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An Economics Simulation on the Smart Community Connecting the 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, as shown in Lithium ion, NAS and redox flow batteries. Therefore, in this study, we would like to analyze economics of smart community connecting the commercial and residential sector using photovoltaic cell (PV) and electricity storage system (ESS) under various cost conditions in the present and in the future.

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. The present FIT system also gives some distortions to the sound developments of the smart community.

For the expansion of smart communities, the cost reduction of smart facilities is important as a future subject. Of these, the cost reduction of the electricity storage system would play a key role particularly. We also need to reconsider the suitable FIT system.

Keywords: smart community, PV, electricity Storage, FIT, battery

Contents

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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. Because of the East Japan great earthquake and Fukushima nuclear accident, the discussions on the reduction target of GHGs were wandered so largely in recent 4 or 5 years and finally converged into the above-mentioned conclusion.

However, in the long-run, Japan must intensify her GHGs reduction measures basically, because she already agreed 50% (or 80%) reduction of GHGs in 2050 in the past several Summits etc. In addition, the Paris agreement on post Kyoto GHGs reduction was finally approved by many countries including various developing countries in December 2015.

The GHGs emissions in Japan have increased to the large extent from the 1990 level (the base level in Kyoto Protocol), though the first commitment period of Kyoto Protocol finished in 2012. Especially, the continuous increases in GHGs emission in the commercial and residential sectors were largely influenced to the whole increases in Japan.

In recent years, the progress of information and communication technologies such as cloud computing is very remarkable. The storage system of electricity such as NAS and redox flow batteries is also being made a large progress. Therefore, in this study, we would like to analyze economics of smart community connecting the commercial and residential sectors using photovoltaic cell (PV) and electricity storage system (ESS) under various conditions including cost improvements. We also would like to discuss the future subjects of smart community.

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 connecting the commercial and residential sectors. 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 average daily pattern of solar power generation was estimated by month using NEDO Sunshine Database [6]. The electricity supply and demand patterns and the PV generation pattern were reported in detail in the preceding paper [7].

The number of households in the residential sector was assumed to be 1,000 and the total floor area in the commercial sector was also assumed to be 25,000 m^2. The capacity of PV for each house in the residential sector was assumed at 4 kW. In the simulation, first, we determined the starting point where purchased electricity from power company outside could be made absolutely zero (a kind of extreme case). There were two cases: one was PV maximum (PV capacity 40,000 kW and ESS capacity 20,000 kWh) and the other was

ESS maximum (ESS capacity 39,000 kWh and PV capacity 5,500 kW). We made various simulations by reducing both PV and ESS capacities from these starting points step by step.

As for surplus PV electricity, the direct supply to the own sector, the direct supply to the other sector, the charging into the ESS and the selling to the outside electricity company has a higher priority in this order. Thus, the last remaining surplus PV electricity was sold to the outside electricity company. The charging of electricity storage system is made from 0:00 to 6:00 for cheap purchased electricity in midnight if necessary (limited by the minimum requirement) and from 6:00 to 18:00 for surplus PV electricity, and the discharging of electricity storage system is made in necessary hours judging from electricity consumption.

The 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 surplus PV electricity under the FIT system .

The present cost assumptions on PV were reported in detail in the preceding paper [7]. In summary, the cost of PV was assumed to be 350,000 Yen/kW for the house use (small-scale) and 300,000 Yen/kW for the building and mega solar use (large scale). The cost of ESS was assumed to be 200,000 Yen/kWh. The present situations on subsidy to PV and ESS were also reported in detail in the preceding paper [7].

In addition, the various differences of electricity charge between daytime and night were assumed. 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.

Final surplus electricity generated by PV was assumed to be sold at FIT (Feed in tariff) price of 33 Yen/kWh for the residential sector and the 27 Yen/kWh for the commercial sector (actual FIT prices in 2014). The economics simulations on the smart community connecting the residential and commercial sectors were also made by lowering FIT prices to (1) 24 Yen/kWh for the residential sector and 14 Yen/kWh for the commercial sector and (2) 7 Yen/kWh for both sectors. In addition, the necessary cost reductions of PV and ESS were also estimated in these simulations in order to improve the economics worsen by the lowering of FIT prices.

Results

(1) Electricity supply pattern of the two starting points (absolutely zero purchased electricity)

Figure 1 shows the electricity supply pattern of the commercial and residential sectors and the electricity storage system on the starting point of PV maximum case (PV capacity 40,000 kW and ESS capacity 20,000 kWh). In order to reduce the elecricity purchased from the outside power company to absolutely zero for all months in the year, extreamly large size of megasolar is installed in the commercial sector and almost all the

