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Smart Grid as New Big Opportunity of Information and Communication Technology

Kazuyoshi HIDAKA
Affiliated Fellow

1 Introduction

The next generation power supply system, holding the promise of gaining higher reliability, lower cost, and reduction of load on the environment by utilizing Information and Communication Technologies (ICT), is often referred to as the Smart Grid. The smart grid may have a greater significance if viewed as an arena for the next stage of developments in ICT industries, providing a new social and economic infrastructure.

Major differences between the conventional electric power system and the smart grid are shown in Fig. 1.1,[3] The conventional electric power system consists of three components: generation (concentrated fire/water/atomic power generation), distribution (power transmission and distribution), and power consumption by the customers. The flow of electric power is unidirectional from upstream: generation, transmission, distribution, and then consumption. Advanced power systems, such as implemented in Japan, provide a flow of information, mainly used for detecting failures in the sections from generation to transmission.

The smart grid has additional system elements, e.g. distributed power sources that utilizes renewable energy such as solar power and wind-power generation, and stored power sources. On the customer side, they not only consume electricity, but also generate and store electricity using solar photovoltaics. New vehicles with electricity generation and storage functions, as well as electricity consumption, (such as the Plug-in Hybrid Electric Vehicle (PHEV)) will become involved in the distribution system. Two-way flow of electric power and information will take place among these constituent elements.

A still more importance change in the smart grid comes from electric appliances (e.g. air conditioners and refrigerators) and "electricity consuming artifacts" such as light fixtures: all of these will be connected to the network and constitute new elements that exchange information as along with consuming electricity.

In line with the global trend toward a low-carbon society, the effort to save energy has become a ubiquitous need in all areas of our activities including our personal lives, business operations, and local societies. The trend has also been giving support globally to accelerate research and development toward commercial realization of the smart grid. The reason underlying this trend is that, for social implementation of renewable energy sources (e.g. photovoltaic generation, wind-power generation) and sources expected to effect substantial reduction of CO_2 emission (i.e. PHEV), a high-level control system is needed to coordinate these new sources with conventional ones. In addition, further pursuit in saving energy requires visualization of electricity consumption, introduction of market mechanisms, and power supply control from the supply side, and all of these need higher-level control such as provided by the smart grid.

In the United States, where the power system is becoming decayed and outdated, introduction of the smart grid is an urgent necessity for enhanced reliability (electric outage prevention), promotion of demand control (saving energy), and introduction of distributed electric sources. Special emphasis here is placed on the demand control facilitated by the implementation of smart meters (see the discussion below). This approach is expected to have a substantial effect at a cost smaller than total renovation of the outdated distribution system,[4] and it also would contribute to the construction of a new social service infrastructure.

In Japan, not a few people have a skeptical view toward the U.S.-led way in which the smart grid implementation is promoted. One major reason for this is the fact that, in decisive contrast to the situation in the United States, Japan currently has a very stable power supply situation[6] and infrastructure supporting it. The move toward introduction of the smart grid in Japan is motivated by the desire to implement a management system that coordinates conventional power systems with the new array of next-generation environment/energy technologies such as photovoltaic power generation, wind-power generation and PHEV. Concerns on environmental issues, such as the reduction of CO_2 emission, are likely to add momentum toward a wider utilization of these technologies, but the subject of to what extent these motivations will affect the development of the "smart grid" is still controversial.

The original idea of the smart grid was to supply stable and environmentally-friendly electric power. It is quite understandable, therefore, that we often try to find the key to our future evolution in new electric power technologies and industries that are related – especially in conjunction with renewable energy and secondary batteries - to electric power generation, transmission, and power storage. This is not an erroneous view, but we should not overlook the potential expansivity of the areas that seem to be a subsidiary to the main stream. That is, let us not lose sight of the potentiality that a much scaled-up version of a communication network – many-fold greater in scale than the current Internet – is expected to emerge, having a huge impact on the technological and industrial aspects of our society in the future.

Especially in the United States, the move toward the smart grid has been gaining great momentum both in the government and industrial sectors. A group of leading companies in the ICT industry – Google, AT&T, Cisco, Oracle, and IBM – has entered into the technical development and business in this field. The current situation indicates that the economic circle in the United States sees this field as a coming important market for the ITC industry.

The smart meter, slated to be installed in households in coming years to bring the smart grid to practical use, will likely serve the role of an interface for connecting a variety of electric appliances and sensors to the external communication network, leading these "electricity consuming artifacts" in each household more and more into the arena of Internet connectivity, in addition to the heretofore actor, i.e. "people." As

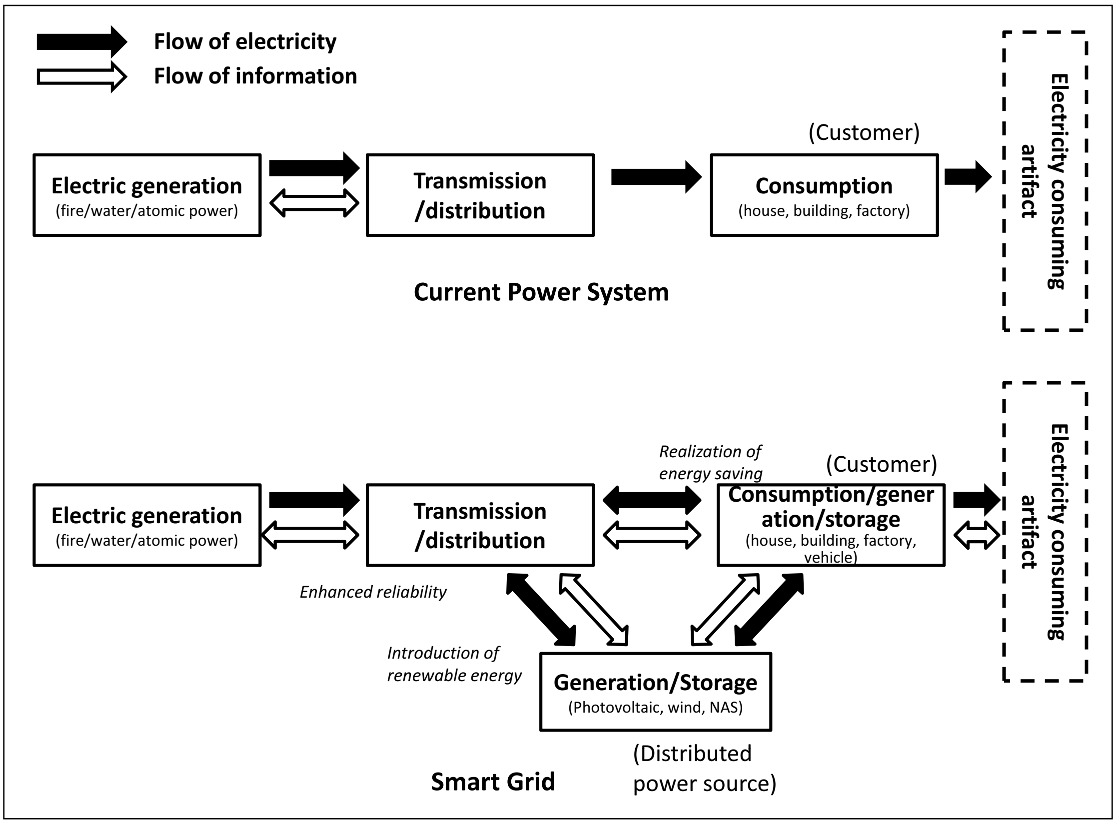

Figure 1 : Smart System vs. Current System

Prepared by STFC based on Reference[1,3] exemplified by the high expectation that “replacement of all 2.7 billion domestic power meters with smart meters will create a huge market for the semiconductor manufacturers,”[4] it is important to understand that it will spur the growth of a huge ICT market for semiconductor and communication equipment manufacturers, as well as for the software and related services used in these devices and instrument.

