Chapter 9
Sustainable Smart Grids, Emergence of a Policy Framework

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Glossary

Cost-benefit analysis	Cost-benefit analysis is an economic approach to policy evaluation. It measures the timeline of expected costs and benefits associated with policy implementation, discounting future values to produce a net present value. Cost-benefit ratios are also used to evaluate a policy relative to the status quo or an alternative policy formulation.
Demand response	Demand response is a means of reducing customer consumption of electricity in response to supply conditions. It is different from energy efficiency, which involves using less electricity to perform a particular task.
Distributed generation	Distributed generation involves the production of electricity from many small energy sources (including, for instance, natural gas turbines and solar photovoltaic panels). It is distinct from the prevailing generation of electricity at large centralized facilities.

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Feed-in tariffs	Feed-in tariffs provide incentives for the generation of renewable electricity. Governments and utilities provide guaranteed purchase contracts for electricity generated from renewables; the particular tariffs may change over time to track the development of technology and cost reduction.
Natural monopoly	Natural monopolies occur when economies of scale reduce production costs, such that one firm can produce at lower costs than multiple firms. Many public goods are typically provided by natural monopolies, such as electricity, railway, and water.
Public good	A public good is a good that is non-excludable and non-rivalrous. It is costly to keep nonpayers from enjoying a public good, and one's consumption of a public good does not affect another's ability to consume the good. Natural defense and clean air are two examples of public goods.
Renewable electricity standard	Renewable electricity standard is a policy target that sets minimum requirement for electricity generated from renewable energy sources.
Renewable energy certificates	Renewable energy certificates are tradable energy commodities. One certificate often represents one megawatt-hour of electricity generated from renewable energy.
Time-of-use pricing	Time-of-use pricing refers to electricity prices, which change based on time of consumption, such as peak and off-peak periods.

Definitions of Smart-Grid Policies and Their Importance

A smart grid is an electricity network that can (1) cost-efficiently integrate a diverse set of generators, (2) enable consumers to play an active role in managing the demand for electricity, and (3) operate at high levels of power quality and system security [1]. Policies to promote smart grids include net metering tariffs and time-of-use pricing; interconnection and technology standards; subsidies, targets and goals; customer privacy protection laws; and rules governing the ownership of renewable energy credits (Fig. 9.1).

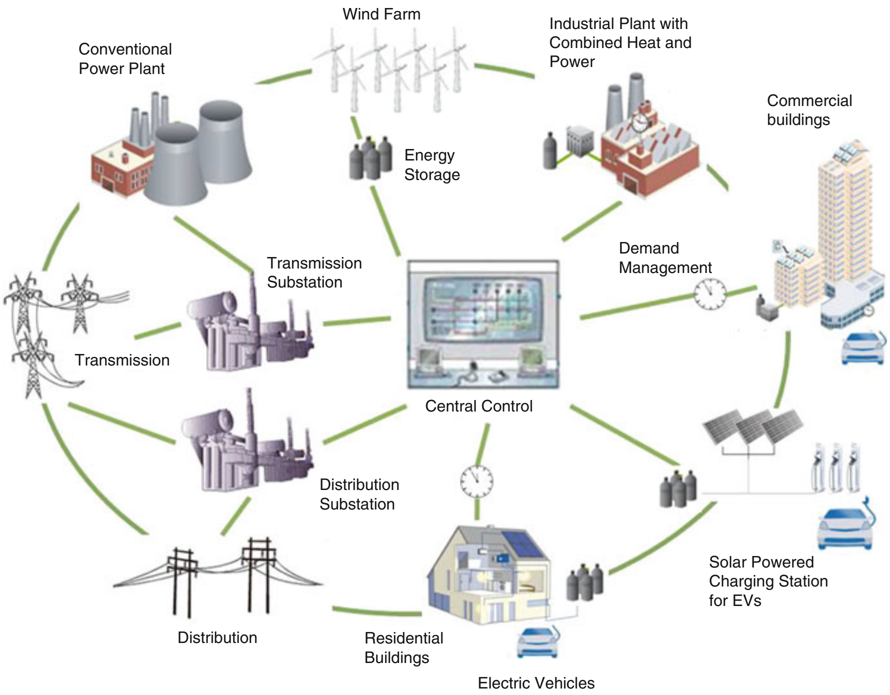


Fig. 9.1 Smart grid: a vision for the future

- Smart grids facilitate the connection and operation of generators of all sizes and technologies. Recent improvements in the cost-effectiveness of distributed generation (DG) have underscored the importance of this ability to interconnect utility-owned DG assets (such as wind and solar farms) as well as customer-owned DG (such as industrial cogeneration facilities and building-integrated photovoltaics). The ability to integrate low-carbon and sustainable energy resources is essential to reducing the environmental impact of electricity supply systems.
- Smart grids also enable consumers to play a part in optimizing the operation of the system by providing them with greater information and options for how they management their energy consumption. With the help of smart-grid technologies and demand response programs, consumers can be motivated to reduce their peak electricity consumption, thereby reducing capital spending for power generation, transmission, and distribution investments [2, 3]. Enduring concerns about oil security combined with recent advances in electric vehicles have created the hope that smart grids could help support the electrification of transportation.
- Through proactive grid management and automated response, smart grids can provide system security and reliability as well as the high levels of power quality needed for increasingly digital economies. The smart grid implementation

workshop held by the US Department of Energy (DOE) in 2008 emphasized the ability of smart grids to anticipate and respond to system disturbances in a self-healing manner and to operate resiliently against natural disasters and physical and cyber attack [2].

In sum, smart grids offer the potential to improve the efficiency and affordability of power delivery, mitigate environmental impacts, and reduce oil dependence while maintaining high levels of power system reliability and resilience [1, 4]. These numerous benefits include two critical positive externalities: climate change mitigation and energy security [137]. However, various obstacles inhibit smart grids from gaining rapid and widespread market share. Thus, with the recent introduction of smart-grid technologies has come the emergence of smart-grid policies, which are government interventions designed to protect the public's interest in affordable, dependable, and clean electric power by promoting the deployment of the smart grid.

Introduction

The electric power infrastructure in most industrialized nations has been designed to support a large, monopolistic, centrally controlled power system. Before 1990, the electricity system in most countries consisted of vertically integrated (generation, transmission, and distribution) monopolies that were highly regulated. The rationale for this system design was the assumption that electricity production is a natural monopoly, where a single firm can produce the total market output at a lower cost than a collection of competing firms. At the transmission stage, the case for natural monopoly and continued regulation remains relatively strong, but the natural monopoly rationale for electricity generation and distribution has been weakened by the introduction of distributed electricity resources and small-scale electricity producers. While local distribution and generation systems in many countries have recently benefited from the introduction of some elements of market competition, the prevailing utility monopoly continues to play a dominant role in the production and distribution of power and generally oppose consumer-owned DG. For this reason, and because of other impediments discussed later in this chapter, smart grids remain an emerging technology.

Vertically integrated power systems have also become increasingly vulnerable to power outages and interruptions. Large-scale blackouts caused by rising electricity peak demand, aging infrastructure, extreme weather conditions, and terrorist attacks produce significant economic and social costs. For the United States alone, power outages and interruptions cost Americans over $150 billion each year [4]. Outages are more frequent and are affecting an increasing number of people in recent years [4]. The 1987 blackout in Japan caused by high peak demand in the summer affected 2.8 million households [5]. The US–Canadian blackout of August 14, 2003 impacted 50 million people in eight US states and two Canadian provinces, with estimated total costs between $4 and $10 billion [6]. In 2006, 2.5 million customers experienced power outages after Hurricane Katrina hit the US Gulf Coast [7].

These events have stimulated growing public awareness of the need for grid modernization. Transitioning to a smart grid, however, will require implementation of policies to address barriers to smart-grid deployment and to regulate data access and equity concerns.

Technological breakthroughs often precipitate the parallel development of new policy frameworks. This has been the case in the medical profession with stem cell research and cloning, in transportation with the development of commercial space travel and intelligent transportation systems, and in the communications industry with the creation of the Internet and widespread utilization of smart phones. In all of these cases, as with the smart grid, policy frameworks must be created to ensure that the public's interests are protected. Thus, with the recent introduction of smart-grid technologies has come the emergence of new smart-grid policies.

This chapter begins by providing an overview of the barriers that hinder smart-grid deployment, the drivers that motivate it, and the policies that are commonly used to encourage smart-grid investments. Attention then turns to a review of experiences with smart-grid policies beginning with an analysis of US policies and an overview of US stakeholders. To characterize the smart-grid policy initiatives introduced by individual states and utilities, activities of four states are investigated: California, Georgia, New York, and Texas. This chapter also provides some insights into European Union smart-grid policies, with a special focus on Great Britain and Italy. To illustrate the smart-grid policies used in other hemispheres, we also describe policy initiatives in China, Korea, and Japan. This chapter ends with a brief discussion of future directions and conclusions.

Barriers to the Deployment of Smart Grids

Stakeholders worldwide have widely acknowledged the importance of grid modernization. Although many of the technologies needed for smart-grid development are available nowadays, widespread deployment of these technologies is still limited. Effective policies that facilitate the evolution of the electricity grid generally are those that address key barriers to the deployment of smart grids. This section provides a brief description of barriers that have been identified to date.

High Costs. Large upfront cost is one of the greatest challenges to the deployment of smart grids [8]. Like many other green technologies, deployment requires significant initial investment, yet the resulting benefits are not fully realized for many years [3]. Without guaranteed cost-recovery timelines or precedents for smart-grid investment, utilities and policy makers tend to be reluctant to move toward a smart grid [8].

Technical Risks. Implementation of smart grids requires upgrading of the whole electric system. One great technical challenge is to handle the potential impacts of the high-level penetration of new technologies on existing infrastructure [8]. Developing such an integrated system also places demanding requirements on a wide range of technologies, especially advanced metering infrastructure (AMI) technologies and cost-effective energy storage systems [8]. Moreover, from the perspective of policy makers, the uncertainties associated with smart-grid technologies call for highly flexible regulations to guide the path of its development [8].

Regulation and Monopoly Structure. Most of the electricity markets in the world are still operated by natural monopolies. A typical utility business model today is based upon a negotiated rate of return that adequately recovers utilities' capital investments [3]. As their profits are linked with sales, utilities have a financial incentive to maximize the throughput of electricity across their wires; hence they are often reluctant to adopt technologies that improve the efficiency of power supply. Moreover, rate-of-return regulation requires that utility rates are set to provide a "reasonable" return on invested capital, and utilities have to demonstrate the cost-effectiveness of added investments. As many societal benefits associated with smart grids are not fully understood by regulators, utilities that bear all the cost of smart-grid investments have little incentive to invest in these technologies.

From the consumer's perspective, the current rate design does not reflect the marginal cost of electricity production or the conditions of the wholesale electricity market, which in turn prevents the involvement of the demand side in electricity markets [9]. Without an appropriate pricing mechanism, customers who only receive an end-of-the-month bill tend not to be interested in smart-grid technologies or end-use efficiency [10].

