Feasibility and Issues of Smart Community in Japan

Yoshiki Ogawa

Abstract

East-Japan earthquake broken out on March 11, 2011 and a large accident in Fukushima nuclear power plant caused by its tsunami (seismic sea wave) produced quite serious influences on the energy and environment sectors in Japan and the world. Now, in Japan, the many discussions for revival plans from the East-Japan large disasters are started and the movements to realize the plan of environmental-friendly future town called as smart community are animated actively. It is expected that the smart community would be one of important issues in the revival plans from the East-Japan large disasters, relating to the feed-in tariff scheme for renewable energies to purchase whole electricity generated by renewable energies. In this study, I would like to discuss the feasibility and issues of smart community in Japan from the various viewpoints.

In conclusion, it should be deeply discussed what kind of merits are brought to demand-side consumers in the area where the environmental-friendly future town (smart community) is realized. In the present discussion, it seems that logics of supply-side players would be revealed too strongly. Specific and concrete contents of smart community project should be thoroughly considered, because the survival competitiveness is strongly required in the competitions with so many similar projects planned at various places in Japan from now on. It is quite important to organize and utilize a public-private partnership (PPP) combining central government, local governments, NPO, related private enterprises, and consumers for the projects making the most of local special qualities and competitiveness. The function of comprehensive project manager such as Accenture and IBM is required to achieve a smart community project. In Japan, we need to train such a player without delay.

Contents

1. Introduction

East-Japan earthquake broken out on March 11, 2011 and a large accident in Fukushima nuclear power plant caused by its tsunami (seismic sea wave) produced quite serious influences on the energy and environment sectors in Japan and the world. The people's anxiety to safety of nuclear power plants is now growing large and the matters that the restart of nuclear power plant is not permitted after stopping operation for regular checks is now also expanding at various places in Japan. The situation such as the disapproval for the restart of nuclear power plants seems to have quite serious and large influences in Japan for several years from now on.

Now, in Japan, the many discussions for revival plans from the East-Japan large disasters are started and the movements to realize the plan of environmental-friendly future town called as smart community are animated actively. The establishment of smart community started in Europe and the USA has become a big topic drawing public and private attentions for recent five years. It is expected that the smart community would be one of important issues in the revival plans from the East-Japan large disasters, relating to the feed-in tariff scheme for renewable energies to purchase whole electricity generated by renewable energies.

In this study, I would like to discuss the feasibility and issues of smart community in Japan from the various viewpoints. First, I would like to compare smart community projects in the USA, Europe and Japan and to discuss special characteristics and differences of these projects from the several viewpoints. Second, I would like to check the results on demonstration tests for smart community made at four different cities such as Yokohama, Toyota, Keihanna and Kitakyushu in Japan. Third, I also would like to check project proposals submitted to public invitation of environmental-friendly future town project by Japanese government. Forth, I would like to make economic simulations on the introduction of storage battery and photo voltaic cell which are an important facility for the construction of smart community. Finally, I would like to discuss issues and problems on the development of smart community in Japan.

2. Programs on smart community made in overseas

2.1 Examples and aims of smart community programs in USA and Europe

Table 1 summarizes several representative examples on smart community programs in USA and Europe together with special characters, concrete contents, project leader and consortium partners.

Table 1 Examples and Special Characters of Smart Community Programs in Europe and USA

Area concerned	Specific characters	Concrete contents	Project leader	Consortium partners
SGC Boulder, Colorado, USA	Monitor & control of power networks, Intr-oduction of PHEV, Practical use of HEMS, Smart house	Use of hybrid vehicles as a home storage battery, Monitor & control of power supply net-works by ICT, Introduction of smart houses by HEMS	Xcel Energy	Accenture, Ventyx, OSI soft, SEL, CURRENT, Grid Point, Smart Synch etc.
SmartConnect California, USA	Efficiency improvement by making visible, Con-struction of HAN, Mo nitor & control of power networks	Install of smart meter to make visible, Expansion of PHEV and storage battery function, Realization of zero net energy home, Grade-up of power supply networks	SCE	IBM, e-Meter, Itrons ZigBee Alliances, CORIX Utilities etc.
ASC, Amsterdam, Netherlands	Smart building, Electr-ification of vehicles & ships, Local market for-mation by power matcher	Install of smart meter, Revamping to smart building, Expansion of electric vehicles and preparation of charging station, Electrification of ships and grid connection by V2G	AIM Liander	Accenture, Nuon, IBM, Philips, Cisco, ECN Vodafone, TNT, TNO Plugwise etc.
EDISON, Bornholm, Denmark	Wind power, Cooperative control of electric vehicles, Storage battery, Quick battery charg-ing	Real time tuning of wind power and electric vehicles, Expansion of battery changeable electric vehicles, Real time sim-ulation of energy system	Dansk enegie	Center for Elteknologi, Informatics, IBM, Dong Energy, Siemens, DTU OSTKRAFT etc.
MOMA, Rain-Neckar, Germany	Real time pricing, Con-trol of home equipments, Construction of new model for power trading market	Automatic control by Energy Butler, Effective use of existing power lines and communication infrastructure, Creati-on of virtual energy market, Control of power networks	MVV Energie	IBM, Power PLUS Communications, Papendorf Software Engineering, DREWAG, University Duisburg etc.
E-DeMa, Rain-Rule Germany	Cooperative control of Microcogen & home eq-uipments, Cooperation between large power Co & public power Co	Smart homes made by ICT gate way, Network between town center and suburbs, Efficiency improvement by incentive system	RWE Energy	Siemens, Miele, ef.ruhr, Prosyst Software, Stadtwerke Krefeld RUB, TU etc.
e-Telligence, Cuxhaven, Germany	Wind power, Cold stora ge warehouse in harbor, Hot spring, Cooperative control of CHP	Automatic control using price mechanism, power consumption fitted with dispersed power sources, System integration of suppliers and consumers	EWE	OFFIS, BTC, energy&metrosystems, Fraunhofer-erbun d Energie etc.

(Note) CHP: Combined Heat & Power, PHEV: Plug in Hybrid Electric Vehicle, HEMS: Home Energy Management System, HAN: Home Area Network
(Source) Made from data gathered through various materials

The construction of smart community is a town development based on the smart grid system which is defined as a new electricity and information infrastructure interactive between supply-side and demand-side. In the USA, where the liberalization of power markets had made a progress in 1990's, people has been troubled with the blackout problems caused by the vulnerability of superannuated power generation and supply networks. Therefore, the smart grid system attracts people's attention as a stable and effective system for electricity use on the whole in the USA.

The reason why the smart grid in the USA was taken a close-up from all over the world is because President Obama positioned the smart grid as the first priority task and promoted the new policy called "Green New Deal" immediately after his inauguration. As shown in Table 1, the forefront demonstration project of smart grid was started in Boulder, Colorado from 2008 and various smart grid projects such as the Smart Connect project in California followed it at various places in the USA.

On the other hand, in Europe, the smart grid system was started from the introduction of smart meters for the sake of preventing electricity stealing. The main important purposes of smart grid in Europe was to solve network linkage problems of renewable energies such as wind power which was positively promoted to expand and to make multi-national trading smoothly through real time monitoring and operation.

In Europe, as shown in Table 1, the forefront demonstration projects of smart community were made in Netherland and Denmark. Of these, Germany picked up six projects on E-Energy and tackled with the realization of smart grid system eagerly. The attempts in Europe are greatly characterized by the rebuilding of local community through full utilization of local individuality. These movements are also expanding to other European countries such as France and the United Kingdom.

The important point found from the examples of smart community programs in the USA and Europe is the definite existence of comprehensive project manager such as Accenture and the definite existence of players taking charge of contents making in application sector such as IBM and Google, as shown in the example of Bolder and Amsterdam.

