but not vital)	Useful (but not vital)	Useful (but not vital)	Not relevant	Not relevant	Not relevant
Infrastructure to host electric vehicles	Not relevant	Not relevant	Vital - enabling	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
Embedded sensing, automation, protection and control	Facilitating	Vital - enabling	Useful (but not vital)	Useful (but not vital)	Useful (but not vital)	Useful (but not vital)	Useful (but not vital)	Not relevant
Integrated distributed communication and data security	Facilitating	Facilitating	Facilitating	Facilitating	Facilitating	Not relevant	Not relevant	Not relevant
Advanced system operation	Facilitating	Vital - enabling	Facilitating	Useful (but not vital)	Useful (but not vital)	Useful (but not vital)	Useful (but not vital)	Not relevant
Advanced system management	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
Advanced system planning	Facilitating	Facilitating	Useful (but not vital)	Not relevant	Not relevant	Useful (but not vital)	Useful (but not vital)	Not relevant
Innovative network technologies	Vital - enabling	Not relevant	Facilitating	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant
Electricity network reinforcement	Vital - enabling	Facilitating	Useful (but not vital)	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

2. Development and Deployment: Barriers and Best Practice Policies

Barriers to Smart Grids Development and Deployment

No single smart grid solution is appropriate to all electricity markets or networks. Each electricity market has its own set of political, regulatory, and commercial drivers that will influence the capabilities required of the electricity network. Each electricity network will require a different level of technological development to deliver the desired capabilities. Levels of smart grid capabilities, barriers to development and deployment, and solutions will also differ significantly among countries, markets, and individual networks. Even so, each country will face various common barriers, which are broadly categorized and summarized in Figure 8.

Figure 8. Key barriers to Smart Grids Deployment

Market Barriers	**Policy & Regulation**	• Market uncertainty and unclear policy on market structure and rules • Revenue uncertainty due to regulatory structures
	Financing	• Difficulties in defining priorities of technology investments • Business case fragmentation
Public Barrier	**Consumer Engagement**	• Low public awareness and engagement
Technology Barriers	**Technology**	• Lack of R&D coordination • Lack of large-scale deployment projects
	Standards	• Interoperability and scalability assurance • Fragmentation and lengthy process for technology standards
	Skills and Knowledge	• Insufficient skilled resources • Limited understanding of smart grids in public planning
	Cyber Security & Data Privacy	• Threats to cyber security in networks and consumer information • Concerns about private data misusage

Market Barriers

The fundamental question that each market will face is how to provide incentives for electricity companies to invest in and implement the right level of smart technology. "Electricity companies," in this case, should be viewed in the broadest sense. They include both traditional utility network companies that will be responsible for the provision of the underlying electricity network infrastructure and a wide range of non-utility companies providing diverse technologies, solutions, applications, and services to deliver the full value from smart grids deployment (e.g., communications companies behind home-area networks, companies providing micro-generation and devices to support advanced end-user services, electric vehicle and battery manufacturers, and companies that will provide the associated e-vehicle charging and billing infrastructure, etc.). In market terms, a smart grid supports a whole new range of product offerings, services, and opportunities that create value for users, electricity companies, and the host governments.

Although smart grids provide an essential supporting infrastructure for energy efficiency and environmental measures (e.g., intermittent renewable generation), by themselves they create benefits outside of network operational efficiencies. Wider societal value scales up (e.g., through real-time consumer propositions and carbon reduction) only when all of these "electricity companies" interact to provide the range of commercial services that a smart grid supports. To be effective and efficient, any market stimulation must be designed to overcome barriers to the development of the supporting smart grid infrastructure and commercially viable associated products, offerings, and services.

Different countries have different drivers for, and expectations of, a smart grid, and contain one or many different market and regulatory structures that will need to support their development. This report outlines some key characteristics and barriers associated with market and regulatory structures.

Policy and Regulation

Market uncertainty

Unclear policy increases market uncertainty with regard to how the overall market structure and rules will develop, which technologies merit investment, and the levels of capability required of the network. Market uncertainty varies depending on the market structure. Competitive-leaning markets place the emphasis on market participants, motivated by profitability and/or growth, to most efficiently allocate capital and select which technologies to apply. Centralized markets are subject to a more directed approach by the government or regulatory body acting within powers set by the government.

Governments and regulators in competitive-leaning markets will avoid the charge of "picking winners" and will attempt to let the market decide on the best structure and technology, often through lengthy consultations. However, where there is a lack of clarity about future market structure, roles, and rules, competitive markets tend to "lock up." Companies then base investment decisions on the status quo and use tried-and-tested technologies to avoid the risk of picking the losing market technology. However, once the new market structure is defined and technologies are proven, rapid adoption of technology and associated innovation can be expected.

Network companies within centralized markets are more likely to be subject to government or regulatory directives, whereby direct mandates are given to the market participant(s) to invest in certain areas. Although this approach will gain quick results in the short term, a centralized market will, by its nature, provide political/ regulatory risk, and not necessarily offer the rewards that could encourage the innovative new markets and services needed to realize the full potential value of a smart grid. This implies the need for a trade-off between 1) being sufficiently directive to provide clarity to companies on the future shape and rules for the market, and 2) providing sufficient incentive for companies to invest in innovative technologies and services.

Revenue uncertainty

While regulation can help in implementing smart grids technologies, regulatory structure and other factors can create revenue uncertainties. If a company is required to invest in smart grids technologies, the revenue model must align with the benefits expected and provide assurance of return—at least for the payback period of investment.

Table 3 illustrates two contrasting regulatory models and their impacts on revenue.

TABLE 3. COMPARISON OF DIFFERENT REGULATORY MODELS AND IMPACT ON REVENUE UNCERTAINTY

Periodic RPI-X	Long-Term Cost Plus
• For every regulatory period (e.g., five years), the regulator sets the revenue allowed to the network company. It is typically based on prior period operating and capital expenditures, adjusted for forecast throughput, cost inflation, service level performance incentives, and efficiency requirements. • The network business is given incentives to improve efficiency and service levels. • Capital investment plans that support reduction of throughput, rather than meeting a growing load, may not be compensated under the revenue model. • Long-term investments that rely on benefits beyond the regulatory period are at risk of having those benefits scaled back through the RPI-X formula at the next price control.	• The network business files a rate case with the regulator and an allowed amount of revenue is assigned to them based on delivery of defined standards of service and annual operating and capital expenditures. • This rate case is reviewed periodically but is reopened when a substantive change in assumptions occurs (e.g., a major change in service levels or an extraordinary expenditure required). • The network business has more discretion over where to invest, as long as service levels are maintained. Revenues are not at risk of major change, so longer-term investment payback periods are possible.

Perhaps the most glaring, and often quoted, disparity between current revenue drivers and smart grids drivers in many markets is the link between revenue and throughput. If smart grids technologies are successful, energy efficiency measures will be supported that will reduce throughput. The network company in this unreconstructed market would be investing to reduce its own revenue.

Network companies are rewarded for their success in delivering (approved) capital expenditure programs, providing the capacity to avoid network congestion—many by having revenue directly tied to the value of their asset base. Smart grids investment will reduce the need for network reinforcement capital expenditure. Networks could operate more efficiently, with less headroom than currently required, if peaks in demand are smoothed out through demand response offerings enabled by smart grids technologies. On the face of it, investment in smart grids technologies in many regulatory environments would be undermining a utility's growth and revenue model by placing downward pressure on the requirement to build additional capacity.

To restructure the regulatory model to address issues such as revenue assurance, utilities and policy-makers need a broad understanding of the primary role that smart grids technologies can play in meeting energy and environmental policy. This understanding will help them define a suitable regulatory regime that can align utilities' rewards with the benefits that their investments bring.

Financing

Business case fragmentation and technology investment

A key market barrier is business case fragmentation, particularly in competitive-leaning fragmented markets. A network business operating separately from generation and supply companies, with different companies operating in each part of the value chain, is an indicator of a fragmented market. In contrast, a concentrated market has one or two vertically integrated companies.

The importance of the business case will vary from country to country. In some centralized markets, the development of a smart grid may be a matter of policy, driven primarily by security of supply, environmental, or R&D aspirations. In competitive-leaning markets, an economic business case may be more important, with clearly defined internal rate-of-return hurdles to jump.

Creating a complex business case for smart grids technologies is difficult: all networks within a market, and circuits within networks, will have different levels of capability required, all driven by interdependent supply and demand characteristics, making cost estimation difficult. Benefit estimation is similarly complex as benefits will depend on the levels of capability in different network areas and will comprise direct and indirect benefits that are difficult to quantify (e.g., carbon and pollution reduction, improvement in security of supply).

In a fragmented market, creating a commercial model means allocating investment, reward, and risk among the stakeholders. This allocation will be driven by the extent to which each party captures benefits and best manages different risks. However, the number of different entities involved makes the business case and commercial model particularly difficult. For example, a smart grid project benefits power generation companies through avoided capital expenditure required for generation, or support for the introduction of intermittent energy supplies (e.g., from wind). For networks, benefits include improved operational efficiency and reduced losses, and for retail it can support the introduction of innovative offerings and help trim load curves. A networks-only investment into smart grids technologies will therefore support huge opportunities for other parties.

For a vertically integrated market, most of these benefits accrue to the lead incumbent company, and therefore the immediate benefits (excluding societal), investment, and risk are borne by the same party. This makes business cases more straightforward—assuming that societal benefits can be adequately captured.

Public Barriers

Customer Engagement

Low public awareness and acceptance
Public perception can create a key barrier to implementing policy and accelerating smart grids deployment. This is especially the case in open and competitive-leaning markets that consult widely on policy implementation. Public pressure against a perceived societal disadvantage can force policy abandonment. For example, in the Netherlands, the rollout of smart meters was quashed by a small but vocal group concerned about the increased level of personal information that the meters would provide.

Smart grids technologies demand behavioral changes in power consumption as demand response involves consumer participation. Although consumers are becoming more aware of climate change and energy efficiency, the majority are not aware of the necessity to evolve electricity networks as a means of reducing emissions. The integration of renewable energy sources and demand response will, in many cases, require making the existing network stronger and smarter and building new infrastructures. The public may negatively perceive changes in their electricity experience, particularly if it is accompanied by rising bills.

Technology Barriers

Technology

Many of the technologies necessary for smarter grids are available today as discrete capability building blocks. However, the levels of maturity and commercial viability differ. Research and development (R&D) efforts continue to advance the development of these technologies, particularly those essential to the advanced capabilities of smart grids solutions: communications, embedded sensing, automation, and remote control.

Each of these technologies has differing requirements for R&D to reduce technology and deployment risk, lower costs, and secure confidence that they can be implemented at scale. The challenge is to develop all component technologies necessary for an integrated smart grids solution to a level of maturity sufficient to deploy them all at scale at the same time. For this to occur, R&D for some components may need to be accelerated. An emerging area for R&D is the integration of all component technologies to ensure interoperable, coordinated, secure, and reliable electric system operations. This focus area includes the integration of high-penetration renewable energy (e.g., wind, solar), distributed generation, and electric vehicles into the electric grid.

Lack of R&D coordination
Technology development efforts lack coordinated R&D for both individual technology components and integrated smart grids projects. Smart grids are potentially a global solution, albeit, in different forms for different markets. However, R&D is not entirely coordinated, and there is a natural tendency for institutes and companies to choose to develop those technologies most closely aligned to their own capabilities and interests. This may leave some technologies with less focus than others. Given the high cost of R&D, technologies with less potential economic payback in their own right may well get left behind, leaving a maturity gap in the smart grids technology chain.

Lack of large-scale deployment projects
Demonstration and pilot projects are essential for smart grids deployment, so that the whole chain of technologies can be tested together. This allows weaker areas to be identified and refined, and deployment and commercial models to be tested. Although many pilot and demonstration projects exist globally, there are limitations on their effectiveness. Few are at a scale large enough to provide a thorough understanding of how they will operate in full-scale deployment or to make them economically and functionally viable. Limited, although not coordinated, learning and knowledge sharing is emerging from these projects.

Standards

Global standardization is essential for the deployment and successful operation of smart grids. While progress is being made, challenges remain due to fragmentation among stakeholders in the process of standards development, the lack of well-defined standards for smart grids interoperability, and intellectual property issues. At the same time, standards defined too early risk stifling innovative technological advances.

Interoperability and scalability assurance
While smart grids technologies continue to progress, without well-defined and technology-neutral interoperability standards, further innovations and opportunities for deployment at scale are limited. Global cooperation for defining standards has not kept pace with technology innovation and development, which could impede large-scale development and rollout. Therefore, interoperability and scalability should be priorities, while taking care to avoid stifling innovation.

Fragmentation and lengthy process in technology standards
Since smart grids technologies encompass a diverse scope of technology sectors, including electricity infrastructure, telecommunication, and information technologies, misinterpretation and error may arise where there is a lack of interface standardization and related communication protocols. Therefore, even after standardization of the respective technologies, conformity testing and certification of interoperability may prove problematic for providers, since each technology must go through a conformity assessment specifically designed for the particular technology.

Existing international standards development organizations (SDOs) include the following:

- IEC – International Electrotechnical Commission (www.iec.ch)
- IEEE – Institute of Electrical and Electronics Engineers (www.ieee.org)
- ISO – International Organization for Standardization (www.iso.org)
- ITU – International Telecommunication Union (www.itu.int)

In addition to the international standards organizations, a large number of country or region-based standard associations influence the smart grids standards community. A key barrier is the lengthy process to develop and reach international consensus on a standard. For example, the average development time for IEC publications in 2008 was 30 months (IEC website). Even after one of the SDOs has defined a standard, it still has to go through the harmonization process.

Skills and Knowledge

In all phases of smart grids development (R&D, design, implementation, and operation), a multi-disciplinary approach is needed as technical, societal, and communication solutions are brought together.

Insufficiently skilled workforce

Key barriers include the lack of suitable skills in the existing and future workforce, a requirement to understand the new skills required of those working around smart grids technologies and systems, and lack of a clear roadmap for ensuring that the workforce of the future is able to sustain the smart grids technologies of the future.

