

# **An Analysis on the Smart Community Connecting Commercial and Residential Sectors**

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## **Abstract**

In recent years, the progress of information and communication technologies is remarkable. The storage system of electricity is also being made a progress. Therefore, in this study, we would like to analyze economics of smart community connecting the commercial and residential sector using photovoltaic cell and electricity storage system under various conditions.

The introduction of smart communities connecting with houses and offices is one of important options to reduce purchased electricity from the power company. It is essential to strengthen the flexibility of electricity accommodations using demand differences between houses and offices and using PV generation and electricity storage system. Though the introduction of PV cells becomes more reasonable owing to the FIT (Feed-in-Tariff) system, the cost up by the electricity storage system disturbs the expansion of smart communities due to the lowering economics.

The role of PV cells is to fulfill electricity in the houses and offices as much as possible. The fixed price to receive PV electricity by FIT should be lowered. The cost reduction of electricity storage system would be important particularly from the viewpoint of technology. Recently TESRA announced about a quite cheap electricity storage system for housing use. This is a good news which should be welcomed.

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## Introduction

Recently Japanese Government has determined the new target of GHGs reduction to achieve 26% reduction from the emission level in 2013 up to 2030. After the East Japan great earthquake and huge nuclear accidents in Fukushima, the discussions on the long-term energy supply-demand plan and the new GHGs reduction target for post-Kyoto wandered so largely and finally reached to this conclusion. Anyway, Japan must intensify her GHGs reduction measures basically in the long-run, because she already agreed 50% (or 80%) reduction of GHGs in 2050 in the past Summits etc.

Up to 2013, GHGs emission in Japan has increased largely from 1990 level (the base level in Kyoto Protocol). We must say that Japan could not achieve a domestic reduction target in this period except in 2009 after the Lehman Shock. Especially speaking, the continuous increases in GHGs emission in the commercial and residential sectors were one of main factors on the increases.

In recent years, the progress of information and communication technologies is remarkable. The storage system of electricity is also being made a progress. The introduction of smart community connecting both sectors using photovoltaic cell and electricity storage system is an important future option in Japan. The purpose of this study is to analyze the economics of smart communities connecting both sectors under various conditions and to discuss their future subjects. .

## Methods

In this study, we made economics simulations on the introduction of smart facilities such as photovoltaic cell and electricity storage system as important functions of smart community. First of all, the average electricity demand pattern in a house and an office building was estimated by month based on the METI survey report [1], EDMC survey data [2] and Cogeneration Comprehensive Manual [3]. We also surveyed present situations on photovoltaic cell, and electricity storage system [4, 5].

The number of households in the residential sector was assumed to be 5,000 and the total floor area in the commercial sector was also assumed to be 300,000 m<sup>2</sup>. Figure 1 shows the electricity consumption pattern in the commercial sector and Figure 2 also shows the electricity consumption pattern in the residential sector for January, April, July and October.

The capacity of photovoltaic (PV) cell for each house in the residential sector was assumed at 4 kW. The number of household which the photovoltaic (PV) cell was installed was changed from 0 to 5,000 by 2,500. The capacity of photovoltaic cell in the commercial sector was also changed from 0 MW to 75 MW every 25 MW. In addition, the various differences of electricity charge between daytime and night were assumed.

The cost of photovoltaic (PV) cell for the house use (small-size) was assumed to be 400,000 Yen/kW. The