Under current policy schemes, smart-grid technologies face disadvantages when competing conventionally regulated power systems. In order to ensure system reliability, utilities and regulators often pose strict and discriminating rules on interconnection and DG. Incumbent electricity providers and distribution (and transmission) companies have incentives to discourage the deployment of smart grids in light of its potential to increase competition in the electricity market.

There is also a lack of consistency among policies at different levels of governments, which prevents effective collaboration and integration across regions [9].The development of codes and standards often lags behind the development of smart-grid technologies. More efforts are still needed to create universal standards that promote interoperability and compatibility of smart-grid equipment [9].

Incomplete and Imperfect Information. Many consumers still do not see the benefits of a smart grid, nor do they understand the social and economic costs associated with today's outdated power grid system [9]. Utilities and policy makers could play important roles in the process of defining and communicating the benefits of smart grid to customers [3].

Privacy and Security Concerns. Many technologies that enable the deployment of the smart grid, such as smart meters and sensors, can increase the vulnerability of the grid to cyber attacks [3]. As the number of participants and distributed generators in the electric system increases, so does the complexity of security issues [9]. The tension between protection of consumer privacy and development of smart grid also imposes challenges on privacy protection rules. On the one hand, it is essential for both customers and smart-grid service providers to have access to energy consumption data in order to optimize the use of smart-grid technologies. On the other hand, consumer privacy protection may be in favor of the incumbent utilities that are currently controlling the meters and data, hence create barriers to market entry for new smart grid players [10].

Drivers Toward Smart Grids

Apart from barriers, effective policies must also consider drivers that promote investments in smart grid technologies. Over the past few decades, electricity markets and technologies have experienced rapid growth and development, with increasing focus on reliability. The desire for cleaner air through renewable resources and for oil dependence through electric vehicles also motivates interests in the smart grid.

Increasing Electricity Demand. Global electricity demand is expected to increase by over 150% between 2007 and 2050 under the International Energy Agency (IEA)'s Energy Technology Perspectives 2010 Baseline Scenario [11]. Modeling results show modest increases based on high levels of current demand in developed countries and high growth rates in developing countries such as China and India [11].

Electricity demand also varies across time and seasons. There are usually several peak times during the day while peak loads in a year typically occur in summer and winter (Figs. 9.2, 9.3). Due to the rapid development of home appliances and a lack of real-time pricing signals, peak demand increases steadily over time. Since 1982, growth in peak demand for electricity in the United States has exceeded the growth of transmission system by almost 25% every year [4]; and the US peak demand is expected to grow at an average annual rate of 1.7% between 2009 and 2019 [12]. Rising peak demand stresses the electricity system and requires higher reserve margins for unforeseeable outages. Smart-grid technologies can help reduce demand by enabling time-of-use pricing mechanisms and demand response programs and can improve the efficiency of electricity supply through better integration of renewable DG.

Energy Price Escalation and Electricity Reliability Concerns. Rising petroleum prices have underscored the uncertainties associated with the long-term electricity market. Under EIA's Reference and High Oil Price Scenarios, world oil prices are forecast to increase from \$59 per barrel in 2009 to \$135 and \$210 per barrel, respectively, in 2035 [14]. Many countries are responding to the trend of higher

Fig. 9.2 An example of California load curve in July 2005 (MWh)

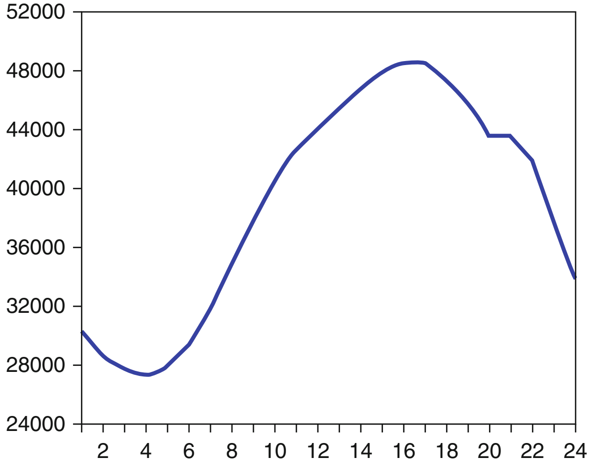
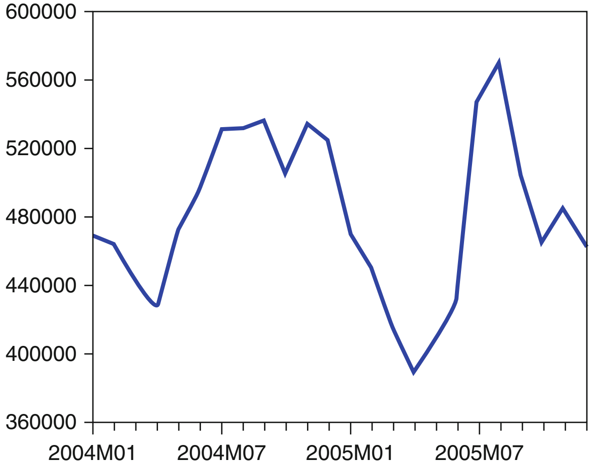


Fig. 9.3 California average daily demand for electricity (MWh) [13]



oil prices by increasing electricity generation from more economical sources and reducing the petroleum dependence of their transportation sector.

At the same time, the aging infrastructure has become increasingly vulnerable to power outages and faces challenges associated with the new demands it needs to meet. The electric systems in many developed countries are largely based upon design requirements and technologies developed in the early twentieth century. The huge economic and social losses caused by supply failures have stimulated efforts to enhance the reliability of electricity supply. Electricity is different from other energy commodities as it cannot be stored in a large scale or be traded at the global level [11]. Electricity production and consumption are highly dependent on grid infrastructures, thus must be continually monitored and controlled to prevent widespread electric service interruption. Smart-grid technologies such as sensors and smart meters allow utilities to monitor the grid system based on real-time information, and enable greater use of demand response programs and distributed renewable energy generation.

Climate Change and Clean Air Concerns. Energy-related human activities are a major source of greenhouse gases and air pollutants. In 2009, the electric power sector in the United States emitted 2,160 million metric tons of CO_2, 2,400 and 5,970 thousand metric tons of NO_x and SO_2 [15, 16]. The electric power and transportation sectors were the largest carbon emission sources in 2009, accounting for 39.8% and 34.1%, respectively, of US total emissions [15]. Many countries have set targets for low-carbon and renewable electricity generation to combat climate change, which require extensive changes to the current power systems. A smart grid could exploit the full potential of carbon emissions reduction and air quality improvement in energy sectors, as it encourages low-carbon power generation and transport systems, and can reduce emission in the transmission process.

Deployment of Renewable Power and Electric Vehicles. Efforts to combat climate change have led to a rapid development of environmentally friendly power generation and transportation technologies. As of 2007, 18.4% of world electricity was generated by renewable energy, and the number will increase to 22.7% by 2035 [14]. The transport sector is also undergoing an electrification revolution, which is expected to consume 10% of total electricity by 2050 [11]. As electric vehicles gain market share, it may become difficult for conventional grid infrastructures to provide reliable and stable electricity services [11]. In particular, the intermittency of renewable energy and electric vehicle charging have to be managed intelligently to avoid supply failures, which provide an excellent opportunity for the deployment of smart grids.

Types of Policies to Promote Smart Grids

This section provides an overview of major smart-grid policies. Current policies address many of the barriers identified above, and are aligned with many key drivers (see Table 9.1).

Net Metering

Net metering allows customers to use a single meter to measure both the inflow and outflow of electricity, thus enabling them to install and interconnect their own generators with utility grids. With net metering, customers can use the electricity generated from their on-site facilities to offset their electricity consumption and sell excess generation to the utility typically at a retail price, which encourages the deployment of customer-owned distributed energy systems. By allowing utilities to

Table 9.1 Smart grid policies to tackle barriers and leverage drivers

	Barriers					Drivers			
Smart grid policies	High costs	Technical risks	Regulation and monopoly structure	Incomplete and imperfect information	Privacy and security	Increasing electricity demand	Rising energy prices and reliability concerns	Climate change and clean air	Deployment of renewable power and electric vehicles
Net metering	×	×	×			×	×	×	×
Interconnection standards	×	×	×	×	×	×	×	×	×
Dynamic pricing	×		×	×		×	×		×
Smart metering targets			×	×		×	×	×	×
Renewable energy subsidies and regulations	×	×	×			×	×	×	×

buy back surplus electricity, net metering helps overcome financial barriers faced by distributed renewable facility owners. The buy-back price is determined by utility regulators to reflect the value of electricity delivered to the grid; therefore, it can differ across regions. In some US states, such as California, net surplus compensation policy is closely related to the state's renewable energy policies, as it includes provisions on the ownership of renewable energy credits associated with the purchase of surplus electricity [17].

Additional policy goals for net metering may include diversification of energy sources, improving system reliability, reducing environmental impacts and distribution costs, and stimulating economic development [18]. Net metering has been widely implemented in countries like the United States and Canada. According to the US Energy Policy Act of 2005, all public electric utilities are required to provide net metering service to their customers upon request [19]. As of June 2011, 43 US states have adopted a net metering policy [20].

Net metering usually requires utilities to offer net metering programs to eligible customers and to design a net energy metering tariff scheme to compensate customers for the electricity generated in excess of on-site load. Customer eligibility for net metering programs varies across regions. Eligibility criteria are commonly defined by sectors (e.g., residential, commercial, and industrial), types of renewable resources (e.g., solar, wind, and combined heat and power (CHP)), and generating capacity (e.g., less that 10 KW or up to 1 MW). Net metering rules are often updated by policy makers to meet the needs and priorities of the market. In general, the trend is to increase the system capacity cap, as in the cases in New York and Massachusetts [21] and to broaden the eligible renewable resources.

Interconnection Standards

Interconnection standards establish uniform processes and technical requirements for utilities when connecting DG systems to the electric grid. It allows DG developers to predict costs and time, and ensure the safety and reliability of interconnection processes. Technical requirements often include protocols and standards that guide how generators shall interconnect with the grid, ranging from system capacity limit, the types of qualifying generators, the types of interconnection equipment required for reliability purposes, to the types of eligible generation technologies. Interconnection policy also includes simplified and standard application, connection and operation procedures, which can reduce uncertainties and prevent time delays that customers could encounter when obtaining approval for grid connection. For example, small systems may qualify for a streamlined interconnection process, with fees and application forms specified in the rules.

Interconnection standards have been widely developed and adopted by both governments and nongovernmental organizations. By 2011, 42 US states adopted an interconnection policy [20]. The US Federal Energy Regulatory Commission (FERC) has developed interconnection standard procedures for generators up to 2 MW, generators between 2 and 20 MW, and generators larger than 20 MW that connect to a utility's transmission system [22]. Other organizations such as the National Association of Regulatory Utility Commissioners (NARUC) and the Institute of Electrical and Electronic Engineers (IEEE) have also developed interconnection standards for distributed resources [23, 24].