At the technical level, new skills and knowledge are required over and above the engineering expertise typically applied to current electricity systems. The high degree of required technical innovation will be challenging to meet, particularly given the "skills gap" between expertise demand and workforce availability. In many countries with an aging workforce, it is unclear where the next generation of experts will come from as they report a lack of adequate education and training (McNamara 2009). With the supply of skills falling on one hand, and a huge program of investment in smart grids technologies required on the other, there is a shortfall of critical skills (engineering, business and finance, etc.) to design, plan, and build smart grids and to operate the new system.

Limited understanding of smart grids in public planning

A key risk is posed by limited understanding of the importance of smart grid technologies among public sector officials and infrastructure and town planners. Those responsible for the development of low-carbon environments will need to understand the benefits and costs associated with smart grid technologies, and understand the partnerships required to implement them.

Many development visions will require smart technology at their center. For example, increasing numbers of city and town development plans outline a vision of new electric vehicle infrastructure; smart, energy-efficient buildings; distributed and micro renewable generation; and advanced offerings for electricity. These visions will be of limited technical feasibility without smart grid technologies. To make these visions a reality, public officials and planners will need to understand the technical and commercial aspects of smart grid technologies and will need to develop partnerships with the many different parties within the new electricity value chain.

Cyber Security and Data Privacy

Various cyber security intrusion studies have demonstrated the vulnerability of communication, automation, and control systems to unauthorized access. Many real-world cases of intrusion into critical infrastructures have occurred, including illegal access into electric power systems for transmission, distribution, and generation, as well as systems for water, oil and gas, chemicals, paper, and agricultural businesses. Confirmed damage from cyber intrusions include intentionally opened breaker switches and the shutdown of industrial facilities. Very few of the incidents have been publicly reported, and initiatives aimed at creating an open repository of industrial security incidents encounter resistance.

Threats come from hackers, employees, insiders, contractors, competitors, traders, foreign governments, organized crime, and extremist groups. These potential attackers have a wide range of capabilities, resources, organizational support, and motives.

Threats to cyber security in networks and consumer information

The possible vulnerability of the utility's system, business and customer operations, and consumer premises represent serious security risks; therefore, security must be approached and managed with an extreme level of care.

Apart from active, malicious threats, accidental cyber threats are increasing as the complexities of modern data and control systems increase. Security risks are growing in diverse areas, including the following:

- Risk of accidental, unauthorized logical access to system components and devices and the associated risk of accidental operation
- Risk of individual component failure (including software and networks)
- Number of failure modes, both directly due to the increased number of components and indirectly due to increased (and often unknown) interdependencies among components, devices, and equipment
- Risk of accidentally misconfiguring components
- Failure to implement appropriate maintenance activities (e.g., patch management, system housekeeping)

A power utility needs to define its own selection of security controls for system automation, control systems, and smart devices, based on normative sources and as appropriate for the utility's regulatory regime and assessment of business risks. The security controls need to be defined within each security domain, and the information flows between the domains need to be based on agreed risk assessments, established corporate security policies, and possible legal requirements imposed by the government. Also, limitations related to the existing legacy systems must be accommodated in a manner that does not hamper organizational security.

Concerns about private data misusage

The massive amount of potentially sensitive data collected in a smart grid, particularly with the implementation of consumer technologies, offerings, and services (e.g., advanced metering infrastructure [AMI] and demand side management [DSM]), inherently creates data privacy and security risks. Utilities implementing consumer technologies, offerings, and services within a smart grids environment that fails to address these issues will encounter consumer and political opposition, restricting their ability to realize the economic promise of smart grids technologies. They may face angry regulators and customers as well as liability issues.

In the consumer context, the "right to privacy" means the consumer's ability to set a boundary between permissible and impermissible uses of information about themselves. What is impermissible is a matter of culture, as expressed in law, markets, and what individuals freely accept without objection (i.e., consensus values).

Consumer-based smart grids technologies put privacy interests at risk because a core purpose is to collect information related to a particular household or business. Meters already collect a unique meter identifier, timestamp, usage data, and time synchronization every 15 to 60 minutes. Soon, they will also collect outage, voltage, phase, and frequency data, and detailed status and diagnostic information from networked sensors and smart appliances. These data show *directly* whether people were present, when they were present, and what they were doing.

If customers believe a utility is misusing personally identifiable data, or is generally enabling the use of personal information beyond what they deem acceptable (whether or not legal), then they are likely to resist the implementation of vital smart grids functionality related to consumer offerings and services. Consumers may refuse to consent (where required), hide their data, or awaken political opposition. Utilities may face customer liability claims or regulatory fines if inadequate privacy or security practices enable eavesdroppers, adversaries, or bad actors to acquire and use collected data to a customer's detriment. Utilities must take privacy and security concerns into account when designing consumer technologies, offerings, and services, and must persuade consumers, regulators, and politicians that privacy interests are adequately protected.

What constitutes permissible uses of personally identifiable information varies from culture to culture and over time, yet what goes on *inside* a residence is generally an area of special privacy concern. The collected data reveal more about what goes on inside a residence than would otherwise be known to outsiders, and the collection and use of such data would reduce the scope of private information. Although "privacy" is generally considered a personal right, businesses typically have analogous rights.

Once a utility establishes the permissible uses of consumer data, it is in its best interest to assure that unauthorized uses do not occur. For example, if an electricity service provider is allowed to sell appliance-related data to a manufacturer or retailer, the utility will want to protect its economic interest by preventing access or use by others who might become competitive data brokers. Every utility will want to avoid regulatory sanctions for violating express or implied privacy policies, as well as damages claims based on compromised customer data or facilities.

Concerns about data privacy in smart gird environments and AMI, in particular, are now being widely discussed. In the Netherlands, for example, the formerly compulsory AMI roll out was made voluntary.

Current Best Practice Policies

Policy, Regulation, and Finance

The barriers identified in the previous section include market uncertainty, business case fragmentation, and revenue assurance. A number of initiatives exist to address these areas, in some cases setting out legislative and market frameworks to provide the right market environment for smart grids development, in others cases implementing full-scale projects that develop business cases and test financing arrangements. This section highlights a few examples of current initiatives for discussion and is not intended to be a comprehensive review.

Legislative and Market Frameworks

One of the key barriers to smart grids—market uncertainty—can be largely overcome by defining a clear roadmap or strategy for smart grids development, together with supporting legislation that designates targets and incentives for those responsible for delivering the required infrastructure. The European Climate and Energy Package establishes a compelling rationale for the development of smart grids to support the introduction of renewable energy and energy efficiency measures that will help meet its targets. However, until this package is backed up by a stable and transparent carbon market that places a value on those targets, other interests will likely drive smart grids development (e.g., security of supply and reliability issues).

In the United States, the American Recovery and Reinvestment Act (ARRA) allocated a total of US$4.5 billion to help subsidize smart grids modernization efforts and an additional US$7.25 billion in loans for transmission infrastructure projects, coinciding with the U.S. Energy Independence and Security Act of 2007 (EISA 2007) and the American Clean Energy and Security Act of 2009 (ACES 2009). Over the past year, such clear government support has generated a great deal of movement in smart grids and demand response initiatives in the United States .

The recently proposed ACES 2009 includes a mandate for load-serving entities (distribution and retail companies) or state entities to publish peak demand reduction goals. Reduced capacity by demand response is already being traded in a U.S. wholesale power market (e.g., PJM).

In most cases, a clear mandate, together with associated incentives from the government, is required to quickly drive an industry forward. For example, in Italy ENEL originally developed its own business case for its smart meter program, originally recovering its investment through a significant cost reduction and increase in efficiency. Later, recognizing the benefits for the entire electricity system, the regulator decided to compensate this initiative through the tariff. This led to the rapid rollout of a program to replace 30 million electromechanical power meters with smart meters and the preparation of the supporting system hardware and software architecture.

Selected Policy Measures

Climate and Energy Package 20-20-20 (EU)

The EU Climate and Energy Package 20-20-20, passed by European Parliament in 2008, resulted in specific carbon reduction targets on countries, their industry, and utilities. Voted for by more than 550 members and voted against by fewer than 100 members, this package focuses on three major policy areas: greenhouse gas emissions reduction, renewable energy, and energy efficiency. An important instrument to achieve the goal set by Europe is the Strategic Energy Technology Plan (SET Plan) including 7 priority energy technologies to be deployed, one of which being the Smart Grids.

EISA, ACES (U.S.)

The United States enacted the Energy Independence and Security Act of 2007 (EISA 2007) to decrease their dependence on imported energy. It required standards around renewable fuels, vehicle efficiency, and electric appliance efficiency, and outlined a general federal policy on electric grid modernization.

In the American Clean Energy and Security Act of 2009 (ACES 2009), more specific details are set out to promote clean and efficient energy, to facilitate the deployment of a smart grid with demand response applications, and to require electric utility providers to integrate electric vehicles into current grid infrastructure.

Regulatory Review (UK)

The UK regulator, Ofgem, is undertaking a full- scale regulatory review (RPI-X@20) to ensure that companies are rewarded for performance that aligns with the government roadmap toward delivery of a low-carbon energy sector.

Where a full-scale direct mandate does not match the market philosophy of a country, other measures are required. In the UK, the Office of Gas and Electricity Markets' (Ofgem's) regulatory review will set a long-term regulatory environment for the development of a low-carbon energy market. However, this is supplemented in the shorter term by a £500 million fund to promote the development of networks, including smart grids projects aimed at initiating smart grids infrastructure spending and innovation (Ofgem 2009).

Pilot projects

Many private companies are participating in pilot projects, anticipating being able to make a business case through deployment. It will be difficult for all different parties to gain profit even through deployment if societal value is not included in the framework. Without a clear understanding by various stakeholders, many current investors are likely to lose interest even before deployment. The text box illustrates the project in Republic of Korea that is aimed to demonstrate business case through technology deployment.

JEJU ISLAND CASE, THE REPUBLIC OF KOREA

Jeju bears an outstanding qualification for large-scale test-beds as the risk of a nation-wide power interruption is minimized; Jeju operates an independent electricity system including wind- and thermal-power generation, connected to the national power network through HVDC.

The planned site will accommodate 6,000 households. Ongoing projects on Jeju include 1) Smart Homes, 2) Smart Transportation, 3) Smart Renewables, 4) Smart Grids and 5) Smart Electrical Services. The project results will be used to establish domestic technology standards.

The proposed plans state that the government will subsidize consortiums consisting of private companies, paying up to 50% of required capital to compensate for the risks undertaken. This is likely to result in an influx of technology from leading companies, and encourage competition to improve the quality of the program. The trial will also be open for foreign investment, and the resulting injection of foreign capital is expected to help establish Jeju as an international platform for Smart Grids technology.

Technology

A number of regional smart grids pilot and trial programs are active globally.

Europe

In Europe, several countries are engaged in studying, demonstrating or deploying smart grids technologies within their wider national development programs.

In terms of publicly funded R&D activities, a strong example is the Italian research activities for smart grids technologies and distributed generation that are carried out under the umbrella of the Research for Electrical System projects (Plan 2009–2011) managed by the Ministry of Economical Development (MiSE). The plans cover the entire lifecycle of a smart grid, and include:

- Renewable energy sources and their integration in the electrical system
- Asset management and system optimization
- Communication techniques
- Power quality
- Planning of electrical active networks
- Operation of power systems in the presence of large quantity of non-dispatchable renewables
- Scenario analysis and business cases evaluation
- Electricity storage and technologies
- Electrical vehicles

- Demonstration and verification of active system technologies by means of trial testing in an experimental testing facility

Elsewhere, European funds are dedicated to the development and demonstration of smart grids technologies and architectures. In particular, under the so-called Framework programs FP6 (2005–2008) and FP7 (2008–2013), several projects are in progress. These projects include ADDRESS (Active Distribution networks with full

CURRENT SMART GRID INITIATIVES: EUROPE

EEGI: European Electricity Grid Initiative
To implement its Strategic Energy Technology Plan (SET-Plan), the European Commission is coordinating the launch of several Industrial Initiatives to foster specific low-carbon technologies. Among these initiatives, the SmartGrids Technology platform and, more recently, the European Electricity Initiative (EEI) deal with the development of electricity networks. The objectives of the *EEI,* proposed by the European Electricity Grid Initiative (EEGI), are to enable the transport and distribution of a considerable proportion of electricity from dispersed and concentrated renewable sources by 2020, and carbon-free electricity production by 2050; to integrate national networks into a market-based, pan-European network; to guarantee a high quality of electricity supply to all consumers and engage them as active participants in energy efficiency; and to anticipate new developments such as the electrification of transport. The EEGI proposes a strongly integrated R&D and demonstration program to identify and implement the most suitable grid architectures. R&D concentrates on new technologies to improve the flexibility and security of the network and to mitigate future capital and operational expenditures. R&D incorporates the necessary modelling and planning tools for designing and testing innovative, pan-European grid architectures. In parallel, large-scale demonstration projects covering diverse geographic, social, and climate conditions are proposed to validate solutions before their market rollout in all sectors, from home energy efficiency through smart meters to the system integration of variable energy sources to the automation and control of whole networks.

E-Energy Project, Germany
The German Federal Ministry of Economics and Technology is coordinating implementation of a set of Smart Grid demonstration projects. The six coordinated projects, resulting from a national competition, consider all energy-specific business activities at the market and operational levels. The cluster comprises, among others, the following leading projects: eTelligence (intelligence for energy, markets, and power networks), E-De-Ma (decentralized integrated energy systems on the way to a marketplace), MEREGIO (model houses generating power on the roof, using mini-CHP plants and advanced demand response), MOMA (renewables and decentralized energy sources), E-Dema (intelligent ICT infrastructure applied to decentralized integrated energy sources), and RegModHarz (optimization of energy management in a region by centralized generation, storage, and consumption).