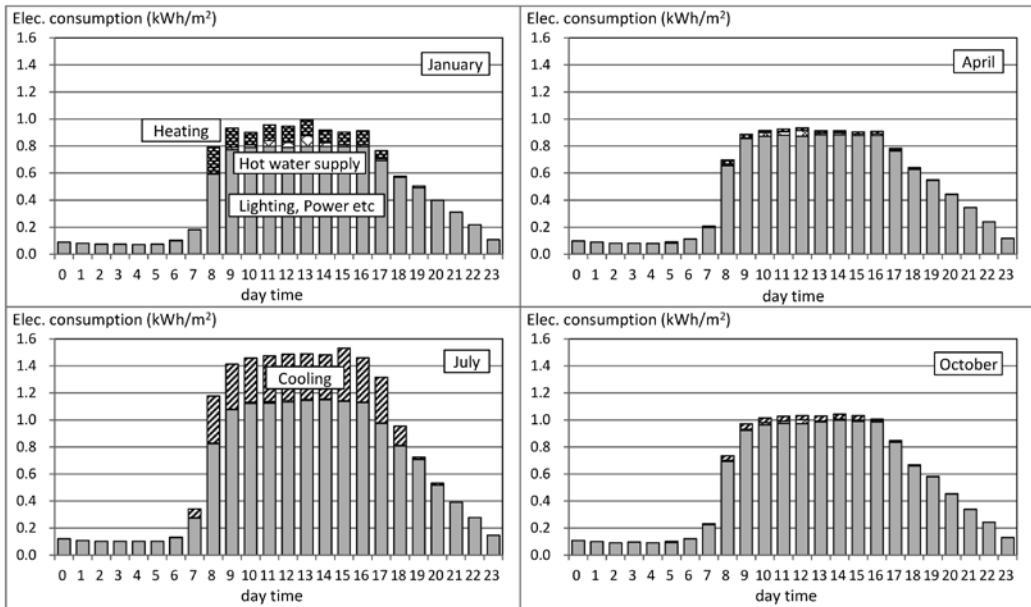


Fig. 1 Electricity consumption pattern in the commercial sector

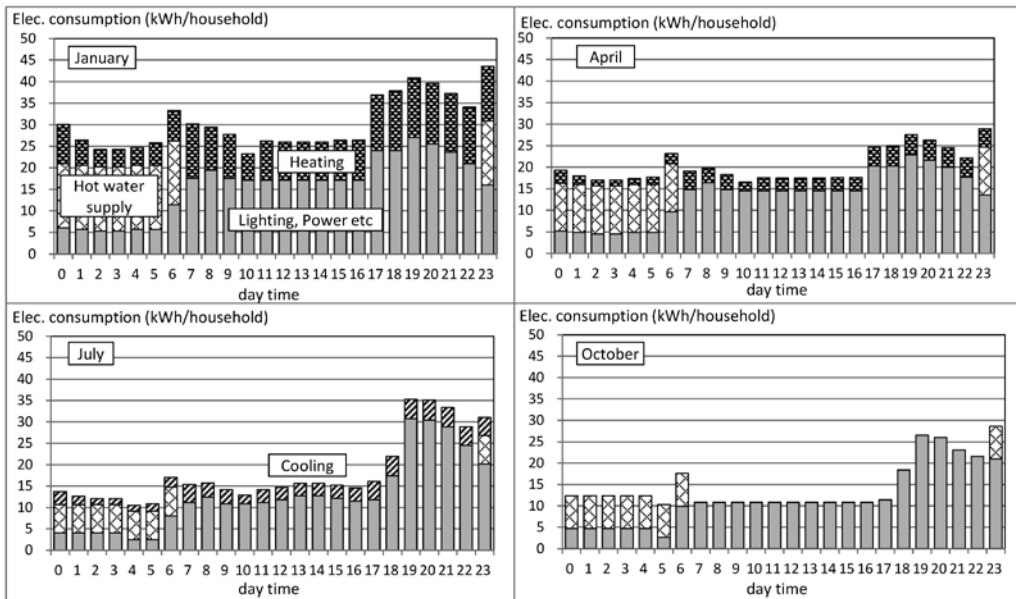


Fig. 2 Electricity consumption pattern in the commercial sector

subsidy to photovoltaic (PV) cell for this use was assumed to be 20,000 Yen/kW by the central government and 50,000 Yen/kW by the local governments on the basis of various surveys. The cost of photovoltaic (PV)

cell for the building use and mega solar (large-size) was assumed to be 350,000 Yen/kW. The subsidy to photovoltaic (PV) cell for this purpose was assumed to be one third of initial cost.

The capacity of electricity storage system was changed from 0 kWh to 120,000 kWh every 40,000 kWh in the simulation. The charging of electricity storage system is made from 0:00 to 6:00 for cheap purchased electricity in midnight if necessary and from 7:00 to 18:00 for surplus PV electricity, and the discharging of electricity storage system is made in necessary hours judging from electricity consumption. The cost of electricity storage system was assumed to be 150,000 Yen/kWh and the subsidy to the electricity storage system was assumed to be one third of initial cost.

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]). Figure 3 shows the typical PV electricity generation pattern in the metropolitan area used in this study.