This report covers current developments of the smart grid from the perspective of ICT.

2 Global ICT Related Smart Grid Market

The global size of the ICT-related smart grid market is around 89 billion USD (about ¥9 trillion) as of 2010, and is forecast to continue a 20% growth rate into a size of 170 billion USD (about ¥17 trillion) in 2014 (Fig. 2: a document from Zpryme research & consulting). Market size analysis of smart grid related element technologies forecasts 18% yearly growth in the sensor and device sector, 21% in the IT software and hardware (computer) sector –used to administrate/

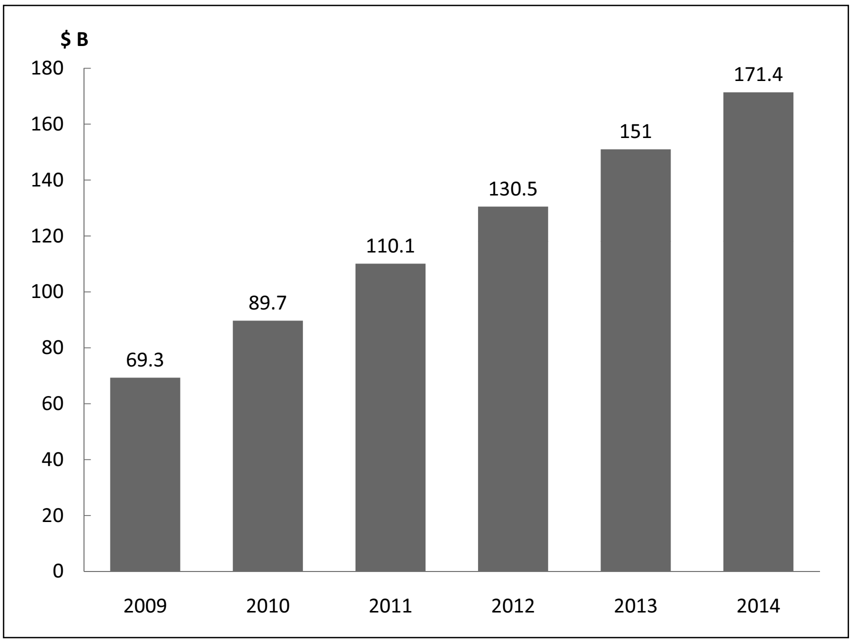

Figure 2 : Global Market Forecast: Smart Grid Related ICT
Prepared by STFC based on Reference[19]

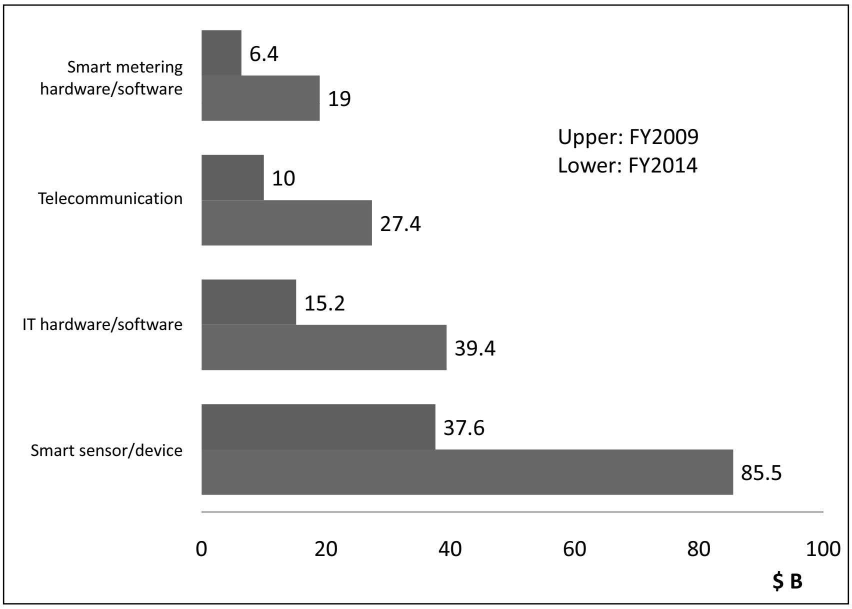

Figure 3 : Global Market Forecast: Smart Grid Related ICT (Sector by Sector)
Prepared by STFC based on Reference[19]

control the entire system, 22% in the communication related sector, and 24% in smart meters. The first three sectors combined - sensor and device, IT software and hardware (computer) to manage/control the entire system, and communication – make up 89% of the entire smart grid related market. In view of the economic situation in recent years and the fact that there is scarcely any sector capable of achieving 20% yearly growth, the smart grid and related ICT sectors represent a growth market of primary importance.

The number of smart meters on a global installation base will grow from 7.6 million in 2009 to 210 million in 2014.[3] The penetration rate of the smart meter is estimated to reach 18% globally in 2015, and in North America, the rate is forecast to grow from the current 5% up to 55%.[3]

3 Trends in the United States and Japan

3-1 Trends in the United States

3-1-1 Scale of Government Investment and its Estimated Effect

In the United States, investment in smart grid related fields is quite active centered on modernization of the power system led by the diffusion of smart meters.

The federal government has invested 4.5 billion USD in the smart grid accompanied by the enforcement, in 2009, of the American Recovery and Reinvestment Act (ARRA).

Out of this investment, 3.4 billion USD is allotted to the ground programs, which serves to build facility infrastructure for enhancing the reliability of the power network and promotion of demand control. Under the plan, this investment has an effect of introducing smart meters to 40 million households, roughly one-third of all households in the United States.

Aside from this, 6.2 billion USD is allotted to regional demonstration programs and energy storage demonstration programs, where introduction of distributed power sources plays a central role.[3]

The effect obtained from these 3.4 billion and 6.2 billion USD investments is estimated as follows:[3]

- Lowers the frequency of electric outages, reducing loss by 150 billion USD in a year (500 USD per capita)
- Reduces peak demand by 1400MW or more (capital cost 1.5 billion USD) and lowers the power charge
- Makes the grand objective attainable (i.e. 20% of energy will be supplied from renewable sources)
- Creates jobs for several tens of thousands of workers
- Induces 4.7 billion USD of investment from private sectors

3-1-2 Coalition among Utility and ICT Companies, Universities, and Public Research Organizations

Table 1 shows the list of major projects to be undertaken in line with the grand program.