TELEGESTORE project, Italy
ENEL Distribuzione SpA, the major Italian electricity distributor, has introduced through its TELEGESTORE Project (>€2.5 billion investments) a set of innovative smart grid tools in its industrial management procedures. The implementation of the project has led to the replacement of the 31 million electromechanical power meters with smart meters, the preparation of the system hardware and software architecture, the complete automation of more than 100,000 distribution substations (with automatic fault clearing procedures), the radical change in the management of the operating workforce (through the logistic support to ENEL crews by means of cartographic support available directly on board and interfaced through mobile applications), the optimization of asset management policies based on a GIS census of network assets, a database of network events (power outage notification, fault detection, etc.), and the optimization of network investments based on a risk analysis. This is by far the most significant, operative implementation of smart grid technologies and processes in the world.

CURRENT SMART GRID INITIATIVES: EUROPE (CONT.)

Smart Grid Initiatives, France

To reach its CO_2 emission target, the French government has allocated funds for energy demonstration projects that: develop intelligent electrical networks that allow the integration of renewables, and the facilitation of wider use of renewable distributed energy sources; allow significant demand side and intermittent production management to limit CO_2 emissions, preserve system balance, avoid congestion, and limit investment; anticipate the evolution of the network environment (including smart meters, smart building, electrical vehicles, etc.); and others. The French DSO, ERDF will launch a smart meter project (LINKY) in 2010 to deploy 200,000 meters in an urban area (Lyon) and 100,000 in a rural area (around Tours). The project includes a nationwide deployment to replace 35 million meters at consumers' premises. ERDF is preparing innovative smart grid functions based on this metering infrastructure that will both improve its distribution network performance and facilitate demand-side management.

Amsterdam Smart City, Netherlands

The city of Amsterdam and its grid operator, Alliander, are implementing a set of pilot programs for smart grid technologies. Amsterdam has divided the Amsterdam Smart City (ASC) project into four groups: sustainable living, sustainable working, sustainable municipality, and sustainable transport. About 1,300 homes will be equipped with smart meters and behavior-changing initiatives, and the ITO Tower (a large office building) will be equipped with energy-saving technologies. All municipal buildings will have smart meters installed and behavior-changing technologies applied. The project will install 73 shore-power connections at the Port of Amsterdam and build 100 charging terminals for electric vehicles in the city center. In total, the city will undertake 20 pilots in 2009–2010. Based on these pilot programs, the project aims to find an economically viable method to incorporate smart grid and other green technologies into the existing grid system. The ASC project will help initiators and partners realize significant economic and social benefits (Amsterdam Smart City 2009).

integration of Demand and distributed energy RESourceS), dedicated to the demonstration of Active Distribution Networks (ADN) that are able to balance power generation and demand in real-time, and SUSPLAN, which is investigating the development of regional and Pan-European guidelines for more efficient integration of renewable energy into future infrastructures. Globally, technology transfer efforts are in progress by the technology transfer clearinghouse under the United Nations Framework Convention on Climate Change (UNFCCC).

Latin America

In Latin America, a permanent Smart Grid Forum has been created to develop an open discussion on smart grids topics, promote the implementation of innovative technologies in the network, and make recommendations to overcome the barriers to smart grids deployment. Most of the current smart grids projects in Latin America are smart meter pilots with a particular focus on non-technical energy losses. Ongoing pilots of smart grids technology are being pursued in Brazil, Chile, and Ecuador.

North America

In North America, the U.S. federal government, under the American Recovery and Reinvestment Act of 2009 (ARRA), recently announced funding for a demonstration program for regional smart grids applications and grid-embedded storage, as well as a Smart Grid Investment Grant program for fast deployment of proven technology. And, similar to some pilots in Europe, a number of small pilot projects in North

America are focusing on implementing automated meter reading (AMR)/AMI and upgrading aging power grids. The following text box illustrates an ongoing project in Colorado, North America, to implement a SmartGridCity concept based on wide-range of advanced technologies, solutions and applications.

SmartGridCity, Boulder, Colorado, United States

Xcel Energy initiated a broad program to bring the smart grid concept to its network in Boulder, Colorado. The program included a fully network-connected system that identified all aspects of the power grid, communicated its status, and analyzed the impact of outside sources. Along with its consortium partners, Xcel Energy aimed for the automating processes and distribution of energy across 50,000 premises with 25,000 new meters, and the integration of data flows and grid system analytics across five substations with feeders connecting 327 network elements.

The SmartGridCity program also launched efforts to integrate plug-in hybrid vehicles, vehicle-to-grid (V2G) technology, and renewable generation sources onto the smart grid. As a result, Xcel significantly improved its environmental performance. The project helped increase demand response capabilities, installed advanced meter systems in-home, and, overall, created efficient and smart energy-saving homes (Xcel Energy 2009).

Asia-Pacific

Currently there are no physical implementations anywhere in APAC that could be considered smart grids solutions, mostly because of aging assets and infrastructure. Another reason is lack of incentives due to the heavily regulated T&D industry. Some transmission networks, such as in Japan and Korea, do have a very high degree of monitoring and control that are not labeled smart grids technologies, but could be considered “smart.” Utilities in Australia do not consider any activities in their transmission networks to be smart.

The first major smart grids development can be expected in Australia with the announcement in early 2010 of the successful consortium under the federal government's $100 million smart grids initiative.

In India, Malaysia and Singapore, initial stages of a smart grids strategy are formulated and in most cases smart metering will be the initiator for more advanced smart grids initiatives. The Japanese government has also announced a national Smart metering initiative and utilities such as Kyushu Electric Power and Okinawa

KEPCO, The Republic of Korea

The Republic of Korea has made an early start in using information technology to increase reliability and efficiency in the transmission and distribution grid. By applying advanced technology around real-time load monitoring system, distribution automation system, and energy management systems, in 2008 KEPCO (Korea Electric Power Corporation) was able to decrease its transmission and distribution loss to 4.01%, decrease its SAIDI (System Average Interruption Duration Index) to 16 minutes, and increase its load factor to 76.6%. Under its Power IT Program, KEPCO has continued to make efforts to apply information technology in the electricity industry since 2005. Its mission is “the development, integration, and application of technologies to facilitate the transformation of the electric infrastructure to cost-effective, secure, high-quality, reliable electricity services to consumers.” The program is a cooperative effort between the government, KEPCO, academies, research and development institutions, and industries. Recently, Korea has extended the Power IT Program to smart grids and is currently re-defining its roadmap to implement smart grids countrywide (KEPCO 2008).

> **STATE GRID CORPORATION OF CHINA**
>
> Recognizing the value of smart grids for implementing a new energy strategy the priorities for their implementation in China are focused on the transmission network. First of all, a smart grid must be a "strong grid". China's primary energy resources and booming economic areas are unevenly distributed, as clean energy resources are mainly located in remote areas in West and North China, while energy loads are primarily concentrated in the East of the country. This situation generates the need for large scale, centralized transmission control and optimized allocation of power resources. The core of the smart grid should therefore be its strengthened capacity to optimize the resources and withstand the risks, provide access to all types of energy, be more flexible in operational control and stable in network security. A smart grid must also be a "green grid", environmentally friendly, to accommodate the need of clean energy development in the frame of a synergic development of networks (with communication, TV and internet) in view of upgrading power usage techniques raise electricity share in the energy mix of consumers and maximize energy efficiency. A smart grid must moreover be an "innovative grid" including new technologies, materials and equipments to spur the development of distributed generation, smart power scheduling, smart appliances, transportation and city life. The Chinese government attaches great importance to smart grids development. The plans for the development comprise: by 2010 complete centralized planning of smart grids developments and roll-out of key technology R&D and pilot projects, State Grid releases the latest achievements in building; by 2015 develop the breakthroughs in key technologies and equipments; by 2020, implement smart grids installation (Zhenya 2009).

Electric Power announced smart grids programs commencing later in 2009. Meanwhile, investments in China seem to be focused on the high voltage transmission networks.

Standards

Fragmentation in technology standards and interoperability and scalability assurance are key barriers to standards development. There are a number of bodies established to organize and promote the development of technology standards, from formal standards development organizations (SDOs) to less formal alliances and user groups.

Standards Development Organizations

SDOs operate under similar rules worldwide. In general terms, members of standards committees who perform the development work are restricted by anti-trust rules or laws from engaging in anti-competitive behavior, such as market division, pricing discussions, and the like. Intellectual property is treated as a potential source for standards "language," and requires disclosure by the holder. For balloting, candidate voters are carefully balanced with respect to the interests they represent is performed to provide a measure of fairness and balance. Standards usually begin as *de facto* standards (i.e., sufficient commonality exits among a representative number of producers to call the product/approach/protocol "standard"). Beyond this, SDOs compose *de jure* standards (i.e., those that are codified in a manner similar to laws). Given the careful attention to balloting balance, open rules, and open participation, standards may be adopted in place of laws in certain jurisdictions.

The National Institute of Standards and Technology (NIST) in the United States has started a three-phase smart grids interoperability plan to expedite development of key standards that incorporate and align the results of efforts by industry players and research institutes until now. In particular, EPRI has participated in the NIST's plan, especially for consensus building among industry participants, government agencies and research institutes. By the end of the year 2009, NIST will complete a testing-and-certification plan and issue the initial set of priorities, standards and action plans. The Federal Energy Regulatory Commission then plans to institutionalize the proposed standards.

In September 2009 NIST released a report expanding their initial 16 preferred standards to a list of 77 standards, which are all available for review in the full report (NIST 2009). However, there were about 70 other broad sectors of the smart grid where NIST has yet to come up with specific recommended standards. Of those, NIST has focused on 14 priority areas where key regulators – namely, the Federal Energy Regulatory Commission – has said it needs them sooner rather than later.

Of those 14 'action plans', only one – a standard for upgrading existing smart meters – has been completed, for which responsibility is with The National Electrical Manufacturers Association (NEMA). Finally, only one more – a plan for common scheduling mechanisms for energy transactions – is likely to be completed by year's end, the report stated. In short, while there are steady moves towards establishing standards, much remains to be done.

Selected SDO Groups Focused on Smart Grid Standards

IECEE CB

The CB (Certification Body) Scheme of the IECEE (IEC System for Conformity Testing and Certification of Electrotechnical Equipment and Components) is a strong example of international cooperation; it encourages efficient international trade by slowly abolishing technical barriers and identifying national differences. The IECEE CB has obligated participating countries to conform to IEC standards for various electronic components, equipments, and products while providing evidence (CB Test Certificates) that applicants have successfully passed the requirements of IEC standards. If national standards do not adhere entirely to IEC standards, variances are permitted after formally declaring and detailing these to the IECEE.

IEC SG3

The International Electrotechnical Commission (IEC) formed the Standard Member Board as a strategic group around smart grids to establish the interoperability of smart grid devices and systems. It has developed a framework for standardization that will help many countries take the first step toward addressing challenges in achieving energy efficiency. In addition, the IEC opened a global smart grid portal to provide a comprehensive catalogue of standards for smart grid projects.

Alliances

Distinct from SDOs are alliances, entities and individuals that recognize the value of a particular technology and form an interest group to promote, for example, the codification of the design and marketing of that technology. The difference between an alliance and a standards group lies with both the rules and the work products. Because any number of interested parties can form an alliance, the rules under which they operate vary widely. One example is the ZigBee Alliance, which has 15 members (or "promoters") made up of technology vendors and two other classes of membership, "participant" and "adopter." The work products of the ZigBee Alliance are known as "profiles," or agreed-upon specifications. Since an alliance is not required to have a balanced membership and to follow certain anti-trust regulations, the work products must be submitted to an SDO to become true *de jure* standards.

Each alliance combines different participants across the industry to meet their stated goals. Often, the alliance promotes specifications as standards, before they are officially codified in a formal manner. In August of 2008, the ZigBee and HomePlug alliances announced a joint effort to provide some harmonization to their efforts.

One of the primary goals of most alliance efforts is product interoperability, followed by some form of certification program to demonstrate that capability. In electronic and power technology—unlike physical technology—interoperability is at best an aspiration of the community that developed the standard. This highlights the need for a dedicated users' community to identify interoperability challenges and requirements, write tests to validate products, and certify results.

EXAMPLE OF AN ALLIANCE ON SMART GRID STANDARDS

GridWise Architecture Group

Another group laying the foundation for true interoperability is the GridWise Architecture (GWAC). In a partnership with NIST (National Institute of Standards and Technology), the GWAC sponsors the Grid-Interop conference, which has the goals of achieving system-to-system interoperability, business process interoperation, preparing for a sustainable electricity system, developing policies for integrated smart energy and a holistic view of generation to consumption.

User Groups

In addition to SDOs and alliances, a third important entity is a user group. User groups often permit more free discussion between those using the standards and specifications. An example of the relationship is shown by the IEC 61850 standards developing committee (Technical Committee 57, Working Group 10) and the UCA International User's Group (UCAIug) IEC 61850 committee. The IEC technical committee is made up of national experts, nominated and accepted by the IEC. Each committee follows a prescriptive process for producing IEC standards, in this case the IEC 61850 suite of standards. Part 10 of that suite is interoperability tests. The UCAIug IEC 61850 committee is composed of experts that meet on a semi-annual basis to discuss how the compliance of products to IEC 61850 is demonstrated. The committee validates that the standard tests are applied in a consistent, transparent, and fair manner, and thereby conforms products meet the goals of the standard. Also within the UCAIug are task forces such as OpenHAN (Home Area Network) and AMI-SEC (Advanced Metering Infrastructure SECurity), which have published system requirements specifications. These specifications allow the consumer and vendor communities to communicate with each other through a common document and to understand the complexities of what is needed to meet business objectives. The specifications are also written in a manner that facilitates work by standards groups to develop *de jure* standards that lead to products that meet the desired requirements.