Smart Metering Targets

A smart meter is a device that can measure real-time electricity consumption and communicate the information back to the utilities. It usually involves a mix of technologies, including real-time or near real-time sensors, power outage notification, and power quality monitoring. Smart meters, in combination with dynamic pricing, are essential for the promotion of price responsive demand and the success of a smart grid [25]. Smart metering targets have been widely adopted, which often establish smart meter deployment plans for utilities, including the timeline, and the type and number of smart meters to be installed. Sometimes, utilities are required to conduct cost-benefit analysis (CBA) of the proposed smart metering programs.

Demand Response and Dynamic Pricing

Demand response is defined as changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when grid reliability is jeopardized [26]. Many types of demand response programs have been offered by electric utilities and other stakeholders, such as dynamic pricing, peak time rebate, direct load control, and interruptible load. Demand response programs could contribute significantly to peak load reduction. To take the United States as an example, over 500 entities have reported offering demand response programs by 2010, with an estimated demand response resource of more than 58,000 MW (MW), or 7.6% of US peak demand [26].

As one of the most widely implemented demand response programs, dynamic pricing is a market-driven approach to boost demand response in the electricity market. The fundamental idea is to provide accurate price signals to customers and let them decide whether to continue consumption at higher prices or to cut electricity usage during peak times. Under dynamic pricing schemes, utilities charge different rates for electricity based on time, generating cost, and conditions of the grid; hence customers are exposed to some level of electricity price volatility.

There are many types of dynamic pricing policies. The most common ones include time-of-use pricing, critical peak pricing, and real-time pricing.

- **Time-of-Use Pricing (TOU)** sets and publishes electricity prices for different time periods in advance. Electricity prices in peak periods are higher than off-peak, which encourages customers to shift electricity consumption to a lower cost period and reduce the peak demand. The rates for each time block are usually adjusted two or three times each year to reflect changes in the wholesale market; however TOU does not address unforeseen weather conditions or equipment failures.
- **Critical Peak Pricing (CPP)** is similar in rate structure to TOU pricing, but it adds one more rate that can vary with the wholesale market. Electricity prices during a limited number of hours of the year, which refer to the "critical peak hours," rise to levels designed to recover the full generation cost, while electricity prices during other times are lower than the critical periods. There can be a number of CPP event days in a year, and utilities usually will notify customers of the events and rates ahead of time.
- **Real-Time Pricing (RTP)** reflects the hourly or an even smaller time-interval marginal cost of electricity, which can be announced at the beginning of the time period or in advance. RTP can capture most of the true variation in the wholesale market, but it gives customers little time to react to price changes [27]. Technology innovations of the last decade have enhanced customers' ability to respond to real-time prices, and eliminated the conflicting issues between greater advanced price notification and more accurate price signals, enabling the greater use of RTP [27].

Compared to flat rate pricing scheme, dynamic pricing is more effective in promoting energy conservation. There is misperception that customers may be averse to dynamic pricing due to the price volatility and the possibility of paying higher bills; some also argue that customers are insensitive to real-time prices [28]. Research has shown that residential customers generally respond to higher electricity prices by reducing consumption, and both TOU and CPP rates could induce reduction in peak demand [29]. There is also empirical evidence that most low-income customers would save money on their utility bills from dynamic pricing, rather than being negatively affected [30]. Moreover, dynamic pricing may also remove the subsidies embodied in flat rates, which are preserved for social policy reasons but are actually barriers to energy conservation [28].

Enabling dynamic pricing schemes requires the deployment of AMI, which costs from \$100 to \$200 per meter; however, these costs can be offset by various operational benefits, as well as savings from reduced peak load and avoided capital investment for additional power generation facilities [31]. For instance, the annual long-run benefits associated with a 5% reduction in peak demand in the United States are projected to be \$3 billion, representing a discounted present value of \$35 billion over a 20-year time horizon [31].

Renewable Energy Subsidies and Regulations

Renewable energy is an essential part of smart grids. Policy makers have developed both financial and regulatory policies to encourage power generation from renewable energy sources, such as feed-in tariffs (FITs) and renewable electricity standards (RES).

FITs are one of the most widely used policy mechanism in the world to encourage the deployment of renewable energy technologies and expansion of renewable energy generation. FITs provide guaranteed long-term purchase agreements for electricity generated from renewable energy sources. Governments usually offer a price for every kilowatt-hour (kWh) of electricity produced based on the types of generation technology, system capacity, and project location. The tariffs might decline over time to track and encourage technology innovation and cost reduction. By 2010, 75 jurisdictions (countries, states, and provinces) have enacted a FIT policy, some of which are developing countries like China, India, Tanzania, and Kenya [32]. FITs create an open and straightforward framework, which not only ensures the long-term stability of revenue from electricity sales, but also reduces risks and overall costs of renewable energy development for society [33]. By 2008, FITs had driven the deployment of 75% of global photovoltaics and 45% of global wind [34].

An RES sets a minimum requirement for the percentage of generation or installed capacity to be provided by renewable energy. Most RES policies require a 5–20% share for renewable energy to be achieved by 2020 and beyond. To achieve RES targets, entities are often allowed to trade renewable energy certificates (RECs), with each certificate representing the certified generation of one unit of renewable energy (typically 1 MWh). As of 2010, RES policies have been implemented by 10 national governments, and 46 state/provincial governments around the world [32].

Other

Many other policies have been designed to address issues in the development process of smart grids, such as consumer protection rules and energy storage policy. Consumer protection rules are particularly important as they create a fair marketplace for both consumers and suppliers [10]. In general, this type of policy includes mandatory disclosure statements and terms and conditions for the contract, which help customers better understand smart grid services. Policy makers also set up rules that regulate the access and usage of customers' personal information and energy consumption data by electric utilities, customers, and third parties. Utilities often have to receive customer consent before releasing the data to a third party.

The inclusion of energy storage systems in grid design and operation can benefit the deployment of smart grid technologies. Related policy issues include cost

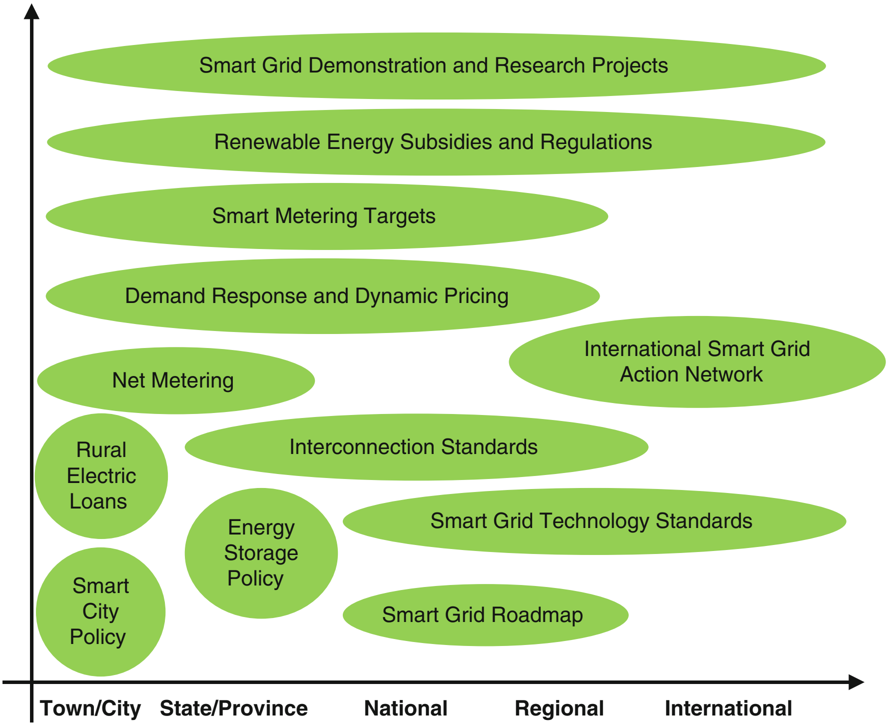


Fig. 9.4 Smart grid policies: moving from the local to the international scale

recovery models of energy storage technologies, incentives to increase private investment, and coherence between energy storage and electric vehicle policies [35]. California is one of the few states that have adopted an energy storage policy. This policy sets up mandatory requirement for developing energy storage systems in the grid. Electric utilities have to procure energy storage systems with a total installed capacity equal or larger than certain percentage of their total peak demand.

Other policies include smart-grid technology standards, customer privacy protection laws, rules governing the ownership of renewable energy credits, smart city policies, and approaches that are tailored to meet the needs of particular regions or market sectors. As shown in Fig. 9.4, these policies span the geographic scale from the local to the international.

Smart-Grid Policies of the United States: Federal Efforts

The United States has been a pioneer in pursuing a low-carbon economy. The government recognizes that a smarter, modernized, and expanded electric system is essential to America’s world leadership in a clean-energy future [36]. Development

Table 9.2 Recovery Act overview [39]

Projects	Total obligations (in million $, 2009)	Number of award recipients
Smart grid investment grant	$3,483	99
Smart grid regional and energy storage demonstration projects	$685	42
Workforce development program	$100	52
Interconnection transmission planning	$80	6
State assistance for recovery act related electricity policies	$49	49
Enhancing state energy assurance	$44	50
Enhancing local government energy assurance	$8	43
Interoperability standards and framework	$12	1

of policies has occurred at both federal and state levels to facilitate the evolution toward a twenty-first-century grid. This section first summarizes major policy efforts of the federal government, and provides a stakeholder analysis of the smart grid policy regime in the United States.

Smart-Grid Legislation and Policy Context

In 2005, Congress passed the Energy Policy Act of 2005, which directs utility regulators to consider time-based pricing and other forms of demand response for their states [19]. Utilities are required to provide each customer a time-based rate schedule and a time-based meter upon customer request [19]. The Energy Independence and Security Act (EISA) of 2007 is the key legislation for modernizing the nation's electricity transmission and distribution system. Title XIII of EISA mandates the Secretary of Energy to establish a smart grid advisory committee and a smart grid task force, to assess the impacts of smart grid deployment, and to take the lead in smart grid technology research, development and demonstration projects [37]. It also requires the National Institute of Standards and Technology (NIST) to develop a smart grid interoperability framework that provides protocols and standards for smart-grid technologies [37]. Under Section 1306 of EISA, a smart grid investment matching grant program was established to provide reimbursement of 20% of qualifying smart-grid investments [37].

The American Recovery and Reinvestment Act (ARRA) of 2009 accelerates the development of smart-grid technologies by appropriating $4.5 billion for electricity delivery and energy reliability modernization efforts [38]. Utilities and other investors can apply stimulus grants to pay up to 50% of the qualifying smart grid technology investments. To date, the Smart Grid Investment Grant (SGIG) has 99 recipients, with a total public investment amounting to$3.5 billion [39]. Table 9.2 shows the total obligations and award recipients for the projects authorized by the Recovery Act.

