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World Energy Perspective

Smart grids: best practice fundamentals for a modern energy system

World Energy Council

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1. Introduction

The transition towards a low-carbon economy will change both the way power is produced and the way it is consumed. Smart grids are an essential element to facilitate this transformation.

Smart grids can help reduce transmission and distribution losses, optimise the use of existing infrastructure by helping to regulate power flows and meet peak demand, accommodate significant volumes of decentralised and renewable energy into the grid, and improve energy efficiency by managing the consumption patterns of new and existing users connected to the grid. Smart grids are essential for achieving energy security, affordable energy and climate change mitigation—the three elements of the "energy trilemma".

Smart grids can benefit both energy consumers and producers. Smart grid technologies provide predictive information and recommendations to utilities, their suppliers, and their customers on how best to manage power. This is achieved through advanced sensors and computer-based remote controls designed to limit outages and network losses. These devices are linked to integrated communications networks to enable consumer participation and to manage the integration of distributed energy sources (renewables, energy storage, combined heat and power) through intelligent advanced systems and operations management.[1] This allows the interconnected components to be optimised and monitored to help ensure efficient and reliable system operation.

Figure 1 graphically represents the smart grid vision and the different players involved, converting a traditional one-directional power grid into a fully interconnected network.

To fully capitalise on the potential benefits of smart grids, the energy sector will need to overcome two main challenges. The first is at the level of implementation: issues of standardisation and certification, operation, system testing, and consumer participation. The other is financial: large amounts of funding are needed throughout the lifecycle of smart grid development. In the United States alone, realising a fully functioning smart grid could reach an estimated total cost of USD 476 billion spread over 20 years—equivalent to an annual cost of USD 24 billion per year.[2] Innovative mechanisms to finance these investments are therefore an absolute necessity if the smart grid vision is to become a reality.

To facilitate the deployment of smart grids, the energy sector must develop a positive business case with a precise indication of how investments are paid for, reflecting the benefits for the wide range of stakeholders including consumers, utilities, information technology (IT) providers, manufacturers and the environment.

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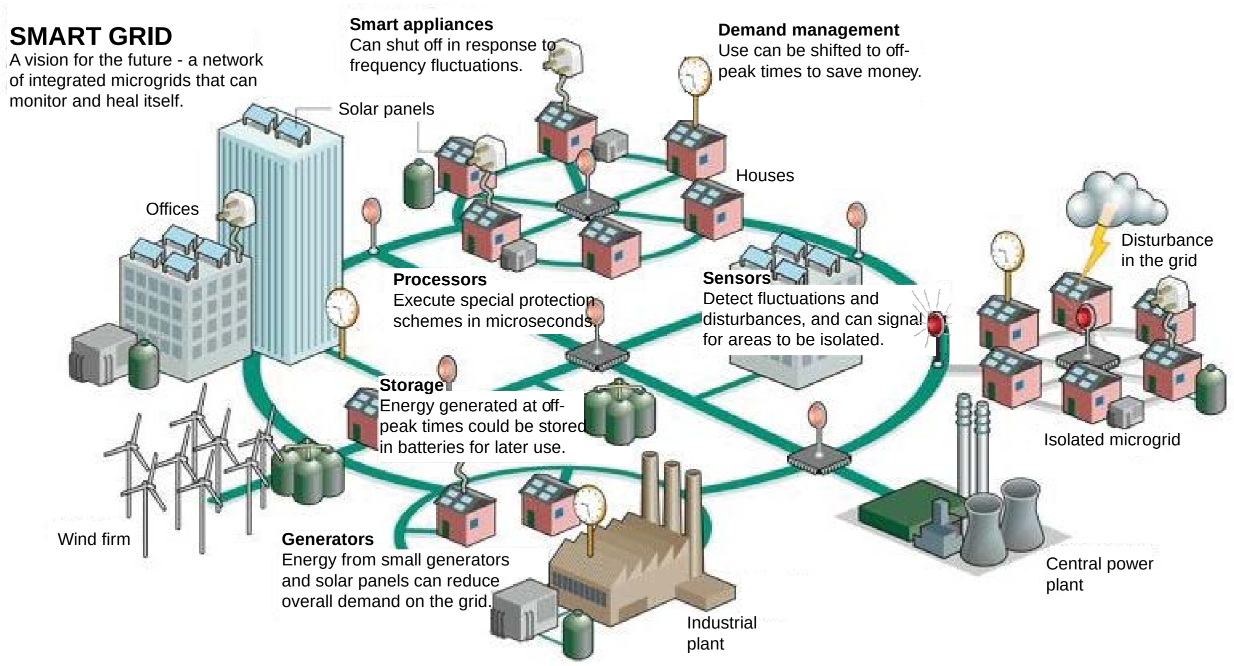
[1] Confusion exists when discussing smart meters and smart grids. Therefore, it is important to highlight that smart meters are part of a smart grid, while a full smart grid includes many more technologies than just smart meters

[2] Electric Power Research Institute (EPRI), Inc., 2011: *Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid*

Figure 1

Smart-grid power system

Source: Smart Grid 2030 Associates, *SG2030™ Smart Grid Portfolios*



The development of smart grids is a long-term process that binds capital over many years. It therefore requires strong commitment from all stakeholders and a viable business model. Given that the development of smart grids is a cross-sectoral effort, it is of the utmost importance that policymakers, industry (including IT companies), and network operators should work closely together. In addition, they must jointly educate the public about the benefits of smart grids.

To help facilitate the deployment of smart grids, the World Energy Council (WEC) has put together this report to shed light on the current status of smart grids and the financing mechanisms for their development. The report aims to serve as a compendium of best practice examples of successful smart grid development and the factors contributing to their success.

This report identifies the main drivers for smart grid technologies and major challenges for the implementation of smart grids by looking at a number of different countries (India, Japan, China, South Korea, and Brazil), Europe as a region, and North America, with a special focus on the United States. The report then surveys the best practice projects in those countries or regions, and analyses how the funding mechanisms of those projects have helped contribute to their success. In the annexes, more detailed information is offered for each of the countries and regions. These annexes are available online on the WEC website at www.worldenergy.org

2. Regional context and drivers

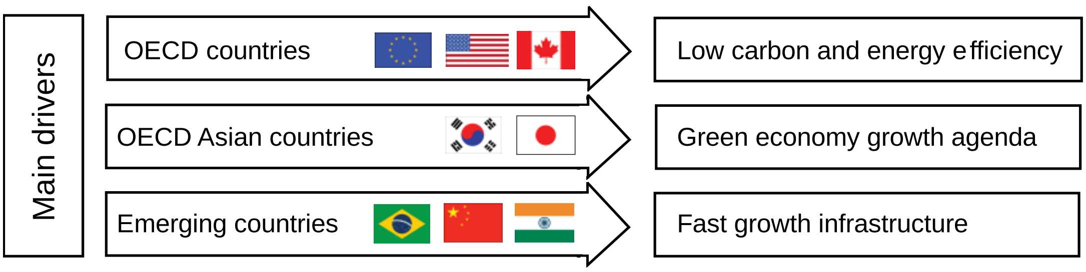
The improvement and performance of the power network continues what network operators have been doing for several decades, each region with its own approach and focus. The future structure of the network depends on different drivers, e.g., market conditions, energy consumption, as well as low-carbon and energy-efficiency targets (Figure 2). The smart grid environment is extremely dynamic and changes rapidly, with emerging economies playing an increasingly important role.