2.2 Developments of smart community in new rising countries

As discussed in the preceding section, the construction of smart community was started in the USA and Europe, but concerns to smart community by new rising countries such as China and India have increased rapidly in recent times and the smart community project takes concrete shape in these countries. We can list up Masdar City in Abu Dhabi and Tianjin Eco-city in China as a typical example.

The main purpose of smart community in new rising countries is to prepare the new infrastructure which can make necessary energy supply to drastic expansion of energy demand accompanied with rapid economic development. We should pay attention to the fact that the US companies such as IBM, Google, GE, Accenture and Cisco, especially speaking information companies, play an important and leading role in the construction of smart community not only in Europe but also in new rising countries.

The smart community projects in new rising countries, from China down, begin to take on aspect of hard trade war, and not only enterprises in the USA and Europe but also countries such as Singapore and South

Korea are now expanding their activities strategically in order to acquire the market of smart community projects. It is not too much to say that Singapore and South Korea are stepping up their demonstration projects of smart community in the own country aiming to hold a dominant position in the trade war.

3. Challenges to smart community programs in Japan

3.1 Discussions on smart community in Japan

In Japan, after the preliminary discussions on the smart grid system, the comprehensive full-scale examinations on smart community started from 2009. After piling up various discussions and results on various viewpoints of smart community centering by discussion meetings of the Ministry of Economy, Trade and Industry (METI), the forum on systems related to smart community was organized by 22 large domestic companies, the final report by this forum was completed in June, 2010 (The Secretariat of Smart Community Forum [2010]). Based on the various issues presented in this final report, the challenges to establish smart community in Japan are now making a progress strategically.

Firstly, the platform with public and private partnership (PPP) called "Smart Community Alliance" was established. The total 652 companies joined to this alliance on June, 2011 and concrete measures and market strategies for the smart community are now discussed in the four working groups such as international strategy WG, international standardization WG, road map WG and smart house WG in this alliance.

Secondly, the works on international standardization have a quite important position on Japan's international expansion of smart community. The 26 important items to realize smart community were picked up in the report on international standardization of next-generation energy system made by the working group (METI [2010a]). The works on international standardization of these items are now being developed concretely.

3.2 Domestic demonstration projects on smart community and international expansions

The council on next-generation energy and social system was set up as a committee under the Agency of Natural Resources and Energy, and the domestic demonstration projects on smart community were started from 2010. After submitting 19 project proposals from different domestic areas, four demonstration projects in Yokohama, Toyota, Keihanna and Kitakyushu were adopted. Each proposal from 19 areas showed its individuality quite abundantly (METI [2010c]).

Table 2 summarizes the outline of four demonstration projects adopted and their specific characteristics. We can easily find that four demonstration projects have interesting contents and individual characteristics by

Table 2 Domestic Demonstration Projects of Smart Community in Japan and their Characteristics

	Outline and size of project	Characteristics on demonstration	Other characteristics	CO_2 reduction target	Partners
Yokohama	✓Large size demonstration of 4,000 houses, rich menus ✓30% introduction of renew -able energies ✓Integrated large size energy management among 3 areas, Minatomirai, Knazawa, and Kouhoku	Adjustments on supply-demand balances among 3 areas with differ -ent location char -acters	Effective use of unused energy such as river water (heat) etc.	30% reduction to the 2004 level up to 2025 (Total)	Yokohama City, Meidensha, Accenture, Panasonic, Tokyo gas, Toshiba, Nissan, Tokyo power
Toyota	✓Target demonstration size: Houses ✓Introduction of photovoltatic, fuel cell, heat pump and next-generation vehicles ✓About 3,100 next-generation vehicles (EV/PHV) and buses	Home self-suffice -ncy as a rule, support this by area adjustments	Effective transport system centering by next-generation vehicles	30% reduction to the 2005 level up to 2030 (Total)	Hybrid City Toyota, Toyota City, Toyota, Chubu Power, Denso, Sharp, Dream Incubator
Keihanna	✓Demonstration area: developing bed town surrounded by Kyoto, Osaka and Nara ✓Demonstration target of ener -gy management: houses, office buildings, university & research organization	Area adjustments of energy supply-demand of plural houses, Suppleme -ntary role of houses	Demonstration of advanced technol -ogy (to specify power origin, to make virtual com -bination of energy source & demand)	30% reduction to the 1990 level up to 2020 (Total)	Kyoto Prefecture, Kansai Power, Mitsubishi Heavy Industry, Omron, Osaka gas, Kansai Research Promoti -on Organization
Kitakyushu	✓Install smart meters to all consumers in demonstration area (70 companies & 200 houses) ✓Real time changes in power prices, Energy management to control house equipments	Control of supply -demand balances including not only houses but also basic networks	Pipeline supply of by-produced hydr -ogen from factory to local area	50% CO_2 reducti -on to the present level (to the stand -ard area)	Kitakyushu City, Shin-nihon Steel, Fuji Electric, Imagination@ work, IBM, NTT West Japan

(Source) Made from data in METI [2010b]

the combination of different partners, respectively.

Aiming to achieve the international expansion of smart community, so many projects have been planned and carried out already, as represented by the Munbai project in India. In Japan, various activities related on smart community have been developed for only two or three years from 2009 by cooperating with the public and private partnership so as not to be behind in international wars for market acquisition.

3.3 Intermediate results and extracted problems on demonstration projects

The four demonstration projects started from August 2010 have almost passed two years. Table 3 summarizes intermediate results and remaining items on four demonstration projects on smart community in Japan (METI [2011]).

In about two years passed from starting, four demonstration projects on smart community made several interesting results, respectively, as shown in Table 3. First, as for the Yokohama project, the installation of solar power and solar heat equipments, fuel cells and electric vehicles to the demonstration condominium was finished. In addition, the battery storage system and the system to control charge or discharge of battery by communicating with the storage battery system was also developed and the standard proposal for the

Table 3 Intermediate Results and Remaining Items of Four Demonstration Projects

	Items already done and results	Items will be done from now
Yokohama	➢Introduction of solar power, fuel cell, solar heat, electric vehicle etc. to the condominium ➢Development of both control system and battery storage system. The latter can make charge or discharge by communicating from the former. ➢Submit standard proposal to IEC TC57 for interface between control system and battery storage system	✧Start the demonstration for accommodation of electricity and heat in the condominium from April ✧Aim at 40% reduction of energy use by the introduct -ion of renewable energies, dispersed energies etc. ✧Plan to make a demonstration of B route (to supply electricity use data to home directly), first in Japan
Toyota	➢Constructed 67 smart houses, of these moved into 42 ➢Reduced 8.6% of electricity use by making visible ➢Self-sufficiency rate of smart house reached to 50% ➢About 30% of electricity saving by making visible and by demonstration of demand response with point incentives ➢Linked control between storage battery and fuel cell using HEMS	✧Demonstration of electricity supply from storage battery on vehicle to house in next autumn ✧Commercialization of V2H system in next winter ✧Self-sufficiency rate of smart house to 70% ✧Demonstration of avoiding response to congestion with point incentives ✧Demonstration of car sharing system using ultra-small EV ✧Demonstration of electricity supply from fuel cell bus
Keihanna	➢Making visible to 51 houses, Introduction of HEMS to 14 houses and Li storage battery to 10 houses ➢Monitoring function of CEMS in operation, desk verification of BEMS completed ➢Introduction of 60 EV completed, Linkage between FEMS and discharge system of EV storage battery (V2X) completed ➢Development of modal shift simulator completed	✧Large-scale demonstration using installed and devel -oped systems ✧Considering new business developments such as net shop using terminal for making visible, healthcare, security check etc., together with ESCO to home ✧Demonstration of demand response using CEMS ✧Receiving electricity from wide areas by lumping together and operating CEMS by electricity company itself
Kitakyushu	➢Home display of power price information by CEMS ➢Demonstration of peak time power price change from Level 1 (15 Yen/kWh) to Level 5 (150 Yen/kWh) ➢Energy saving effects of 11.9% at Level 2 and 26.4% at Level 3 ➢Almost zero electricity purchase in daytime using home storage battery system ➢Use of by-produced hydrogen from Shin-Nippon Steel on fuel cell at home	✧Covering 30% of heat demand by effective use of solar heat and 40% reduction of electricity charge ✧Further checking of peak cut effects by price raising at peak time (maximum 10 times up) within this year ✧Promoting power saving by showing electricity uses at home and power price information from CEMS through home terminal display

(Source) Made from data in METI [2011]

interface between both systems was submitted to IEC TC57. The further complicated demonstrations on the accommodation of electricity and heat among related sectors will be done in next one or two years.