Building on the policy direction set forth in the key legislation, the Federal government published "A Policy Framework for The 21st Century Grid: Enabling Our Secure Energy Future" in June 2011 [36]. This framework identifies and highlights policies that form the nation's overall grid modernization efforts, presenting them within the context of four policy goals: enabling cost-effective smart-grid investments, unlocking the potential for innovation in the electric sector, empowering consumers and enabling them to make informed decisions, and securing the grid [36].

Roles of Government Agencies

The federal government's commitment to grid modernization has spurred efforts of many federal agencies and organizations. DOE is leading the nation's efforts in research, development, and demonstration of smart-grid technologies, and FERC and NIST have been actively engaged in smart-grid technology standard development and implementation. Deployment of smart grids is also closely linked with tasks and missions of many other departments, such as the Environmental Protection Agency's clean energy and climate change initiatives, the Department of Homeland Security and Department of Defense's interest in the security and resiliency of electric grid, and the Department of Commerce's focus on clean energy technology innovation. A summary of responsibilities of major US government agencies is presented in Table 9.3.

Deployment of smart grids involves a wide array of stakeholders, ranging from electricity utilities, consumers, and manufacturers, to government officials. It is critical to understand the impacts of smart-grid deployment on every stakeholder, and his/her potential influences in smart grid policy-making process. Regulatory framework are expected to take into account the conflicting goals and create aligned incentives for various groups. Table 9.4 presents a stakeholder analysis for smart-grid policies in the United States.

Smart-Grid Policies of the United States: State and Local Efforts

The scope and pace of smart-grid deployments naturally vary according to the diverse needs, regulatory environments, energy resources, and legacy systems of different states. Decentralized smart-grid deployment efforts provide local flexibility and stimulate experimentation and innovation in policy design and implementation. Thus, it is useful to examine smart-grid policies developed at the state and local level [138]. In this section, four US states are selected for in-depth investigation: California, Georgia, New York, and Texas.

Table 9.3 Roles of US governmental entities in smart-grid deployment

Agencies	Responsibility
Federal energy regulatory commission (FERC)	Facilitate smart-grid development via its regulations for electricity transmission and wholesale sales: Approve and enforce mandatory reliability standards for bulk power systems Adopt interoperability standards and protocols Provide guidance for the development of smart-grid standards
Department of energy (DOE)	Implement Recovery Act funds for smart-grid deployment Conduct research and development of smart-grid technologies and policies Monitor the progress of smart-grid deployment
Department of agriculture (USDA)	Support grid modernization in rural areas Provide loans for generation, transmission, and distribution of renewable energy
National institute of standards and technology (NIST)	Develop standards for smart-grid technologies Communicate with industry groups to accelerate the adoption of new standards
Smart grid task force	Ensure awareness, coordination and integration of the diverse activities of the federal government related to smart-grid deployment
State public utility commissions	Develop rules to implement state and federal smart grid legislations, such as: Smart-grid standard Dynamic pricing schemes Net metering and interconnection requirements

California

California is one of the leading states in the United States driving the deployment of smart-grid technologies. Its policy efforts are discussed in detail in the following section.

- Net Energy Metering Tariffs
  According to Section 2827 of California Public Utilities Code, all electric utilities in California, except the Los Angeles Department of Water and Power, are required to offer net energy metering (NEM) tariffs to customers who install small solar and wind while investor-owned utilities generation facilities are also required to offer NEM tariffs to biogas and fuel cell customer-generators [40]. NEM tariffs are applicable to qualifying facilities (1 MW and less) in residential, commercial, industrial, and agricultural sectors. The cumulative generating capacity of eligible customer-generators is not to exceed 5% of an electric utility's aggregate customer peak demand.

  NEM customers can get compensation from utilities for electricity generated in excess of on-site load. Net excess generation will be credited to customers' next bill at the retail rate. By the end of a 12-month period, customers can choose to roll over credit indefinitely or to receive financial compensation for credit at a rate that is determined by the California Public Utility Commission (CPUC).

Table 9.4 Stakeholder analysis of smart grid policies

Stakeholder	Pros	Cons	Dominant position	Potential impact on smart grid deployment
Federal government	Job creation, affordable energy, economic competitiveness, energy security, deployment of clean energy resources, emissions reductions	Costs of smart grid demonstration and research projects; reluctance to pick technology winners	Very favorable	High
State legislatures and utility commissions	Job creation, energy security, deployment of renewable energy, emissions reductions	Cost recovery of smart grid investments, vulnerability to cyber attack	Very favorable to slightly favorable	High
Electric utilities	Reduction in peak load, improved grid stability, improved operational efficiency	Reduction in electricity sales, higher workloads vulnerability to cyber attack	Mixed	High
Smart grid and renewable manufacturers	Increased technology and product sales	None	Very favorable	Medium
Conventional energy companies	None	Reduction in sales of fossil fuels	Unfavorable	High
Environmental groups	Decreased emission of criteria air pollutants and greenhouse gases	None	Very favorable	Medium
Customers	Better energy management, reduced energy bill new products and services	Increased risk of privacy invasion, investment costs	Mixed	Low

Table 9.5 Deployment of smart meters by California's large utilities [44–47]

	Pacific Gas and Electric Company	San Diego Gas and Electric Company	Southern California Edison Company
Goal	5.1 million electric meters; 4.2 million gas meter modules	1.4 million electric meters; 0.9 gas meter modules	5.3 million electric meters
Total costs	Ratepayer funding for $1.74 billion approved; $466.76 million approved for proposed project upgrade	$572 million approved	$1.63 billion for upgrade requested
Net benefits	$103.9 million	$40–$51 million	$9–$304 million
Deployment timeline	2007–2011	2007–2011	2008–2012

The owner of renewable DG facilities owns the RECs associated with the electricity generated from the facilities, but utilities could receive RECs for the excess electricity that they have compensated the customers.

- Interconnection Standards: Rule 21

  In 1999, the CPUC instituted rulemaking to address interconnection issues [41], becoming one of the first utility commissions to do so. The resulting Rule 21 has been revised continuously to keep consistency with the requirements of the ANSI/IEEE interconnection standards [42]. Rule 21 mandates that DG facilities meet standard interconnection, operating, and metering requirements. Applicants pay an $800 initial review fee and a $600 supplemental review fee before the utility evaluates the interconnection of the generating facility. For generating facilities that cannot be interconnected to a utility's distribution system via simplified interconnection, additional interconnection studies and fees are required. Rule 21 exempts eligible customers for net energy metering under Public Utilities Code Section 2827 from paying for costs associated with application review fees, interconnection studies, and distribution system modifications. However, eligible customers are responsible for all costs associated with their interconnection facilities.
- Smart Metering Targets

  In 2004, the CPUC directed the three largest investor-owned utilities (IOUs) in California to submit AMI business case analyses and deployment proposals [43]. The three utilities have developed deployment plans for smart meters as part of their smart-grid roadmap and have been given authorization to deploy smart meters throughout their territories (see Table 9.5). The deployment of smart meters is expected to be completed in 2012, when approximately 12 million electric meters and 5 million natural gas meters will be installed, generating hundreds of millions of dollars in net benefits.
- Smart-Grid Legislation

  California passed Senate Bill (SB) 17 in 2009, which establishes regulatory approaches for the CPUC and utilities to deploy smart-grid technologies. The goal of this bill is to maintain reliable and secure electrical service with infrastructure that can meet future growth in demand, and to achieve other objectives such as the integration of DG resources, demand-side resources, and smart technologies [48]. SB 17 required the CPUC to create a smart grid deployment plan, which laid the groundwork for all IOUs to submit their smart grid deployment plans to the CPUC. The CPUC is also required to conduct impact assessments on relevant state energy initiatives, such as the deployment of AMI, the RES, and greenhouse gas emissions reduction. The bill requires that standards adopted for California be compatible with standards from NIST, FERC, the Gridwise Architecture Council, IEEE, and the North America Electric Reliability Cooperation (NERC). If utilities fail to meet the standards or to present a plan to meet them by the deadline, they will be subject to a penalty.

To facilitate the implementation of SB 17, the CPUC set detailed requirements for utilities' smart-grid deployment plans. Utilities must present a vision of smart grid that is consistent with the legislative initiatives, requiring at least eight topics in their deployment plan, including smart-grid vision statement, deployment baseline, smart-grid strategy, grid security and cyber security strategy, smart-grid roadmap, cost and benefits estimates and metrics [49].

- Customer Privacy Protection Rules
  SB1476 on customer privacy related to AMI became effective in 2010. This bill prohibits utilities from sharing, disclosing, or making accessible to any third party a customer's electrical or gas consumption data [50]. It also requires utilities to protect customers' energy consumption data from unauthorized access, destruction, use, modification, or disclosure, as well as to allow customers to access the data without being required to agree to share their personally identifiable information with a third party [50].
- Dynamic pricing
  The CPUC mandated that dynamic pricing tariff options for all types of customers should be addressed in each utility's comprehensive rate design proceeding application [51]. Furthermore, the CPUC directed each utility "to incorporate default critical peak pricing tariffs for large customers into their next comprehensive rate design proceeding or other appropriate proceeding if directed by the Commission" [52]. In 2010, the CPUC directed the Pacific Gas and Electric Company to implement default and optional critical peak pricing and time-of-use rates (together, referred to as Peak Day Pricing) (see Table 9.6) [53]. There will be between 9 and 15 Peak Day Pricing event days for each calendar year, and for their first year on a Peak Day Pricing rate scheme, customers will be afforded bill stabilization and can choose to opt out any time [53].

  Southern California Edison Company has also developed several dynamic pricing schemes. It offers voluntary CPP for all its customers, real-time pricing rates to customers with monthly peak demand greater than 500 kW, and agricultural and pumping real time pricing rates to customers who use 70% or more of the electricity for general agricultural purposes, or for general water or sewage pumping [54].
- Energy Storage Bill
  The California State Assembly passed the nation's first energy storage bill (Assembly Bill 2514) in September 2010. This bill mandated utilities to procure

Table 9.6 Pacific Gas and Electric Company peak day pricing transition plan [53]

Applicable sector	Type of rates	Options
Residential customers with advanced meters	Peak day pricing; non-time-differentiated residential tiered rates	Allows customers to transition to either of the two rates
Large commercial and industrial customers (≥200 kW)	Peak day pricing rates that include time-of-use rates during non-peak day pricing periods	Default; Allows customers to opt out to a time-of-use rate or other time-variant rate
Small and medium commercial and industrial customers (≤200 kW)	Peak day pricing rates that include time-of-use rates during non-peak day pricing periods	Default; Allows customers to opt out to a time-of-use rate or other time-variant rate
Large agricultural customers (≥200 kW)	Peak day pricing rates that include time-of-use rates during non-peak day pricing periods	Default; Allows customers to opt out to a time-of-use rate or other time-variant rate
Small agricultural customers (≤200 kW)	Time of use	Default

new grid-connected energy storage systems [55]. Before October 2013, the CPUC will determine two energy storage procurement targets for utilities to achieve by 2015 and 2020 [55].