Utility companies, in coordination with major players in the IT industry, are approaching projects in such areas as dynamic management, price setting, automation, surveillance, and network management. The venues for implementation and tests for these projects are provided mainly by schools and universities. For example, the project carried out by Florida Power & Light Company aims at, using smart meters, developing a more stable and intelligent power supply, and a test will be performed on the photovoltaic generation platforms installed in universities and schools. Three hundred units of PHEV will be introduced to universities (Miami Dade College, Florida International University, and the University of Miami) on a trial basis, and around fifty charging stations will be installed to support them. Other development objectives include: household energy displays, power saving devices for automatic selection of low-consumption mode at the time of peak demand, programmable thermostats controlled by a smart meter, and demand management and demand-response software to control household appliances and lighting fixtures. These development efforts will be carried out in cooperation with IT companies.[22]

Table 2 shows the list of major projects carried out based on the regional feasibility program. Coordinated groups of utility companies, ICT companies, universities, and public research organizations are approaching specific demonstration themes, where a special focus is placed on gathering basic data supposed to have increased importance in the future - relation between human activities and energy usage, and cyber security. For example, the demonstration project of Los Angeles Water and Electricity Bureau selected a university campus as the site of regional infrastructure feasibility studies, the results of which may be applied to commercial, medical, retailer, and industrial areas. In this project, the plan also includes advanced research and development in the broad context of information technology, as well as that directly related to information equipment such as: a comprehensive analysis of human activities and energy usage as affected by the construction of information infrastructure, a feasibility study of the next generation server security technology, and usage pattern analysis of electric vehicles operated by users without charging equipment.[23]

3-1-3 Active Moves of ICT Companies

In addition to the familiar players in the electric power management market such as GE, IBM, and Accenture, a growing band of IT companies is trying to enter into this market, targeted at general consumers. Take, for example, that AT&T aims at expansion of wireless networks, Cisco Smart Grid Solution supports household IP networks, Cisco is geared toward establishing building energy management infrastructure, Oracle is trying to open energy management systems to general consumers, Google takes sight of household energy management (Google Power Meter) and other emerging businesses in this line, and Microsoft is developing a household energy consumption management system taking advantage of cloud computing.[2]

Some information companies are trying to take equipment directly related to power monitoring into

Table 1 : Major Granted Programs

Utility Company	Federal grant, State granted, Number of smart meters	Target	IT company
Central Point Energy	200 mil. USD. Texas, 220 mil.	More than 550 sensors, automatic switch	IBM, GE, Itron QuantaServices
Baltimore Gas & Electric	200 mil. USD. Maryland, 110 mil.	Expanding program capability for dynamic charge setting and direct load control.	(N/A)
Duke Energy Business Services	200 mil. USD. North Carolina, 140 mil	Dynamic charging program, two-way communication, advanced automatic distribution applications, PHV	Cisco, Echelon
Florida Power & Light Company	200 mil. USD. Florida, 260 mil	9,000 intelligent distribution equipments and advanced monitoring equipments.	GE, Cisco, Sliver Spring, SunPower
Progress Energy Services	200 mil. USD. North Carolina, 16 mil.		IMB,Telvent

Prepared by SFTC based on Reference[3]

Table 2 : Major Projects Included in the Regional Demonstrative Program

Demonstrative Project	Government grant Target region	Content	Utility company	University, IT enterprises, and others
Northeast Pacific Coast Demonstrative Project	88 mil. USD Washington	・Two-way communication (dispersed sources, secondary battery, source of demand, existing grid) ・Implementation of SG cost-gain calculation ・Interconnectivity, security	Twelve utility companies in Battle Memorial Institute region.	University: UW, WSU Enterprise:IBM, 3tiers, Netzza, QualityLogics
Ohio Grid Smart demonstrative project	75 mil. USD Ohio	・Demonstration of 13 technologies (automated distribution, smart meter equipment, Home Area Network (HAN), PHEV, storage, renewable energy, etc.)	Columbus Southern Power Company	Research Institute: EPRI, PNNL Enterprise: Battele, GE, Silver Spring, Lockheed Martin
Los Angeles Water and Electricity Bureau regional demonstrative project	60 mil. USD California	・Demonstration within premises of universities ・Energy usage of general consumers, cyber security technology, and integration with PHV.	Los Angels Department of Water & Power	University: USC, USLA, CalTech
Demonstration of open grid with safety and interconnectivity	45 mil. USD New York	・Security, peak demand reduction, enhanced reliability (renewable energy, grid monitoring, EV, automated transmission, consumer system)	Consolidated Edison Company of NY	University: EPRI, Columbia Enterprise: Boeing, Prosser, CALM Energy
Irvine demonstrative project	40 mil. USD California	・From transmission/distribution system to smart devices. ・Focus on interconnectivity and security	Southern California Edison (SCE), PG&E	University: USC, EPRI Enterprise: CE, Cisco, IBM, Boeing

Prepared by SFTC based on Reference[3]

their own businesses. For example, IBM provides a solution utilizing a smart meter, or a household power meter with an embedded two-way communication function and PC capabilities (Fig. 4). The provision of this solution is a part of its strategy to construct the Intelligent Utility Network (IUN), which serves as a transmission and distribution system with enhanced efficiency.[7]

Google, on the other hand, developed a suite of software called Google PowerMeter and distributes it through the Internet. This software allows access by way of Internet browsers. The PowerMeter allows obtaining power consumption information from the contracted utility company for easy monitoring at home and in the office. Visualized monitoring of electricity consumption is expected to have an effect toward saving energy. The software also enables the consumer to obtain information, through the network, from a clip-on power meter that allows installation on a distribution board.

3-1-4 Emergences of New High-Tech Companies

In the United States, it is also to be noted that a new breed of advanced companies, different from those described in the previous section, is emerging aiming at the new businesses that have evolved accompanying the smart grid. These include new starters as well as emergences from different fields. For example, Silver String Network, Itron, and Landis+Gry provide demand side equipment used in Advanced Metering Infrastructure, Comverge and EnerNoc provide demand-response instruments, and GridPoint provides equipment related to household networks.[9] Many of these started business around 2000 or later, mainly in the field of meter-related equipment manufacturing, and are geared to cultivate a new smart grid business by linking their products to the network. As seen from Table 3, these companies have steadily or dramatically expanded their sizes and sales.

For example, Silver Spring Network, a spin-out venture from Google, was established in 2002 and now has a workforce of about 200 employees,[9] and it has already gained major utility enterprises as customers in and outside of the United States. The customers include American Electric Power, CitiPower&Powercor Australia, Florida Power & Light, Jemena, Modesto Irrigation District, OG&E Electric Services, Pacific Gas and Electric Company, Pepco Holdings, Sacramento Municipal Utility District, Powerful, and lnfluential Leadership.[10] In the background of the growth of Silver Spring Network lies the company's policy to embrace all aspects of the business (i.e. providing solutions and services as well as products), and its success in establishing collaborative relationships with various companies in diverse fields (demand-response, distributed power sources, electric vehicles, home networks, communication, and software) seems also to have given the company an edge (see Table 4).

GE, accompanied by four venture capital corporations, unveiled its plan to set up a fund of 200 million USD to promote the development of smart grid related new technologies.[24] Such a fund could induce further new entries and encourage new businesses.

3-1-5 Standardization and Legislative Preparation

The basic idea underlying the smart grid technology development in the United States is to secure interoperability.

The Internet represents, just as the word consists of "inter" and "net," a network that provides interconnection among networks. By the same token, the basic idea of the smart grid is to provide a "grid between grids," or a grid connecting various types of grids.