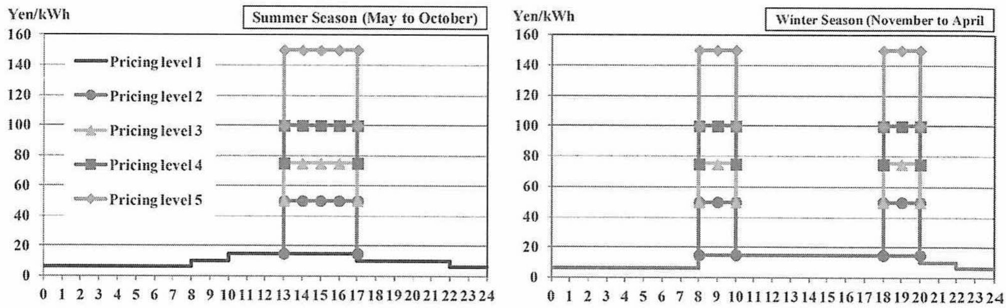
Second, as for the Toyota project, 67 smart houses were constructed and of these, 42 smart houses were already moved in. The rate of energy self-sufficiency reached to 50% and the 8.6% reduction of electricity use was made by the making visible function of smart house. The Toyota project also tried the demonstration of demand response using point incentives. Because of both factors, about 30% of electricity saving was achieved up to now. In addition, the linked control was made between storage battery and fuel cell using CEMS system. In the Toyota project, further demonstration items will be also tried in next one or two years.

Third, as for the Keihanna project, the making visible function was installed total 51 houses, the HEMS system was introduced to 14 houses, and the Li storage battery for home use was installed to 10 houses. 60 electric vehicles were also introduced in the demonstration area. The linkage between FEMS and the discharge system from electric vehicle storage battery (V2X system) was developed and completed as a quite

Fig. 1 Electricity Price Changes Prepared for Demand Response by Dynamic Pricing

(Unit: Yen/kWh)

Time Grouping	Season	Time range	Level 1	Level 2	Level 3	Level 4	Level 5
Peak time	May - October	13:00 – 17:00	15.18	50.22	75	100	150
	November - April	8:00 – 10:00 18:00 – 20:00	15.09	50.02	75	100	150
Day time	May - October	10:00 – 13:00	15.18	15.18	15.18	15.18	15.18
	November - April	10:00 – 18:00	15.09 –15.18	15.09 –15.18	15.09 –15.18	15.09 –15.18	15.09 –15.18
Living time	May - October	8:00 – 10:00 17:00 – 22:00	10	10	10	10	10
	November - April	20:00 – 22:00					
Night time	Whole year	22:00 – 8:00	5.94	5.94	5.94	5.94	5.94



(Source) METI [2012a]

important component technology. The Keihanna project also plans to make large-scale demonstrations using these installed and developed systems.

Forth, as for the Kitakyushu project, the electricity price information was supplied to the home display terminals of 50 offices and 230 houses in the demonstration area using the CEMS system (the local energy management system). Fig. 1 shows electricity prices changes prepared for the demand response demonstration by dynamic pricing in the Kitakyushu project. The electricity saving effect of 11.9% was observed at the dynamic price level 2 of peak time and the same effect of 26.4% was also observed at the dynamic pricing level 3.

In addition, almost zero electricity purchase in daytime was made at the condominium in the demonstration area, using a home storage battery system. The by-produced hydrogen from Shin-nippon Steel was used for the fuel cell operation at the houses in the demonstration area. In the Kitakyushu project, further demonstration trials will be made as the same as other projects.

We need to thoroughly consider about the way of promoting the demonstration projects from the following viewpoints: (1) to reconsider the positioning of smart community (especially on the relation with large disasters), (2) to accumulate know-how of smart community and to strengthen the project managements, (3) to expand and develop further demand response businesses and (4) to enhance the promotion activities of smart community to domestic and overseas.

In the sector of rules making for smart community are listed up the following issues: (1) the liberalization of low-voltage electricity sending, (2) the promotion of specified electricity business and specified electricity supply, (3) the receiving electricity in a lump, (4) the supply of electricity network information and (5) the independence of electricity supply system at emergency.

4. Plan of environmental-friendly future town and its issues solved

Japanese Government made a proposal report on the framework of revival from the East-Japan large disasters in June, 2011 (Cabinet office [2011a]) and the construction of communities practically applying renewable energies was recommended in the report. Based on this report, the invitation of proposal for environmental-friendly future town (smart community) projects was made by Japanese Government and several projects were adopted. The large-scale demonstration trials for smart communities are quite meaningful from the viewpoint of green innovation, but there are many issues and problems to be considered and to be solved.

As discussed in the preceding session, the smart community is a quite important theme which has been eagerly dealt by both public and private sectors in Japan in recent two years. Considering the discussions mentioned above, the invitation of environmental-friendly future city project was made by the Japanese government. Total 30 proposals for the future city project submitted and 11 proposals were adopted by the government. Table 4 shows outline and specific characters of these 11 projects together with partners.

As shown in Table 4, Iwate Pref. Miyagi Pref. and Fukushima Pref. suffered from the East-Japan large disasters severely submitted their proposals and two proposals for each Prefecture were adopted specially by the government. The remaining 5 projects were generally adopted with no relation to the disaster area. One common special character of all submitted proposals is to close up the expansion of renewable energies. Another common special character is to deal with problems and measures to future great age society.

Table 4 Outline and Special Characters of Environmental-friendly Future Town Projects