Figure 3 shows that most of the growth in energy consumption is expected to occur in the emerging economies, where demand for electric power is driven by strong, long-term economic growth, and the aspirations of a rapidly growing middle class. Countries such as Brazil, China, and India currently have very low per-capita consumption of electricity, which is far below the global average (for example, India's per-capita power consumption was four times lower in 2008–09 than the global average).

However, with increasing industrialisation and population, the energy demands of these countries are expected to increase drastically. China, for example, is tackling the problem continuously and very strategically. China's 12th Five-Year Plan includes the improvement of the existing grid by reducing overloads and avoiding outages as well as expanding the grid to rural areas.[3] For more information see Annexes 5, 6 and 7.

In emerging countries, high-capacity power lines that enable long-distance electricity transmission which supply rural areas with electricity, while featuring efficient and flexible operation and control, require high automation and self-adaptation mechanisms. Moreover, with the large-scale exploitation and utilisation of renewable energies, connecting renewable energy power to the grid becomes an urgent task.

Figure 2
Main drivers in smart grid development

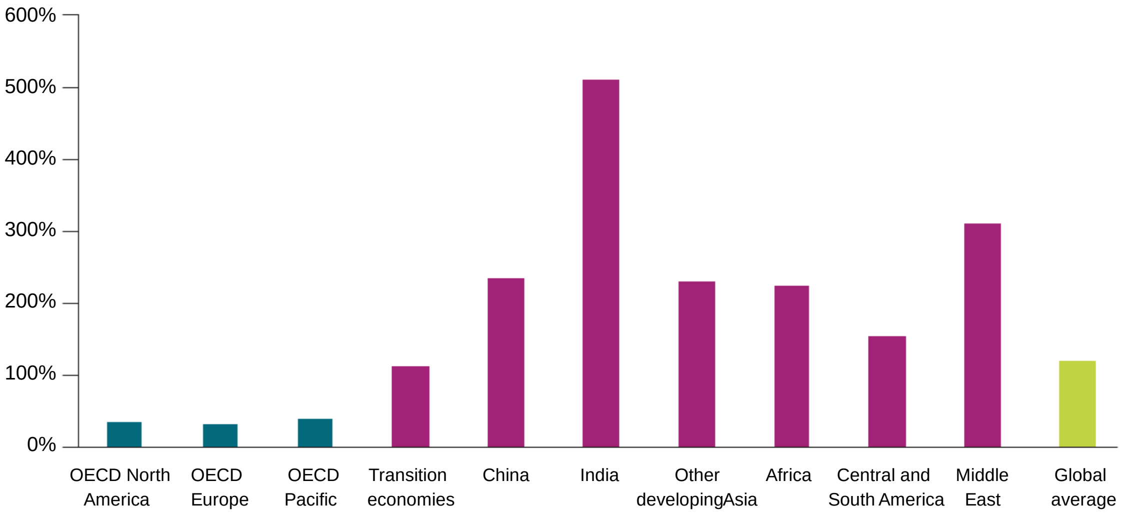


[3] APCO Worldwide, 2010: *China's 12th Five-Year Plan—How it actually works and what's in store for the next five years*

Figure 3

Electricity consumption growth 2007–2050 (BLUE map Scenario)

Source: IEA, 2011, *Technology Roadmap Smart Grids*



In contrast, the situation for the members of the Organisation for Economic Cooperation and Development (OECD) is very different: electric power infrastructures are well developed; population growth is expected to be slow or even decline in some cases; and Gross Domestic Product (GDP) growth is slower than in emerging countries. Electricity generation in comparison to the emerging economies is lower, with a predicted average increase of 1.2% per year for OECD Europe and an average annual rate of 0.8% for the United States from 2008 to 2035.[4]

In North America, the emphasis is on creating a more efficient system by eliminating manual meter readings, reducing theft, detecting outages faster, and upgrading old equipment. The 2003 blackouts experienced in large parts of the northeast of the United States heightened concerns over the ageing and inefficient state of the underlying electric power grid. In addition to improving the reliability of electric vehicles, and accommodating more of these vehicles, the integration of renewable energy and consumer engagement also play crucial roles. Accordingly, in 2007, the U.S. Congress passed the Energy Independence and Security Act.[5] In its Title XIII, a clear reference is made to the modernisation of the nation's electricity transmission and distribution (T&D) system to improve the reliability, security and efficiency of the electric grid, to deploy and integrate distributed resources and generation, to develop and incorporate demand response (DR), demand-side resources, and energy-efficiency resources. Furthermore, a specific chapter on smart grids in the American Recovery and Reinvestment Act (Recovery Act) was implemented in 2009. For more information, see Annex 2.

In Europe, as well as replacing an ageing infrastructure and developing interconnected networks among countries, the integration of decentralised and intermittent renewable energy sources is the major driver in the development of the grid's infrastructure. The latter is driven by the European Union's "20-20-20" target goals, according to which by 2020 renewable energy should account for 20% of the EU's final energy consumption (12.4% in 2010).[6] This additional renewable energy will mainly come from intermittent renewable sources such as wind and solar energy, which are characterised by strong daily and seasonal variations and require accurate

[4] U.S. Energy Information Administration (EIA), 2011: *International Energy Outlook 2011*

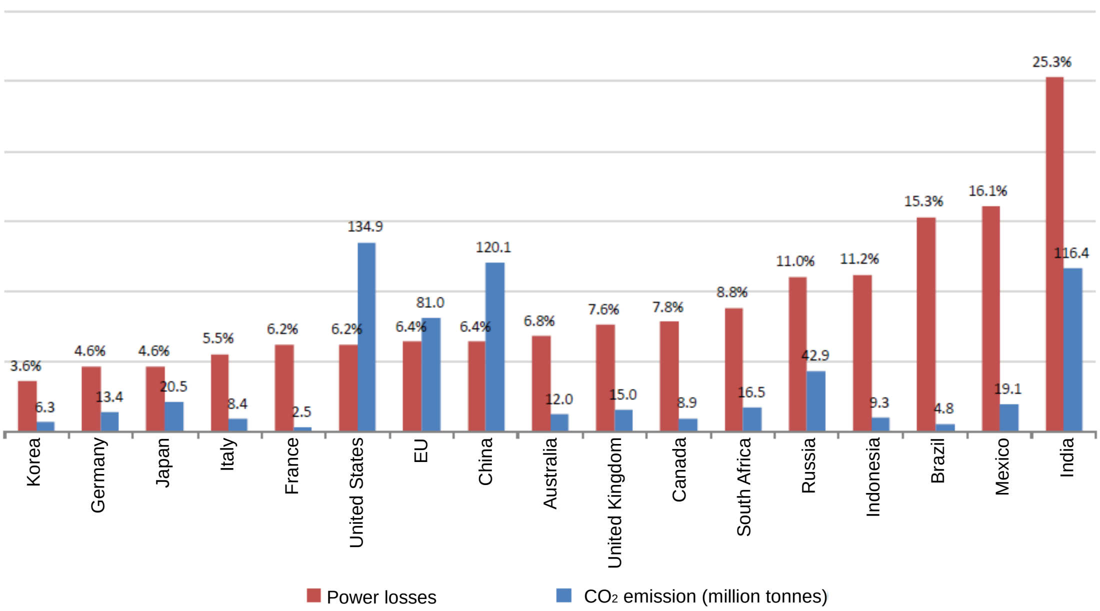
[5] http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf

[6] European Commission: http://ec.europa.eu/clima/policies/package/index_en.htm http://ec.europa.eu/enterprise/newsroom/cf/itemdetail.cfm?item_id=6015&lang=en

Figure 4

Power losses at the grid and resulting CO_2 emissions of MEF countries in 2006

Source: Major Economies Forum on Energy and Climate, December 2009, *Technology Action Plan: Smart Grids*



forecasting. Increasing system flexibility while maintaining the stability and balance of the network are new requirements for the entire electricity system, which have to be met. Alongside these developments, the need for market integration and maintaining the reliability and quality of supply are important drivers that need to be taken into account.[7] For more information, see Annex 1.

The main drivers for a smart grid in South Korea are similar to those for North America and Europe—reduce greenhouse gas (GHG) emissions significantly, improve energy efficiency, and increase the share of renewable energy. Increasing the share of renewable energy will improve the country's energy security as it currently imports almost 97% of its total energy. According to the National Energy Plan 2008–2030, South Korea aims to produce 11% of the energy it consumes from renewable energy sources by 2030 (less than 2% in 2009).[8] Besides these targets, South Korea intends to develop new growth engines with various smart grid projects. Because South Korea has the relevant IT industry technologies and infrastructure, the promotion of smart grids plays a critical role in transforming the country's economy into a more knowledge-based economy.[9] For more information, see Annex 4.

The drivers in Japan are similar to those for South Korea; however, Japan's Strategic Energy Plan is currently under review, taking into account the devastating earthquake and tsunami in 2011 that caused the accident at the Fukushima Daiichi nuclear power plant and its impact on Japan's energy system. The deployment of smart grids, smart meters, and relevant energy management systems are expected to play a large, increasingly important role in achieving Japan's energy goals. For more information, see Annex 3.

Non-technical losses in the power sector are small in advanced economies (Figure 4). For example, Japan's electricity grid is among the most efficient and reliable in the world with average distribution losses of less than 5% (2000–2010).[10] In contrast, the situation tends to be significantly different in developing countries. In fact, India's T&D losses

[7] International Energy Agency (IEA), 2011: *Technology Roadmap Smart Grids*

[8] Korea Smart Grid Institute (KSGI): *Korea's Smart Grid Roadmap 2030*

[9] Global Smart Grid Federation (GSGF), 2012: *The Global Smart Grid Federation 2012 Report*

[10] Zpryme Research & Consulting, LLC, March 2012: *Japan: Tsunami Wakens the Smart Grid*

are among the highest in the world, averaging 26% of total electricity production. Adding non-technical losses, such as energy theft, which typically occurs through illegal connections to the grid, total losses are as high as 50%.[11] A similar situation exists in Brazil with an overstrained and ageing electricity network, where power losses were as high as 15.3% in 2006[12]—nearly twice the global average. Therefore the priorities for India and Brazil are to build a grid able to carry enough capacity for the rising demand for electricity, as well as reducing the high levels of electricity losses. For more information, see Annex 6 and 7.

Smart grids can help control and expand these grids by optimising the operation and improving the efficiency of the network through enhanced automation, more monitoring devices, protection and real time operation, as well as faster fault identification. The India Electricity Act of 2003 and the National Electricity Policy of 2005 have set clear objectives on the reliability and quality of power, as well as the availability of electricity. Additionally, the government of India launched the Restructured Accelerated Power Development and Reforms Programme (R-APDRP) in 2008, an incentive scheme for strengthening and upgrading the sub-transmission and distribution network through the adoption of IT and the implementation of smart grid technologies.

[11] Zpryme Research & Consulting, LLC, September 2011: "India: Smart Grid Legacy," *Smart Grid Insights*
[12] Major Economies Forum on Energy and Climate, December 2009, *Technology Action Plan: Smart Grids*

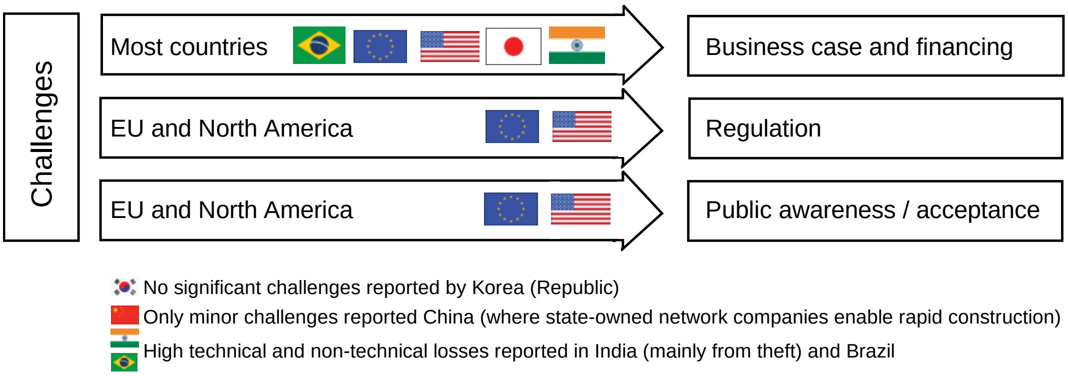
3. Challenges

A common challenge among the analysed countries and regions is the need for more public funds and tariff incentives for all stages of smart grid development: research and development (R&D), large demonstration projects (which show the impact on the system), and full deployment, in both advanced and emerging countries (Figure 5). All countries, regardless of whether they are developed or emerging, face a number of challenges and government intervention can demonstrate and accelerate the deployment of smart grid technologies.

Financing and business models

Total estimated costs to realise a fully functioning smart grid in the United States could reach USD 476 billion spread over 20 years, with an annual cost of USD 24 billion per year.[13] In Europe, the ambitious 20-20-20 targets require a significant amount of investment in the coming decades. According to the European Commission, an investment of EUR 40 billion (USD 50 billion) is forecast for storage and smart grid applications at the T&D level.[14]

Figure 5
Main challenges for smart grid development



[13] Electric Power Research Institute (EPRI), Inc., 2011: *Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid*
[14] Compare for the figures: Council of the European Union, 2011: *Commission Staff Working Paper—"Energy Infrastructure Investment Needs and Financing Requirements*"

In 2009, the Chinese State Grid Corporation (SGCC), which covers 88% of China, announced a plan for the development and construction of a "strong smart grid" in three phases with a total cost of USD 101 billion by 2020.[15] Despite the fact that Brazil's smart grid market is in its infancy, investments are projected to reach USD 36.6 billion by 2022.[16] South Korea's total costs are estimated to be USD 25 billion by 2030 for the successful deployment of a smart grid with approximately USD 18.6 billion in infrastructure.