If there were standardization work to be done by the state for the realization of the smart grid, it would be the establishment of a protocol for securing grid-to-grid interconnectivity. In the United States, this

Figure 4 : A Smart Meter from IBM[7]

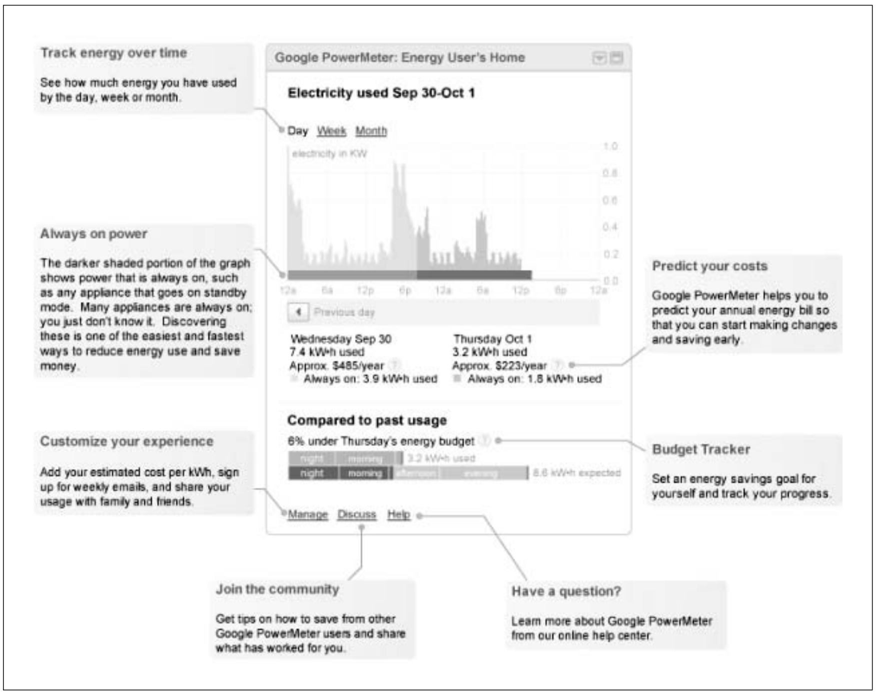

Figure 5 : A Screen Display from Google PowerMeter[8]

Table 3 : New Entries into The Smart Grid Related Fields

Enterprise	Home city	Established	Overview
Itron	Liberty Lake, WA	1977	・Released the first product in Idaho in 1977 ・Acquisition of Schlumberger Advanced Metering (2004) and Actaris (2007) ・Customers include more than 8,000 utility companies. AMR*, AMI** etc. ・Sales: 664 (2006), 1,464 (2007), 1,910 (2008) (mil. USD). Payroll ≥ 8,500.
Landis + Gyr	Switz.	1886	・Purchased by an Austrarian investing company in 2004. ・Has sold more than 300 million meters. ・Sales: 1,364 mil. USD. Payroll: 5,070.
Sensus	Raleigh, NC	2003	・Established in the late 19th century as a meter manufacturer in Pittsburg. Assumed current trade name after undergoing several acquisitons (by Rockwell and others). ・AMR*, AMI**, etc. Payroll: 3838. Sales: 633 (2006), 694 (2007), 671 (2008) (mil. USD).
EnerNOC	Boston, MA	2001	・Customers include 1,650 commerce/industrial businesses. Supplies up to 2050MW of electricity. ・Sales increasing: 26 (2007), 61 (2007), 106 (2008) (mil. USD).
Echelon	San Jose, CA	1988	・Provides Networked Energy System. ・Payroll: 325. Sales: 137 (2007), 134 (2008) (mil. USD)
Comverge	East Hanover, NJ	1997	・Established by a merger between PowerCom and a Lucent business unit (1997). Acquired a business unit of Scientific Atlanta (1999) and Sixth Dimension (2003). IPO in 2007. ・Has sold more than five million units of equipment. SDGE (CA), Public Services Company of New Mexico, PacifiCorp, New England ISO etc. ・Sales: 34 (2006), 55 (2007), 77 (2008) (mil. USD).
Ambient	Newton, MA	1996	・Internet based smart grid (AMR* inclusive). ・Sales: 2.3 (2006), 12.6 (2008) (mil. USD). Payroll: 38.
Silver Spring Networks	Redwood City, CA	2002	・Internet based AMI** and demand handling. ・Major customers: Florida Power & Light, PE, Pepco, Jemena, Electricity Networks, and United Energy Distribution.
Trilliant Networks	Redwood City, CA	2004	・Predecessor established in 1985. Current business started in 2004. ・AMI**. Has distributed more than a million meters. Customers include more than 200 electric power businesses.

Prepared by SFTC based on Reference[2]

Table 4 : New Entries into The Smart Grid Related Fields

Technology	Cooperative firms
Advanced Metering	Elster, GE Energy, Itron, Kinects Solutions, Landis + Gyr, Nansen, PRI
Demand Response / Energy Management	Comverge, EnerNOC
Distribution Automation	ABB, DC Systems, S&C Electric Company
Electric Vehicles	ClipperCreek
Home Area Networks and Devices	Arch Rock, Carrier Corporation, Control4, Energate, Exegin, Invensys, LS Research, Onzo, Radio Thermostat of America, Tendril
Networking	Cisco, Digi International, Sierra Wireless
Software	eMeter, Freestyle Technology, GEEnergy, GridPoint, Itron, OSIsoft, Oracle

Prepared by SFTC based on Reference[10]

standardization work is being undertaken by the National Institute of Standards and Technology (NIST), an organization under the Department of Commerce. The standardization work will, in the future, guarantee interconnectivity among the advanced technology grids with different origins, thus allowing independent development efforts.

In line with the stipulations of the Energy Independence and Security Act (EISA) established in 2007, the U.S. federal government invested a 500 million USD budget into NIST for the development of standards to secure total operation of the smart grid in terms of ICT, and maintenance of security. As aptly described in the notes of a NIST report – "protocols and standards for information management for interoperability of smart grid devices and systems" – the work places a focus on standardization for information exchange. In the background of these standardization activities lies, according to some reports, an implicated strategy – "The Obama administration has a strategy to eventually gain global supremacy on the smart grid market, by first investing massively in this field for the development and commercialization of related technologies, and to push up the level of U.S. companies in this field."4] In the United States, a bill stipulating mandatory provision of real-time smart meter information to customers was introduced to Congress11], indicating that legislative preparations are also under way to activate smart grid operation.

3-2 Trends in Japan

Several demonstrative projects have already begun in Japan as well. These include: a smart grid experiment using 3,000 power meters undertaken by Kansai Electric Power Co. Inc., Demonstrative new system energy introduction project for isolated islands undertaken by Okinawa Electric Power Company, Incorporated,[12] a smart grid demonstrative experiment in Rokkasho village that introduces wind-power,[13] and a demonstrative experiment for the optimization of a next generation transmission/distribution system[14] – a joint project participated in by Tokyo University, Tokyo Institute of Technology, and many electricity enterprises.

The new Energy and Industrial Technology Development Organization (NEDO) has organized a smart grid demonstrative experiment under the initiative of Japanese enterprises in New Mexico in the United States. Various legislative controls in Japan often make technological experiments difficult, but these can be carried out relatively free of constrains in the United States. In the background of the project also lie such factors as: the state of New Mexico has differentiation from other states in mind by introducing Japanese companies' technology, and New Mexico is especially suited for photovoltaic power generation experiments due to it having the highest level of insolation among all states. Note, however, that this project is heavily concentrated on experiments related to photovoltaic and secondary battery technologies, thus information technology is not one of its major concerns.

The Next Generation Energy and Social System Council – a cross-sectoral project team in the Ministry of Economy, Trade and Industry (METI) – has decided to carry out a domestic experimental implementation of a "smart community" aiming at creating the next generation urban area utilizing innovative ICT, energy, and traffic systems. In concrete terms, Yokohama city (Kanagawa pref.), Toyota city (Aichi pref.), Keihanna science city (Kyoto pref.), and Kitakyushu city (Fukuoka pref.) have been selected as the sites for this project.