	Outline of project	Specific characters	Partners
Shimokawa-cho Hokkaido Pref.	Development of autonomytype forest industry Self-support of renewable energies centering biomass good life by forest and constr -uction of local social model	Proposal based on forest Self-support ratio of energy 100% Expansion of employment for old age workers	Shimokawa-cho, Shimokawa Forest, Forest Research Institute, Kamikawa North Forest Management, NPO Hokkaido University etc.
Kashiwa-shi Chiba Pref.	Smart city based on higher level of CEMS and IT Venture support combining basic research with business Program on healthy body and long life	Strong relation with Industry, government and academy Using old people as citizen health supporter Making gap fund	Tokyo University, Chiba University, Kashiwa-shi, Mitsui Real Estate, Smart City Planning, Kashiwanoha Urban Design
Yokohama-shi Kanagawa Pref.	Smart city using solar cells, EV and CEMS Programs on super great age by NPO and support network Base for innovation	Accumulation of know-how on environment and energies Expansion of advanced water management technology Creative activities on culture and arts	Yokohama-shi, Yokohama Smart City Project, JICA, Yokohama Water, JBIC, Yokohama Green Power, NPO etc.
Toyama-shi Toyama Pref.	Construction of compact city Centering LRT Effective use of forest biomass, mini-hydro power etc. Effective use of biotechnol -ogy	Rich renewable energies Tradition of Japanese & Chinese drugs and medical goods Conversion to public trans-port, bicycle etc.	Toyama-shi, Toyama Light Railway, Toyama Local Railway, Drug companies, Electricity companies NPO etc.
Kitakyushu-shi Fukuoka Pref.	Construction of smart comm -unity Project on forest in town Preparation of welfare net -work	Expansion of international environment business Effective use of local power and connection Plantation by citizen	Kitakyushu-shi, Kitakyushu Smart Community, Urban Renaissance Agency, Kita-kyushu Eco town Project, NPO etc.
Ofunato-shi Rikuzentakada-shi Sumita-cho Iwate Pref.	Mega solar power plant with local storage battery system Construction of dispersed co -mpact city on hill Linkage by EV buses	Revival as disaster prevention future city Agricultural revival by plan -tation factory Dispersed energy society	Sumita-cho, Ofunato-shi, Rikuzentakada-shi, Electricity companies, Mega solar companies, Battery maker etc.
Kamaishi-shi Iwate Pref.	Revival by local energies Effective use of various energies such as forest, wind etc. Unification of health, medical, welfare and care	Wood supply by combination of different businesses Making good life of old people Town development using his -torical environment	Kamaishi-shi, Eurus Energy, Private companies, NPO etc
Iwanuma-shi Miyagi Pref.	Group transfer to compact city Construction of smart grid centering mega solar power Linkage of health and medical managements	Coexistence with natural env -ironment Effective use of medical cloud Education for disaster preve -ntion	Iwanuma-shi, NPO, Private companies, Agricultural organization, Medical Organization etc.
Higashimatsushima-shi Miyagi Pref.	Construction of autonomy type system centering biomass etc. Promotion of healthy houses using health check list Care and Medical services using multi-media terminals	Self-support ratio of natural energies from 1% to 120% Effective use of multi-media terminal Self-support school	Higashimatsushima-shi, Higashimatsushima-shi Revival Projects Promotion Organization, Okumatsushima Public Co., Private companies etc.
Minamisoma-shi Fukushima Pref.	Large introduction of renewable energies Construction of compact city and generation recycle Making local recycle industry	No-nuclear and low carbon society Recovering and strengthening of community functions Future agriculture by plants	Minamisoma-shi, Electricity companies, Agricultural Organization, Private companies, NPO etc.
Shinnchi-cho Fukushima Pref.	Local produce and use of en -ergies using solar & biomass Upgrading of On demand tra -nsport system by EV Large-scale vegetable factory	Town with sea where people can coexist with nature Town where people can grow ties with other people Town where people can position life as top priority	Shinchi-cho, Nihon Applied Research Institute, Ratio International, Nissan, Apple Mitsubishi Estate Co. etc.

(Source) Made from data in Cabinet Office [2011b]

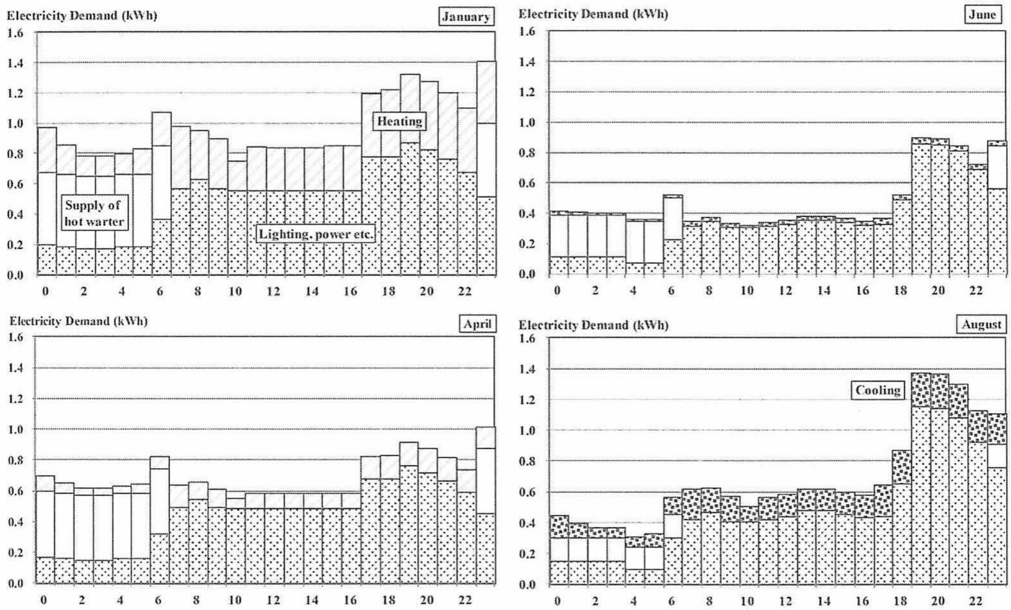
5. Economics simulations on the role of storage battery and photovoltaic cell

In this section, we would like to discuss the results of economics simulations on the introduction of storage battery and photovoltaic cell which are a representative and important facility for the construction of smart community.

5.1 Assumptions for economics simulation

The several assumptions explained below were adopted for the economics simulations for the introduction of storage battery and photovoltaic cell. First of all, the average electricity demand pattern in a house was estimated by month based on the METI survey report (METI [2012b]) and Cogeneration Comprehensive Manual (ACEJ [2004]). The category of consumptions was classified into "Lighting, power etc.," "Hot water supply," "Heating," and "Cooling." Fig. 2 shows the estimated average daily patterns of electricity demand for several months such as January, April, June and August.

Fig. 2 Average Electricity Demand Pattern of House by Month



The assumptions on storage battery are as follows. The capacity of storage battery installed in a house was changed from 1 kWh to 8 kWh every 1 kWh in the simulation. The cost of storage battery was assumed to be 200,000 Yen/kWh by examining various data on storage batteries. The one third of initial cost of storage battery was assumed to be subsidized by the Government. The charging of storage battery is made for 6 hours from 0:00 to 6:00 and the discharging of storage battery is made in other hours judging from electricity price.

The assumptions on photovoltaic (PV) cell are as follows. The average daily pattern of solar power generation was estimated by month using NEDO Sunshine Database (NEDO [2006]). The capacity of photovoltaic (PV) cell was changed from 1 kW to 5 kW every 1 kW in the simulation. The cost of photovoltaic cell was assumed to be 350,000Yen/kW by examining various data on photovoltaic cells. The one third of initial cost of photovoltaic cell was also assumed to be subsidized by the Government. Surplus electricity generated by photovoltaic cell was assumed to be sold at FIT (Feed in tariff) price of 42 Yen/kWh.

Electricity price assumption is as follows. Electricity price is changed from the pricing level 1 to pricing level 5 shown in Fig.1 for the peak time (13:00 – 17:00 in summer, and 8:00 – 10:00 and 18:00 – 20:00 in winter). This price assumption is actually used in dynamic pricing in Kitakyushu case of the smart community demonstration project.

The economics of the introduction of storage battery and photovoltaic cell is judged from the simple payback year which is calculated by dividing the net initial cost (excluding subsidy) of storage battery and photovoltaic cell by the annual profit. The above-mentioned annual profit is estimated from the difference between A (= total costs of purchased electricity in the case without storage battery and photovoltaic cell) and B (= total costs of purchased electricity in the case with storage battery and photovoltaic cell minus the revenue of sold surplus electricity generated by photovoltaic cell).

5.2 Individual introduction of storage battery and photovoltaic cell to house and their economics

First, the changes in electricity demand and supply pattern brought by the introduction of storage battery to the house was examined. As described already, the charging of storage battery is made in 6 hours between 0:00 and 6:00 every day when the price of purchased electricity is the lowest. On the other hand, with the first priority, the discharging of storage battery is made in 4 hours from 13:00 to 17:00 in summer season (May to October), and from 8:00 to 10:00 and from 18:00 to 20:00 in winter season (November to April) when the price of purchased electricity is the highest because of the peak time pricing.

With the second priority, the discharging of storage battery is then made in the day time, and after then, with third priority, it is made in the living time, as both shown in Fig. 1. If the discharging capacity of storage battery still remains, the discharging of storage battery is finally made in the night time except the above-mentioned charging time of storage battery.