In this study, several cases of the electricity charges different from hour by hour were assumed under the condition that the total electricity charge revenues to standard electricity consumption of average household based on the existing survey would be the same (neutral) among plural cases. The finally remaining surplus electricity generated by photovoltaic cell was assumed to be sold at FIT (Feed in tariff) price of 37 Yen/kWh for the residential sector and the 32 Yen/kWh for the commercial sector (actual value in fiscal 2013).

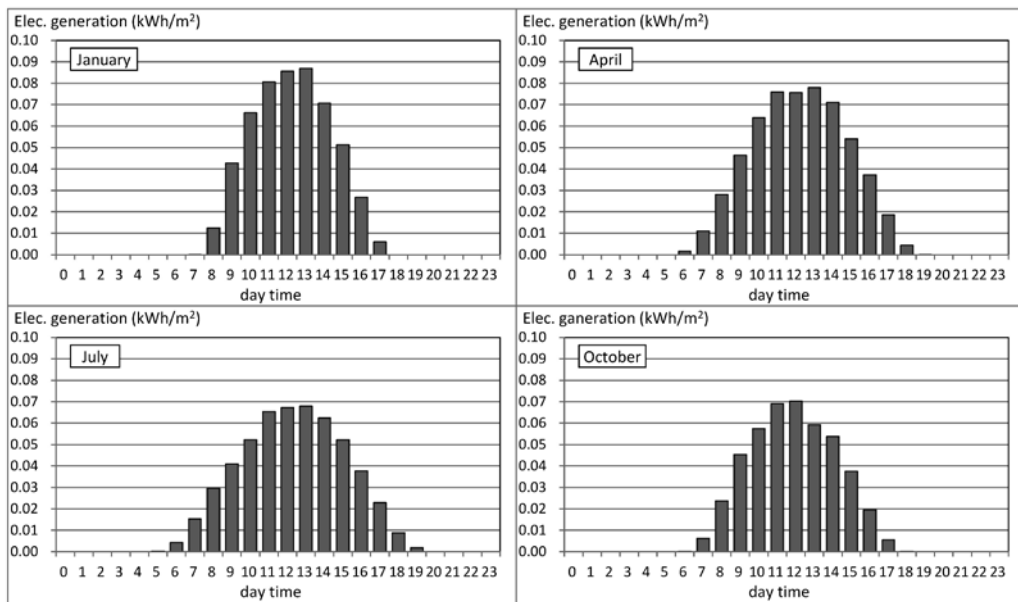


Fig. 3 Typical PV electricity generation pattern in the metropolitan area

The economics of the introduction of smart facilities is judged from the simple payback years which is calculated by dividing the net initial cost (excluding cost covered by the subsidy) of necessary facilities by the annual profit brought by the reduction of purchased electricity and the sales of remaining surplus PV electricity under the FIT system .

## Results

### **(1) Changes in daily electricity supply-demand pattern by the introduction of electricity storage system**

Figure 4 shows changes in daily electricity supply-demand by the introduction of photovoltaic (PV) cells (4 kW for 5,000 houses in the residential sector and 50 MW in the commercial sector) and electricity storage system of 40 MWh as for January, April, July and October. Figure 5 shows changes in daily electricity supply-demand by the introduction of the same photovoltaic (PV) cells as the case of Fig. 4 and electricity storage system of 120 MWh.

In the case of 40 MWh electricity storage system, the large extent of surplus PV electricity is sold to outside, especially in January, because the capacity of electricity storage system is small, as shown in Fig. 4. In July, required electricity demands in both sector become quite large, thus surplus PV electricity sold to outside is reduced to some extent.

The PV electricity charged into the electricity storage system is limited because of the small capacity of electricity storage system, and thus the electricity discharged from the electricity storage system cannot cover necessary demands in all hours. Thus, the electricity purchased from the power company need to cover night demands in the residential sector, and electricity purchased is also required for charging into the electricity storage system, especially in January.

Because of the small capacity, the accommodations of PV electricity between both sectors do not work effectively in the 40 MWh electricity storage system case.

In the case of 120 MWh electricity storage system, the large extent of surplus PV electricity sold to outside is reduced, especially in July, because the capacity of electricity storage system is enough large, as shown in Fig. 5. In July, required electricity demands in both sector become quite large, thus surplus PV electricity sold to outside becomes almost zero.