In another development, the "smart community forum" – a forum for gathering and discussion between the smart grid and smart community related enterprises under the secretariat of METI – was inaugurated in 2009. The ideas underlying this forum are: pursuit of action possibilities undertaken by the demand side, sharing of a smart community vision as it ought to be, clarification of the proper system architecture and individual elements, and establishment of alliances and strategies for overseas deployment as a system.[15] As one outcome of this forum, the "smart community alliance" was established, in June 2010, based on 352 impeller enterprises, under the secretariat of Endowing, and in line with the concept of this alliance, working groups for international strategy, international standardization and roadmaps for smart houses have started their activities.

The Japanese cabinet approved the New Growth Strategy in June 2010. The "green innovation" project – one of the priority areas of the strategy – endorses realization of the smart grid.

In and around the 1990s, Japan had a project called OpenPLANET, undertaken by Shikoku Electric Power Co., Inc, which did not gain widespread momentum. The lack of success is ascribed to the following reasons: communication infrastructure in those times – such as power line communication (PLC) and PHS – was still in an immature state, and there was no way to propose such new household services that benefited from CPU-installed power meters.[16] As illustrated by this example, the success of the project seems to depend largely on the proposal of "killer applications."

4 ICT in Smart Grid

4-1 The Role of ICT

Figure 6 illustrates the role of ICT in the smart grid. The following research and development have already been under way and have attained a certain level of realization: a supervising system for power generation, supply and demand control system for optimum power generation, coordinated system surveillance/control and an automatic distribution system for stable power transmission and distribution. Meter-reading has already been automated in part. As described earlier, the smart grid provides power generation and storage functions additionally to the demand side. Introduction of these dispersed power sources will make the entire system drastically more complex and will require a much higher level of system control. In addition to the functions provided by conventional ICT, a higher level of data collection, transmission, storage and processing will be required to cope with the enormous information flow incoming from generators, transmission/distribution systems, and distributed power sources. Functionality for surveillance, control, and support for decision-making based on the flow of information will also be required. The smart grid will also call for new technological developments for the demand side – typically the Advanced Metering Infrastructure (AMI), where Building Energy Management System (BEMS) and Home Energy Management System (HEMS) play a central role.

Examples of ICT introduction to electric power systems in Japan include the case where Tokyo Electric Power Company embedded a communication function in almost all of the power lines upon installation, enabling hazard detection both in the backbone and distribution networks. As a result, the yearly average of blackout time per household in Japan has been reduced down to 16 minutes, proving the superior effect of the control system construction (See Fig.7).

Advanced use of the control system will be required for the introduction of renewable energy to each region and household. As supply and demand must always be balanced in an electric power system, conventional power systems have the ability to boost output in quick response to an increase in demand. Renewable energy sources (e.g. photovoltaic generation, wind-power generation) depend largely on the weather, resulting in fluctuation of power output. An advanced power system is required for the existing power systems to accommodate the power fluctuation. In Japan, METI announced the introduction plan of photovoltaic power generation of as much as 53GW by 2030, but the Federation of Electric Power Companies – a joint council of ten power utilities – estimated the upper limit as 10GW. The reason underlying this upper limit is the fact that photovoltaic power output fluctuates substantially, having a serious effect on the operating quality of the system. Introduction of a management system based on the smart grid is expected to alleviate this deleterious effect.[3]

In the United States, research and development investment on the management system, for coordinating the power system with local/home networks, has been gaining momentum. In view of the situation that the introduction of renewable energy into social networks will still take a while, industrial sectors are giving priority to home networks as the platform for technological development and social implementation.[3] The management system is realized by implementing Advanced Metering Infrastructure (AMI) – a monitoring/control system for demand side instruments, which consists of management systems for smart meters, home appliances, and communication, and the Home Energy Management System (HEMS). The component of special importance in the system is the smart meter, or the power meter with communication capabilities for data input from and control over the household appliances. Addition of a wireless communication function to the conventional power meter provides connectivity with household appliances (e.g. air conditioners, lighting fixtures) and sensors such as thermometers, enabling it to collect information such as power consumption and temperature. As the smart meter is also connected to the external network, all household appliances, sensors and power meters in the world become communicating agents of the Internet via the networks.

One of the merits of introducing a smart meter into

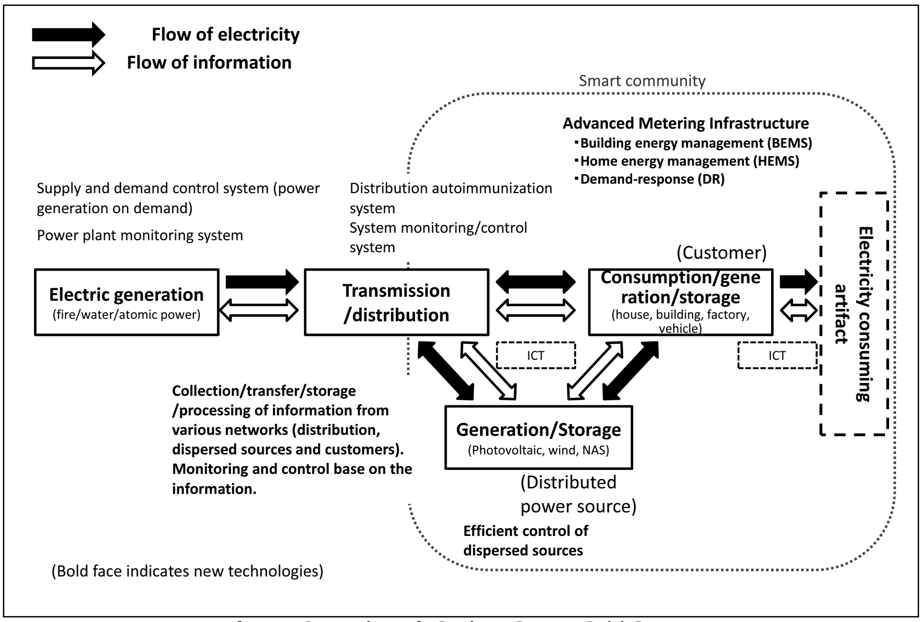

Figure 6 : Roles of ICT in a Smart Grid System

Prepared by SFTC based on Reference[1,3]

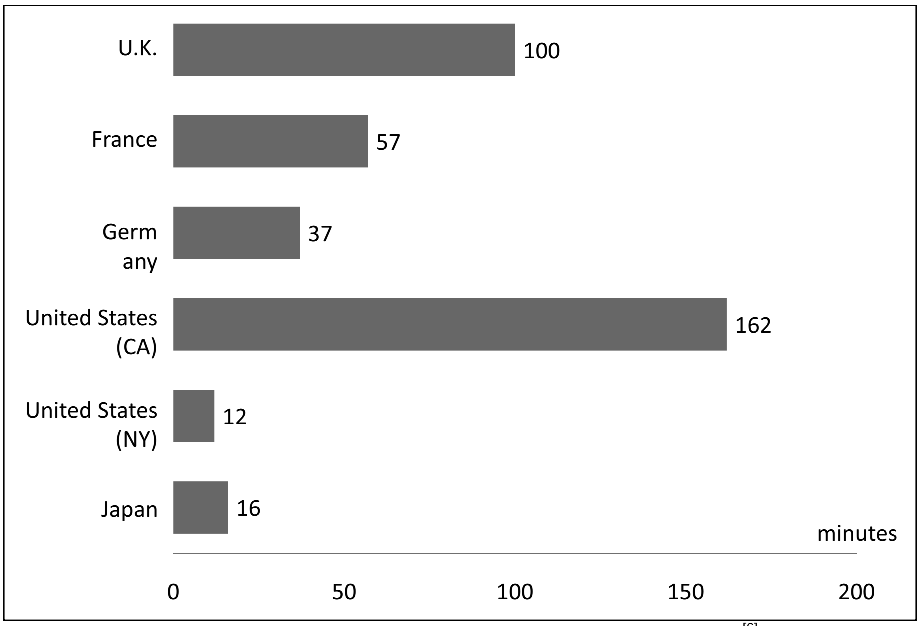

Figure 7 : Yearly Blackout Hours in Major Countries (See Reference[6] for the year)