In Europe, the current tariff schemes in most countries do not include sufficient incentives to launch the large-scale research, development and demonstration (RD&D) projects that are needed, as the majority of current tariff structures allow the financing of line reinforcement but not necessarily the deployment of "smarter" solutions. However, some large-scale demonstration projects have already been launched in the past few years, many financed under the EU's Seventh Framework Programme[17] (described in detail in Chapter 4). Finding appropriate funding for the launch of all the necessary large-scale demonstration projects and the consequent deployment of smart grid technologies remains one of the key challenges.

Furthermore, appropriate regulatory frameworks (i.e., adequate incentives) are needed to increase efficiencies, foster market integration and security of supply, and support related research activities. These regulatory incentives should encourage network operators to earn revenues, decoupling them from additional sales, and relying instead on efficiency gains and lower peak investment needs, moving from a "volume-based" business model to one based on quality and efficiency.

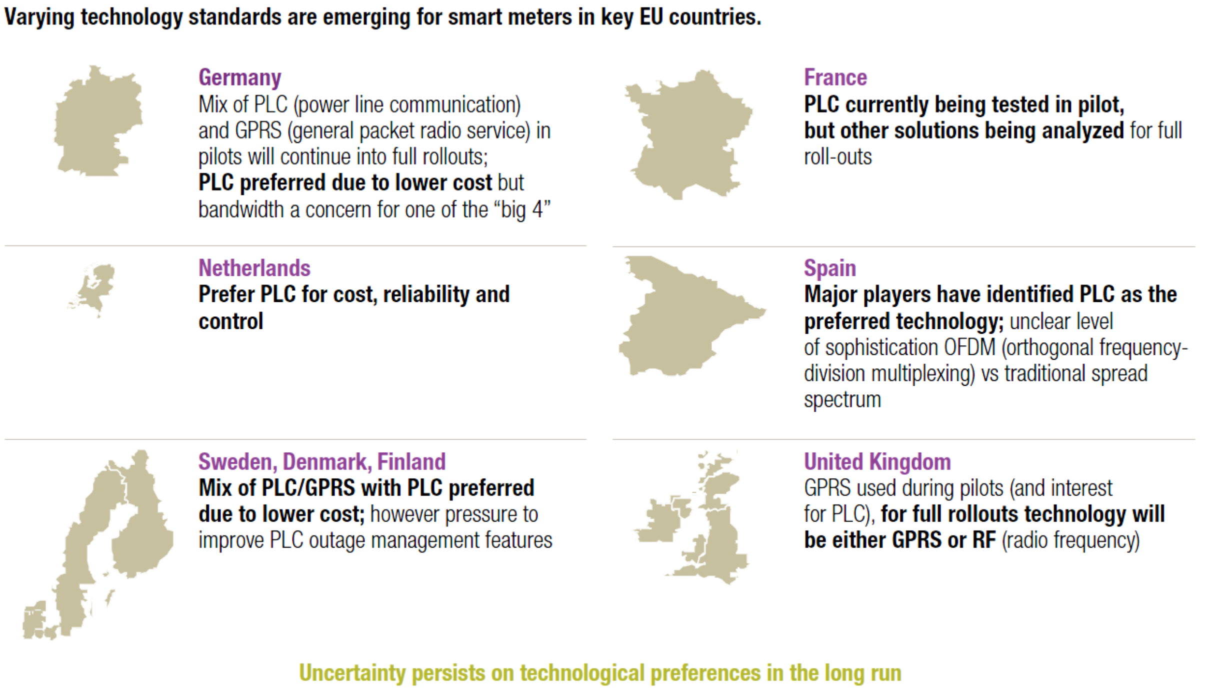
Similarly, energy-saving technologies like smart grids in North America are challenged by a traditional business model where the main driver is increasing energy sales. Furthermore, budget deficits in many states and general uncertainty about the state of the economy as a whole are common and do not help to set the right financial environment for smart grid projects. If states do not have sufficient funding to incentivise renewable energy and energy efficiency, while attempting to balance their budgets, incentives that drive smart grid development stand to be reduced, if not eliminated altogether.

Low recovery of revenues is common in India, pushing most distribution companies into dire losses, and leaving the states' utility companies with hardly any funds to upgrade distribution networks. Hence in general, the states look to the central government to provide funding and technical direction to strengthen the distribution system.

South Korea's future directions for smart grid infrastructure are to provide incentives in the early stages of infrastructure-building, establish a foundation of standards and certification for international markets, and establish a security

[15] Zpryme Research & Consulting, LLC, January 2011: *China: Rise of the Smart Grid*
[16] 'Smart grid' vai turbinar a rede elétrica do país, http://oglobo.globo.com/tecnologia/smart-grid-vai-turbinar-rede-eletrica-do-pais-4952797
[17] European Commission (EC) CORDIS: *EU's Seventh Framework Programme (FP7)*, http://cordis.europa.eu/fp7/home_en.html

Figure 6
Various technology standards for smart meters in key EU countries
Source: McKinsey & Company; 2010: *How Europe is approaching the smart grid*



programme for the safe construction and operation of a smart grid. As the development and deployment of smart grid technologies is considered to be a new economic growth engine, with the already highly competitive semiconductor and IT industries, South Korea will emphasise core technology development and industrialisation, the diffusion of successful business models, the rapid build-up of related infrastructure and systems, and the modification of legal and institutional structures. By completing a nationwide smart power grid by 2030, which would be the first in the world, South Korea expects to become the leading country in the global smart grid market.

In China, where projects require large investments and a long construction period, enterprises are challenged by high return on investment (ROI) requirements. It is therefore urgent to create fiscally-friendly policies that create incentives for private enterprises to finance these important projects.

Huge investments cannot be completely provided by government funds alone. Intelligent funding systems are needed to motivate private investors, who look for secure returns that match or exceed other investment opportunities (compare best practices in Chapter 4).

Regulations

In Europe, full deployment and the replication of smart grid technologies present themselves as a major challenge. One key issue is the definition of clear technology standards for smart grid technologies that would allow for a massive deployment. The standardisation of solutions and interoperability of technologies will help reduce deployment costs, essential to establish a positive business case. Furthermore, as is the case for large-scale demonstration projects, defining clear regulatory frameworks that support the full-scale deployment of smart grids requires strong actions by each national and European regulatory authority (Figure 6).

In India, electricity is a matter where both the central and state governments have specific, sometimes overlapping powers that complicate technical and investment-related decisions. As most distribution companies in India are state-owned, the political pressure is high to keep tariffs down and distribute electricity at low rates to certain sectors like agriculture and small industries. Although the central government has addressed the matter, support for implementation levels is unsatisfactory. The primary reasons for failing to implement smart grids are the lack of incentive for participating companies, the lack of adequate skilled workers, the lack of transparency of the systems, and the lack of political will. R-APDRP, the newly structured programme, tries to look into solutions into many of these implementation lacunas.

On the other hand China, with the same need to build a new infrastructure to respond to the increasing demand for electricity, will introduce smart grid technologies in the transmission infrastructure from the outset. Furthermore, China's enormous state-owned transmission companies and streamlined regulatory processes enable rapid construction with few barriers.