The PV electricity charged into the electricity storage system is enough to cover necessary demands because of the large capacity of electricity storage system, and thus the electricity discharged from the electricity storage system can cover necessary demands in all hours in April and October. Thus, the electricity purchased from the power company is required in January and July, and electricity purchased for

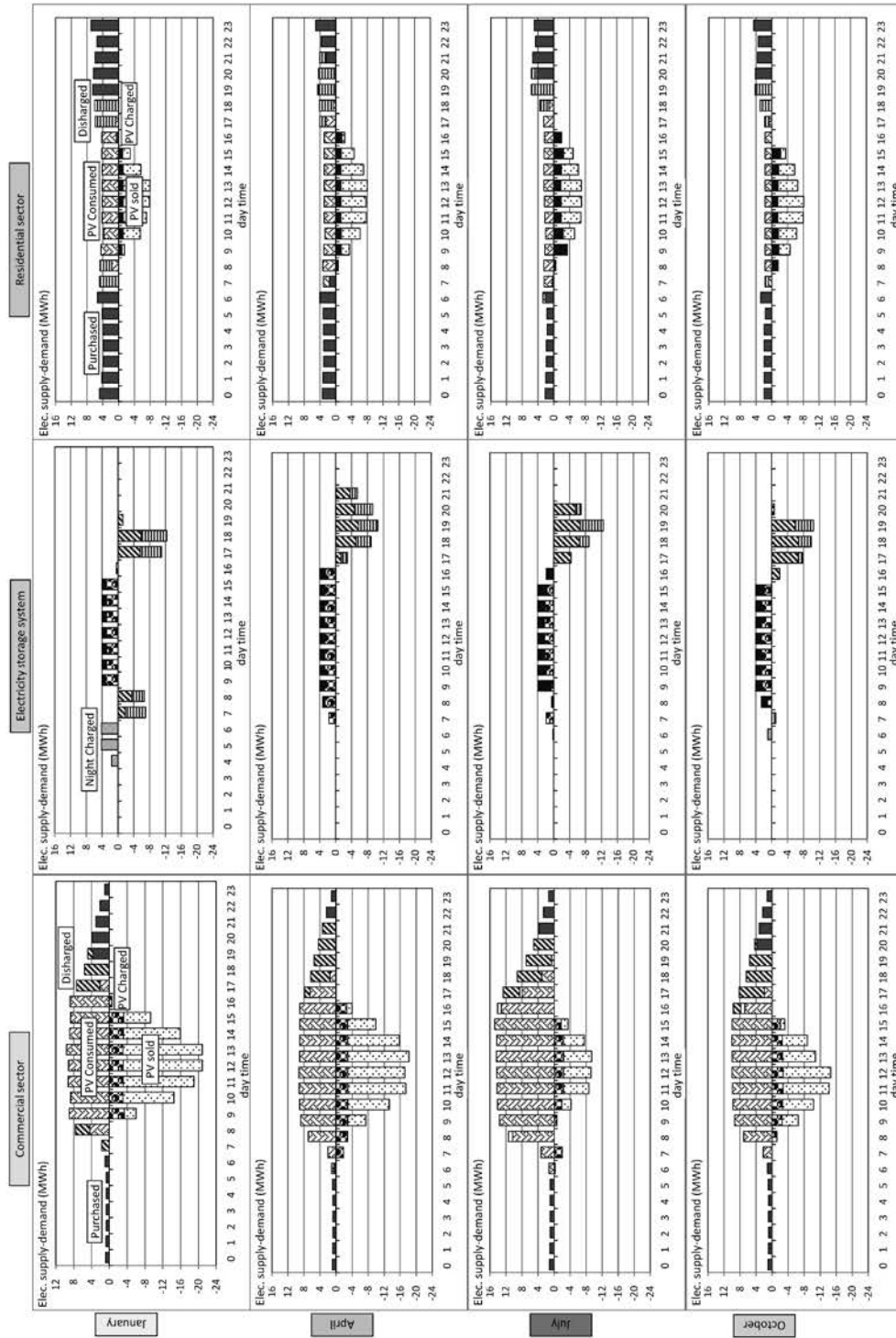


Fig. 4 Changes in daily electricity supply-demand by the introduction of PV system and electricity storage system (40 MWh)