Prepared by SFTC based on Reference[6]

a household is visualization of power consumption status, promoting a spontaneous power-saving attitude in every household. Monitoring of electric appliances and implementation of an on/off control function enable the demand side to have the management capability for more efficient power usage. In addition, the supply side (utility companies) will be able to exercise forced supply control at the time of peak demand. In the future, when photovoltaic generation becomes a common practice in every household, and trade of redundant electric power becomes widely available through, for example, the introduction of PHEV, the smart meter is expected to play an important role as an access point to guarantee stability of the power market, which is dynamically driven based on market principles. It is also probable that an array of new businesses will be created by grasping lifestyles based on the detailed power usage information provided by the household. However, privacy protection will remain an important issue in this future society.

4-2 Emergence of a Giant Network

In the future, millions of smart meters, water heaters, household appliances and a vast number of sensors will be connected to the existing social infrastructures (i.e. the power system, renewable energy system, gas supply system and water supply system), causing the emergence of a far-flung, global network much larger in size than the current Internet. When this situation becomes a reality, robust networks and advanced information processing systems are required to collect and analyze the vast amount of data from the connected devices for controlling them. Underlying these networks, architectures and information security technology will play a critical role for interconnecting various types of dissimilar nodes.

In contrast to the Internet as we know it today, where only abstracted trains of bits (0101…) are transmitted, newly emerging networks transmit physical entities as well, causing a substantial increase in the complexity of the networks. In the newly emerging networks, just as is the case with the current Internet, such functions as collection, transfer, storage, processing, search, and presentation of data, security, and protection of privacy will be required.

4-3 Elements of ICT Underlying the Smart Grid, and Their Standardization

Table 5 shows a list of element technologies underpinning the smart grid (compiled by the United States Department of Energy).

In this classification, importance is placed on two-way communication technology to make the smart grid an efficient and reliable real-time system. A two-way communication architecture - based on the concept of Plug-and-Play that guarantees expandability and ease of modification - must be established to realize mutual compatibility. Next comes the need for control technology supported by state-of-the-art algorithms, used for handling the vast amount of information incoming from smart meters and intelligent home appliances, and for control/diagnostics/price setting and resource management. Emphasis is also placed on the interface and decision-making support system that enable efficient and accurate operation, as well as the sensor and measurement technology.

In terms of two-way communication, drastic upgrade of short-distance wireless communication technology and its widespread implementation are expected. This includes such technologies as ad-hoc networks, mesh networks, and sensor networks that support multi-hop communication and networking household appliances. The development of distributed control systems is also a must for controlling them. As an example, ZigBee (a short-range wireless communication standard based on IEEE 802.15.4,) is receiving attention for monitoring and controlling the networks because of its capability to construct multi-mesh networks and lower power consumption than WiFi and Bluetooth. The ZigBee Smart Energy Profile specification has been set out in recent years, which stipulates the method for reading a meter, controlling instruments, real-time calculation of electric charges, transmitting text messages, data encryption, and unit authentication.[2,20] In addition, to facilitate the move toward the smart grid, a communication standard, Smart Utility Network (SUN), has been established as a part of standardization efforts around IEEE 802.15.4g. IEEE 802.15.4g is expected to be the wireless network standard in the age of the smart grid: it allows consolidating information collected from multiple home networks (within a radius of several hundred meters to several kilometers) into an information gathering facility of utility (electricity and gas) companies, and also enables two-way control.[21]

It is very likely that a variety of smart appliances (household appliances with ICT capabilities) will be developed in the future. The standard that stipulates the interface for connecting a smart appliance and a smart meter already exists, i.e. OpenHAN. Much of the standardization efforts for OpenHAN have been undertaken by major electric power businesses such as Pacific Gas & Electric Co. (PE&E) and South California Edison Co. (SCE), and American Electric Power.[2]

4-4 Issues Concerning the Smart Grid in Japan: A view from ICT

The Smart Community Forum, held under the auspices of METI, summarized the issues around the smart grid as viewed from ICT as described below, and made them public in June 2010.[15] In Japan, although there have been discussions toward realization of smart communities, research and development investment has been focused mainly on renewable energy (e.g. solar power) and secondary cells. Efforts toward enhanced research, development, and commercialization of ICT around the smart grid have not been sufficiently activated nor have they taken a concrete shape yet.

(1) Information System Architecture

The information system architecture must be so designed that it an optimized connectivity within and outside the home network, paying due attention to the roles played by the smart meter and home server. There must be a thorough discussion as to which of the two - the home server (computer) and the smart meter – is more desirable, or both hand in hand, to serve as the home gateway connecting all of the household instruments. The choice is important, because it determines whether a utility firm or the home server provider (communication company, home appliance manufacturer, housing manufacturer, ICT service provider, and other energy related businesses) carries out the task of collecting power usage information and controlling household instruments.

It is critical for the architecture to provide sufficient compatibility between openness and reliability of the home network. Openness of the interface is required for the home appliance network so that it will not, for the convenience of the user, tend to be a manufacturer specific interface. On the other hand, it must impose a certain level of discipline on connected devices (e.g. authentication) to maintain reliability. Therefore, the architecture must provide a balance.

Table 5 : U.S. Department of Commerce Counts On The Following Element Technologies for Establishing Smart Grid

Technology	Examples
integrated two-way communication Two-way communication makes the Smart Grid a dynamic, interactive, real-time infrastructure.	・An open architecture creates a plug-and-play environment that securely networks grid components and operators, enabling them to talk, listen and interact.
advanced components Advanced components play an active role in determining the electrical behavior of the grid, applying the latest research in materials, superconductivity, energy storage, power electronics and microelectronics to produce higher power densities, greater reliability and power quality.	・*Next-generation FACTS/PQ (power quality) devices* ・*Advanced distributed generation and energy storage* ・*Plug-in hybrid electric vehicles (PHEVs)* ・*Fault current limiters* ・*Superconducting transmission cables* ・*Microgrids* ・*Advanced switches and conductors* ・*Solid-state transformers*
advanced control methods Advanced control methods monitor power system components, enabling rapid diagnosis and timely, appropriate responses to any event. They also support market pricing, enhance asset management and efficient operations, and involve a broad application of computer-based algorithms.	・*Data collection and monitoring of all essential grid components* ・*Data analysis to diagnose and provide solutions from both deterministic and predictive perspectives* ・*"Diagnosis" and subsequent appropriate action processed autonomously or through operators (depending on timing and complexity)* ・*Provision of information and solutions to human operators* ・*Integration with enterprise-wide processes and technologies*
sensing and measurement technologies Sensing and measurement technologies enhance power system measurements and facilitate the transformation of data into information to evaluate the health of equipment, support advanced protective relaying, enable consumer choice and help relieve congestion.	・*Smart meters* ・*Ubiquitous system operating parameters* ・*Asset condition monitors* ・*Wide-area monitoring systems (WAMS)* ・*Advanced system protection* ・*Dynamic rating of transmission lines*
improved interfaces and decision support Improved interfaces and decision support will enable grid operators and managers to make more accurate and timely decisions at all levels of the grid, including the consumer level, while enabling more advanced operator training. Improved interfaces will better relay and display real-time data to facilitate:	・*Data reduction* ・*Visualization* ・*Speed of comprehension* ・*Decision support* ・*System operator training*

Prepared by SFTC based on Reference[17]

The following factors, in concrete terms, will be required: standardization and openness of home server APIs, standardization of home server middleware, and standardization of communication interfaces for connectivity with household appliances.