The changes in electricity demand and supply caused by installing the storage battery to the house is shown in Fig. 3. As shown in this figure, in the case of the smallest installing capacity (1 kWh), the discharging of

Fig. 3 Changes in Electricity Demand and Supply Pattern in the House by installing the storage battery

(Storage battery: 1kWh) (Storage battery: 4kWh) (Storage battery: 8kWh)

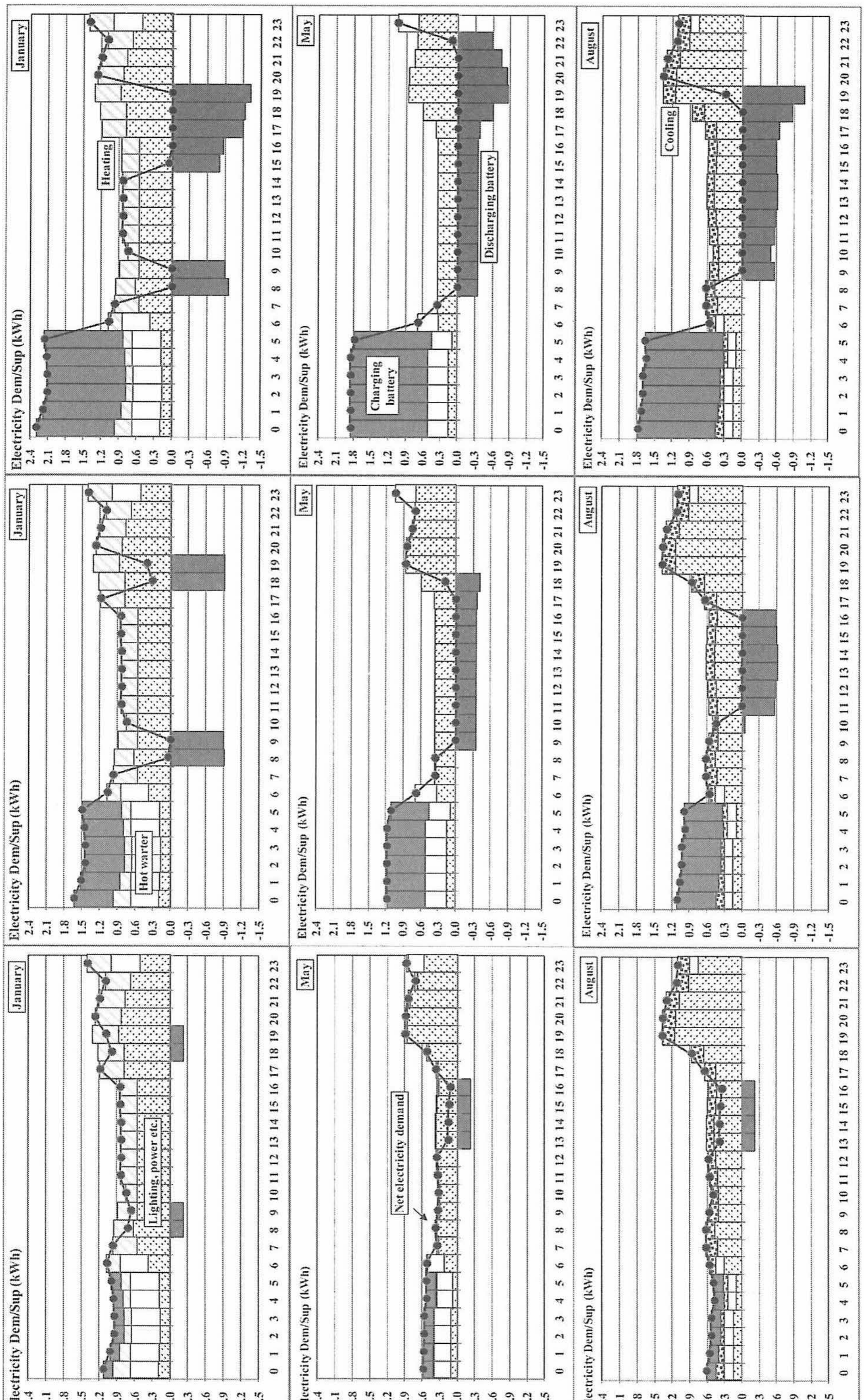
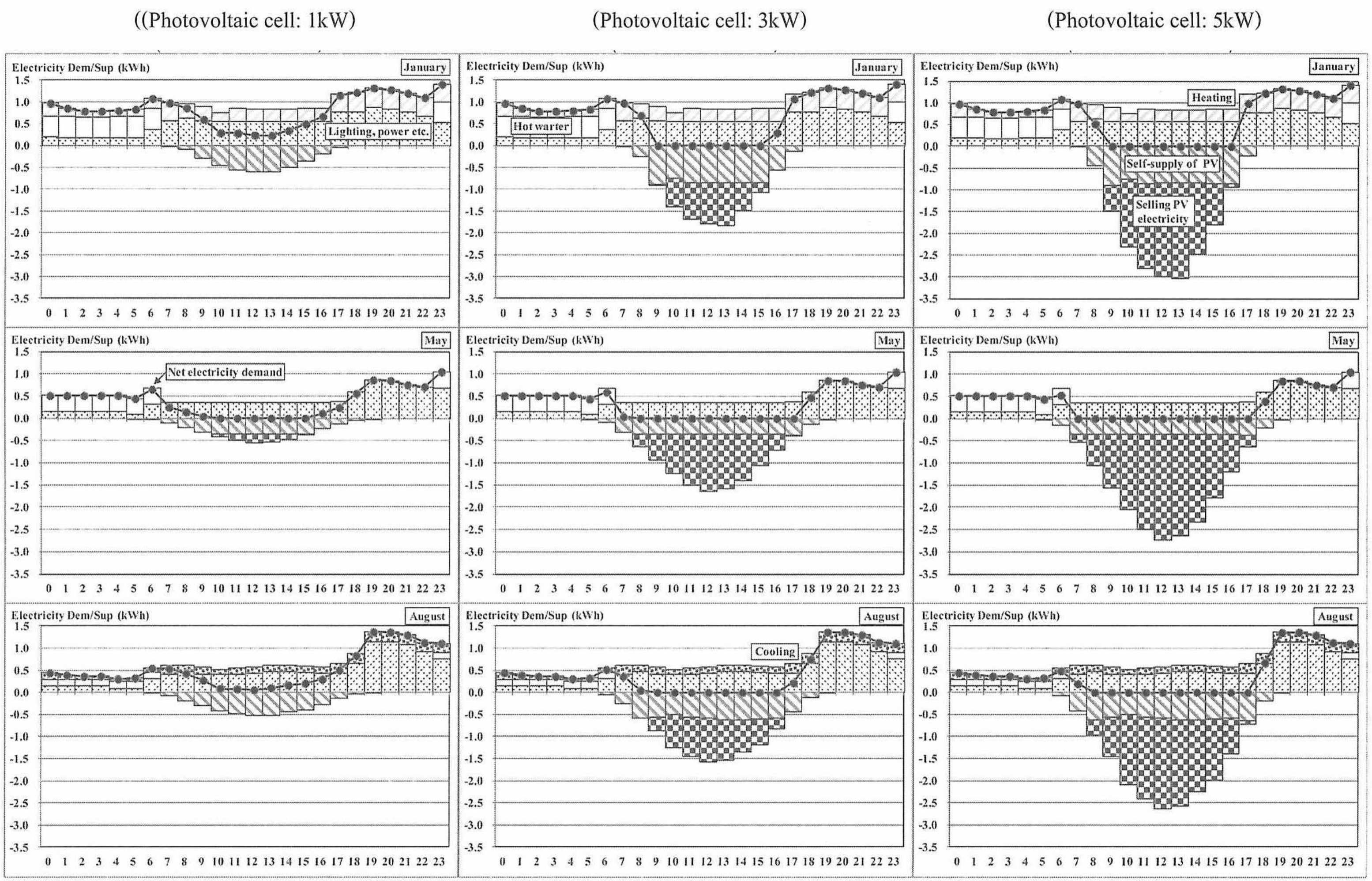


Fig. 4 Changes in Electricity Demand and Supply Pattern in the House by installing the Photovoltaic Cell



storage battery is made just in the peak time through the whole year. On the other hand, in the case of the highest installing capacity (8 kWh), the discharging of storage battery is made in the peak time, of course, and in the part of day time as for January (winter), in the peak and day times and the part of living time as for August (summer), and in the peak, day and living times and the part of night time as for May (spring or autumn).