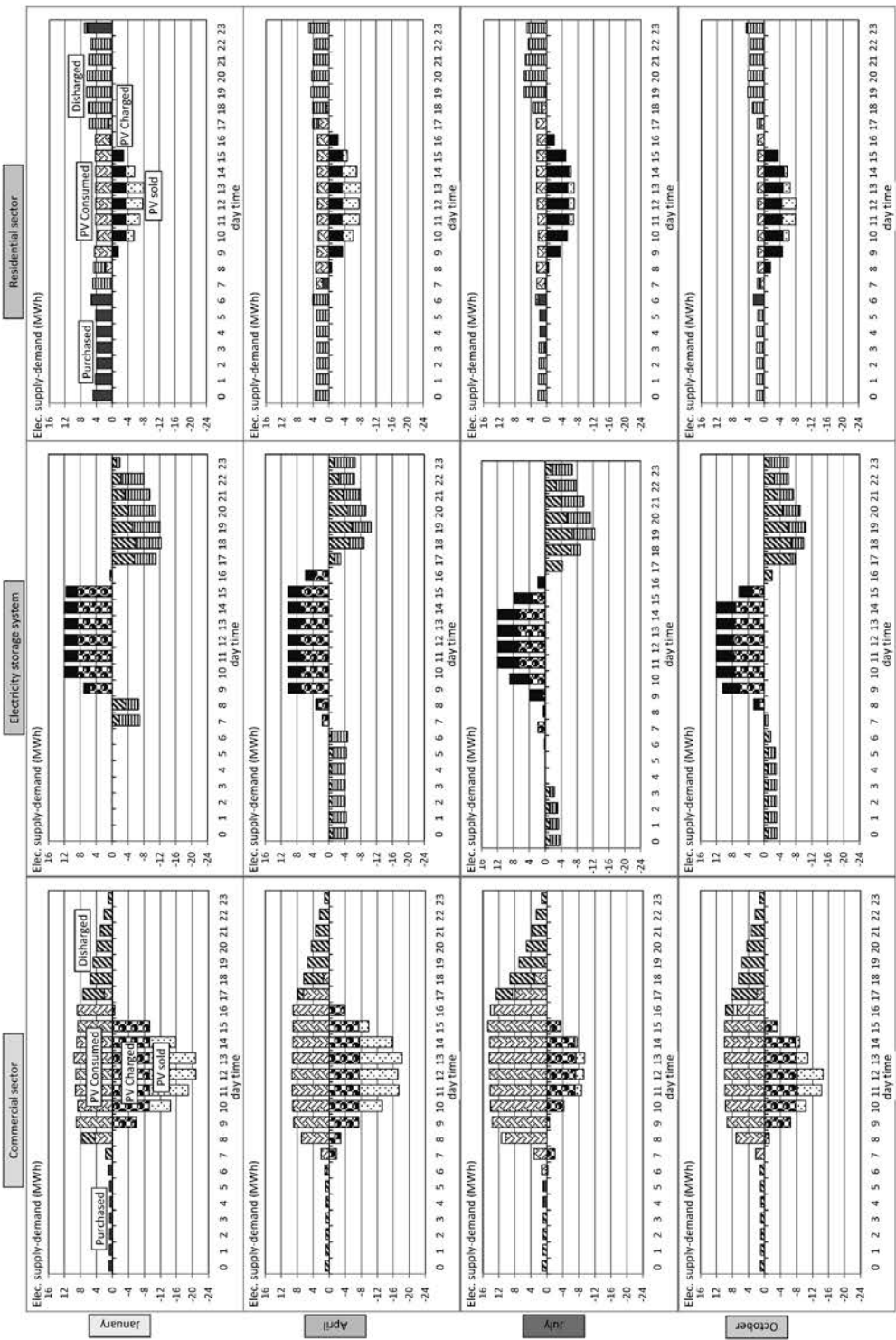


Fig. 5 Changes in daily electricity supply-demand by the introduction of PV system and electricity storage system (120 MWh)

charging into the electricity storage system is not required at all.

Because of the large capacity, the accommodations of PV electricity between both sectors work well in the 120 MWh electricity storage system case.

In the 40 MWh electricity storage system case, the cheap electricity purchased from the power company in midnight and before dawn is larger both in the commercial and residential sectors than in the 120 MWh electricity storage system case. Especially in January, the purchased electricity from the power company is charged into the electricity storage system.