The majority of countries do recognise the importance of regulations for the implementation of smart grids. In a country like China with a central government, a standard set of regulations can easily be implemented; in other countries, agreeing on clear technology standards as well as defining a set of regulations and their consequent implementation impose a huge challenge.

Public awareness

Finally, the benefits provided by smart grids need to be clearly communicated in order to raise public awareness. The lack of customer interest, especially in developed countries, not only stems from a generally low level of awareness of the size of electricity bills, but also from a limited understanding of smart grids and how their implementation can create value. Therefore, a key challenge is explaining in simple terms what a smart grid is, and more importantly, the direct benefits customers will incur with a massive deployment of all the necessary technologies.[18]

For example, in California (United States), some customers of the utility Pacific Gas & Electric have been opposed to smart meters being installed in their homes due to privacy, health, and safety concerns. The same issue has surfaced in the states of Maine and Illinois, where customers have opposed smart meter rollouts. All this opposition has led the respective states' public utility commissions to consider smart meter opt-out options, where consumers pay an initial fee and monthly charge for choosing to opt out.

[18] McKinsey & Company; 2010: *How Europe is approaching the smart grid*, http://www.mckinsey.com

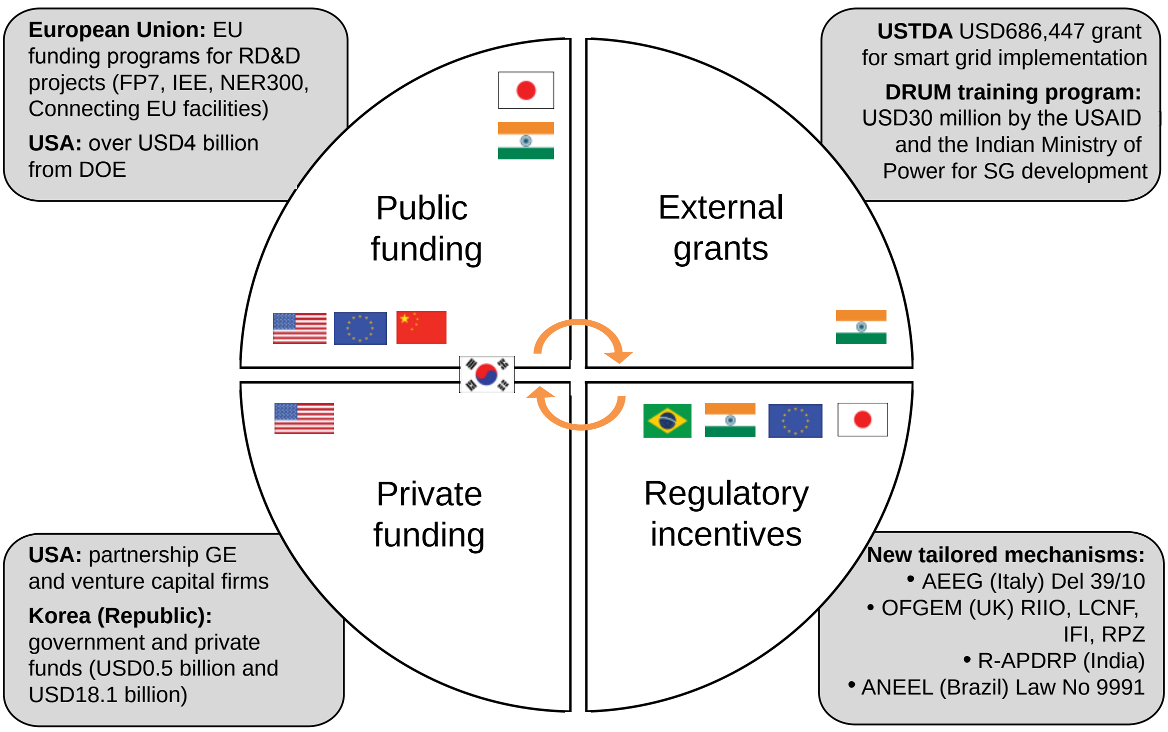
4. Currently available financing mechanisms

Several financing mechanisms to drive forward the development of smart grid technologies and incentivise private sector investment have been established in various countries (Figure 7).

In Europe, research and demonstration projects, e.g., the large-scale demonstration projects GRID4EU and EcoGrid EU, are funded under the Seventh Framework Programme (FP7) of the European Commission.

- The aim of the GRID4EU project is to carry out large-scale demonstrations of advanced smart grid solutions with wide replication and scalability potential for Europe. The project involves 27 partners from 12 EU countries, is coordinated by ERDF, France's main distribution system operator (DSO), and technical management is by Enel Distribuzione, Italy's largest DSO. The initiative will implement six large-scale smart

Figure 7
Overview of available financing mechanisms



grid demonstration projects in Italy, France, Germany, Sweden, Spain, and the Czech Republic. The project tests a series of advanced smart grid solutions, including dynamic management of the supply and demand of electricity, further integrating renewables, and enabling consumers to become active participants in the grid. The project has a total budget of EUR 54 million, of which EUR 25 million is funded by the European Commission and the rest by industry.[19]

- The EcoGrid EU is a large-scale smart grid demonstrating real-time, market-based integration of distributed energy resources (DER) and DR. The key objective of the EcoGrid EU project is to demonstrate the efficient operation of a distribution power system with a high penetration of intermittent renewable energy resources. The total budget for the EcoGrid EU is EUR 21 million, of which half is financed by the EU. The project will run for four years from mid-2011.[20]

Given that transmission and distribution are natural monopolies, these activities are a regulated business in Europe. Therefore grid investments closely linked to tariff schemes defined by the regulatory bodies in each EU country and specific regulatory incentives for RD&D projects are the exception rather than the rule. Only a few examples can be mentioned for Europe, with Italy and the United Kingdom being at the forefront of innovative financing mechanisms, where tailored regulatory incentives are developed by the Office of Gas and Electricity Markets (OFGEM) in the United Kingdom and the Autorità per l'energia elettrica e il gas (AEEG) in Italy (see the following boxes for a description of both mechanisms).

United Kingdom’s available regulatory financing mechanisms

OFGEM introduced its first innovation incentives in 2005. The Innovation Funding Incentive (IFI) was designed to promote general technical innovation by allowing up to 0.5% of annual revenue to be spent on innovation. The Registered Power Zones (RPZ) instrument was focused on encouraging innovative ways of connecting distributed generation.

For example, the Orkney distribution company benefited from both funding mechanisms and implemented a project on Active Network Management (ANM), which controls the electricity output of new generators and thereby improves its grid-hosting capacity without upgrading the connection. The IFI covered R&D costs, and the RPZ rewarded R&D outputs.

Furthermore, allowances to recover RD&D expenditures via regulated tariffs for distribution network operators (DNOs) have been provided more recently. The Low Carbon Networks (LCN) Fund from OFGEM has helped DNOs to support RD&D projects on networks. The £500 million (USD 790 million) LCN Fund, running from 2010 to 2015, provides two tiers of funding, with an inherently different financing mechanism.