- Distributed Generation and Renewable Energy Credits

  Because RECs are critical to the cost-effectiveness of renewable DG facilities, the CPUC has issued several decisions to clarify the participation of renewable DG in the renewable electricity standards. Specifically, "the owner of the renewable DG facilities owns the RECs associated with the generation of electricity from those facilities" [56]. Decision 07-01-018 further states that "utilities will not be counting the output of renewable DG facilities that have received ratepayer incentives toward their renewable portfolio standard obligations." In other words, renewable DG facility owners will retain the RECs produced by their facilities irrespective of whether or not they receive ratepayer funding from programs such as SGIP (see below) or net metering [57].

  The CPUC established the Self-Generation Incentive Program (SGIP) to encourage the development and commercialization of DG technologies. SGIP provides financial incentives to certain entities that install DG (such as micro-turbines, small gas turbines, wind turbines, photovoltaics, fuel cells, and internal combustion engines) to offset some portion of the customer's on-site load (see Table 9.7) [58]. Due to insufficient funds, the SGIP was terminated in early 2011 [59].

Georgia

Georgia has a broad array of dynamic pricing programs, but relative to California its net metering and interconnection standards are more restrictive. The State also has one of the lowest rates of renewable electricity generation in the country [60].

Table 9.7 Financial incentives and eligibility of the SGIP [57]

Incentive category	Incentive offered	Maximum percentage of project cost (%)	Eligible system size	Eligible technologies
Level 1	$4.50/W	50	30 kW	~1 MW
	Photovoltaics;			
		Fuel cells operating on renewable fuel; Wind turbines		
Level 2	$2.50/W	40	≤1 MW	Fuel cells operating on nonrenewable fuel and utilizing sufficient waste heat recovery
Level 3	$1.00/W	30	≤1 MW	Microturbines utilizing sufficient waste heat recovery and meeting reliability criteria; Internal combustion engines and small gas turbines, both utilizing sufficient waste heat recovery and meeting reliability criteria

- Net Metering
  Georgia General Assembly passed the Georgia Cogeneration and Distributed Generation Act of 2001 to encourage private investment in renewable energy [61]. This act requires utilities to provide net metering for all eligible customers. DG facilities are customer-owned and they use photovoltaic systems, wind turbines, and/or fuel cells. The peak generating capacity of eligible systems must be smaller than 10 kW for residential customers and 100 kW for commercial customers. The cumulative generating capacity of net-metered systems is limited to 0.2% of a utility's annual peak demand in the previous year (recall that California's cap was much higher, at 5% of an electric utility's aggregate customer peak demand). Utilities are required to offer bidirectional or single directional metering depending on how the DG facilities are installed. Systems connected on the customer's side of the meter are required to use a bidirectional meter, and any net excess generation will be credited to the customer's next bill at tariffs filed with the Georgia Public Service Commission. Systems connected on the utility's side use a single directional meter, and the customer will be charged with a minimum monthly service fee.
  In particular, solar photovoltaic generation is encouraged under Georgia's net metering policy scheme. Georgia Power, the dominant utility in the state, operates the Solar Buyback Program, which allows customers to sell electricity produced by solar panels [62]. Georgia Power is responsible for meter installation, but it charges a $3.97 and a $1.31 monthly metering fee, respectively, for single directional metering and bidirectional metering. The solar purchase tariffs are subject to change according to state policies. Through 2010, the Solar

Purchase Price was 17 cents per kWh, and the aggregate energy purchases were limited to 2.9 MW. Starting in 2011, solar photovoltaic electricity is purchased at Avoided Solar Cost.

- Interconnection Standards
  The Cogeneration and Distributed Generation Act of 2001 allows certain residential (smaller than 10 kW) and commercial (smaller than 100 kW) facilities that use photovoltaic system, wind turbines, and fuel cells to interconnect and receive net metering tariffs from utilities [61]. This act requires customers to meet applicable interconnection requirements, such as the National Electrical Code, National Electrical Safety Code, and the IEEE standards.
- Smart Metering Targets
  Georgia Power has installed about one million smart meters since 2008, and it plans to provide every customer with a smart meter by the end of 2012 [63]. No additional service charge will be added to customers' energy bill. Few of these smart meters provide real-time information to consumers; they mostly automate the collection of consumption data by the utility.
- Dynamic Pricing
  Georgia Power has been very successful in implementing dynamic pricing programs. An array of dynamic pricing programs is offered to various types of customers, with electricity rates ranging from 1.25 cents per kWh during super off-peak time to 19.29 cents during on-peak hours (see Table 9.8). For instance, TOU rates are available to residential customers and electric vehicle owners, as well as small, medium, and large businesses. RTP for some customers are based on day-ahead or hour-ahead power supply prices. In 2005, Georgia Power's commercial and industrial real-time pricing programs alone had 1,600 participants, which represented over 5,000 MW of qualifying load [64].

New York

The State of New York was one of the first states to develop standard interconnection requirements, which specified application fees as well as limits to customer costs for interconnection equipment.

- Net Metering
  New York Public Service Law requires utilities to provide interconnection and net metering for solar, wind, farm waste, micro-CHP, and fuel cell generating facilities [66]. The generating capacity cap varies by technology and sector (see Table 9.9). The aggregate generating capacity cap for wind was 0.3% of a utility's total electric demand in 2005, and the aggregate generating capacity cap for solar, biogas, micro-CHP, and fuel cell systems combined is set at 1.0% of a utility's 2005 electric demand (this is between the lower value for Georgia and a higher value for California). The New York State Public Service Commission (PSC) and utilities are encouraged to increase the cap for aggregate generating capacity.
- Interconnection Standards

Table 9.8 Dynamic pricing programs offered by Georgia Power Company [65]

Applicable customers	Type of rates	Electricity rate (cents per kWh)	
Residential	Time-of-use rate	On-peak: 2–7 pm, Mon–Fri, June–Sept	19.29
		Off-peak: all hours not included above	4.36
Plug-in electric vehicle	Time-of-use rate	On-peak: 2–7 pm, Mon–Fri, June–Sept	19.29
		Off-peak: 7 am–11 pm for weekends, holidays, and Oct–May; 7 am–2 pm and 7 pm–11 pm, Mon–Fri, June–Sept	5.83
		Super off-peak: 11 pm–7 am, Mon–Sun for all calendar months	1.25
Small business	Time-of-use rate	On-peak: 2–7 pm, Mon–Fri, June–Sept (not including holidays)	16.17
		Off-peak: all hours not included above	June–Sept: 7.30 Oct–May: 7.30 for the first 1,500 kWh; 2.79for usage above 1,500 kWh
Medium Business	Time-of-use rate	On-peak: 2–7 pm, Mon–Fri, June–Sept (not including holidays)	11.69
		Shoulder: 12–2:00 pm and 7–9 pm, Mon–Fri, June–Sept (not including holidays)	5.61
		Off-peak: all hours not included above	2.11
Large business	Time-of-use rate	On-peak: 2–7 pm, Mon–Fri, June–Sept (not including holidays)	9.56
		Shoulder: 12–2:00 pm and 7–9 pm, Mon–Fri, June–Sept (not including holidays)	4.32
		Off-peak: all hours not included above	1.51
Customers with a peak 30-min demand larger than 250 kW each month	Real time pricing – day ahead	Hourly prices are determined each day	
Customers with a peak 30-min demand larger than 5,000 kW each month	Real time pricing – hour ahead	Prices are updated each hour, 60 min before becoming effective	

Table 9.9 Generating capacity cap for eligible distributed facilities in the state of New York [66]

Applicable sector	Solar	Wind	Biogas	Micro-CHP and fuel cells
Residential	25 kW	25 kW	–	10 kW
Nonresidential	2 MW	2 MW	–	–
Farm-based	–	500 kW	1 MW	–

The New York PSC first developed the Standard Interconnection Requirements (SIR) for DG units in 1999, and has amended it many times [67]. The SIR of 2010 contains interconnection and application procedures for distributed facilities 25 kW or less and systems between 25 kW and 2 MW [68]. There is no application fee for applicants proposing to install systems 25 kW or less, but they are responsible for costs of installing the dedicated transformers and other safety equipment if deemed necessary. For systems above 25 kW and up to 2 MW, a nonrefundable $350 application fee is required, and the utility will conduct a preliminary review and a coordinated electric system interconnection review to determine if the proposed facility results in any relay coordination, fault current, and/or voltage regulation problems. The SIR also determines the maximum expense for interconnection equipment that has to be paid by customers. For technical standards, the SIR sets requirements for the design and operation of DG facilities, which are consistent with the IEEE standard 1547.

- Smart Metering Targets
  In an order issued in 1997, the New York PSC views advanced metering as a potential way to develop a robust and competitive retail market [69]. Eligible large commercial and industrial customers were to have the option of owning a Commission-approved meter. Utilities are to provide at least 24 months of customer's energy consumption data at no cost upon a customer request; and they will provide any third party the same data with the customer's approval. This order also states that utilities will invest in smart metering technologies only if it is cost-effective. In 2006, the New York PSC adopted an order to encourage utilities' investment in cost-effective smart metering programs and pilot projects to test various proposals for smart metering deployment [70]. Utilities are also required to file plans and proposals for integrating smart meters into their systems.
- Dynamic Pricing
  In 2005, the New York PSC directed major utilities in the state to accelerate and implement mandatory hourly pricing (MHP) for their largest customers [71]. An order issued in 2006 requires major utilities to develop methods for deriving retail hourly prices, to assess the impacts of MHP, and to submit a report on program implementation [72]. Consolidated Edison Company of New York, Inc. was directed to offer MHP to customers with peak demand greater than 1,500 kW. As of July 2011, this program has been expanded twice and it is now available for customers with peak demand greater than 500 kW [73]. The 2006 order also mandates National Grid to implement MHP for its medium-sized

commercial and industrial customers, and requires New York State Electric & Gas Corporation, Rochester Gas and Electric Corporation, and Orange & Rockland Utilities, Inc., to implement MHP for their time-of-use customers at or above 1,000 kW [72]. In 2011, New York PSC approved Rochester Gas & Electric's plan for expanding its MHP program to customers with peak demand greater than 300 kW, which would add an additional 585 MHP customers to this program [74].

Texas

Texas is the only one of the four States examined in this chapter that requires utilities to offer unlimited cumulative generating capacity under their net metering programs.

- Net Metering

  Texas does not have a statewide net metering policy; however, utilities can, but are not required to, compensate customers for electricity that is generated from distributed renewable resources and sent back to the grid. According to the Public Utility Commission of Texas (PUCT), utilities in Texas are required upon customers' request to provide one or two meters that can separately measure both the inflow and outflow of electricity [75]. Qualifying facilities include distributed renewable generators with a capacity up to 2,000 kW [75]. Beginning in 2009, the PUCT requires each utility to offer qualifying renewable generation facilities that have an aggregate design capacity of 50 kW or less the option of interconnection through a net meter [76]. Excess generation will be purchased by utilities at the avoided cost, and there is no limit on the cumulative generating capacity under the net metering program [76].