In terms of connection between an external and a home network, the communication scheme for network construction has to be determined. Eligible candidates include power line communication (PLC), wireless communication (3G/LTE, WiMAX, PHS, multi-hop communication), and wired communication (optical fiber ADLS, cable television). Who incurs the cost of network construction and how to guarantee security pose another issue. Regarding this connection, a decision has to be made as to the transmission scheme by which the network is constructed. The options for this decision are: an indiscriminate transmission scheme (or Internet scheme) with a cost advantage, and a specific application priority scheme (guaranteed transmission scheme) with higher reliability.

(2) Creation of New Services That Utilize Availability of Household Information

Availability of visualizable household energy information is expected to promote the creation of new services, for example, that make the user more energy-saving conscious by presenting visualized energy information. Other examples include the creation of optimum energy management services, where feedback information from power usage monitoring is used for effective use of renewable energy and expulsion of adverse effects on the system, or local management of the charging schedule for electric vehicles is utilized to optimize energy management and guarantees successful changing service within a given system capacity.

Other candidates of new services include: whereabouts/failure detection and remote repairing/maintenance of household appliances, information sourcing for the development of new products, on-demand home delivery service, and utilization of television sets as a household gateway monitor (provision of administrative information and on-line administrative procedures, TV conferencing for teleworkers, and information exchange among neighborhood residents).

(3) Establishment of Rules for Gathering/Managing/Utilizing Household Information

On the flip side of the various beneficial effects, there can surface an array of problems such as that the need for establishing rules that govern the activities to gather/manage/utilize household information (sensitive personal information may be contained) has been pointed out. It is considered appropriate that the following items are included in these rules: explicit indication of the intended purpose and use of data, and the name and substance of the agent that collects data, obligatory feedback of household information to the user, secured information portability, conditions to allow access to the home gateway, security requirements for networks and home gateways, and conditions to prevent information leak and illegal access.

(4) Other suggestions

Many other suggestions and opinions were put forward and discussed by the members of the Smart Community Forum. Among these, ICT related subjects are summarized, based on the reference material,[15] in Table 6.

5 Predictable Future

5-1 Global Competitiveness of Smart Grid Related ICT Industries

As I reported above, the smart grid is expected to provide a huge growth field for ICT industries. Especially from the viewpoint of ICT, however, the efforts toward research, development, and commercialization in Japan have not yet been brought well into shape.

Figure 8 shows schematically the differences in future international deployment strategy between the United States and Japan, as viewed from investment activities in technological development. The area of technological development can be broadly classified into three sectors: conventional power generation and transmission, renewable energy, and ICT. In the figure, the darker the color of the item, the higher the stage of development, and the lighter, the less developed.

In the United States, investment pervades every sector of industry. This will likely promote, in the United States, the evolution of systems with expandability and mutual compatibility in the near future, where coalition among ICT, renewable energy

Table 6 : Issues discussed in the Smart Community Forum

1) The need for investigation on economic efficiency and the mechanism of cost sharing
2) The importance of priority definition: domestic and overseas deployment requires different models and strategies
3) For overseas deployment, localized strategy is important, taking into account the local needs (including climate and cultural background)
4) A view toward creation of new businesses should be included: preoccupation with the discussion of energy supply and demand will not be enough.
5) The importance of maintaining balance between human control and utilization of natural force
6) The importance of open/black-box strategy: the key to the success of overseas deployment
7) The importance of total smart grid design for proper coordination between the distribution system and trunk power transmission system
8) The importance of investigation as to how Japanese element technologies will be fit into the unstable systems in Asian developing countries
9) The need for discussion toward construction of information strategy and business models in conjunction with the deployment of the smart grid.
10) The system must have added values from the viewpoint of users.
11) The need for urgent demonstrative implementation of the smart grid driven by public-private partnership.
12) The government is expected to develop the global deployment strategy, with an eye toward the market situations in developing countries.
13) The systems to be exported must be tailored to the situation of the target country (geographical, historical background, and needs)
14) The need for discussion as to the proper selection and coordination of the smart meter and household controller (home server).
15) The need for discussion toward proper ownership and installation of the smart meter.
16) The merit of introducing smart meters in the case charging scheme must be switched for mobile and house applications: usage of electricity is expected to extend to mobile (EV) applications.
17) The need for the review of security and the mechanism to share the cost, especially for controlling household appliances.
18) The need for an autonomous and effective network for the smart grid, when viewed as an entity that includes demand side users.
19) The need for the construction of the user participatory energy/social system.
20) The smart community presents a concept for municipal organization (Machizukuri) by providing “shared” space connecting “nature,” “place to live,” and “energy.”
21) Connecting household appliances to the smart grid will dramatically evolve an ordinary house into a theater of service provision.
22) The key points of discussion directly related to the introduction of smart meters: 1) the extent of functions that a smart meter should provide, 2) the issue of networks accessed (how the utility company network and public network should be compartmentalized), and 3) the level of openness that the public network should provide (scope for utilization of various communication providers).
23) Recipiency on the side of the consumers to demand-response services: a thorough understanding from consumers is needed as to the software (e.g. charging menu) from the viewpoint of best protecting consumer interests.
24) A thorough investigation is needed as to the cost burden and return on investment toward commercial realization of the smart community.
25) Careful distinction should be made as to the differences in services and cost burden in and outside of the smart community.
26) In conjunction with meter replacement for higher functionality, the time required for replacement and the effect it may have on metering performance should be taken into consideration.
27) Extended utilization of the smart meter should be investigated in the future (the possibility of application specific charges)
28) Both the public and self-initiative nature of the business should be considered, as well as regional characteristics and the facilities it possesses, before introducing smart meters.
29) The information handled in the home network should be classified from the viewpoint of security (open or closed system).
30) To gain overseas presence for the projects, thorough investigation of the regional legal system and local problems is needed, in addition to the enhancement of applications.
31) The importance of thorough explanation of the merits on the side of the users, and gaining understanding of the cost burden.
32) The importance of the discussion, from the viewpoint of the users, on how to draw incentives and encourage actions.
33) The utilization of existing infrastructure should be accounted for in the construction of the smart community.
34) To gain global presence, the smart community system to be exported must comply with the regional market pattern.
35) To help the private sector join an overseas project, government intervention is important to establish inter-government coordination.
36) The smart community project should be pushed forward as a combined and coordinated effort among environmental technology, financial technique, and public policy.
37) The concept of specific districts will play an important role for overseas deployment.
38) System thinking is always important: preoccupation with the performance enhancement of individual equipment will produce Japan-specific products.
39) For the commercial realization of the smart grid, an alliance between the public and private sectors, under the initiative of a government-led strategic framework, is most important, while maintaining ample scope for voluntary activities of the private businesses.
40) Patent strategy plays a key role in standardization strategy (i.e. open or closed system).
41) “Componentization” is also an important issue to be discussed, as well as system standardization.
42) Europe provides an eligible option when Japan contemplates international standardization.
43) Thorough investigation should be made as to which item should be completed by when, and it is important to define the time schedule based on this. Discussion should be made as to how to evaluate risks from a medium- and long-term prospect, and how to share the burden with the government.

and power systems will be realized. Expandability and mutual compatibility are the enablers to promote technology export to other countries, likely to provide the United States-bred renewable energy and ICT with a strong global competitive edge in the future.