Next, the changes in electricity demand and supply pattern brought by the introduction of photovoltaic (PV) cell to the house was examined. The electricity generated by the photovoltaic (PV) cell is supplied to the house in order to fulfill the electricity demand of house with first priority, and the remaining surplus electricity generated by the photovoltaic cell is sold to the local electricity company with the FIT price of 42 Yen/kWh.

The changes in electricity demand and supply caused by installing the photovoltaic (PV) cell to the house is shown in Fig. 4. As shown in this figure, in the case of the smallest installing capacity (1 kW), almost all of the electricity generated by photovoltaic cell is used the electricity demand of house almost through the whole year. Only in the middle season such as May, the quite small surplus electricity from the photovoltaic cell is sold to outside. On the other hand, in the case of the highest installing capacity (5 kW), through the whole year, there is large surplus electricity generated by the photovoltaic cell after supplying necessary electricity to the house, as shown in Fig.4.

As the changes in electricity demand and supply pattern by the installation of storage battery and photovoltaic cell, respectively, could be estimated, the simple payback year of both equipments were calculated as the next step and then, the economics of storage battery and photovoltaic (PV) cell were evaluated from the payback year. The results of simple payback year on storage battery and the ratio of cost reduction by the installation of storage battery are shown in Fig. 5.

The simple payback year of storage battery is more than 45 to 60 years under pricing level 1, but is drastically improved to about 10 years under pricing level 2. As the capacity of storage battery becomes larger, the simple recovery year increases more, because the increasing discharge is made in lower electricity price levels and thus, the ratio of cost reduction is lowered gradually, as shown in Fig. 5.

The results of simple payback year on photovoltaic (PV) cell and the ratios of PV self-supply to the house and PV surplus electricity selling by the installation of photovoltaic cell are shown in Fig. 6. Under pricing level 1, the simple pay back year of the smallest capacity of photovoltaic cell (1 kW) is more than 10 years, but the simple payback year is drastically improved to about 5 to 8 years, as the capacity of photovoltaic cell becomes larger. The reason is because the ratio of PV surplus electricity selling is drastically increased and on the other hand, the ratio of PV self-supply to the house is saturated, as the capacity becomes larger, as

Fig.5 Estimated Simple Payback Year of Storage Battery and Ratio of Cost Reduction

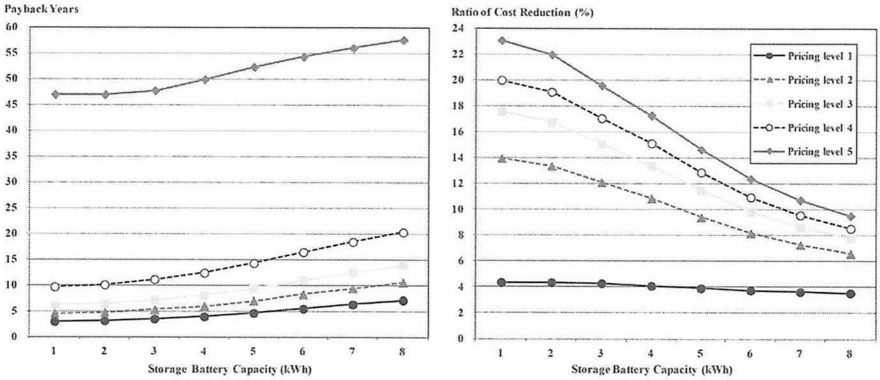
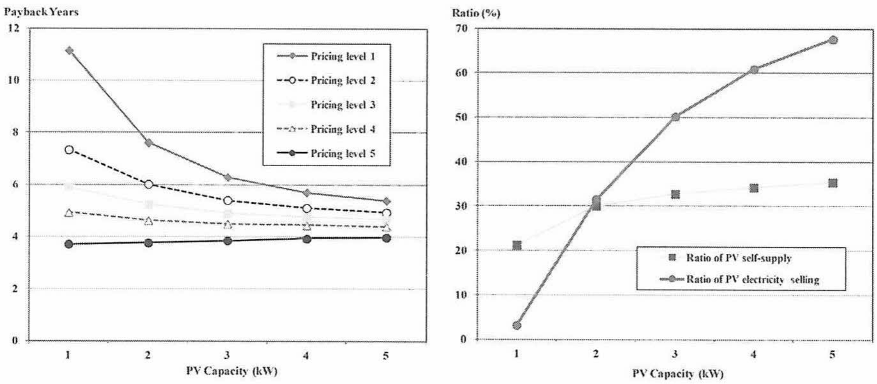


Fig.6 Estimated Simple Payback Year of PV and Ratios of Self-Supply and Surplus Selling



shown in Fig.6.

Under pricing level 2 and 3, similar changes of the simple payback year mentioned above are also observed, but the simple payback year of the smallest capacity (1 kW) is less than 10 years and the changes in the payback year by increasing capacity of photovoltaic cell is not so drastic, also as shown in Fig. 6. Under pricing level 4 and 5, the simple payback year of the smallest capacity (1 kW) is 4 to 5 years and the payback year by increasing capacity is almost the same.

If the capacity of PV cell reaches to more than 3kW, the simple payback year becomes 4 to 6 years, because the ratio of selling surplus PV electricity is more than 50%, as shown in Fig. 6. This result means that the FIT price of 42 Yen/kWh is quite attractive and the payback year is largely improved by selling PV surplus electricity to the local electricity company.

5.3 Combined introduction of storage battery and photovoltaic cell and its economics

As the next works of economics simulation, we would like to discuss the combination of storage battery and photovoltaic cell in this subsection. As the typical standard capacity of photovoltaic cell required to the house is from 3 to 4 kW, we fixed the capacity of photovoltaic cell at 4 kW in this economics simulation. On the other hand, we changed the capacity of storage battery every 1kWh from 1 kWh (the lowest case) to 8kWh (the highest case).

We adopted two cases for how to use these two equipments. One is that the discharging electricity from the storage battery is supplied to the house electricity demand with the first priority and the electricity generated by the photovoltaic cell is sold to the electricity company as much as possible (Storage battery first, and then PV cell). The other is that the electricity generated by the photovoltaic cell is supplied to the house electricity demand with the first priority and the discharging electricity the storage battery is supplied to the remaining house electricity demand (PV cell first, and then storage battery).

First, the changes in electricity demand and supply pattern caused by the combination of storage battery (4 kWh: the middle case) and PV cell (4 kW) is shown in Fig. 7. In the case of "Storage battery first, and then PV cell," the discharging electricity from storage battery replaces the electricity from PV cell in 8:00 to 10:00 for January, 9:00 to 19:00 for May and 10:00 to 17:00 for August, respectively. As the results, the selling PV surplus electricity is increasing.