  Many municipalities and large utilities in Texas have their own net metering programs. For instance, Austin Energy offers a net metering program for renewable energy systems with a generating capacity less than 20 kW [77]. Eligible technologies include solar, wind, geothermal, hydroelectric, wave and tidal energy, biomass, and biomass-based waste products.
- Interconnection Standards

  PUCT rules address the technical and procedural aspects of interconnection of on-site DG facilities [78, 79]. The rules establish interconnection standards that apply to generating facilities with a maximum capacity of 10 MW and connection at a voltage less than 60 kV. In particular, requirements for generators, network interconnection of DG, and control, protection, and safety equipment are specified to ensure safety and reliability of the interconnection. Customers who fail to comply with the standards may be disconnected from the grid. Pre-interconnection studies and fees will be considered based on the characteristics of DG facilities; for instance, customers with DG facilities less than 500 kW that export less than 15% of the total load and contribute less than 25% of the

Table 9.10 Deployment of smart meters by the three largest utilities in Texas

	Center point	Oncor	AEP Texas
Goal	2.1 million electric meters	3.4 million electric meters	1.1 million electric meters
Achievement as of August 31, 2010	615,518 electric meters	1,251,838 electric meters	78,705 electric meters
Deployment timeline	2009–2012	2008–2012	2009–2013

maximum potential short circuit current on a single radial feeder will not be charged with the pre-interconnection study fee [78].

PUCT also published a Distributed Generation Interconnection Manual to help utilities process interconnection applications. It includes safety and technical requirements of DG installations, applicable rules, application procedures and forms, Texas utility contacts, and equipment pre-certification requirements [80]. Texas utilities are required to evaluate applications based on prespecified criteria, including equipment size and the relative size of the DG system to the feeder load.

- Smart Metering Targets
  Currently, there is no legislation that requires mandatory deployment of smart meters in Texas. However, the state legislature has taken actions to provide more regulatory incentives for smart meter deployment. In 2005, Texas passed House Bill (HB) 2129 to encourage energy saving measures. This bill recognizes the important role that smart meters can play in grid modernization and energy conservation, and encourages the deployment of smart meters by utilities in Texas [81]. It also directs the PUCT to establish a non-bypassable surcharge for a utility to recover reasonable and necessary costs incurred in deploying advanced metering and metering information networks [81]. A subsequent Texas law encourages the development of net metering and advanced meter information networks to allow demand-side energy management and to facilitate demand response initiatives [82].

  Although there is no mandatory smart metering policy, utilities in Texas have been very active in deploying smart meters. The three largest utility companies have all received approval from the PUCT regarding the deployment of smart meters in their territories (see Table 9.10) [83]. As of August 2010, two million smart meters have been installed, and the total number will reach 6.6 million by the end of 2013. Electric utilities in Texas also established the Smart Meter Texas web portal in 2010, which can provide 15-min energy usage data to retail electric providers and customers with a smart meter [84].
- Customer Privacy Protection Law
  HB2129 sets requirements regarding data security and privacy of smart meters. It states that all meter data, including data used to calculate charges for service, historical load data, and any other proprietary customer information, shall belong to a customer. A customer could allow retail electric providers (REPs) to access the data under rules and charges established by the PUCT [81].

- Dynamic Pricing
  A demand response study by FERC found that Texas has the most potential for demand response initiatives, with more than 18 GW expected by 2019 [12]. However, currently there is very little demand response in place, and no mandatory regulations on dynamic pricing. Nevertheless, several electric utility companies offer voluntary dynamic pricing rates. For instance, TOU rate is available for TXU Energy's residential customers who have had smart meters installed at their premises [83]. Participating customers pay 21.9 cent per kWh during summer afternoons (1–6 pm on weekdays from May to October), and 7.9 cent per kWh during off-peak hours.

Smart-Grid Policies of the European Union

The European Union (EU) is the second largest energy market in the world, with over 450 million customers [85]. The objective of European energy policies in the twenty-first century is to achieve a sustainable, competitive, and secure energy supply [86]. Deployment of smart grid forms an essential part of EU's climate change and clean energy initiatives, as it promotes revolution in traditional electricity markets and networks. This section summarizes EU's policies and regulations relating to the deployment of smart-grid technologies. It also examines the smart-grid policy efforts of two EU member countries: Italy and the UK.

Smart-Grid Legislation and Policy Context

- Directive 2001/77/EC
  This Directive requires member states to ensure the transmission and distribution of electricity produced from renewable energy sources without prejudice [87]. Member states are required to publish interconnection standards and rules to facilitate the integration of renewable energy sources into the grid. Transmission and distribution system operators shall provide a comprehensive and detailed estimate of interconnection costs upon customers' request, and publish standard rules regarding the sharing of installation costs.
- Directive 2003/54/EC
  This directive establishes common rules for electricity generation, transmission, distribution, and supply [88]. It mandates member states to publish technical rules and standards governing the interoperability of systems and interconnection activities. Member states are encouraged to implement energy efficiency/demand side management programs to achieve social, economic, and environmental objectives.
- Green Paper on Energy Efficiency or Doing More with Less (2005)
  This Green Paper calls for wide deployment of smart meters and implementation of dynamic pricing programs to promote more economical and rational energy

consumption [85]. Policies shall also be designed to encourage the shift from centralized generation to DG.

- Green Paper – A European Strategy for Sustainable, Competitive, and Secure Energy (2006)
  This Green Paper which was published in 2006 emphasizes that Europe has entered into a new energy era [86]. It provides suggestions and options that form the basis of a new energy policy scheme. This document proposes a European grid code that encourages harmonized grid access conditions and allows customers to purchase electricity and gas from suppliers in other member states. It also suggests that member states develop a plan to increase the interconnection levels between countries.
- Directive 2006/32/EC
  This directive aims to encourage cost-effective and efficient energy consumption in the EU. Member states are required to achieve an energy saving target of 9% by the ninth year of application of this directive. The deployment of appliances and information technologies in residential and commercial sectors will play a significant role in reducing electricity consumption in the future. For instance, this directive recommends intelligent metering systems as one of the eligible energy efficiency improvement measures [89]. Member states are encouraged to subsidize the deployment of improved metering and informative billing.
- Directive 2009/72/EC
  This directive recognizes that innovative pricing formulas, intelligent metering systems, and smart grids are important measures to promote energy efficiency [90]. It mandates member countries to conduct CBA of smart metering programs and requires that 80% of consumers shall be equipped with intelligent metering systems by 2020. This directive also mandates member countries to encourage the development of smart grids to promote decentralized generation and energy conservation.
- Conclusions of the European Council of February 4, 2011
  The Conclusions set the goal of adopting technical standards for electric vehicle charging systems by mid-2011 and for smart grids and meters by the end of 2012 [91].
- Communication “Smart Grid: From Innovation to Deployment”
  This Communication summarizes the current and past policy initiatives that address challenges to smart-grid deployment [92]. Five aspects of government efforts are highlighted: developing common European smart-grid standards, addressing data privacy and security issues, regulatory incentives for smart-grid deployment, smart grids in a competitive retail market in the interest of consumers, and continuous support for innovation and its rapid application.

Smart-Grid Standards

The Conclusions of the European Council of February 4, 2011 confirm that there is an urgent need to adopt European standards for smart grids. To date, the European

Commission (EC) has issued three mandates to European Standardization Organizations (ESOs) relating to European standardization policies.

- European Commission Standardization Mandate for Smart Meters (M/441)
  This mandate invites ESOs to develop European standards which will enable interoperability of smart utility meters (electricity, gas, water, and heat) [93].
- European Commission Standardization Mandate for Electric Vehicles (M/468)
  ESOs are requested to develop European standards or to review existing standards to ensure the interoperability and connectivity related to the charging of electric vehicles [94].
- European Commission Standardization Mandate for Smart Grids (M/490)
  This mandate requires ESOs to develop a framework that consists of technical reference architecture, a set of consistent standards and sustainable standardization processes and collaborative tools to enable the continuous standard enhancement and development in the field of smart grids [95].

Government Agencies and Organizations

The EC's Directorate-General for Energy leads the policy development and implementation of energy-related topics, such as smart grids, energy efficiency, security of energy supply, nuclear energy, and renewable energy. Its sub-Directorate B for Security of Supply, Energy Markets & Networks is the most active player in the EU smart grid policy arena. The work of the Directorate-General for Energy is supported by other important government agencies including the Agency for the Cooperation of Energy Regulators (ACER) and the Executive Agency for Competitiveness and Innovation (EACI).

In November 2009, the European Smart Grids Task Force was established to advise the EC on smart-grid policies between 2010 and 2020. It also coordinates and cooperates with other major stakeholders in this area to facilitate smart grids deployment in Europe, including the Smart Grids European Technology Platform, Smart Grids Forum, and the European Electricity Grids Initiatives (EEGI).

funding mechanisms

The research and development of smart-grid technologies have been receiving financial support from the Framework Program (FPs), the main financial tool through which EU supports research and development activities in a wide range of scientific subjects. The current FP – the Seventh FP (FP7) runs from 2007 to 2013, with a total budget of €50,521 million ($71.5 billion US dollars) [96]. Over the last decade, around €300 million ($424.4 million US dollars) has been spent on smart grid pilot projects [92].

The EC adopted the Recommendation on Mobilizing Information and Communications Technologies to facilitate the transition to an energy-efficient, low-carbon economy in October 2009 [58]. Information and Communications Technologies (ICTs) are seen as important contributors to the achievements of EU's energy and climate goals [97]. Many smart grid projects are funded by the FP-ICT for Energy Efficiency and the Competitiveness and Innovation Framework Program (CIP)-ICT Policy Support Program [98].

- The ADDRESS project
  Active Distribution Network with Full Integration of Demand and Distributed Energy Resources (ADDRESS) is a large-scale project funded by the EC under the seventh FP in the Energy area for the "Smart Energy Networks – Development of Interactive Distribution Energy Networks." The total budget for this project is €16 million ($23 million US dollars), with €9 million ($13 million US dollars) financed by the EC [99]. It is being carried out by a consortium of 25 partners from 11 European countries between 2008 and 2012, under the coordination of one of the largest utilities in Europe – Enel Distribuzione. Partners include universities, research institutes, distribution and transmission network operators, energy supply and retail companies, electric equipment manufacturers, home appliance manufacturers and consultants, and ICT providers and electric equipment manufacturers. The goal of this project is to enable the participation of small and medium customers in the electric market, and finally realize the vision of the European Smart Grids Technology Platform – developing a network that is flexible, reliable, accessible, and economic.