On the other hand, Japan possesses a highly sophisticated electric power system, at least at present, and investment in technical development is focused mainly on renewable energy and storage. This situation in Japan is likely to promote development in renewable energy technology, and the element technologies will have a global competitive edge. However, it is also likely that they will be exported as "components" to be incorporated into a upper systems.

The value of a technology can be enhanced only when it is properly positioned and developed in the grand design. Especially, ICT can be considered as a vehicle to bring the grand design to reality. In terms of the smart grid, and from the viewpoint of ICT, being left behind in the train of research and development and the move toward standardization may isolate Japanese ICT from the mainstream of the smart grid market, just as was the case with the mobile phone.

5-2 Toward the world of "Internet of Things"

It would be worth mentioning that, in regard to the future smart grid, the following items were pointed out in the Smart Community Forum in Japan described in the previous section.[15]

- As the world of the information network, hitherto a closed network relating only to PCs and cellular phones, will extend itself to home networks that include household appliances, energy equipment, and automobiles, it will promote the emergence of the so-called "Internet of Things."
- Remote operation of demand-response, output control of photovoltaic generation, and charging time allocation of electric vehicles will become everyday matters, and utility companies' information control networks are connected to every household. This will promote a fusion of information networks and energy equipment (i.e. a smart house).
- These will promote the emergence of such systems as the new information network (2nd Internet), novel information networks connecting things to things and things to people, and systems that integrate energy equipment and information networks.

That is, the world of "Internet of Things," previously discussed with the words of RFID and IPV6, will further extend itself to include household appliances and automobiles accompanied by the smart grid, enabling the emergence of a new network where all objects (people, things, and energy) are connected

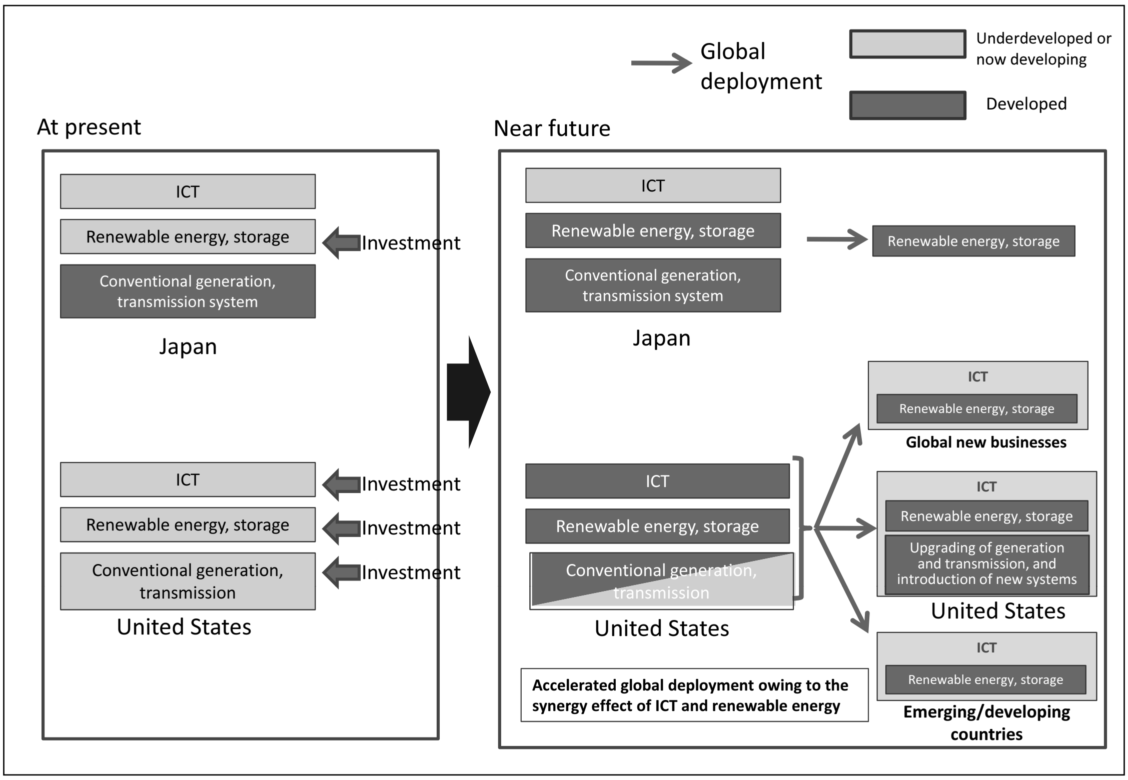

Figure 8 : Global Deployment Forecast of Technologies in Smart Grid

through information. This can be viewed as the popularization of informatization that takes place in the immediate vicinity of our lives, and has the potential of bringing major change in our society. The merit of this change resides in the fact that we will be able to realize a nearly totally optimized world, owing to the establishment of infrastructure that enables us to grasp all of the information regarding the instruments and objects in our home and society such as location/availability/resource consumption, and it will give us the ability to control them as well. On the other hand, there is a concern over the occurrence of security and privacy problems, hitherto being confined within the community of networked computers, in such daily objects as air-conditioners, refrigerators, and lighting fixtures.

IBM defines it latest business strategy as the realization of a "Smarter Planet." Smarter Planet is a concept aiming at realizing social and economic innovation by integrating physical phenomena, physical infrastructure, and digital infrastructure, by means of ICT, that surround every aspect of society - electric power, water, traffic, finance, logistics, and medical care. IBM predicts that Smarter Planet is capable of providing concrete solutions to such social and economic issues as saving energy, water shortage, traffic congestion, financial risk, lacking parts, and coordination of medical care. The concept of Smarter Planet can be viewed as a more generalized and expanded version of the Smart Grid. In the background of the strategy lies a concept that "information itself can set social and economic reality in motion." The concept underlying this strategy is a totally new thinking of "informatization": intimate attachment of digital infrastructure to the real world, and actions based on efficient information gathering and analysis will actually set the society and economy into motion.

Since the advent of computers, ICT has undergone an evolution supported by dramatic growth of such entities as semiconductors and computer networks, and it is now stepping into a new stage where ICT creates tangible values in society and economy. The objectives of the Smart Grid constitute one of the regions where the real-life challenges of ICT are tested.

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Profile

Kazuyoshi HIDAKA
Affiliated Fellow
Professor at Graduate School of Innovation Management, Tokyo Institute of Technology
At IBM Research (Tokyo), the author performed research on optimization technology, discrete algorithms, mathematical analysis technology, business solutions, mathematical organization theory and others. He was a project leader in some of the research. He also performed research at the IBM Watson Research Center (strategy section). He is a councilor in the Japan Society of Industrial and Applied Mathematics, a member of the Information Processing Society in Japan, and a member of the Operations Research Society of Japan. He joined the faculty of the Japan Advanced Institute of Science and Technology in August 2009. Doctor of Philosophy (science).

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