As shown in Figs. 4 and 5, in the 120 MWh electricity storage system case, the amount of PV electricity charged into the storage system is larger than that in the 40 MWh electricity storage system case and almost all of necessary electricity in the commercial sector and residential sector is covered by PV electricity generated in both sectors.

In the 120 MWh electricity storage system case, the surplus PV electricity sold to the power company using the FIT system is reduced largely, as compared with the 40 MWh electricity storage system case.

## (2) Changes in monthly electricity supplies by the capacity expansion of electricity storage system

In the preceding section, changes in average daily pattern of electricity supplies caused by the introduction of smart facilities such as photovoltaic (PV) cell and electricity storage system are discussed. In this section, changes in monthly electricity supply-demand which are brought as the results of the summation of daily pattern will be discussed. Figure 6 shows changes in monthly electricity supplies by the capacity expansion of electricity storage system.

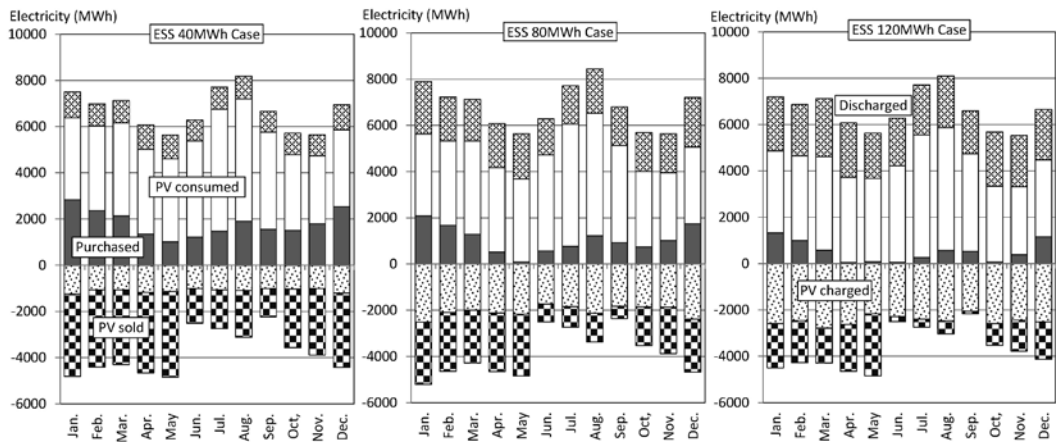


Fig. 6 Changes in monthly electricity supplies by the capacity expansion of electricity storage system

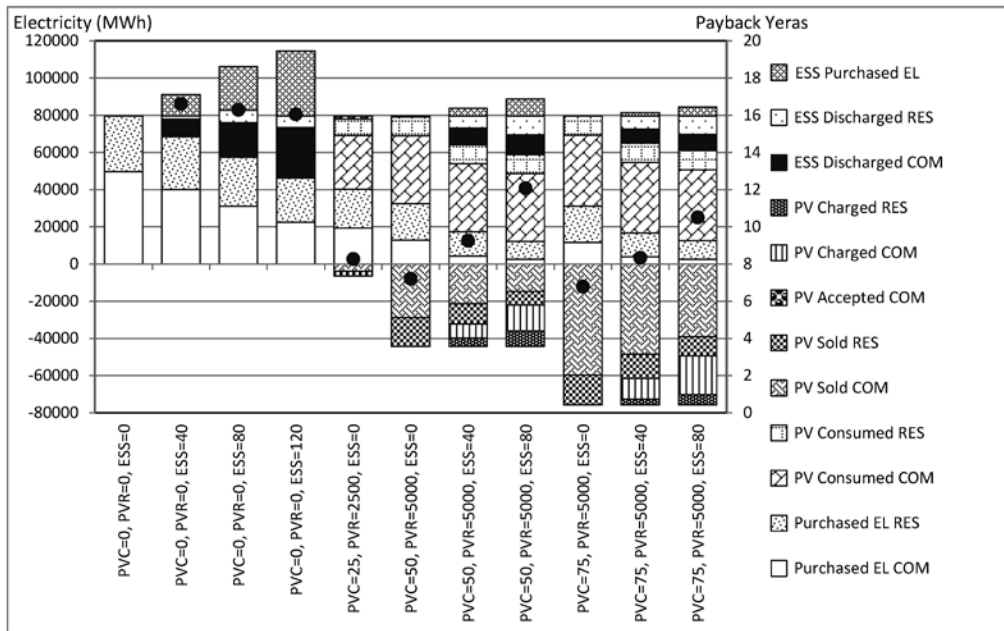


As the capacity of electricity storage system increases, the electricity purchased from the power company is reduced more especially in intermediate months such as April, May and October. The remaining surplus PV electricity sold to the power company is reduced especially in summer months such as June to September. The discharged electricity from the electricity storage system is increased in whole months, but the increase in discharged electricity for summer months has some delay to the capacity increase of electricity storage system.