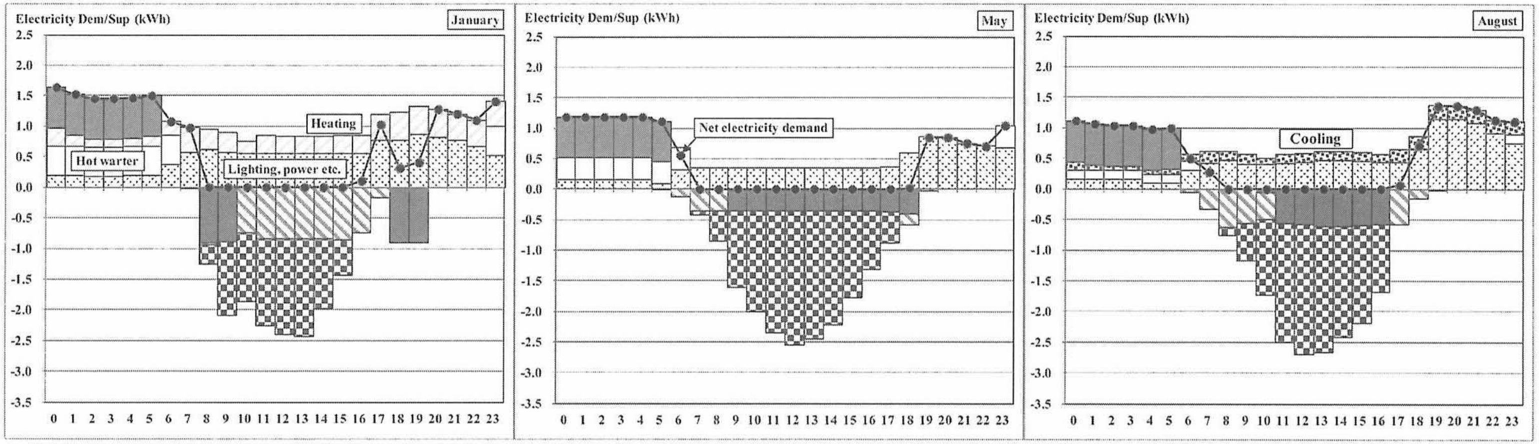
On the other hand, in the case of "PV cell first, and then storage battery," necessary supply of the house electricity demand in day time is made almost all by the electricity generated by PV cell. Thus, the discharging electricity from storage battery is mainly used for the house electricity demand in peak time and living time starting from evening that is, after 17:00 to 22:00.

Next, the changes in electricity demand and supply pattern caused by the combination of storage battery (8kWh: the highest case) and PV cell (4 kW) is shown in Fig. 8. In the case of "Storage battery first, and then PV cell," the discharging electricity from storage battery further replaces the electricity from PV cell in the wider range such as 8:00 to 10:00 and 15:00 to 18:00 even for January, 6:00 to 20:00 for May and 6:00 to 20:00 for August, respectively. In addition, the remaining electricity of storage battery is discharged to the house electricity demand in evening and night.

In the case of "PV cell first, and then storage battery," the increasing electricity stored in the battery is further used for the house electricity demand in from evening to late night. Except severe winter season such as January, the capacity of storage battery at 8kWh is not fully operated, because there is no additional house electricity demand which should be covered by the discharging electricity from storage battery, for example, in the case of May and August, as shown in Fig. 8.

Fig. 7 Changes in Electricity Demand and Supply by Combination of Storage Battery (4 kWh) and PV (4 kW)

(Storage battery first, and then PV cell)



(PV cell first, and then storage battery)

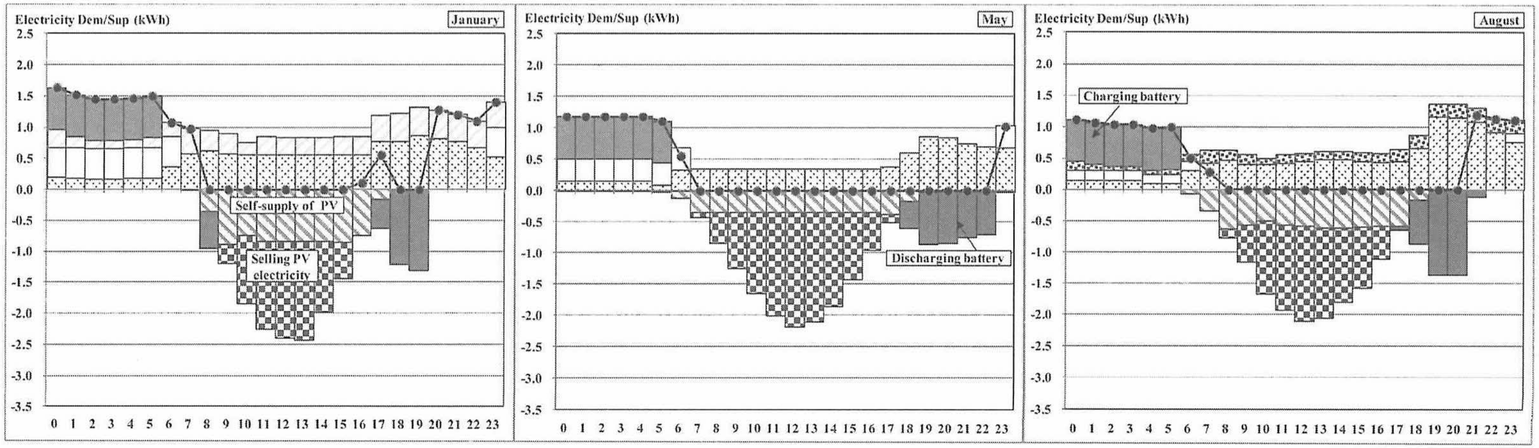
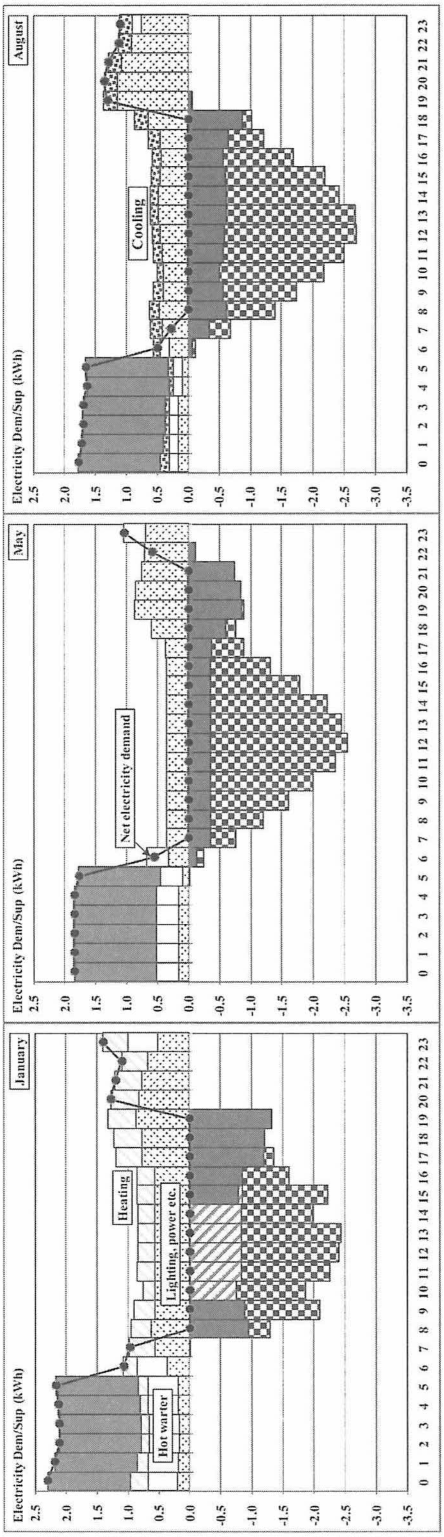


Fig. 8 Changes in Electricity Demand and Supply by Combination of Storage Battery (8 kWh) and PV (4 kW)

(Storage battery first, and then PV cell)



(PV cell first, and then storage battery)