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[19] GRID4EU: http://www.grid4eu.eu/
[20] ENERGIMET.DK: http://energinet.dk/en/forskning/EcoGrid-EU/sider/EU-EcoGrid-net.aspx

The First Tier provides a regulatory allowance to recover demonstration expenditure via tariffs, with up to £16 million (USD 25 million) a year, and is spread across all DNOs to spend against set criteria. Before a project is funded OFGEM issues a project direction, setting out the project-specific terms that the DNO has to abide by as a condition of the funding, and a funding direction, which sets out the amount of money which each DNO will be allowed to recover from customers over the course of the next regulatory year.

While the First Tier is considered an input-based regulatory mechanism, which provides direct pass-through of RD&D costs to customers, the Second Tier provides funding awards based on an annual competitive process to help fund a small number of flagship projects by up to £500 million (USD 790 million).

In addition, discretionary rewards for successful project completion and exceptional projects are available following output-based principle, and DNOs are in turn incentivised to deliver the projects to a high standard. They will be eligible to apply for a delivery reward (called the Second Tier Successful Delivery Reward) if they meet the delivery criteria set out in the project direction.

Furthermore, DNOs are required to disseminate the learning that the projects generate. The LCN Fund conducts a review to ensure that lessons can be incorporated to improve the process, as a “learning by doing mechanism”. Any changes will be reflected in the next version of the LCN Fund Governance Document. Results from the trials will also inform the development of the regulatory framework for networks and help DNOs to prepare well-informed business plans for the next electricity distribution price control (RIIO-ED1).

In addition, the United Kingdom has set the RIIO (Revenue = Incentives + Innovation + Outputs) price control mechanisms, which provides network companies with incentives to overcome the challenges of delivering low-carbon energy. Price control frameworks will be set for an eight-year period from 1 April 2013 to 31 March 2021 and the intention is to deliver a low-carbon, sustainable energy sector with incentives to reward innovation and respond to the need for replacing the ageing infrastructure.

RIIO is an output-based regulation, offering the possibility to include expenditure for technical and commercial innovation projects in business plans and raise revenues from customers constrained by project deliverables.

Italy’s available regulatory financing mechanisms

Temporary enhanced Return on Revenue (RoR) for demonstration projects with capital expenditure (CAPEX) has been provided in Italy under Resolution ARG\elt 39/10.

On the basis of a competitive process, the resolution provides an additional 2% extra on Weighted Average Cost of Capital (WACC) remuneration for a period of 12 years on the part of the distribution regulatory asset base

(RAB) associated with investments needed for the demonstration project. The total cost of the demonstration projects approved for extra remuneration is about EUR 16.4 million. However, it has to be noted that it only covers capital expenditure and not operative costs, which in the case of R&D projects can be substantial. Therefore, while providing a first step in the financing of these projects, further reinforcement of these mechanisms is necessary to ensure they cover all costs, especially those related to Operational Expenditure (OPEX).

Under Resolution ARG\elt 39/10 nine pilot projects were presented, of which eight were granted financing, with the Isernia project led by Enel Distribuzione receiving the highest marks. Requested financing for the projects ranged from EUR 642,000 to EUR 6.2 million. Specifically related to the Isernia project, the demo will test system solutions that combine generation from distributed energy resources with a reliable and safe management of the system under real operating conditions. The project tests a new approach to distributed generation management with the installation of a storage facility. The project also includes the installation of nearly 8,000 “smart info®” devices and a charging station to power five electric vehicles.

With Resolution ARG\elt 198/11, the Autorità per l'energia elettrica e il gas (AEEG) [the Italian Energy Authority] maintained incentives for smart grid projects granted under the aforementioned Resolution 39/2010 for the regulatory period 2012–2015, providing an additional 2% extra WACC remuneration on new smart grid related pilot projects, to be defined, for a period of up to 12 years.

The Italian Energy Authority also supported pilot projects aimed at testing different market models for electric vehicle charging services under Resolution ARG\elt 242/10. Five new pilot projects have been allowed, with an annual contribution of EUR 728/year per charging point up to 2015 for the construction and operation of charging infrastructure, according to three market models:

- Distribution model
- Competitive service provider model
- Sole service provider model

Other examples of financing mechanisms include new incentives for innovation investments provided in Finland’s 2012–2015 regulatory regime, and Portugal’s 2012–2014 regulatory period, where a 150-basis point premium will be added to the ROR, while weighing innovative investments in the RAB.

Although Italy and the United Kingdom show a path that could be followed by other regulatory authorities, additional work is required to support the financing of large-scale demonstration projects where solutions are validated at system level.

It is of fundamental importance to involve national regulatory authorities in the early stage of smart grid development, as this will allow them to better understand the benefits of the technologies and provide appropriate regulatory mechanisms to support their full deployment.

In the United States, alongside federal financing, smart grid technologies and developments are financed by private investments. A best practice example is the partnership between General Electric Corporation (GE) and venture capital firms, where start-up companies, entrepreneurs, and scientists are invited to share their ideas on how to improve the grid. Additionally, GE announced in late 2011 it would provide a unique smart grid business model to small and mid-sized utilities. Grid IQ™ Solution offers utilities subscription-based, hosted smart grid service ‘‘packages” as well as smart grid technologies moving the integration, financial, and deployment risks away from the utility, thereby providing cost-effective smart grid solutions. Since its launch in November 2011, GE has amongst others partnered with the city of Leesburg and the company, Electric Cities of Georgia (ECG), agreeing to implement smart grid technologies.[21] The project with total estimated costs of USD 20 million is half-funded by federal grants from the U.S. Department of Energy. The project will provide 24,000 customers with smart meters. The new system is expected to save Leesburg USD 15 million in electric operations over the next 20 years, according to the Leesburg City Commission.[22]

[21] http://www.gedigitalenergy.com/press/Norcross/index.htm

[22] http://www.telecomengine.com/article/ge-energy-provides-city-20-million-smart-grid-system

Significant progress in smart grid development has been made under the ARRA of 2009, including:[23]

- Providing USD 4.5 billion in awards for all programmes described under Title XIII[24]
- Funding a USD 2.4 billion programme designed to establish 30 manufacturing facilities for electric vehicle batteries and components
- Funding the deployment of 877 phasor measurement units[25]
- Providing USD 812.6 million in federal grants for advanced metering infrastructure deployments
- Providing USD 7.2 billion to expand broadband access and adoption.