Skills and Knowledge

Skills and knowledge development are facilitated by government policies, such as the U.S. Green Jobs Act and Workforce Investment Act, which formalize investment in next-generation skills development. There are also international efforts like CCiNet (Climate Change Information Network) of the UNFCCC, which includes education, training, and public participation programs. Currently, major initiatives specifically dedicated to develop smart grids skills are few in existence, with a noted exception being the workforce development in the United States for the electric power sector to implement a national clean-energy smart grid. This $100 million USD initiative—as part of the ARRA $4.5 billion USD investment to grid modernization—targets new curricula and training activities for the current and next-generation workforce,

Example of an Initiative to Build Skills and Knowledge

UK's Power Academy

To cope with the progressively decreasing number of power engineers (a decreasing trend of acceptance for study at UK power engineering courses ranging around 28% in the period 2002 – 2007 has been observed) a group of seven leading UK universities and 17 companies (including utilities, manufacturers, service providers, Transmission and distribution system owners and operators) have joined forces founding the Power Academy, with the aim "To address with quality power companies and universities the shortfall in engineering expertise in the electricity power industry by attracting new talent into the industry primarily at undergraduate level leading to graduate employment."

Students supported by the Power Academy receive a bursary, a book allowance, a financial contribution towards university fees, the participation to a summer seminar, eight weeks of training experience under the supervision of a Company mentor and the free membership to the UK Institution of Engineering and Technology. This initiative has seen in 2008 more than 240 applications and the leading 3 Companies in the scheme (mostly TSOs or DSOs) have supported in four years nearly 40 scholars each.

It has been argued that, since its foundation, the Power Academy has been a success with increasing numbers of scholars coming onto the scheme and a significant majority of positive responses being found in annual survey of their experiences. However, the level of influence it has on the degree choices by school and college leavers is yet to be determined and remains a challenging area, not only for the Power Academy partners, but also for the UK Government in respect to its overall skills agenda. One of the benefits of the Power Academy partnership is that collective efforts gives the best chance of addressing these challenge and of influencing the government in its future course of action.

including cross-disciplinary training programs spanning the breadth of science, engineering, social science, and economics.

Cyber Security and Data Privacy

Cyber Security and Vulnerability

Emerging smart grids systems and solutions have to be thoroughly tested by qualified laboratories to ensure that new digital communications and controls necessary for the smart power grid do not open up new opportunities for malicious attack. The responsibility for this security rests with all market participants—both industry and governments.

Grid Security in the United States

In August 2009, U.S. President Barack Obama cited smart grid security as one reason for creating a new White House cyber security position. The announcement came after a string of press reports emerged about intrusions into power system security. These accounts included an anonymously sourced *Wall Street Journal* article claiming that foreign spies had infiltrated a grid system, and claims by cyber security firm IOActive that it had proven it could hack into smart meters, potentially cutting the power to millions of homes at once and causing the grid to fail.

Worldwide, initial security gaps have been highlighted by security companies and were discovered within pilot projects, which are not designed to resist sustained cyber attack. While such systems are now broadly secure against elementary hacking techniques, situations where an 'insider', who knows the system and can exploit the vulnerabilities, are of particular concern to smart grids technology stakeholders. All parties involved in managing network operations centers or the relevant IT systems have to be trained and alert to tamper from the inside. Specially trained security officers need to be implemented in all potentially vulnerable areas.

The idea of extending an IP-based network to the meter level does open up the potential for both internal and external hacking. To protect against those threats, the structure of the system architecture should be considered carefully. By having a distributed intelligence in the grid we mitigate a single point of failure.

Every company thinking about providing equipment and services for smart grids technology enterprises should be cognizant of security and standards, with thought given to security certification for hardware and software providers.

Data Privacy

The handling of personal data is another core consideration. Consumer involvement applications and solutions (e.g., advanced metering infrastructure [AMI] and demand side management [DSM]) put privacy interests at risk because information is collected on energy usage by a particular household or business. With granularity to a minute, smart meters can already collect a unique meter identifier, timestamp, and usage data. Future functionality will enable them to collect outage, voltage, phase, and frequency data, and detailed status and diagnostic information from networked sensors and smart appliances. Interpreted correctly, such data can give convey precisely whether people were present in the home, when they were present, and what they were doing.

How much of a privacy risk AMI creates depends on its design. AMI can employ various technologies, alone or in combination, such as sensors, wireless transfers, Internet connections, mesh networks, and local and remote appliance and HVAC command and control systems.

What constitutes permissible uses of personally identifiable information varies from country to country; but what goes on inside a residence is generally an area of special privacy concern. Even illicit activity within a home has special legal protection. In the United States, for example, law enforcement may not use sense-enhancing technology to reveal activity within a home if the technology is capable of revealing both illegal and legal actions, and residents would not expect such technology to be used against them. Because AMI data reveals more about what goes on inside a residence than would otherwise be known to outsiders, the collection and use of such data reduce the scope of private information. Although privacy is generally considered to be a personal right, businesses typically have analogous rights.

3. Actions to Accelerate Development and Deployment of Smart Grids Technologies

This plan has outlined the potential for greatly reducing GHG emissions from the generation and use of electricity through deployment of smart grids technologies. Effective smart grids implementation is not based on "one size fits all" solutions. Specific country and regional factors will determine the appropriate set of technologies, applications and solutions for each geographic area and country that wishes to implement effective smart grids policy. Nonetheless, all countries seeking to catalyze progress on smart grids technologies should consider similar categories of action. Countries can also work together to expedite their programs and develop standards that enable the wider dissemination of smart grids technology.

To achieve transformational gains in smart grids globally, MEF countries have developed a menu of opportunities to develop and deploy such technologies. Many of these actions rely on, or can be effectively leveraged through, coordinated action among countries, including support for existing international technology forums. This chapter discusses both opportunities for individual country action as well as opportunities for cooperative action among MEF partners.

Menu of Opportunities for Individual and Collective Action

Chapter 2 illustrates multiple best practices that point to specific individual and collective country actions that can help to reduce market barriers and realize the full potential of smart grids. Key categories of action for consideration include the following:

- Supporting innovation:
  - Develop new technologies.
  - Demonstrate new technologies.
- Accelerating deployment:
  - Establish voluntary industry standards and otherwise reduce investment risk.
  - Build deployment capacity.
  - Improve relative economics between advanced clean energy technologies and conventional technologies to encourage market-based adoption.
  - Establish and strengthen regulation.
- Facilitating information sharing:
  - Share best practices and knowledge.
  - Enhance public awareness.

The following section outlines a menu of actions within each category, generally listed in increasing order of ambition. Interested countries should consider the actions in each category to identify those that may be appropriate to their unique circumstances.

Supporting Innovation

Technology

- Identify and support opportunities for effective partnerships between government agencies, research institutions, and industry stakeholders to accelerate progress on key technology R&D goals.
- Coordinate diverse R&D initiatives to maximize effectiveness and to disseminate learning, including subjects devoted to address the aspects of R&D that go beyond the specific interests of each individual MEF stakeholder, using public research centers and their international alliances as appropriate.
- Support R&D and manufacturing innovations for next-generation materials and components, including power electronics, for use in smart grids technologies.
- Initiate and facilitate global coordination on development and deployment of breakthrough smart grids-related technologies and large-scale demonstration projects.
- Develop a global smart grids technology strategy to work with current research initiatives to integrate and align current development efforts across the globe.
- Enhance data analysis and computational capabilities to transform real-world data generated by smart grids technologies into comparable and actionable information.
- Assess the application of smart grids technologies to reduce risks and capture benefits from integrating and renewable or distributed energy technologies on the electric grid, including two-way transfer of power with plug-in electric vehicles.
- Develop methodologies for technology validation and testing, and rapid commercialization.

Cyber Security and Data Privacy

- Develop and refine methodologies and simulation/analysis tools able to manage an integrated view of the complexity of smart grids systems, especially regarding cyber security.

Standards

- Support international access to global test-beds to verify the coordination, interaction, and interoperability of the overall smart grids solution.

Accelerating Deployment

Capacity Building

- Foster the development of skills relevant to the roll out of smart grids technologies through support of new education programs at universities and institutions, development of smart grids apprenticeship programs, and skill exchanges between ongoing smart grids programs.

Policy, Regulations and Finance

- Define and support revenue models and incentive schemes that can encourage stakeholders to invest in smart grids technologies.

- Investigate opportunities to include smart grids under existing international agreements and financial mechanisms (e.g., Clean Development Mechanism).
- Facilitate development and implementation of national plans to deploy smart grids technologies, backed up by clear roadmaps and timelines that define the key stages for how smart grids technologies, associated market changes, and enabling legislation are to be implemented to meet goals.
- Consider a package of support for developing countries that may find it difficult to consider smart grids deployment as they focus on expanding electrification and adding conventional generation plants, to reduce the burden of later retrofits and form a foundation for low-carbon technology development.
- Investigate increasing the use of public funds generated in global carbon markets to support developing countries or co-investment by developed countries in implementing large-scale smart grids demonstration projects in developing countries.

Standards

- Establish national smart grids certification centers.
- Establish a platform to enable cross-country and cross-regional smart grids standards development and coordination, using national smart grids certification centers, existing standards associations (e.g., IEEE, IEC, ISO) and their international or local (country specific) alliances.
- Capitalize on existing organizations to form Multilateral Recognition Arrangements (MRA) among various countries to propagate global deployment of technologies.
- Modify the international standards process (e.g., through financial incentives) to accelerate the development and acceptance of standards.
- Consider incentivizing or mandating the use of internationally recognized standards for smart grids technologies.

Cyber Security and Data Privacy

- Develop relevant metrics for aspects of communication and information technologies, including security, that can be used to quantitatively measure the performance and security of smart grids information and communications technology (ICT) systems.; harmonize smart grids metrics internationally to allow cross-country comparison of different architectural solutions.
- Establish demonstration projects to bolster industry and regulatory acceptance of secure, integrated communication solutions from the physical to the application level for smart grids.
- Require utilities to take privacy and security concerns into account when implementing smart grids applications.
- Implement use of methodologies and simulation/analysis tools that provide an integrated view of complex smart grids systems to study the effect of architectural choices (communications, protocols, standard and security) on ICT applications for power systems.

- Adopt and implement security and privacy principles, such as the OECD's Guidelines on the Protection of Privacy and Transborder Flows of Personal Data.
- Support incident response and breach notification procedures and policies.
- Implement or mandate use of decision support tools for investment in new security measures for electricity industry control systems, including general awareness, risk quantification, presentation of avoided costs and damages, etc.
- Facilitate or mandate training of all utility and third-party employees who have access to consumer data or controls.
- Investigate establishing regulatory sanctions for violating express or implied privacy policies as well as damages claims based on compromised customer data or facilities.
- Consider mandating security requirements for smart grids communications infrastructure, prioritizing inclusion of security features at every collection, access, and transfer point.
- Investigate requiring use of separate communications pathways for personally identifiable information and use of single-hop networks to reduce transmission and storage vulnerabilities.
- Investigate establishing policies for what data may be collected from smart grids technologies, including permissible uses and consent requirements, disclosing those practices clearly and conspicuously and obtaining consents as required.
- Consider requiring periodic training and audits to ensure suitable security and privacy requirements are being met.

Facilitating Information Sharing

Finance

- Facilitate cross-country learning on business case development; in particular, the collection and dissemination of business case model elements related to the impact that different levels of smart grids capabilities have on costs and benefits —including non-financial and societal benefits.
- Facilitate cross-country learning on the relative success and performance of different financial and commercial models developed to implement smart grids technologies, including descriptions of how benefits and risks are allocated and what associated funding sources are used.

Technology

- Support national repositories of past and ongoing smart grids R&D, pilot-scale, and full-scale deployment efforts by different entities (institutions, utilities, municipalities, etc.).
- Support a central, global repository with past and ongoing smart grids R&D, pilot-scale, and full-scale deployment efforts by different entities (institutions, utilities, municipalities, etc.).
- Host a regular "International Smart Grids Technologies and Standards Forum," in which the MEF Global Partnership or other appropriate body provides a

leadership role in communications and publicity activities to inform the public about new technology and standards industry activities and developments.

Capacity Building

- Support a program of workshops and communication sessions on best practices in smart grids financing, coordination, and regulation, targeting those in public sector decision-making positions.

Consumer Engagement

- Develop and share best practices for public information campaigns to increase public awareness and engagement with smart grids initiatives, including assurances for consumers and other relevant stakeholders that privacy interests are adequately protected.

Cyber Security and Data Privacy

- Disclose clearly and conspicuously policies for the collection and permissible uses of data gathered from smart grids technologies (e.g., AMI), including consent requirements.
- Identify and share best practices for successful behavior change (e.g., tactics to enhance consumer use of smart grids technologies for demand response).
- Educate management of utilities or other appropriate institutions on the benefits of investment in security measures for electricity industry control systems.
- Promote decision support tools as a way to convince management to invest in new security measures for electricity industry control systems. This could include awareness, risk quantification, presentation of avoided costs and damages, etc.
- Support a policy of security requirements for the smart grids communication infrastructure.

Actions by Individual Countries

To accelerate development and deployment of smart grids, countries should consider adopting some of the actions in each of the categories outlined above as appropriate to their goals and unique national circumstances.

More generally, MEF countries may wish to start by developing a national smart grids roadmap that identifies and appropriately sequences high-impact actions from each category, as appropriate to their unique circumstances. These roadmaps may include targets and timelines, and would define the key stages for how smart grids technologies, associated market changes, and enabling legislation should be implemented to meet those targets. Moreover, they might be integrated with roadmaps for other technologies that are enabled by the deployment of smart grids technologies (e.g., large-scale, renewable generation integration and certain energy efficiency technologies).

In some cases, countries may further wish to define targets for deployment of specific technologies, such as advanced meters, that encourage conservation by providing energy users with real-time knowledge of energy use and prices, renewable energy integration to enable GHG reduction, etc. Certain countries may choose to translate these goals into minimum standards or even mandatory deployment requirements.

Nonetheless, countries will need to assess progress against their own action plan and correct their course as desired. At the very least, they may want to ensure that they are establishing policies or taking other enabling actions on the schedule envisioned in their road map. Similarly, they may establish a matrix of demonstration projects categorized by solution type to ensure they are addressing the full range of promising smart grids technologies.