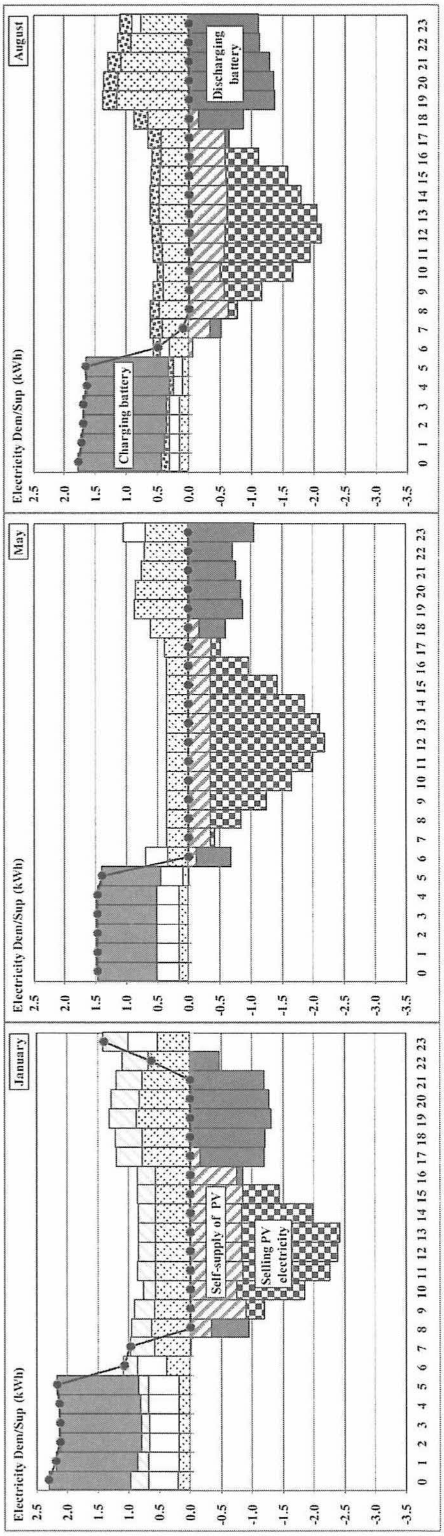
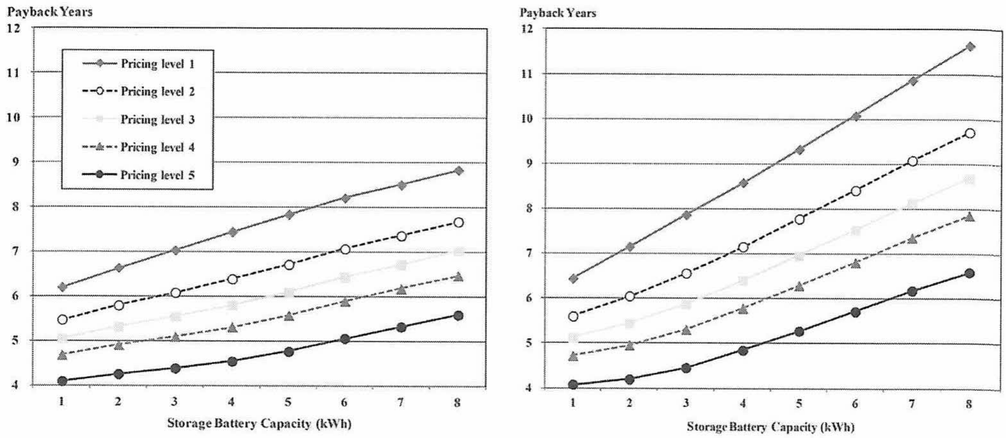


Fig. 9 Comparison of Simple Payback Year by the Combination of Storage Battery and PV Cell

(Storage battery first, and then PV cell) (PV cell first, and then storage battery)



Finally, we would like to compare the simple payback year of both cases such as "Storage battery first, and then PV cell," and "PV cell first, and then storage battery." Figure 9 shows the compared results of simple payback year for both cases.

If the combination of storage battery and PV cell with discharge of storage battery (the first priority) and self-supply of PV cell (the next priority), the simple payback year of total investment becomes 6 to 9 years at pricing level 1. Compared with 45 to 60 years of storage battery only at pricing level 1, the simple payback year is drastically improved by the combination of PV cell.

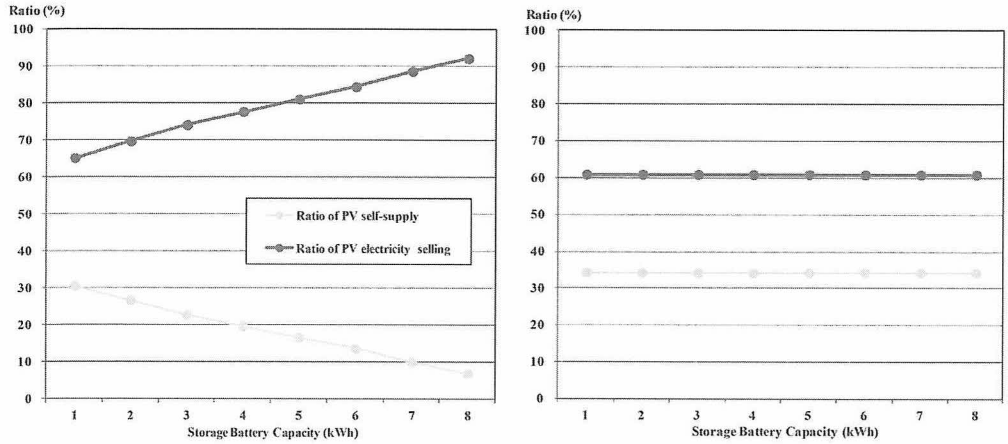
On the other hand, if the combination of PV cell and storage battery with self-supply of PV (the first priority) and discharge of storage battery (the next priority), the simple recovery year of total investment becomes 6 to 12 years at pricing level 1, because surplus PV electricity which can be sold to the electricity company is reduced by supplying to the house electricity demand and the electricity from storage battery is used for the replacement of lower price electricity.

Figure 10 also shows the compared results of changes in the ratio of PV self supply and the ratio of PV electricity selling. As shown in this figure, in the case of "Storage battery first, and then PV cell," the ratio of PV electricity selling is increasing more and the ratio of PV self-supply is decreasing more, as the capacity of storage battery becomes larger. On the other hand, in the case of "PV cell first, and then storage battery," both ratios keep each value with no change, even if the capacity of storage battery becomes larger. The reason is because the electricity generated by PV cell is used for the house electricity demand with the first priority.

The results obtained from the economics simulations made by this study would suggest the following two implications. One is that the FIT price of 42 Yen/kWh for surplus PV electricity is quite attractive for

Fig. 10 Comparison of Ratio of PV Self-Supply and Ratio of PV Electricity Selling

(Storage battery first, and then PV cell) (PV cell first, and then storage battery)



improvement of investment economics for smart community. The other is that the longer and higher prices in day time, that is, the large price difference between day time and night time would be required for the establishment of smart community. The latter point is gradually reflected to recent movements of pricing menu by electricity companies.

6. Concluding remarks

First, it should be deeply discussed what kind of merits are brought to demand-side consumers in the area where the environmental-friendly future town (smart community) is realized. In the present discussion, it seems that logics of supply-side players would be revealed too strongly.

Second, specific and concrete project contents of smart community project should be thoroughly considered, because the survival competitiveness is strongly required in the competitions with so many similar projects planned at various places in Japan from now on.

Third, it is quite important to organize and utilize a public-private partnership (PPP) combining central government, local governments, NPO, related private enterprises, and consumers for the projects making the most of local special qualities and competitiveness.

Finally, the function of comprehensive project manager such as Accenture and IBM is required to achieve a smart community project. In Japan, we need to train such a player without delay.

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