[23] U.S. Department of Energy, February 2012: *2010 Smart Grid System Report*

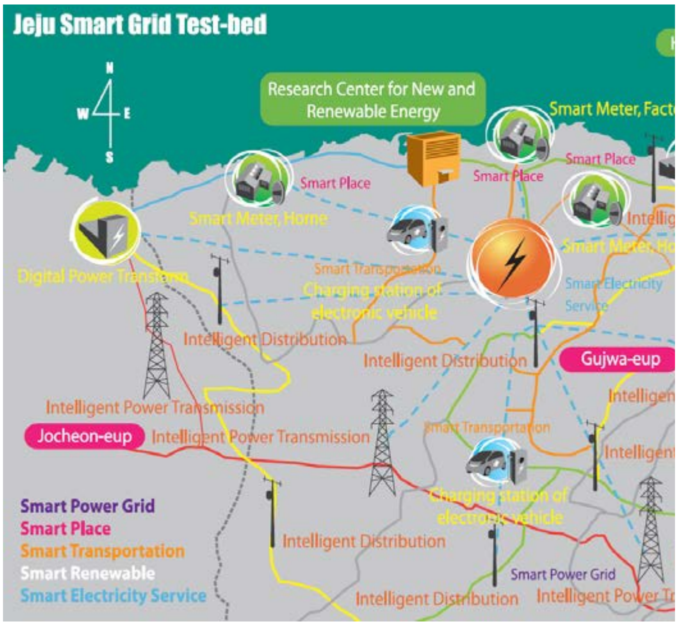
[24] Under Title XIII of the Energy Independence and Security Act of 2007 (42 U.S.C. 17381 et seq.), an additional amount of USD 4.5 billion was provided for ‘‘Electricity Delivery and Energy Reliability”. Funds are available for expenses necessary for electricity delivery and energy reliability activities to modernise the electric grid, to include demand responsive equipment, enhance the security and reliability of the energy infrastructure, energy storage research, development, demonstration and deployment, and facilitate recovery from disruptions to the energy supply, and for the implementation of programmes authorised. See http://www.gpo.gov/fdsys/pkg/BILLS-111hr1enr/pdf/BILLS-111hr1enr.pdf

[25] Phasor Measurement Unit (PMU) technology provides phasor information in real time. Effective utilisation of this technology is very useful in mitigating blackouts and learning the real-time behaviour of the power system. http://www.erlphase.com/downloads/papers/08_CIGRE_PMU_Communication_Experience.pdf

Figure 8

Jeju smart grid test-bed

Source: Ministry of Knowledge Economy (MKE), Korea Smart Grid Institute (KSGI), *For the World's Green Growth – Jeju Smart Grid Test-bed in Korea*



In emerging countries, the cost of financing the development of smart grid technologies is for the most part borne by government finances or external grants. For example, the State Grid Chinese Corporation has been carrying out pilot projects by means of independent investment and public tendering.

Similarly, smart grid projects in India are being implemented on a pilot basis and are mostly funded by government finances or external grants. Among these, Distribution Reform, Upgrades and Management (DRUM) is a USD 30 million bilateral project developed by the U.S. Agency for International Development (USAID) and the Indian Ministry of Power, with USAID training Indian utility personnel in the commercial, technical, safety, communication, and management aspects of electricity distribution. The project is aligned with the R-APDRP, a financial incentive scheme (~USD 9 billion) where the Indian government initially provides loans to the utilities to strengthen and upgrade sub-transmission and distribution networks through the adoption of IT and the implementation of smart grid technologies. If the utilities are able to implement the project within a stipulated period and bring down network losses to stipulated levels, the loan is partly or fully converted into grants.

South Korea's investment plan provides a total fund of USD 25 billion until 2030, which will be used for the most advanced key technology development and the successful deployment of South Korea's smart grids. Even though the initial investment sources came from the government, the higher share of the financial burden will be borne by the private sector (see the box below for a more detailed description).

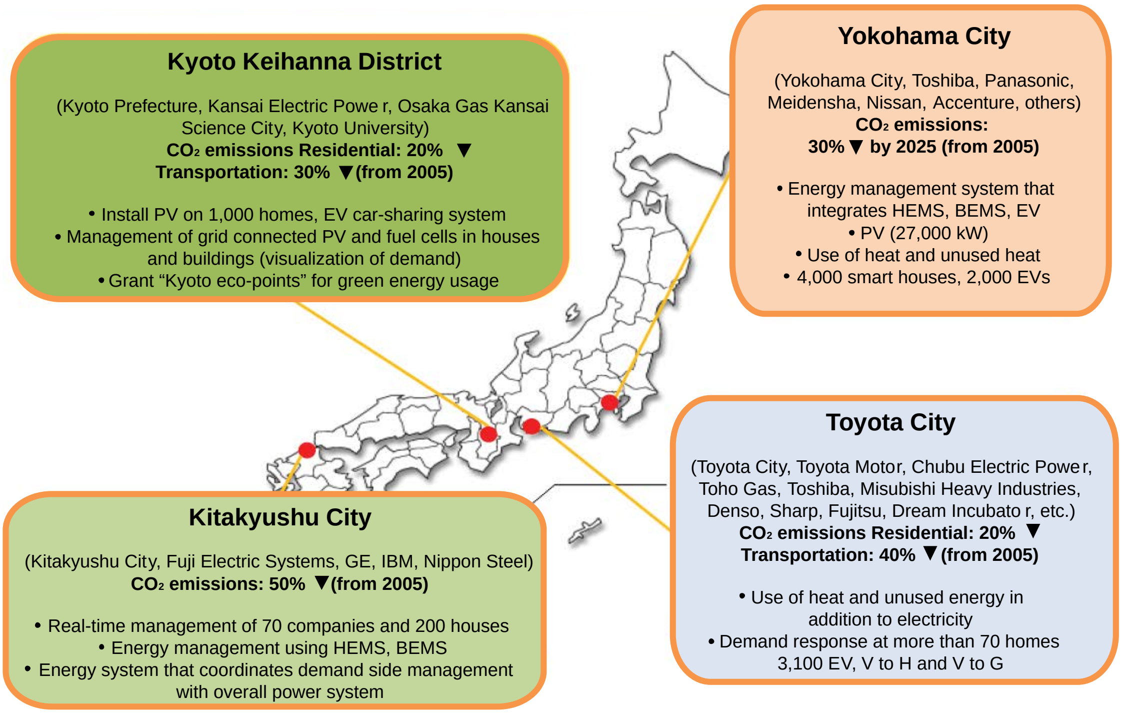
Test-bed Implementation: Jeju in South Korea

South Korea's smart grid test bed is located in the Gujwa-eup, Jeju Island area, covering about 6,000 households. This test bed will serve as the foundation for the commercialisation and industrial export of smart grid technologies through establishing the world's largest and high-tech test bed. The project has two separate phases: the basic stage (December 2009–May 2011) saw the construction of the test-bed infrastructure and in the expansion stage (June 2011–May 2013) the smart grid is integrated in the operating environment.

Figure 9

Large-scale demonstration projects in Japan

Source: New Energy and Industrial Technology Development Organization (NEDO), Japan, *Introduction to Japan's "Smart Community"*



According to South Korea's national roadmap, the Jeju test bed is divided into five strategic areas: smart power grid, smart place, smart transportation, smart renewable energy and smart electricity service. Currently about 12 consortia (171 companies), consisting of smart grid-related companies in areas including power, communication, transport, appliances etc., are participating in the five strategic areas testing technologies and developing business models.

The South Korean government is making great efforts to promote the Jeju test bed and attract private industries' participation. A total of 68.5 billion won (USD 60.8 million) will be invested in the Jeju smart grid to establish the foundation, test domestic and international power exchange, and to fund the total operating centre (TOC) supported by various private companies. In addition, private companies are planning to invest 171 billion won (USD 151.9 million) in the test bed project.