Smart-Grid Policies in Italy and the UK

- Italy
  In line with the provisions of Directive 2009/28/EC, the Italian government issued the "Italian National Renewable Energy Action Plan" in June 2010. The plan provides measures to encourage the modernization of transmission and distribution networks, the integrated management of various generation systems and loads (including electric vehicles), and power generation from renewable sources [100].

  The Interregional Operational Plan for Renewable Energy Sources and Energy Saving was approved by the EC in December 2007, with the aim to "increase the ratio of load supplied by renewable and the energy efficiency, promoting the local development opportunities in four Italian Southern regions: Campania, Puglia, Calabria, Sicilia" [101]. A total of €1.6 billion ($2.3 billion US dollars) was allocated to the program for the period of 2007–2013, with €803 million ($1.23 billion US dollars) provided by the European Regional Development Fund (ERDF) [101]. One focus of this program is to improve the infrastructure of transmission networks to promote renewable energy sources and

CHP generation, which receives €100 million funding from ERDF and Italian state funds [100]. In this context, the Ministry of Economic Development and Enel Distribuzione together launched a €77 million "Smart Medium Voltage Networks" project in southern Italy to make the medium voltage distribution networks more favorable to photovoltaic systems with installed capacity between 100 kW and 1 MW [100]. The Italian utility regulator (Autoritàper l' Energia Elettricaedil Gas) has awarded eight tariff-based financial projects on active medium voltage networks, to demonstrate at-scale advanced network management and automation solutions necessary to integrate DG [102].

Italy has one of the largest and most extensive smart metering programs in the world. Enel Distribuzione, the largest power company in Italy and the second listed utility by installed capacity in Europe, has already completed the installation of smart meters in its electrical distribution system. Thirty-two million customers can have access to more efficient and flexible services brought by smart meters, such as the hourly based tariff system introduced in 2005 [103]. The company has plans to install smart meters for its gas distribution grid, and extend the smart metering system to its distribution grids in Spain, where 13 million smart meters will be installed during the period 2010–2015 [103]. Enel Distribuzione also launched the E-mobility Italy program in three Italian cities: Rome, Milan, and Pisa in 2008 [104]. The program will deliver 100 electric vehicles to selected drivers in the three cities, and build 400 intelligent electric vehicle recharging stations.

- United Kingdom

  The renewable target for the UK is to generate 15% of its energy from renewables by 2020, which requires 30% of its electricity to come from renewables by that time [105]. The British government issued the Carbon Plan in 2011, which sets a firm, long-term and legally binding framework to cut emissions by at least 34% by 2020 and 80% by 2050 – below the 1990 baseline [106]. The British government sees smart grids as an effective approach to meet challenges of energy security and climate change, as well as to achieve a low-carbon economy. In the Carbon Plan, smart metering is identified as a way for energy efficiency improvements, as it can change consumer behavior. Under Sections 88–91 of the 2008 Energy Act, the Secretary of State is allowed to modify energy distribution and supply licenses to force the license holders to install or facilitate the installation of smart meters [107]. This Act also introduces the FITs for low-carbon electricity generation facilities with a generating capacity less than 5 MW. Eligible technologies include biomass, biofuels, fuel cells, photovoltaics, waves and tides, wind, solar power, geothermal sources, and CHP systems with a capacity of 50 kW or less.

  The Energy Bill 2010–2011, together with its provisions for the new "Green Deal," was first introduced in December 2010. It aims to facilitate the country's energy efficiency improvements by providing financial incentives to householders, private landlords, and businesses [108]. Smart metering is an essential part of the Green Deal.

In July 2010, the Department of Energy and Climate Change (DECC) and Office of the Gas and Electricity Markets (Ofgem) published the "Smart Metering Implementation Program: Prospectus" which sets out detailed proposals for the delivery of smart and advanced meters to all homes and small businesses in Great Britain. This prospectus sets design requirements, central communications, data management, and the rollout plan for the deployment of smart meters, and it seeks responses from the public on a number of questions [109].

DECC and Ofgem jointly published the government's response to the Smart Meter Prospectus in March 2011 [110]. According to this document, suppliers are required to provide smart meters to smaller nondomestic sectors, and both smart meters and in-home display (IHD) will be provided to domestic customers. Smart meter equipment and devices will have to meet the technical standards in the Functional Requirements Catalog, which was published alongside this document. With respect to privacy protection, customers will be able to choose how their consumption data is used and by whom, except where data is required for regulatory purposes. The British government expects full rollout of smart metering by 2019. It is estimated that over 50 million electricity and gas meters will be installed, with a total financial investment of over £11 billion ($17.6 billion US dollars) and a net benefit of more than £7 billion ($11.2 billion US dollars) [110]. However, a report published by the National Audit Office concludes that there is a high level of uncertainty with regard to the extent to which smart meters will bring changes in customers' energy consumption patterns [111]. It recommends DECC and Ofgem to develop benefits realization plans and customer engagement strategy to minimize the potential risk.

Smart-Grid Policies of Other Countries

Japan

The electricity supply in Japan is highly reliable with a power failure time per year/per household of only 16 minutes compared to 162 minutes in the U.S. [112]. However, Japan aims to reduce carbon emissions by 30% by 2030 compared to the 1990 level [113]. Renewable energy and energy efficiency are expected to play an important role in achieving this goal. Thus, smart-grid investments are needed.

Japan's deployment approach is slightly different from other countries. Smart-grid deployment is seen as creating an opportunity for Japanese industries to gain competitiveness in the global market. The concept of "smart community," which refers to a new, intelligent, and sustainable way of living, not only stimulates changes in the electricity market, but also motivates innovations in automobiles, telecommunications, and home appliances industries.

The Ministry of Economy, Trade and Industry of Japan (METI) is the major government agency responsible for smart-grid development. Its objectives are to enable further integration of renewable energy, facilitate the development of electric vehicles and the charging infrastructure, and create new services using smart meters and ICT networks [114]. In 2009, the METI invested over $73 million on three demonstration projects: Remote Island Smart Grid Project, Smart Charge Project, and Smart House Project. Technologies that were tested include battery storage, electric vehicle charging system, residential photovoltaics, fuel cells, and demand response appliances. In 2010, the METI launched four large-scale smart community pilot projects in Kansai Science City, Yokohama City, Kitakyushu City, and Toyota City [115]. The primary goal of these projects is to develop Community Energy Management Systems, which are a combination of technologies including smart meters, home energy management systems, building and energy management systems, electric vehicles, photovoltaics, and batteries. Four smart community demonstration projects located in the State of New Mexico (US), Hawaii (US), Lyon (France), and Malaga (Spain) have also been carried out by the New Energy and Industrial Technology Development Organization (NEDO), an administrative branch of the METI [116]. These projects aim to prepare for the large-scale introduction of renewable energy, power storage, and electrical vehicle management systems.

There have been increasing cooperation and collaboration between Japan's public and private sectors in the deployment of smart grids. For instance, the Japan Smart Community Alliance established by NEDO in 2010 provides a platform for the participation of a wide range of stakeholders, including industries, electric utilities, government agencies, and research institutes [117]. Toshiba Corporation, Tokyo Electric Corporation, and the Tokyo Electric Power Company are also working together to launch a venture into the commercialization of smart meters [118]. The large-scale deployment of smart meters will start from 2013, and the goal is to have smart meters installed in all households across Tokyo Electric Power's service area.

Another challenge faced by Japan is energy security, as over 90% of energy consumed by Japan is imported. The Japanese government's goal is to have 70% of its electricity generated from zero-emission sources, and almost double its energy independence by 2030 [113]. In order to achieve this target, the government is developing a FIT scheme to purchase renewable energy generated in Japan. The "New Purchase System for Photovoltaic Electricity" was launched on November 1, 2009 [119]. Surplus electricity generated from solar photovoltaics is purchased at ¥48/kWh ($0.59/kWh) for residential sector, and ¥24/kWh ($0.30/kWh) for industries, businesses, and schools. The buyback prices will decrease each year based on the innovation and price trends of solar photovoltaic technologies.

The Republic of Korea

The electric system of the Republic of Korea is more reliable and efficient compared to many other developed countries [120]. However, the country is highly dependent on imported petroleum and liquefied natural gas. It imports over 90% of the total energy consumed, and has only 2.7% produced from renewable energy sources [121]. The greenhouse gases emissions of Korea also are expected to increase more rapidly than many other developed countries: by 2035, its carbon emissions will increase 35% from the 2002 base line, compared to less than 15% for all the OECD countries [121]. Although as a non-Annex I Party, Korea does not have obligations to reduce carbon emissions under the Kyoto Protocol, the Korean government sets a voluntary goal of reducing its greenhouse gas emissions by 30% below the business-as-usual case by 2020 [121]. Reducing the nation's energy dependence and carbon intensity is one of the top priorities of the Korean government.

The deployment of smart-grid technologies has started since 2005. Korea launched the Power IT National Program in order to develop digital, environmental-friendly and intelligent electric power devices and systems, and advance Korean electric power and electrical industries [122]. Ten projects were selected for systematic implementation, including development of energy management systems, intelligent transmission and distribution networks, advanced substation automation systems, power equipment monitoring systems, power line communication ubiquitous technology, power semiconductor, and consumer portal systems.

In August 2008, President Lee Myung-bak announced "Korea's National Strategy for Green Growth," which proposes a total investment of 107 trillion won (US $101 billion) between 2009 and 2013[121]. The deployment of smart-grid technologies is a key part of this five-year plan. Among the 27 core green technologies listed in the national plan, more than one third is related to the development of smart grid and smart cities.

The Korea government has announced the "Smart Grid Road Map 2030" as a key step to build a low-carbon, green growth economy in the long run [123]. The roadmap will be implemented in five sectors: smart power grid, smart consumers, smart transportation, smart renewables, and smart electricity services. By 2030, a nationwide smart grid and 27,140 power charge stations for electric vehicles will be built; and the penetration rate of smart meters and AMI will reach 100% by 2020. Besides, Korea will have 11% of its energy from renewables, and achieve a maximum of 10% power reduction by 2030. The annual blackout time per household will be reduced from 15 min in 2012 to 9 min in 2030, and the power transmission and distribution loss rate will decrease from 3.9% in 2012 to 3.0% in 2030. A total of 27.5 trillion won ($25.85 billion US dollars) will be allocated for the technology development and infrastructure construction in this plan, which is expected to generate 50,000 new jobs every year and reduce a total of 230 million tons of greenhouse gases by 2030.

As a first step to implement the Road Map, the Korean government started a pilot program on Jeju Island in June 2009, which consists of a fully integrated smart grid system for 6,000 households, wind farms, and four distribution lines [124]. A total of $50 million public funds and $150 million private funds will be invested between 2009 and 2013. More than 100 companies from automobile, renewable, power, telecommunication, and home appliance industries participate in the program.