Many individual countries share the common goal of reducing GHG. Therefore, this allows the creation of a cross-country, cross-region common vision and roadmap to accelerate smart grids development and deployment.

Coordinated or Cooperative Actions

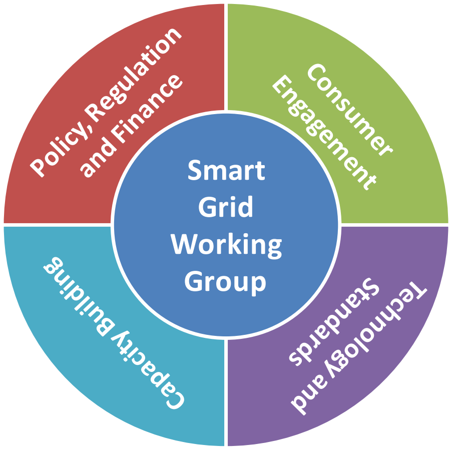
Beyond the individual efforts described above, countries should consider the vital role of international coordination and cooperation for the deployment of smart grids. Many individual countries share the common goals of reducing GHG emissions or improving their use of energy. Therefore, this allows the creation of a cross-country, cross-region common vision and roadmap to accelerate smart grids development and deployment.

The Global Partnership can play an active role in overcoming common barriers faced by all countries to accelerate the development and deployment of smart grids technologies. MEF initiatives would not replace ongoing work (e.g., by the European Union and the United States), but rather enhance cooperation globally. A good example of cooperation that can be leverage by MEF is provided by the International Energy Agency (IEA) where a specific Implementing Agreement dealing with smart grids (Implementing Agreement ENARD – Electricity Networks Analysis Research and Development) gathers experts, regulators, utilities and decision makers from most of the OECD countries with a view of enlarging the participation to other interested parties.

Smart grids are a very complex set of solutions and outcomes based on the specific country and region drivers, objectives, and benefits wrapped around a diversified spectrum of technologies and applications. Therefore, defining smart grids specific performance-based goals globally is very complicated and unrealistic. Nevertheless, to achieve transformational gains in smart grids deployment, MEF members need to establish a level of common measure for smart grids technologies.

The Global Partnership could provide a forum for discussion of industry development and direction, establishing a shared vision for smart grids deployment. To this end, a “Smart Grids Working Group” with associated “Engagement Groups” can be established (Figure 9), with a clear mandate to foster measures that will accelerate smart grids deployment in the areas of: consumer engagement; policy, regulation and finance; technology and standards (including cyber security and data privacy); and skills and knowledge.

FIGURE 9. SMART GRID WORKING GROUP



As envisioned, the Smart Grids Working Group will accomplish the following:

- Promote horizontal cross-country/cross-regional partnerships between various international and country specific technical, business and financial institutions to enable the accelerated deployment of smart grids technologies.
- Be open to non-MEF members (non-MEF countries and professional organizations), and therefore, leveraging from and including the current smart grids work efforts of the existing industry organizations (e.g., IEA, CIGRE, and IEEE).
- Promote technology and knowledge transfer between developing and developed countries. This technology and knowledge transfer could be based on a partnership agreement between the involved parties; therefore, resulting in equal monetary (e.g., grants) and non-monetary (e.g., equipment, resources, technology, IP) contribution levels.

APPENDIX A. DEFINITION OF THE SMART GRID CONCEPT

The concept of a smart grid has many definitions and interpretations dependent on the specific country and industry stakeholders' key drivers and desired outcomes/benefits.

The Smart Grid European Technology Platform (comprising European stakeholders, including the research community) defines "a smart grid [as] an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers, and those that do both, in order to efficiently deliver sustainable, economic and secure electricity supply" (SmartGrids 2006).

In North America, two dominant smart grid definitions are provided by the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI).

- U.S. DOE: "A smart grid uses digital technology to modernize the electric system—from large generation, through the delivery systems to electricity consumption—and is defined by seven enabling performance-based functionalities: customer participation, integration of all generation and storage options, new markets and operations, power quality for the 21st Century, asset optimization and operational efficiency, self healing from disturbances, and resiliency against attacks and disasters" (DOE 2009b).
- EPRI: "The term 'smart grid' refers to a modernization of the electricity delivery system so it monitors, protects, and automatically optimizes the operation of its interconnected elements — from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances, and other household devices." (EPRI 2009).

The World Economic Forum, in partnership with Accenture and the Global Smart Grid Advisory Board, defines smart grid through seven key characteristics such as: self-healing and resilient, [integrating] advanced and low-carbon technologies, asset optimization and operational efficiency, customer inclusion, heightened power quality, and market empowerment (World Economic Forum 2009).

APPENDIX B. SMART GRIDS TECHNOLOGY FACT SHEETS

1 - ACTIVE DEMAND RESPONSE AND INTEGRATION WITH "SMART HOMES"	
Active Demand Response (ADR) refers to end-consumer actions that modify their electricity load profile compared to their normal consumption patterns. This can be in response to price variations over time (market signals) or to signals forecasted by the system when security or reliability is threatened (system signals). The interaction between consumers and distribution networks can be provided by means of simple devices (such as remotely controlled thermostats) or by a local Information and Communication Technology (ICT) platform. This platform supports both energy management and bi-directional communication with energy retailers and distributors.	
Maturity: Smart appliances together with advanced metering infrastructure have been demonstrated to give utilities, system operators, retail companies, and consumers new possibilities for reaching their objectives. The Internet can provide well established widespread communication across the utility value chain.	**Deployment trends:** In some countries, especially in the U.S., a wide range of Demand Response (DR) programs and tariffs are being offered by utilities to encourage ADR. Likewise, competitive energy retailers have structured retail contracts that encourage demand response coordinated with market conditions. In 2008, about 8% of U.S. consumers joined a DR program, saving a total of about 41000 MW (5.8% of peak load). In Europe, several demonstration projects are related to DR. Financing comes from European, national, utility, and industry funds. Projects comprise research and development studies, equipment design and development efforts, and dissemination and awareness campaigns.
Technological barriers to development: • *Interoperability*: Widespread diffusion of DR and home automation applications is hampered by the large number of closed proprietary solutions.	**R&D needs:** • *Automation* of demand response is needed to support integration of resources that could be made available to network and market operations. Because provision of this service requires a change in net power flow, automatic devices on consumer premises are required. • *Interoperability*: The large number of closed proprietary solutions implies a higher cost for the required infrastructure investment, while integration of devices from different manufacturers is very difficult. • *User interfaces*: Extensive development in the design of user interfaces and the tariffs associated with them. Significant consumer participation relies on easy-to-use technology.

<table>
<tr><th colspan="2">2 - SMART METERING INFRASTRUCTURE AND DATA PROCESSING</th></tr>
<tr><td colspan="2">Smart meters are often considered the key component of smart grids. Depending on the level of their “intelligence” and depth of functionality, smart energy meters can be read remotely, can provide a bi-directional flow measure for the user and for the system operators, and perform an important role in managing power demand. They allow electricity consumers to play an active role in the functioning of the electricity markets and distribution networks and constitute a key element towards the improvement of energy efficiency.</td></tr>
<tr><td>Maturity: The Italian distribution system operator justified the deployment of a smart metering system through its business case, without accompanying regulatory support. It was determined that most savings were obtained by the ability of the new system to perform various functions remotely and respond more effectively to consumers, thus proving the maturity of the technology.

However, questions still remain, as one of the biggest barriers to an extensive deployment of smart meters is the limited field-proven interoperability between systems from different vendors.</td><td>Deployment trends: At present, only a limited number of countries worldwide have wide-scale, smart metering systems in place. Implementation plans for smart metering differ significantly from country to country as a result of different local factors, including climate, consumption patterns, stage of market liberalization, etc. Smart meters are far more widespread in the EU than in the U.S. Currently, Advanced Metering Infrastructures (AMI) account for about 4.7% of total U.S. electric meters, with states in the Mid-Atlantic, Florida, and Midwest having the highest penetration rates (approximately 5–10%) and the remaining regions with lower-than-average reported rates. Introduction of smart metering in Europe has been accelerated by EU legislation. At the end of 2006, the Italian regulator announced the mandatory installation of smart meters for all Italian electricity consumers by the end of 2011. Italy was therefore the first to start to adopt the technology as ENEL Distribuzione deployed around 32 million electronic meters in the first half of this decade. Sweden became the first country to achieve 100% penetration in July 2009, when monthly collection meter values become mandatory. Sweden’s mandate is accelerating the deployments in Denmark, Finland, and Norway, where installations are steadily growing. In July 2008, ERDF, the French electricity network business of EDF, announced the first phase of a nationwide rollout of 33 million smart meters, while in Spain, Endesa and Iberdrola each plan to deploy 10 million smart meters to comply with new Spanish regulations.</td></tr>
<tr><td>Technology barriers to deployment:
• Interoperability: Interoperability between products of different vendors, each having its own proprietary protocol, is limited.
• Data security: Electronic meters handle very sensitive data and the adoption of cyber security measures to manage this type of data inhibits certain utilities.</td><td>R&D needs:
• Interoperability issues: To foster the widest application of smart meters, it is essential to specify a comprehensive set of open and public standards for Advanced Metering Infrastructure (AMI), possibly supporting multiple commodities (electricity, gas, water, and heat).</td></tr>
</table>

3 - Integration of Small- and Large-Scale Renewables and Storage	
Distributed generation (DG) is installed within the distribution network. It can comprise different generation technologies, including conventional generation, advanced technologies (e.g., micro-turbines), and renewable sources like photovoltaic generators, wind turbines, small hydro plants, and biomass generators. DG also includes storage systems and load control. All of these resources can be described as Distributed Energy Resources (DER). Such generation, rated typically < 10 MVA, can change the distribution network's characteristics dramatically, moving it from a passive infrastructure in which power traditionally flows toward the end users, to a bi-directional network, where the flow direction is not pre-determined and is time-dependent. Energy storage systems can substantially contribute to alleviating such potential problems by decoupling the production and delivery of energy, improving the power quality, and helping stabilize the network.	
Maturity: Although the hardware to enable DG is mostly commercially available, the technological implications of the integration of small distributed generation plants into the distribution network and its consequent shift toward an Active Distribution Network are still under investigation. In fact, the integration of small amounts of DG in the present electricity system does not cause substantial challenges to the operators; on the other hand, increasing penetration in the future of DG may lead to problems in terms of system balancing, stability, and power quality, particularly in case of weak grids.	**Deployment trends:** Although scarcely documented, the integration of DG in distribution networks is a reality. If we take the example of the major Italian distribution company, the number of connections of DG generators to the low-voltage network has increased in the period 2007–2008 from 2,700 to nearly 23,000. In terms of installed power, the growth has been from 14 MVA (2007) to more than 150 MVA (2008). Nearly 15% of the HV/MV substations already observe bi-directional power flow; more frequently during night periods when the load is at a minimum. There are other examples in Europe: microgrids exist in the Netherlands, Greece, Denmark, Germany, and Spain.
Technology barriers to deployment: • *Safety and protection schemes*: Reverse power flow produced by DG can affect fault detection. DG contributes to the fault currents. • *Grid operational control*: Fluctuating power generation is increasing and the number of small generation units is growing. • *Definition of interfaces:* Grid codes must be set up and revised to define clearly the interfaces between the DG and the network as well as the protection and control schemes to be adopted, the communication protocols and the data structures. • *Next Generation DER units*: The widespread use of DG will imply access from unskilled users: this will not be possible until components with respective Plug&Play (or similar) properties are developed to facilitate their installation, operation and maintenance. Specific standardization to guarantee the compatibility of the applied devices is lacking. • *Univocal test protocols and results:* Lacking international harmonization, each testing center adopts its internal testing protocols, making it difficult to reproduce results. Harmonized international R&D on testing methods and pre-standardization is therefore needed, with particular reference to the behavior of DG in microgrid and multi-microgrid architectures.	**R&D needs:** • *Safety and protection schemes*: High DG penetrations, which can produce reverse power flows in distribution feeders, affect the detection of grid faults. Moreover, distributed generators contribute to the increase of the local level of short-circuit currents. New protection devices have to be developed to allow a safe and reliable grid operation within changing boundary conditions. • *Grid operational control schemes*: Measures need to be set up for the effective controllability of DG generators, including the prediction of their contribution to load supply, and their active involvement in grid control. • *Fast and reliable communication*: DG functionality should be based on fast, reliable, fault tolerant, flexible, and low-cost dedicated communication systems that handle appropriate standard protocols and data structures; these need further development. • *Plug & play equipment:* The wide diffusion of DG and the opening of the technology to a wider set of inexperienced operators introduce the necessity of plug & play (or similar) equipment to facilitate their installation, operation, and maintenance. All these needs require standardization and interoperability to guarantee the compatibility of the applied devices. • *Testing and on-site evaluations of microgrid architectures and operation*: Laboratory and field tests are necessary to set up and validate micro grid operation procedures, both in interconnected mode and in islanded mode; innovative control and management schemes must be designed and tested. • *Electricity storage devices:* Improvements are needed in the performance of energy storage devices (new materials and technologies, improvement of system integration), improvement of the lifecycle duration, reduction of the environmental impact, reduction of installation and maintenance costs.

4 - INFRASTRUCTURE TO SUPPORT ELECTRIC VEHICLES

Recently, much effort has been put into creating possible solutions for electric mobility, which could provide considerable environmental, societal, and industry benefits. Significant adoption of electric vehicles will provide challenges in providing the supporting new services and satisfying increased energy demands while minimizing the costs and maintaining high safety, security, and reliability standards. To achieve the successful integration of electric vehicles, smart grids features will play a fundamental role, allowing an overall optimization of resources.

Maturity: Since the electric vehicles industry is in constant evolution, proposed technologies have to be assessed during forthcoming test pilots.