Japan's Ministry of Economy, Trade and Industry (METI) emphasises measures related to smart grid technology development and demonstration projects. For example, METI has a budget of 12.6 billion Yen (USD 157 million) in 2012 for large-scale demonstration projects, the "Smart Community Demonstration," in four cities in Japan. Yokohama City in Kanagawa Prefecture, Toyota City in Aichi Prefecture, Kansai Science City in Kyoto Prefecture and Kitakyushu City in Kyushu Prefecture were selected as demonstration areas for smart grid projects (Figure 9). In addition, 8.9 billion Yen (USD 111 million) are reserved for the stabilisation of power grids by utilising advanced technologies. The industry is bearing one-third of the incurred costs.

Currently there are no specific financing mechanisms available in Brazil for the development of smart grid technologies. However, general regulatory incentives and R&D funds that support the majority of demonstration projects are also applicable to smart grid demonstration projects. The Agência Nacional de Energia Elétrica or ANEEL, (the National Electric Energy Agency) is the government agency that regulates the energy sector in Brazil and it requires all energy companies in Brazil, with the exception of wind, solar, biomass, small hydro and cogeneration producers, to make 1% of their net operating income available to a Fund for Research and Development (Law No. 9991 of July 24 2000).

Part of the Fund, coordinated by ANEEL, is reserved for R&D projects (40%) and has been used to realise a number of smart grid projects. For example, Ampla, a power distributor in Rio de Janeiro state, deployed smart meters in households in its distribution network to reduce losses from illegal connections. Companhia Energética de Minas Gerais (CEMIG) has started a smart grid project in Sete Lagoas City based on system architecture developed by the IntelliGrid Consortium, an initiative of the California-based Electric Power Research Institute (EPRI) (Conviver and Cities of the Future Projects). CEMIG's total investment until 2013 will be R$45 million (USD 22 million), and includes implementing and developing the infrastructure needed to cater for the new technologies. A project in Parintins, an island in the Amazon River, aims to develop a reference model of smart grid technologies for the distribution companies of Eletrobras. The costs of the pilot project will amount to USD 15 million. The city has about 100,000 inhabitants with 15,000 consumers. Generation is local with 25 MW of installed capacity, all diesel. Several potential solutions to meet the needs of advanced metering infrastructure and advanced distribution automation will be evaluated on site. Furthermore, around 1 MW of local diesel generation will be replaced by photovoltaic panels installed on house roofs.

The Eletrobras Distribution Rehabilitation Project is a USD 709 million modernisation project, in part financed by the World Bank (USD 495 million). The project aims to improve the financial and operational performance and the commercial management of the six distribution companies by reducing electricity losses, increasing bill collection rates and improving quality of service.[26] The Advanced Metering Infrastructure (AMI) is one of these activities. AMI investment is estimated at USD 252 million and will include the installation of reading equipment and telecommunication systems to manage metering and reading, and monitoring consumption by consumers (replace current meters with smart meters; a total of 9,000 medium voltage consumers, 115,000 low-voltage consumers with consumption above 600 kWh/month; installation of modern meters for 780 medium voltage consumers).

To fully utilise the benefits of smart grids technological as well as daunting financial challenges have to be overcome and it is of uttermost importance that policymakers and industry work closely together and include the wider public in their efforts. For industry it is important to elaborate a positive business case with a precise definition of how investments are paid for, reflecting the fact that benefits are incurred to a wide range of stakeholders. The development of smart grids is a long-term process that binds capital over many years and therefore requires strong commitment from all stakeholders and a positive business model.

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[26] World Bank: http://www.worldbank.org/projects/P114204/eletrobras-distribution-rehabilitation?lang=en

Abbreviations and acronyms

AEEG	Autorità per l'energia elettrica e il gas (Italy)
AESO	Alberta Electric System Operator
ADA	Advanced Distribution Automation
AMI	Advanced Metering Infrastructure
ANEEL	Agência Nacional de Energia Elétrica (Brazil)
ARegV	Innovative Regulations Ordinance (Germany)
ARRA	American Recovery and Reinvestment Act of 2009
AT&C	aggregate technical and commercial
BAU	business as usual
BEMS	Building Energy Management System (Japan)
BES	Battery Energy Storage (Japan)
CCEE	Power Commercialization Chamber (Brazil)
CCS	carbon capture and storage
CEER	Council of European Energy Regulators
CEF	Connecting Europe Facility
CEMIG	Companhia Energetica de Minas Gerais (Brazil)
CMSE	Electricity Industry Monitoring Committee (Brazil)
CNPE	National Council for Energy Policies (Brazil)
DA	distribution automation
DCU	data concentration unit
DER	distributed energy resource
DG	distributed generation
DNO	distribution network operator
DOE	U.S. Department of Energy
DR	demand response
DRUM	Distribution Reform, Upgrades, and Management
DSO	distribution system operator
EEGI	European Electricity Grid Initiative
EC	European Commission
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
ESO	European Standardisation Organisation
ETS	Emissions Trading System (European Union)
FP7	Seventh Framework Programme (Europe)
GE	General Electric Corporation
GHG	greenhouse gas
GW	giga-watt
HEMS	Home Energy Management System (Japan)

ICT	information and communications technology
IEA	International Energy Agency
IEE	Intelligent Energy–Europe
IESO	Independent Electricity System Operator (Ontario, Canada)
IFI	Innovation Funding Incentive
IPR	intellectual property rights
IRIN	Innovative Regulation for Intelligent Network (Germany)
ISGF	India Smart Grid Forum
ISGTF	India Smart Grid Task Force
IT	information technology
kWh	kilowatt-hour
LCN	low carbon network
MDM	meter data management
MERGE	Mobile Energy Resources for Grids of Electricity
METI	Ministry of Economy, Trade and Industry (Japan)
MME	Ministry of Mines and Energy (Brazil)
MRA	Mutual Recognition Arrangements
NASPI	North American Synchrophasor Initiative
NERC	North American Electric Reliability Corporation
NMEEE	National Mission for Enhanced Energy Efficiency (India)
NREAP	National Renewable Energy Action Plan (European Commission)
OECD	Organisation for Economic Co-operation and Development
OFGEM	Office of Gas and Electricity Markets (United Kingdom)
ONS	Operator of the National Electricity System (Brazil)
PCI	project of common interest (European Union)
PCS	power conversion service
PMU	phasor measurement unit
PTC	production tax credit
PUC	Public Utility Commission (United States)
PV	Photovoltaic
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
R&D	research and development
RD&D	research, development, and demonstration
REPI	Renewable Energy Production Incentive (United States)
RIIO	Revenue = Incentives + Innovation + Outputs
ROI	return on Investment
RPS	Renewable Portfolio Standards
RPZ	Registered Power Zone

SCADA	Supervisory Control and Data Acquisition
SGCC	State Grid Corporation of China
SGDP	Smart Grid Demonstration Project
SGIG	Smart Grid Investment Grant (United States)
SIN	National Interconnected System (Brazil)
SM	smart meter
SRP	Salt River Project (Arizona, United States)
T&D	transmission and distribution
TBT	Technical Barriers to Trade
TEPCO	Tokyo Electric Power Company
TOC	total operating centre
TOU	time-of-use
TSO	Transmission System Operator
TWh	tera-watt-hour
UHV	Ultra-high voltage
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
V2G	vehicle to grid
WACC	Weighted Average Cost of Capital

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