The People's Republic of China

Since the 1980s, China's energy consumption has been growing at an unprecedented rate due to the rapid development of its economy. Between 1990 and 2010, its electricity generation increased from 621.2 to 4206.5 Terawatt-hours (TWh) [125]. The nation's annual growth rate of electricity demand exceeded 10% in 2001 and reached 15% in 2003, exceeding the projected growth rate of 6% [126]. The country has experienced several power outages since 2005, and the shortfall in electricity has started to hurt China's economy [126]. In order to meet the increasing demand and secure economic growth, the Chinese government has increased its investment in electric infrastructure. In recent years, China also aims to make the transition from a traditional manufacturing economy to a high-tech and high value-added manufacturing and service economy. The new energy industry and transport system are two key sectors that receive government support.

In May 2009, the State Grid Corporation of China announced the plan for developing a national wide "strong and smart grid" in China by 2020 [127]. The Ultra High Voltage (UHV) transmission and highly efficient distribution transformer, which enable the expansion of transmission and distribution capacity and reduce loss are the key technologies to be developed and deployed. This plan shows that deployment of smart grids in China can be quite different from the rest of the world, especially from the developed countries. It focuses more on the transmission side than the distribution side, due to the fact that major power generation sources in China, such as coal and hydropower are located in remote areas, and there are huge disparities among power generation in different regions. Other reasons for the focus on transmission might be the relatively primitive structure at the distribution ends, and the unique asset ownership and management structure of utilities and electric markets [128].

The Amendment of the Renewable Energy Law (2009) urges utilities to develop and apply smart grid and energy storage technologies to improve grid operation and management, and facilitate the interconnection of distributed renewable energy [129]. The Chinese government also supports the construction of independent renewable micro-grids in areas not covered by power grids. Promoting the development of clean energy and smart grids is among the top priorities of the government, as noted in the 12th Five-Year Plan that became effective on March 14, 2011 [130–132].

The 12th Five-Year Plan sets separate targets for energy intensity (16% reduction by 2015), non-fossil fuel energy (11.4% of the total primary energy consumption by 2015), and carbon emissions per unit Gross Domestic Product (GDP) (17% reduction by 2015) [132]. Smart grids and clean energy technologies are seen as effective approaches to achieve these targets. New energy industry (nuclear, wind, solar, biomass, and smart grids) and new energy vehicle industry (plug-in hybrid vehicles and electric vehicles) are identified as two of the seven strategic emerging industries that would receive financial and regulatory support from the government. By 2015, several long-distance UHV transmission lines and 200,000 km of transmission lines (333 kV and above) will be constructed. The Plan also proposes the "Rural Electricity Supply Project" to upgrade the rural electric grid and meet the increasing demand of the rural areas. Some of the targets include: developing 1,000 photovoltaics demonstration villages, 200 green energy counties, 300 hydropower and rural electrification counties, and 10,000 MW small hydropower. Between 2011 and 2015, China will invest 286 billion yuan ($44 billion US dollars) in smart-grid deployment [133].

Countries are in different stages of smart-grid deployment. Smart-grid policies are often designed to address the needs and challenges faced by countries. Table 9.11 summarizes the energy and climate change targets of the five nations and regions, as well as the drivers and focuses of their smart-grid policies.

International Collaboration

The SmartGrids European Technology Platform was established in 2004, with an aim to enhance the level of coherence between the European, national, and regional efforts addressing smart grids. One important role of this platform is to cooperate with other countries, especially North America and Japan, to ensure international development paths for smart grids are complementary and consistent with the development of commercial products [134].

The IEA Implementing Agreement on Electricity Networks Analysis, Research and Development (ENARD) was developed by 14 IEA member countries in July 2006. Its mission is to provide comprehensive and unbiased information, data, and advice to key stakeholders and policymakers of the issues relating to current and anticipated developments in electricity transmission and distribution networks [135]. Some of the work programs that are closely linked to smart grids include Annex II (DG system integration), Annex III (infrastructure asset management), and Annex IV (transmission system issues). ENARD is currently focusing its activities within the IEA member countries; however, it is open to participation by non-IEA member countries, private sectors, and nongovernmental organizations.

Established in April 2010, the Global Smart Grid Federation (GSGF) brings together the key smart grid stakeholders around the world, such as US GridWise Alliance, Smart Grid Australia, Smart Grid Canada, Smart Grid Ireland, Korean Smart Grid Association, India Smart Grid Forum, and the Japan Smart Community Alliance [136].

Table 9.11 National targets, policy drivers and focuses by country

	Targets			
	Carbon reduction	Renewable energy (share of total primary energy supply)	Policy drivers	Policy focuses
USA	17% below 2005 level by 2020	Varies across states: CA – 33% by 2020 TX – 5,880 MW by 2020 NY – 29% by 2015 GA – no target	Power system reliability; Renewable energy and energy efficiency; Economic revitalization	Technical and operational standards; Smart meters; Dynamic pricing and demand response programs
EU	20% below 1990 level by 2020	20% by 2020	Renewable energy and energy efficiency; Carbon emissions reduction	Technical and operational standards; Smart meters
Japan	30% below 1990 by 2030	13% by 2030	Energy security; Carbon emissions reduction; Enhancing competitiveness of domestic industries	Smart community; Solar photovoltaic generation
Korea	30% below BAU by 2020	11% by 2030	Energy security; Carbon emissions reduction; Enhancing competitiveness of domestic industries	Smart power grid; Smart consumers; Smart transportation; Smart renewables; Smart electricity services
China	Carbon intensity: 17% below 2011 by 2015	11.4% by 2015	Economic development; Reducing power generation disparities between regions; Reducing energy/carbon intensity; Strategic economic restructuring	Ultrahigh voltage (UHV) regional transmission; Upgrading and modernizing urban and rural electric grid

Its goals are to facilitate the collaboration of governments and nongovernmental organizations, to support the development of smart-grid technologies and foster knowledge sharing. The International Smart Grid Action Network (ISGAN) was launched at the first Clean Energy Ministerial in Washington, D.C. in July 2010 to accelerate the development of smart-grid technologies at the global level. ISGAN focuses on five principal areas including policy, standards, and regulation; finance and business models; technology and systems development; user and consumer engagement; and workforce skills and knowledge [137]. It includes four projects: the global smart grid inventory, smart grid case studies, benefit-cost analyses, and toolkits and synthesis of insi^ghts for decision makers.

Future Directions

As the interoperability of technologies is essential for a large-scale and integrated deployment of smart grids, development of standards at the national and global level will be particularly important in the future. Establishment of lead agencies to coordinate efforts at various levels of governments would facilitate the standardization process, as well as address the cyber security issue across all sectors.

The electric power industry is facing tremendous opportunities and becoming increasingly important in the new emerging low-carbon economy. The costs required for a full deployment of the smart grid are large. Currently, government is still the key player in smart grid investments. This suggests the need for a policy framework that attracts private capital investment, especially from renewable project developers and communication and information technology companies.

A competitive electricity market that encourages variable business models could enhance the flexibility of the electricity system and support an increasing penetration of renewable generation technologies. Reforming the rate design mechanisms that are currently discouraging utilities' investment in advanced technologies, and ensuring that costs and benefits are shared among all stakeholders are also important future directions. Regulatory changes that remove barriers to a competitive energy market could also optimize overall operations and costs, hence increasing the net social benefits from smart grids.

As the deployment of smart grids progresses, demand response and DG may significantly reduce peak demand and make some generation facilities redundant. This requires sophisticated resource planning and CBA at the early stages of smart-grid deployment. Smart grid customer policies, such as dynamic pricing and customer protection, are highly dependent on the understanding of customer behavior. New policies should be developed based on social science studies on consumer feedback and behavior changes in response to smart grid technologies and regulations.

Collaboration on smart-grid standards and experience sharing of demonstration projects can reduce repetition and overlap in smart-grid deployment efforts. Sharing best practices can be particularly beneficial to those developing countries, where electricity infrastructure is expanding rapidly.

Conclusion

This entry underscores the novelty of emerging smart-grid policies. Along with the recent introduction of smart-grid technologies has emerged a new generation of regulations and fiscal policies to ensure that the public's interests are protected.

Access to real-time metered data is illustrative of the new issues requiring public regulation. States are beginning to set requirements regarding data security and privacy of smart meters. Texas, for example, has determined that all meter data, including data used to calculate charges for service, historical load data, and any other proprietary customer information, will belong to a customer; however, customers can allow retail electric providers to access the data under rules and charges established by the Public Utility Commission of Texas.

The ownership of renewable energy credits from customer-owned renewable facilities is another issue that is only now being clarified. The issue is important because RECs have significant economic value, and clear rules and regulations regarding their ownership could help reduce confusion and uncertainties associated with smart-grid investment. This policy issue is also contentious as it involves the design and consideration of several policy regimes, including renewable electricity standards, net metering, interconnection policies, and utility subsidies for renewable projects.

As is typical of emerging policies designed to address issues associated with technological innovations, there is great variability in the goals and the design of smart-grid policies.

- For example, while most states have net metering and interconnection standards, the specifics of these policies vary widely. Due to different preferences in promoting renewable technologies, eligible technologies and customer types vary across net metering and interconnection standards. The application and evaluation procedures for net metering and interconnection also reflect variations in grid safety and reliability concerns.
- Numerous different types of dynamic pricing rates have emerged over the past decade. As might be expected, different pricing regimes have gained prominence in different market segments. Most often, pilot projects have been first launched by large industrial customers, followed by commercial and large nonresidential customers. Variability among dynamic pricing rates also reflects the differences in the policy goals of cost recovery and demand response programs. In general, opt-out options and bill stabilization measures are provided for customer protection. Outreach and education activities are often conducted to increase public awareness of dynamic rates.
- There also is a wide array of policies to support DG-especially renewables. (More limited efforts have addressed the deployment of fuel cells and CHP systems.) Both regulatory policies and financial incentives are widely used to support DG investments. For example, 29 states have implemented a renewable electricity standard [20]. Financial incentive range from FITs to production tax credits, investment tax credits, and loans. To date, 34 states provide loan programs and 24 states provide tax credits for renewables [20].

Despite this wide-ranging policy variability, some policy principles are emerging:

- Cost estimation and allocation are critical, as they could facilitate investment in new smart grid infrastructures. Policies have also been designed to set up cost-sharing rules between the private and public sector, and sometimes, costs are allocated to all customers that benefit from the project. Government subsidies are often used to constrain interconnection costs to affordable levels. For instance, eligible customers for net metering in California are exempted from fees charged by the government, and pay only the costs associated with their interconnection facilities.

- CBA and evaluation metrics are becoming essential, and some government agencies are beginning to require the collection of such information. In some cases, government agencies will invest in smart metering technologies and will subsidize smart-grid investments only if planning and evaluation data show that the subsidies generate more benefits than costs.

Evidence from the past decade suggests that the rapid and widespread deployment of smart-grid technologies will not occur without supporting policies. This review of emerging smart-grid policies in the United States, European Union, Japan, Korea, and China suggests that considerable progress has been made to develop effective policy frameworks. Nevertheless, further advances are needed to harmonize policies across nations, states, and localities, and to learn from recent experiences with this new generation of electric grid technologies [138].

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