- *Mature technologies*: This category includes all the technologies used to build the electrical and electromechanical components involved in providing power and implementing safety protections. There are also standards and regulations already available for the charging infrastructure.
- *Recent technologies:* This category includes all the new solutions and devices dedicated to smart grids integration. In some cases, the charging point will use the same technologies that are under development for automatic meter management (AMM) solution and remote control of grid devices. In terms of communication technologies to complement the recharging infrastructure, the industry is proposing ZigBee and HomePlug (PLC) solutions for power management.
- *Upcoming technologies:* The latest test pilots are proposing new type of plugs and sockets to be used to connect vehicles to charging points, possibly integrating a telecommunications solution. Standardization is particularly important here.

Deployment trends: Electric mobility is still limited to a number of test pilots and involves a very limited number of clients. Several market projections have been delivered in the attempt to estimate future market penetration of electric vehicles:

- According to U.S. Department of Energy, Plug-In Hybrid Vehicles (PHEV) will reach 1.44% of U.S. market in 2030, totaling 4.3 million.
- The EPRI and Natural Resources Defense Council estimates PHEV market penetration rates medium scenario of 62% in 2050;
- Frost & Sullivan estimates that the European market for electric vehicles could potentially grow to 480,000 units by 2015.

Technology barriers to deployment:

- *Interoperability:* Lack of a common standard for the sockets used to connect the vehicle to the charging points is a clear obstacle to the diffusion of this technology.
- *Standardization* of the interface between a single charging point and the rest of infrastructure is also needed.
- *Protocols:* A common language between different operators is a must for the creation of this new market.
- *Effective management*: The new energy demand generated by a massive introduction of electric vehicles will require sophisticated management.

R&D needs:

- *Standardization* effort on the connection and communication interfaces has to be pushed to achieve a common infrastructure.
- In view of the massive deployment of electrical vehicles, research will be needed on technical strategies to maximize the EV contribution to the electricity grid (e.g., dispersed capacity, ancillary services, voltage control).

5 - EMBEDDED SENSING, AUTOMATION, PROTECTION AND CONTROL	
Grid management and control by transmission and distribution operators (TSOs and DSOs) requires the continuous monitoring of key physical parameters to evaluate and determine the degree of ageing (failure probability or Health Index) of components. Automation includes protection devices to prevent damage to the asset and guarantee security to operators and users in presence of faults. Transmission and distribution automation encompasses a large set of technologies, including SCADA (Supervision Control And Data Acquisition) technologies, Wide Area Monitoring Systems (WAMS), remote sensors and monitors, switches and controllers with embedded intelligence, digital fault recorders and protective relays, and a large number of other technologies	
Maturity: Methods for transmission automation are well known. For the distribution network, the increasing penetration of DG leads to numerous challenges of different nature, mainly in control and protection of the grid. Many new control and protection schemes are proposed to operate an active grid, however, the technology is still not mature and there are no proven solutions yet.	**Deployment trends:** Transmission automation has already highly penetrated the market, while distribution automation is primarily led by substation automation. In the future, WAMS technologies are expected to be incrementally incorporated into the control system of the grid. Advanced electrical system configurations will also be adopted, such as intentional islanding (including microgrids), Direct Current (DC) ring buses, and advanced distribution networks. Solid state breakers and switches will be part of the automation and control systems for fast fault clearing, system reconfiguration, and transient free switching.
Barriers to deployment: • *Interoperability and standardization*: Interoperability standards are needed to enable diverse systems and their components to work together and to securely exchange meaningful and reliable information. • *Man-machine interfaces:* There is the need for improved applications, such as visualization tools that can help operators cope with the increased flow of information associated with the installation of advanced measurement technology. • *Lack of proven performance of advanced distribution automation and protection*: it is necessary to test and deploy new distribution network architectures and control and protection technologies for distributed generation; • *Lack of consolidated models for the determination of ageing degree of most important component*: it is necessary to test and deploy models for the integration of several diagnostic indicators for the determination of the ageing degree.	**R&D needs:** • *Smart and advanced internal system metering*: This includes the measuring equipment and the communication and networking infrastructure. • *Interoperability and standardization:* Interoperability standards are needed to enable different systems and their components to work together and to securely exchange meaningful and reliable information. • *Knowledge management and man-machine interfaces:* Integrating and managing high volumes of information will be a significant challenge, which will require advanced visualization tools to help operators cope with the increased flow of information and decision-aid tools to integrate and elaborate information, to facilitate the decision-making process. • *Knowledge rules for the determination of aging degree.* There will be a growing need for determination of the alert values of the most important diagnostic indicator and integration of the different diagnostic values in a suitable component model able to predict the ageing degree and consequently the risk of failure.

6 - INTEGRATED, DISTRIBUTED COMMUNICATION AND DATA PROCESSING	
Data communication and processing is vital for the deployment of smart grids, and the amount of data generated will increase exponentially compared to normal electricity systems. A wide range of communication technologies are involved in the realization of smart grids infrastructure; such as cable communication networks, fiber-optic cables, power line communications, wireless communication (CDMA, GSM, GPRS, UMTS, WiMAX etc.), radio communication and wireless local area networks (WLAN, WiFi, ZigBee, etc.).	
Maturity: Communication technologies are mature to the point that an assortment of communications products are now procured and integrated to support many applications. However, a different picture must be drawn when we consider data security: an extended set of technologies implementing security in control system architectures is under investigation, covering identification and authentication, access control, confidentiality, audit and accountability, system and communication protection.	**Deployment trends:** Nowadays there is a slow but steady trend to migrate from ad-hoc communication infrastructures with dedicated protocols and dedicated hardware (often supported by a single vendor) towards a public standardized communication infrastructure that uses industrially standardized communication hardware and protocols. The communication infrastructure is not necessarily owned or controlled by the parties involved in the management of the grid, but often third parties provide the communication infrastructure which may be open to multiple users.
Technology barriers to deployment: • *Standardization:* Agreed upon standards will be necessary to develop smart grids communication infrastructure. • *Interdependences:* Relationships among the electricity and communications infrastructure must be studied and evaluated, particularly as delivering communication services is critical for the electric grid operation.	**R&D needs:** • *Standardization:* There are needs to establish an initial set of standards and provide a process for the evolution of smart grids standards. Testing and certification of how standards are implemented in smart grids devices, system and processes are essential to ensure interoperability and security under realistic operating conditions. • *Integration*: The plurality of technological components and standards involved in the new control scheme need to be efficiently integrated with one another. Different applications of the communications components need to be tested for their effectiveness, considering robust control algorithms, communication and protocols among devices and controllers, resulting electric system performances and effectiveness of cyber security measures. • *Interdependence*: The interdependences between electric and communication infrastructure for smart grids architectures must be studied and evaluated, particularly when the delivery of communication services is critical for smart grids operation.

7 - ADVANCED SYSTEM OPERATION	
Power system operations aim to guarantee the reliability of the power supply, by setting up proper operating conditions, and taking into account market constraints. Secure operation requires adequate security margins in terms of voltage, angle, and frequency stability. Operation of the system relies on automation systems and control center personnel. The latter monitor network conditions and decide actions, such as network switching, generation scheduling, emergency control schemes activation, to assure quality and security of the supply. Advanced system operation tools comprise: • *Dynamic security assessment* including the evaluation, by means of simulators, of security margins • *Wide area monitoring (WAMS) and control*, based on satellite navigation technologies to allow a time-synchronized measurement of voltage and current across the system interfaced with appropriate algorithms to support the operators in running the system closer to its limits	
Maturity: The focus for Wide Area Measurement/Monitoring Systems (WAMS) lies in the use of time-synchronized electrical measurements to support power system operation. Representation, by means of suitable graphic interfaces, of voltage magnitude and (especially) angle throughout the network conveys useful information to the operator. Integrating these measurements into SCADA systems allows the real-time interpretation of the events on the system and provides an aid to decision making. All these pieces of technology are readily available even though monitoring functions still require development. An important effort in this respect is also devoted to the training of network operators in the new operational context.	**Deployment trends:** With the restructuring of the power markets worldwide, and the unbundling of utilities removing system control by one vertically integrated company, effective operation has become more critical. Traditional control room tools are becoming insufficient to support the operator: more powerful monitoring capabilities (e.g., voltage phase angles, more accurate and synchronized measurements) are required, because of the faster changes in the operating condition and the need to closely track the stability margin. Most of the advanced TSOs and DSOs are experimenting with advanced system operation tools in parallel and in backup to traditional applications.
Technology barriers to deployment: • *Existing simulation methods* are not sufficient: wide-area disruptive events (including natural events, cascading accidents, and coordinated cyber and physical attacks), interdependencies of the power grid system and critical infrastructures all require new simulation tools. • *Security assessment challenges*: traditional approaches have become impractical and, recently, the use of on-line Dynamic Security Assessment (DSA) has emerged as a strong need and is growing in use worldwide.	**R&D needs:** • *Power system modeling*: Most on-line DSA systems use a simulation model fed by traditional SCADA measurements; new techniques are needed to assist in the task of on-line system model identification. • *Risk Based Security Analysis*: The optimal exploitation of variable energy sources requires increasingly complex management solutions. To solve these problems the adoption of risk-based security assessment is widely discussed. • *Load Modeling*: Load modeling can affect the outcome of all forms of security assessment. Methods are needed to obtain load information and to synthesize this into a form that can model the characteristics of actual load. • *Speed of Analysis*: Current security assessment systems have generally met the specified performance requirements. However, with increasing system complexity, the number of uncertainties considered rise and the dimension of system models increases hugely, requiring the analysis of ever-larger numbers of contingencies. There will be an ongoing need to enhance the performance of security assessment systems.

8 - ADVANCED SYSTEM MANAGEMENT	
At the heart of power system asset management is the capability to load each item of equipment at an optimal level for the system operation, without jeopardizing the health conditions of the equipment. Asset management requires continuous knowledge of the conditions of the main assets, mainly by monitoring sensitive parameters, and with the capability to dynamically control the power flows on the system nodes. Reliability and maintenance diagnostics are a core component of asset management, and efficient maintenance of network components can be attained with condition-based maintenance and predictive maintenance, which enable a just-in-time maintenance regime.	
Maturity: • *Dynamic thermal loading:* In general, it is possible to say that the technology is sufficiently mature, even if technological enhancements are required for transmission of the data to control centers. The evolution from seasonal static line ratings to real-time, dynamic thermal ratings requires technical and procedural changes inside the control centers that need to be addressed to enable dynamic rating. • *Diagnostic & Asset management:* The levels of maturity of condition assessment techniques are at different stages, depending on the component considered: the development of robust algorithms for data evaluation in view of the definition of criticality level is a common goal, and remains to be widely achieved.	**Deployment trends:** • *Dynamic thermal loading:* The first dynamic thermal loading systems were installed in the 1980s, but the growth of electricity throughput on systems has given a strong impulse to increase the transmission capacity of existing lines by installing these systems. Still, only a small percentage of overhead lines are equipped with dynamic thermal rating so far. Innovative, low-sag, temperature-resistant conductors are also being considered. • *Diagnostic & Asset management:* Off-line diagnostic measurement removes a component from the system to diagnose its health. On one hand, this technique produces a robust detection and assessment of defects; on the other hand, the costs of taking a component temporarily out of service are very high. The application of on-line condition monitoring systems will reduce the cost and disruption from assessments significantly, although it is quite rare on distribution networks; in a few cases, systematic measurements are performed in the Netherlands and the United Kingdom (especially on power cables).
Technology barriers to deployment: • *Dynamic thermal loading*: The main barrier is associated with the necessity for control centers that are capable of accepting dynamic line rating information and continuously refreshing alert and alarm mechanisms within the SCADA and analysis applications.	**R&D needs:** • *Dynamic thermal loading*: Research activities are required for determining the impact of weather on transmission capacity; at present, only short-term forecasting is possible due to the difficulties of predicting wind velocities for longer periods (days). The combination of local meteorological data (weather stations) with national forecasts should allow reliable capacity forecasting for the overhead lines. • *Diagnostic and monitoring:* The development of algorithms able to assess the equipment condition and its failure probability is yet to be completed: research activities, including laboratory and on-site tests are necessary.

9 - INNOVATIVE SYSTEM PLANNING	
The advent of smart grids involves a dramatic change in transmission and distribution planning methods. Today, the Transmission System Operators aim to maximize system reliability and security of supply, and support the market to allow an efficient use of generation and minimizing the total costs. Planning for the future transmission of smart grids is a complicated exercise. Uncertainties about generation connection will come from within the grid through Distributed Energy Resources, as well as from planned off-grid connections. Uncertainties about demand growth will be exacerbated as demand reduction also becomes more of a reality, driven by consumers rather than planners, making reinforcement planning difficult. Increasingly complex multicriteria decisions will be required based on sustainability, integration of renewables and regulation options.	
Maturity: Planning activities are essentially based on computer simulation tools, taking into consideration the network functioning, economic, financial, environmental aspects. As far as smart grids planning is concerned, the developments represent an evolution of the existing tools, part of which is already available.	**Deployment trends:** All system operators use planning tools. Their evolution toward meeting the planning requirements for smart grids is underway; international partnership projects are dedicated to this task (e.g., the EU-funded project REALISEGRID), and deployment will be incremental as new versions are released.
Technology barriers to deployment: • *Grid Codes, policies and regulations* should be harmonized for facilitating trans-national projects. • *Market uncertainties*: Increasing uncertainties are prompted by market opening on one side and renewable power integration on the other side. • *Generation mix and ageing*: Generation is affected by major changes resulting from the renewal and/or phasing-out of thermal power plants. • *Grid reinforcements:* The development of offshore wind power will increase the need for grid reinforcements of the existing onshore grid. • *Long-term view:* Need to reconcile short-term market-based needs with longer-term policy-based and security of supply needs.	**R&D needs:** • *Methodologies:* More robust methodologies for transmission planning must be pursued to account for the additional uncertainties to be addressed in the near future: new planning tools should address: system reliability, quality and security, system losses reduction, demand, investment planning, reserve management, environmental sustainability, coordination of transmission and distribution grids. • *Distribution planning:* Advanced tools are needed for the optimal planning of distribution networks in the presence of DG evolution over time and technical constraints, considering active network management such as Generation Curtailment (GC), demand side response, on-line network reconfiguration, and active and reactive power dispatching. • *Transmission-distribution relation:* An aspect rapidly gaining importance among the system operators is the intertwined development of transmission and distribution networks, due to the deployment of distributed generation and smart grids concepts. These aspects are expected to play a crucial role in the evolution of network planning in the near future.