### (3) Changes in annual electricity supplies and economics of smart community under various capacity conditions

Figure 7 shows the estimated results on changes in economics of smart community using photovoltaic cell and electricity storage system under various capacity conditions. If the electricity storage system only (no PV) is introduced, the simple payback year is more than 16 years, as shown in Fig 7. The simple payback year is gradually improved as the capacity of electricity storage system increases.

If the photovoltaic (PV) cell only (no electricity storage system) is introduced, the simple payback year is lowered to 8 years and it becomes lower as PV capacity increases, because the remaining surplus PV



(Note) RES: Residential sector, COM: Commercial sector, EL: Electricity, PV: Photovoltaic cell and ESS: Electricity storage system.

Fig. 7 Changes in electricity supply-demand pattern by the smart community and changes in economics

electricity becomes larger, also as shown in Fig. 7. This means that FIT profit increases more.

If the electricity storage system and photovoltaic (PV) cells are introduced, as the capacity of electricity storage system increases more, the simple payback year becomes worse rapidly, as shown in Fig. 7. This result means the cost of electricity storage system would be quite crucial for the economics on smart community.

As the capacity of photovoltaic (PV) cell increases more, the simple payback year improves more. This result means the increase of remaining surplus PV electricity contribute to improve the total economics on smart community. On the other hand, the large size of electricity storage system would be required to utilize PV electricity fully in houses and offices, though remaining surplus PV electricity sold to outside is reduced more and the economics becomes worse, also as shown in Fig. 7.

In summary, the increase on the capacity of electricity storage system is quite important to reduce purchased electricity by using photovoltaic cell effectively in the smart community. Based on these results in this study, the purchased electricity could be largely reduced if the size of electricity storage system becomes larger.

However, under the present cost conditions such as the photovoltaic system cost 400,000 Yen/kW and the electricity storage cost 150,000 Yen/kWh, the economics of smart community become worse rapidly, judging from the payback years. It is considered that the infiltration of smart communities would be quite difficult in the present stage, because the cost burden of introducing smart facilities, especially the electricity storage system is too large.

The introduction of the electricity storage system only is not largely contributed to improve the economics of smart community. The introduction of the photovoltaic cell can improve the economics of smart community, but as the scale of the electricity storage system becomes larger, the economics of smart community becomes worse.

Based on these results in this study, the purchased electricity could be largely reduced if the size of electricity storage system becomes larger, but the economics of smart community become worse rapidly, judging from the simple payback year. It is considered that the infiltration of smart communities would be quite difficult in the present stage, because the cost burden of introducing smart facilities, especially in the case that the electricity storage system is too large.

## **Concluding remarks**

First, the introduction of smart communities connecting with houses and offices is one of important options to reduce purchased electricity from the power company.

Second, it is essential to strengthen the flexibility of electricity accommodations using demand differences between houses and offices and using photovoltaic (PV) generation and electricity storage system.

Third, though the introduction of photovoltaic (PV) cell becomes more reasonable owing to the FIT (Feed-in Tariff) system, the cost up by the electricity storage system disturbs the expansion of smart communities due to the lowering economics.

Fourth, the role of photovoltaic (PV) cell is to fulfill electricity in the houses and offices as much as possible. The fixed price to receive PV electricity by FIT system should be lowered.

Fifth, the electricity storage system has the largest problem of economics in smart community functions. Under the present cost situations on the electricity storage system, total economics of smart community become worse, as the size of electricity storage system becomes larger.

Thus, the cost reduction of electricity storage system would be important particularly from the viewpoint of technology. Recently TESLA announced about a quite cheap electricity storage system for housing use (about 50,000 Yen/kWh). This is good news which should be welcomed.

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