10 - INNOVATIVE POWER TECHNOLOGIES

The advent of smart grids requires the development of related, cost-effective power technologies that enhance the reliability, efficiency, and resilience of the electric grid, while enabling the effective utilization of emerging generation and demand response technologies and practices. Of particular interest for the network future development are the following technologies:

- *Advanced power electronics including Flexible AC Transmission Systems (FACTS) and High Voltage Directs Current (HVDC) systems*
- *High Temperature Superconducting (HTS) power equipment*: at liquid nitrogen temperature (77K or -196°C), HTS power equipment offers extremely compact, high-power density designs that significantly reduce power losses compared to conventional options.

Maturity:

- *Power electronics:* FACTS devices are commercially available technologies. While the advantages of FACTS have been shown, their integration into the transmission system is still not widespread. High Voltage DC Transmission (HVDC) is another technology that can provide new options for long distance transmission. Almost 50 GW HVDC transmission capacities have been installed worldwide. Transmission distances over 1,000 km to 2,000 km (or even more) are possible with HVDC lines. More recently, the Voltage Source Converter (VSC)-based HVDC is becoming more and more mature.
- *High-temperature superconductivity*: Significant advances have been achieved in the production of first-generation (1G) HTS wires, which can now be purchased from several manufacturers. However, to achieve commercial acceptance as well as broad market penetration, the performance of HTS wire has to be improved and the cost has to be drastically reduced. With the existing HTS conductors, several power equipment prototypes have been developed and field tested (e.g., cables). Second-generation (2G) coated conductor has the potential to overcome the market barriers and enable successful commercialization in the electric power sector.

Deployment trends:

- *Power electronics:* These technologies are readily available in the marketplace and easily integrated into existing networks. Technical personnel will be intimately familiar with these devices and able to install and maintain them quickly and easily. VSC-based HVDC technologies are increasingly used worldwide also for the connection and integration of large offshore wind farms. Some FACTS devices like VSC and STATCOM are projected to have wider development for the integration of renewables (voltage control and reactive power regulation).
- *High temperature superconductivity*: The focus of this area of activity is on applying high temperature superconductivity technology to enhance the capacity of the electricity delivery system. Core activities focus on researching and developing viable 2G coated conductor HTS wires that promise high performance at significantly lower cost than today's HTS wire. With strong industry partnerships, first-of-a-kind HTS electric power equipment using the best available HTS wire are designed and tested under real-world operating conditions to facilitate the introduction of HTS products into the marketplace.

Technology barriers to deployment:

- *Technological ratings:* Achieving high-performance power electronics requires that overall system life-cycle costs for power electronics be comparable or lower in cost than existing devices, and to be more marketable, devices need to be able to withstand higher voltages, current levels, frequencies, and power densities.
- *HTS wire manufacturing:* High-temperature superconductivity will require solving the difficult problem of manufacturing electrical wires from HTS and designing super-efficient electrical systems that use these wires for transmission cables, fault current limiters, transformers, energy storage systems, generators and motors.

R&D needs:

- *Power electronics:* Develop lower cost devices with higher power transfer capability, demonstrate hybrid transmission systems to relieve congestion.
- *High-temperature superconductivity*: Knowledge about cryogenic dielectric materials is still limited as they have not yet been fully characterized, especially in high-voltage AC applications with acceptable performance. Refrigeration systems will need to be customized, reliable, highly efficient, and affordable. In addition, cryostat vacuum reliability needs to be improved for long HTS cable applications.

Appendix C. Major Smart Grids Initiatives by Region

Europe

The development and deployment of smart grids initiatives in European countries are linked with the main commitment to achieve the goals contained in the Climate and Energy Package 20-20-20 (i.e., to achieve a 20% increase in energy efficiency, generate 20% of energy from renewable sources, and reduce GHG emissions within the Union 20% by 2020). Priorities are also linked with the three main pillars of the European energy policy that the European Commission has indicated in its Green Book: competitiveness, security of supply, and sustainability.

This fact implies that the main focus of European smart grids initiatives are concentrated on the integration of renewable energy resources into the energy mix, with the possibility of involving the end consumer in the energy system management, by means of demand-response policies and projects, and driven by the adoption of smart metering infrastructures.

It can be noted that several projects, utilizing a limited number of smart grids technologies (typically smart meters and associated communications), are in full deployment or operation in several countries—with most projects affecting from tens to hundreds of thousands of users, while some of them encompass more extensive populations. North European countries in particular show a good progress of implementing smart grids technologies linked with their specific market conditions. The Italian project Telegestore implemented by Enel Distribuzione represents the most comprehensive integrated smart grids project in Europe. It features more than 32 million smart meters (that have been in operation for several years), several hundred thousand fully automated distribution stations, the use of advanced network operation and asset management tools, and the integration of renewable generation on the distribution system. Other integrated and technology-diverse smart grids projects are being developed in:

- **The Netherlands**: SmartCity Amsterdam—Alliander, AIM, and Accenture
- **Germany:** The E-Energy funding scheme gathering, under the coordination of the Federal Ministry of Economics and Technology—several regional projects, each focused on specific smart grids technologies
- **Portugal**: The InnovGrid project under development by the local utility EDP
- **France**: Smart grids implementation in initial deployment by ERDF, based on a specific advanced communication protocol named LINKY
- **Spain:** ENDESA's SmartCity project

TABLE 4. EXAMPLES OF SMART GRIDS IMPLEMENTATION IN EUROPE

Smart Grids / AMI Activities	Examples of Countries Planning and Implementing Initiatives	Estimated Num. of Initiatives
Advanced Metering Driven Initiatives	Austria, Czech Republic, Germany, Italy, Ireland, Norway, Poland, Portugal, Switzerland, United Kingdom	Approx. 20
Advanced Metering and Wide Range of Smart Grids Technologies Driven Initiatives	Austria, Denmark, Finland, France, Germany, Hungary, Italy, Ireland, Netherlands, Portugal, Russia, Spain, Sweden, United Kingdom	Approx. 40

Source: Various government and private institution databases. Inconsistencies between the various databases do not allow for accurate accounts of the existing SMI / smart grids initiatives (projects).

Spain – IBERDROLA and Smart Metering

IBERDROLA is coordinating the PRIME project, which has the objective of developing an AMI infrastructure for automatic meter management that is public, open, and standard. A number of industrial partners have joined efforts to launch a new, public, open, and non-proprietary telecommunications architecture that will support the automatic meter management functionality and enable the building of the electricity networks of the future. This new architecture is based on the OFDM (orthogonal frequency-division multiplexing) application, the advantages of which have already been proven through field tests carried out on various segments of a low-voltage network.

Spain – ENDESA AND AMM Solution Rollout

Endesa, the main electricity supplier in Spain, has announced the rollout of an innovative AMM solution to manage more than 13 million customers on its LV distribution grid. The meter replacement will last six years (2010–2015), ending three years before the deadline scheduled by the Spanish government. Thanks to this project being carried out jointly with Enel, Endesa will be the first Spanish company to install an AMM system fully compliant with Spanish and European regulations and already designed to enable the upcoming smart grids deployment. This solution represents a new generation of Enel's Telegestore, leveraging its robustness, reliability, and performances. The new AMM solution to be installed by Endesa will also include an evolution of Enel's PLC communication protocol that is going to be opened to proactively contribute to the standardization process promoted by the European Commission. Starting in 2010, a non-profit association based in Brussels will be in charge of managing stakeholder access to the open protocol. An advanced and innovative PLC communication solution based on the unique, proven AMM system in operation on more than 32 million customers worldwide will be made available to the market.

United Kingdom – Registered Power Zones

Electricity generated from renewable sources now accounts for around 3% of the UK's supply, with more planned, including an increase in the amount generated from offshore and onshore wind farms. However, renewable operators face the concerns of stakeholders skeptical about having a wind farm in their community, and electricity distributors face the challenge of connecting those wind farms to their networks and ultimately transporting the power into homes. The energy regulator Ofgem decided to outline an incentive initiative, called the Registered Power Zone (RPZ), to all electricity distribution companies. The initiative encourages distributors to develop and implement innovative solutions to connect distributed generators, such as wind farms, to their networks.

Denmark – Cell Controller Pilot Project

This project aims at helping the Danish power system adapt to future requirements by increasing the extent of system control and monitoring to ensure that power generation and consumption will balance. The basic concept of the Cell Project, which divides the power system into virtual autonomous grid areas in terms of control—the so-called cells—can be realized through the development and implementation of an advanced monitoring and control system capable of monitoring the state of the cell and, in extreme situations, taking control of its individual units such as circuit breakers, transformers, wind turbines, and CHP plants.

Austria – Energy Systems of Tomorrow

The Austrian Federal Ministry for Transport, Innovation, and Technology is funding smart grids R&D and demonstration projects within the funding scheme "Energy Systems of Tomorrow." The first projects started in 2003 with fundamental studies (strategy and planning phase), followed by technology development projects with the participation of Austrian grid operators. Some of the activities have become demonstration-scale deployments, driven by further funding from the Austrian Energy and Climate Fund. Austria anticipates the development of four to six Austrian pioneer regions, covering smart grids technologies in the areas of active distribution grids, system integration of electro mobility (electric vehicles), smart metering, demand response, and other technologies. Currently, Austria's funding budget is €7–9 million per year. In addition, technology providers and researchers, advised by a panel of ministries and stakeholders, have constructed an Austrian Smart Grid Roadmap.

North America

Although the drivers and approaches to smart grids differ between the United States and Canada, their close proximity makes cooperation between the two countries essential. Both already trade power as energy demand peaks in the summer for the United States and in the winter for Canada. A recent trilateral commitment to technology cooperation on smart grids technologies between Mexico, the United States, and Canada was announced at the North American Leader Summit. The three nations will continue to work together on R&D and standardization of smart grids technologies.

Canada

As the electricity system is under provincial jurisdiction, national smart grids implementation will depend on the needs of each province. For example, engaging consumers in demand response may be important for certain jurisdictions with tight supply-demand (e.g., British Columbia and Ontario) but may not be as important for the whole country. One major specific project is in Ontario, where the Ontario Energy Board (OEB) in Canada has mandated a large-scale smart grids initiative. Ontario is already in the implementation phase and serves as an example for successful smart grids cities. Continuing to make smart grids a priority, the Chair of the OEB issued a statement confirming their commitment to creating conditions that foster smart electricity and transmission infrastructure.

Current projections of implementing a smart grids infrastructure throughout Canada are at $238 billion CAD by 2030. Under the Clean Energy Fund Program of Natural Resources Canada, $200 million CAD has been provided for the next five years to the demonstration of promising technologies related to the smart grid concept. Issues of standardization, security, maintenance and regulation remain a concern although continuing talks between President Obama and Prime Minster Harper indicate a definite movement towards smart grids.

United States

In the United States, the reliability of the electrical system (due to under-investment in the infrastructure), growing demand, and the increasing difficulty of building new transmission infrastructures are the primary drivers for a smart grid. Development of a smart grid in the United States is being stimulated by the US$4.5 billion allocated to grid modernization under the American Recovery and Reinvestment Act (ARRA) and by the additional US$7.25 billion in loans to transmission infrastructure projects. The U.S. government is currently pursuing research in promising technologies for smart grids implementation under the Smart Grid Demonstration Program (SGDP), which allocated US$100 million to regional smart grids demonstrations and US$515 million to energy storage demonstrations. In addition, the Smart Grid Investment Grant (SGIG) programs allotted US$3.3 billion for the quick integration of proven technologies into existing electric grid infrastructure (DOE 2009a).

Demand response initiatives are also a primary driver for U.S. government policies. The recently proposed American Clean Energy and Security Act of 2009 includes a section that mandates load serving entities and state entities publish peak demand reduction goals. Technology for reducing capacity by demand response is already being traded in a U.S. wholesale power market (U.S. Congress 2009).

Renewable Portfolio Standards (RPS) requiring the production of energy from renewable sources have also been adopted under state legislation (DOE 2009). Some states have voluntarily adopted RPS even without a federal mandate. Both state and federal agencies have worked together to identify Competitive Renewable Energy Zones (CREZ) in regions with high densities of renewable energies to increase profitable development.

TABLE 5. EXAMPLES OF SMART GRIDS IMPLEMENTATION IN NORTH AMERICA

Smart Grids / AMI Activities	Examples of Countries Planning and Implementing Initiatives	Estimated Num. of Initiatives
Advanced Metering Driven Initiatives	Canada, USA	Approx. 20
Advanced Metering and Wide Range of Smart Grids Technologies Driven Initiatives	Canada, USA	Approx. 40

Source: Various government and private institution databases. Inconsistencies between the various databases do not allow for accurate accounts of the existing SMI / smart grids initiatives (projects).

Latin America

A permanent Latin American Smart Grid Forum has been created, with the objective to develop an open discussion on smart grids topics, promote the implementation of innovative technologies in the network, and make recommendations to overcome barriers to smart grids deployment. Most of the current smart grids projects in Latin America are smart metering pilots with a particular focus on non-technical energy losses. Ongoing smart grids technology pilots are being conducted in a number of countries across the continent.

Latin America has a large variation in population density, climate conditions, economic development, natural resources and regulatory framework. This variety must be taken into account when considering accelerated deployment of smart grids technologies and solutions in this region.

In general, governments and regulators in Latin America are presently focused on the expansion of electricity offerings to keep pace with the region's consumption growth of 3 to 5%. There is an increasing understanding that smart grids technologies could mitigate many technical and non-technical challenges facing the region, including the following:

- Increasing energy demand supported but insufficient existing network capacity
- Aging transmission and distribution infrastructure
- Increasing reliability and power quality requirements
- Limited new network infrastructure development
- Insufficient financial findings in support of infrastructure development
- Significant levels of non-technical energy losses in the network
- Increasing pressure to reduce greenhouse gas emissions due to climate change and environmental restrictions

The underinvested generation infrastructure and high level of grid losses make it increasingly urgent to curtail and manage energy demand in a more efficient manner. The limited level of telecommunication coverage and social inclusion opportunities may represent a positive agenda to motivate government involvement in funding technology improvements in Latin American electric grid.

The ability to measure loads, distinguish between critical and non-critical loads, and to price electricity dynamically are all smart grids benefits that can drastically improve the ability of developing countries to manage demand growth, while maintaining the grid elasticity necessary to operate it safely and effectively. Smart grids technologies also enable power reliability improvements allowing existing businesses to transition to 21st century business operations and improve the quality of life in developing countries.

Incentives for new, large-scale, renewable and distributed generation (e.g., wind, biomass, small hydro) may be competitive—considering the high transmission costs (mainly in Brazil)—which is why biomass is presently a relevant driver of short-term expansion in Brazil.

Given that Latin America, as compared with the United States and Europe, has relatively lower labor/operational costs but about the same generation costs, the most critical smart grids benefits will most likely be driven predominantly by Energy Management solutions and not by hard operational savings.

TABLE 6. EXAMPLES OF SMART GRIDS IMPLEMENTATION IN LATIN AMERICA

Smart Grids / AMI Activities	Examples of Countries Planning and Implementing Initiatives	Estimated Num. of Initiatives
Advanced Metering Driven Initiatives	Brazil, Chile, Ecuador, Mexico	Approx. 5
Advanced Metering and Wide Range of Smart Grids Technologies Driven Initiatives	Brazil	1

Source: Various government and private institution databases. Inconsistencies between the various databases do not allow for accurate accounts of the existing SMI / smart grids initiatives (projects).

Brazil

In Brazil we have now at least four big utilities (Eletropaulo, Celg, Cemig and Copel) working on extensive pilots with smart meters that can be upgraded to full smart grids initiatives.

Brazil's energy regulator ANEEL has allowed the introduction of electronic metering and Brazil's metrology institute has recently certified the first remote metering system. Moreover, ANEEL has just approved a resolution setting out the conditions for the use of the electricity distribution infrastructure for powerline communications. The regulation is expected to help facilitate the rollout of smart grids in Brazil, including remote metering, remote disconnection/reconnection of supply, power supply monitoring and remote monitoring of the grid.

Among the current pilot installations we can mention:

- APTEL pilots and cooperative research: trials established with Narrow Band Powerline Carrier with social and educational purposes.
- Ampla/Endesa: serving a suburban area in Rio de Janeiro State, having noted that traditional energy metering techniques were unsustainable in a portion of network where in some residential areas the losses reached more than 52%, the utility created a more secure secondary network close to the primary feeder, and installed electronic telemetry metering. Currently this Ampla network serves 300,000 smart meters. The results were impressive: consumption per client increased 25%, but total consumption increased 37%, due to the connection and billing of clients that "had never existed before" for the utility.
- AES Electropaulo: is the largest distribution utility in Brazil with more than 5.6 million clients served inside San Paulo City and surroundings. It was the first LA utility to develop a smart grids business plan (BP) in 2006/2007, encompassing the existing 1,500 km fiber optics backbone.
- CEMIG: is a large state utility, and was a pioneer years ago with TWACS. The company has already very low commercial losses. CEMIG has also started the IntelliGrid project, based on EPRI's architecture, and focuses on an

intensified use of information and communication technology in the electricity grid, through an integrated and systematic vision of the system.

Ecuador

Though a small country, in terms of smart grids developments Ecuador is leading the way in Latin America.

Studies and tests on broadband over powerline begun in several Latin American countries in the late 1990s, and have experienced problems around standards and technological challenges. In 2007-2008, the interest of Latin American utilities shifted to a smart grid, especially with a view to reducing electric power theft, a major regional challenge.

In April 2008, BPL Global entered into a partnership with Broadband Powerline Communications Latin America (BPLCLA), a telecom company involved in designing BPL systems for voice, broadband, and television. According to the partnership agreement, BPLCLA became the distributor of BPL Global's smart grids technology in Latin America, a move that accelerated smart grids technology uptake in the region. In September 2008, BPLCLA started to begin operations in Ecuador, where four electricity companies are already active in the development of BPL technology.

The Empresa Electrica Azogues (Emelazogues), which operates in Ecuador's Cañar province, teamed up with Canadian BPL provider Trimax Corporation in March 2007 to successfully complete a BPL pilot in 2008.

Quito-based electricity provider Empresa Electrica Quito (EEQ) signed an agreement in November 2007 with a consortium comprising of telecom companies Telconet, Gilauco, and Brightcell (TGB) to jointly offer services using BPL technology. In April 2008, EEQ submitted a request to Conatel for a broadband license covering the provinces of Pichincha and Santo Domingo. EEQ plans to offer high-speed Internet access services over a fiber-optic and BPL network reaching 70% of its 700,000 electricity users in Quito. This network is also designed to accommodate smart metering and smart grids applications. In July 2008, EEQ and TGB selected Canadian firm Corinex Communications to provide a BPL network spanning over 15,000km of EEQ's electrical cables and covering 800,000 residents in Quito. Speeds of between 256Kb/s and 1Mb/s were considered to be realistic. Work on the project began immediately, and the companies are expected to complete the rollout by the end of next year.

In January 2008, power utility Transelectric inaugurated a 460km broadband network using BPL technology. The US$28 million fiber-optic cable network is overlaid on Transelectric's electricity lines covering the Azuay, El Oro, and Loja provinces in the south of Ecuador. This network is utilized for monitoring and control in the transmission grid.

Chile

Chilectra has implemented a smart metering system with the same technology provider of AMPLA with about 65,000 clients. In 2006, the company also launched a plan for to make Santiago a smart grid city in 20 years, utilizing smart metering, distributed generation and microgrids, smart buildings and homes, electric public transport and electric vehicles, and other facets of smart grids. The development of such a smart grid, however, will require regulatory changes and standards in Chile.

Asia-Pacific

There has been a global shift towards environmentally viable sources of energy and this general trend is becoming more prevalent in the Asia-Pacific region. The smart grid concept has generated much interest because of its potential to improve efficiency and lower carbon emissions; therefore, many countries of the Asia-Pacific have plans to incorporate new smart grids technologies.

The smart grid concept has created a burgeoning market and governments are injecting much capital into the field. However, different approaches are being taken due to geographic and societal differences between countries. Korea, Japan and China all have plans to implement nationwide smart grids systems. Australia, India and Indonesia are focusing on boosting the efficiency of existing grids and looking at smaller-scale programs.

TABLE 7. EXAMPLES OF SMART GRIDS IMPLEMENTATION IN THE ASIA-PACIFIC

Smart Grids / AMI Activities	Examples of Countries Planning and Implementing Initiatives	Estimated Num. of Initiatives
Advanced Metering Driven Initiatives	Australia, China, Indonesia, Singapore, Korea, Thailand	Approx. 5
Advanced Metering and Wide Range of Smart Grids Technologies Driven Initiatives	Australia, China, India, Japan, South Korea, Singapore	Approx. 10

Source: Various government and private institution databases. Inconsistencies between the various databases do not allow for accurate accounts of the existing SMI / smart grids initiatives (projects).

Australia

The Australian government announced the 100 million AUD 'Smart Grid, Smart City' project in 2009 to deliver a commercial scale smart grids demonstration project. The movement exemplifies a series of measures taken towards the installation of the smart grids system. Smart Grid, Smart City is to be the first commercial-scale integrated smart grids project in Australia. The pre-deployment study for this project was published on 30 September 2009, and bids for the competitive project will be due in early 2010.

There is strong industry interest in smart grids applications in Australia, for example through the formation of Smart Grid Australia (SGA) as a lobbying group for the implementation of smart grids systems. Since its formation the SGA has consulted various firms such as Gridwise USA and Smart Grids Europe to explore research activities. The organization has also linked up with various companies to look into the technical aspects; this demonstrates the increasing levels of interest in the field in Australia.

The Mandatory Renewable Energy Target (MRET) has also contributed to the green movement. The MRET was established on 1 April 2001 to encourage additional generation of renewable energy. The scheme requires wholesale purchasers of electricity to contribute proportionally to an additional 9,500 GWh of renewable energy per year by 2010. By mid 2009, the target generation of renewable energy was achieved and an estimated $5.6 billion has been invested in the field. The scheme target has now been expanded and extended to 20% renewable energy by 2020.

Australia is taking steps towards a greener future. There is work by industry and government to support smart metering infrastructure to meet commitments for rollouts, expected to provide enhanced information on energy use; there is the Solar Flagships project to demonstrate integration of solar energy into the market at a large scale. Such steps are likely to improve the efficiency of the overall grid and reduce carbon dioxide emissions in the long run.

China

The Chinese government set forth a $586 billion stimulus plan to invest in water systems, rural infrastructures and power grids. One of the most prominent developments initiated by the plan is the smart grids system.

China aims to reduce its overall energy consumption and make the power distribution network more efficient. The target is a 20% cut before the end of 2010, and for 15% of installed capacity to be sourced from renewable energy by 2020. As part of the efforts to reduce energy consumption, smart grids systems are being considered. China's State Grid Corporation has outlined plans with a scheduled pilot program by 2010 and deployment by 2030. A further feasibility study is currently underway and experts from all over the world are investigating into the potential costs and benefits.

The Joint U.S.-China Cooperation on Clean Energy (JUCCCE) has been established, and it has been making efforts to accelerate the process. The organization held the JUCCCE China Energy Forum in 2008, and it continues to work towards a greener China.

A German-Chinese cooperative project, the Sino-German Platform for Renewable Energies – Wind Environment Research and Training Center, aims to provide knowledge and training about requirements and opportunities for the deployment of innovative technologies to facilitate grid integration of large capacities of renewable energy. In China, the State Grid Corporation of China (SGCC) is involved through the Chinese Electric Power Research Institute (CEPRI) and the German Training Center on Wind Energy in Suzhou. Funded by Germany's International Climate Initiative, this effort began in late 2008 and will run for three years.

India

The Indian government announced the Electricity Act of 2003; aiming to improve the efficiency of the existing power distribution networks and to add capacity for power generation. With an energy growth rate of 12% per year, power distribution has been a key issue in India and the Electricity Act was the first step towards reformation.

The government has set forth the 'Power for All' plan, which requires an additional 1TW of capacity by 2012. India plans to expand its power infrastructure by over 100% by 2020 to meet the growing demand.

India intends to look into smart grids technologies to boost efficiency and reduce power losses. The government hopes to incorporate renewable energy into the formula; there is much potential for wind power in the south and the west, and India already receives about 5,000 trillion kWh of energy per year from solar radiation.

The National Action Plan on Climate Change was announced in 2008, and it placed a significant emphasis on solar power. The National Solar Mission targets an installed solar generation capacity of 20GW by 2020. The fluctuations from such large-scale solar power generation would require a change in the current grid, and smart grids are being looked at as a potential solution to this problem.

Indonesia

Due to a law approved in September 2002, state-utility company PLN's monopoly was ended; the market is now open for competition and this is expected to bring about a positive change in the industry.

PLN sought money from the World Bank to help develop an information technology system for the power grid. It announced the installation of 175,000 new electricity lines in 2003, and has worked with other firms and organizations to boost efficiency in the existing system.

There are governmental plans for an additional 10,000 MW of power using coal, geothermal and renewable resources in 2009–2012. Due to the geographical nature of Indonesia, smart grids implementation and the development of renewable energy sources face many barriers. However, the National Climate Change Council (NCCC) is looking into possible options for reducing carbon emissions whilst meeting Indonesia's increasing energy demands. The NCCC has produced a roadmap consisting of 150 different programs to slash carbon emissions from an expected 2.3 Gt by 2030 to 1.3 Gt.

Japan

Given the potential benefits of smart grids systems, the Japanese government has decided to launch a verification test for smart grids as early as fiscal 2009. The Federation of Electric Power Companies of Japan is to develop a smart grid that incorporates solar power generation; this is to be completed by 2020.

The expected solar power output is 53 million kW by 2030. To accommodate such a large amount of power generated from solar energy, a smart grid system is vital. The Japanese government is to invest about 10 billion yen ($104 million). The Japanese government has also announced a national smart metering initiative and large utilities companies have announced smart grids programs to commence later this year. This demonstrates the strong drive towards smarter, more efficient power distribution systems in Japan.

Republic of Korea

The Korean government has launched a $65 million pilot program on Jeju Island with major players in the industry. The program consists of a fully integrated smart grids system for 6,000 households; wind farms and four distribution lines are included in the pilot program.

Korea plans to slash overall energy consumption by 3% and reduce total electric energy consumption by 10% before 2030. The government also plans to reduce greenhouse gas emissions by 41 million tonnes in this time period. The government has announced that it will undertake a nation-wide smart grids implementation by 2030.

KEPCO (Korea Electric Power Corporation) also announced an investment of $200 million over the next ten years to drive the development of advanced technologies that accelerate the transformation of existing grids to a national smart grids system.

Singapore

The Singaporean regulator Energy Market Authority (EMA) has just launched an initiative to start a smart grids pilot in Singapore. The scope of the pilot is still under discussion but smart metering and electric vehicles are thought to be a central part of it. The pilot is due to be started in Q4 of 2009.

Thailand

In early 2009 the Provincial Electricity Authority (PEA) with the support of the government has started a Smart Meter roll out in the north of Thailand. Currently 50,000 meters are operational and the business case is under review but plans are already announced to extend the roll out. However, while the Thai government realizes the need of green initiatives, plans for a national smart grids approach have to be developed yet.

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