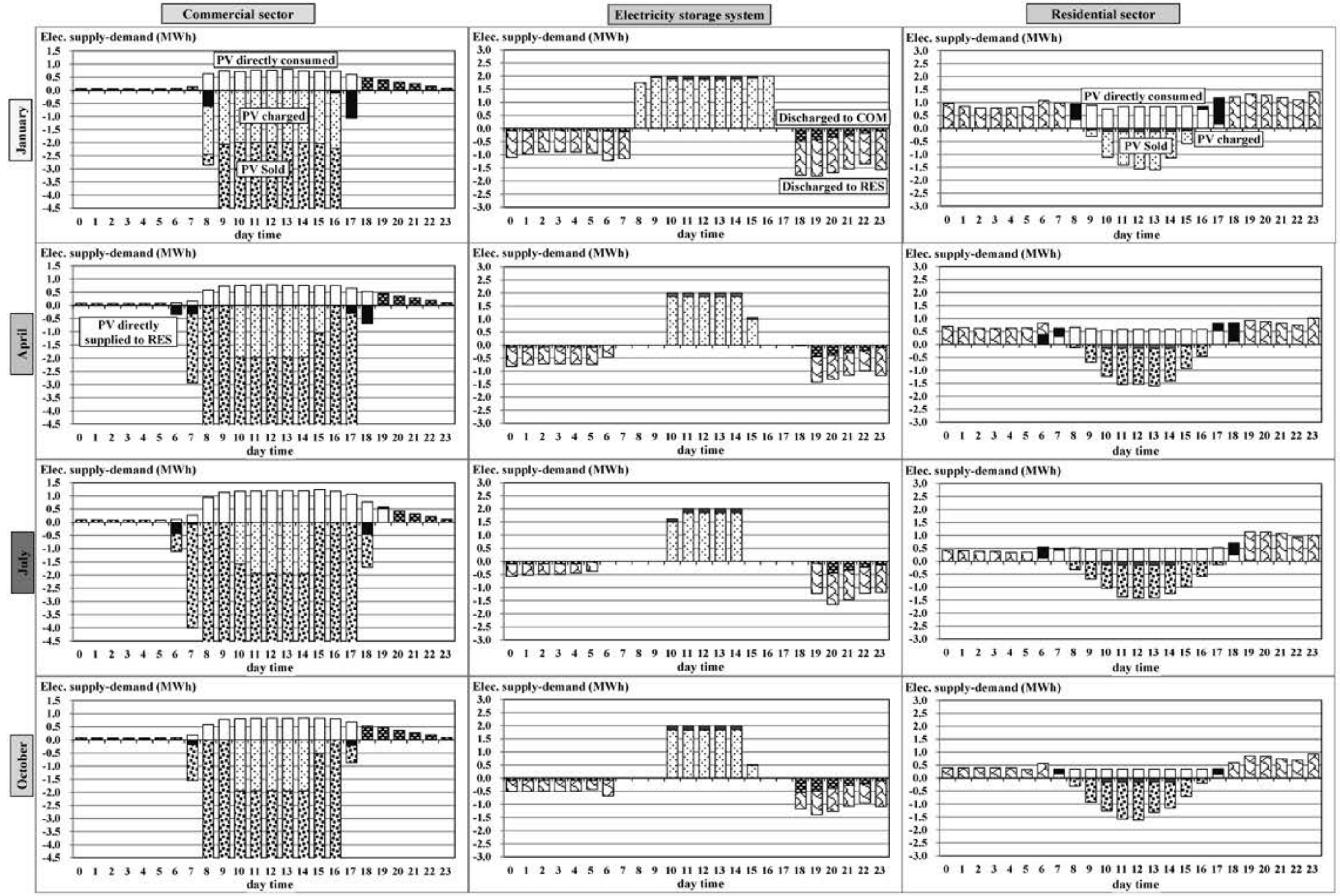


Fig. 1　Electricity supply patterns in the PV maximum case (PV capacity 40,000 kW and ESS capacity 20,000 kWh)

PV electricity generated is sold to the outside power company using FIT system.

As shown in Fig. 1, the quite small part of PV electricity generated is supplied to the own sector firstly, supplied to the other sector secondly, and supplied to the ESS for charging thirdly. The electricty charged into the ESS is discharged for the consumption in the residential and commercial sectors from the evening (18:00 or 19:00) to the early morning (6:00 or 7:00). As a result of these supplies, the electricity purchased from the outside electricity company becomes absolutely zero for all monthes in the year.

Figure 2 shows the electricity supply pattern of the commercial and residential sectors and the electricity storage system on the starting point of ESS maximum case (ESS capacity 39,000 kWh and PV capacity 5,500 kW). Different from the PV maximum case, in this case, in order to reduce the elecricity purchased from the outside power company to absolutely zero for all months in the year, the almost doubled large capacity of ESS is installed and the large part of remaining surplus PV electricity is charged into the ESS.

As shown in Fig. 2, the quite large part of PV electricity generated is supplied to the own sector firstly, supplied to the other sector secondly, and supplied to the ESS for charging thirdly. Then the small part of PV electricity finally remained as the last surplus is sold to the outside electricity company using FIT system. The electricty charged into the ESS is discharged in the same way as the PV maximum case. As a result of these supplies, the electricity purchased from the outside electricity company becomes absolutely zero for all monthes in the year.

(2) Economics simulations on PV maximum case by changing capacity and cost conditions

As for PV maximum case (the starting point: PV capacity 40,000 kW and ESS capacity 20,000 kWh), the economics simulations were made by reducing the PV and ESS capacity from the sarting point, and also made by changing the FIT prices and the investment costs and subsidies of PV and ESS.

Figure 3 shows changes in specific indicators of electricity supply, revenue and saving costs, and paybak years as for the smart community. In this case, the simple payback years is estimated 10 or lower than 10 as shown in Fig. 3, because the sales revenue of PV electricity to the outside electricity company by FIT system is used for the investment recovery of required ESS and PV capacities. In the case of PV maximum, the revenue by selling PV electricity to the outside electricity company using FIT system play a quite important role for the improvement of economics in the smart community.

As the installed capacity of ESS is reduced more, the payback years of smart community is improved more, also as shown in Fig.3. This fact suggests that the investment cost of ESS would largely influence to the economics of smart community. If the capacity of ESS is lowered to 10,000 kWh, the specific indicators such as purchased electricity ratio, ESS discharge supply ratio and PV own consumption ratio are not changed drastically from those in the starting point and the ESS operating rate is improved largely. This result means

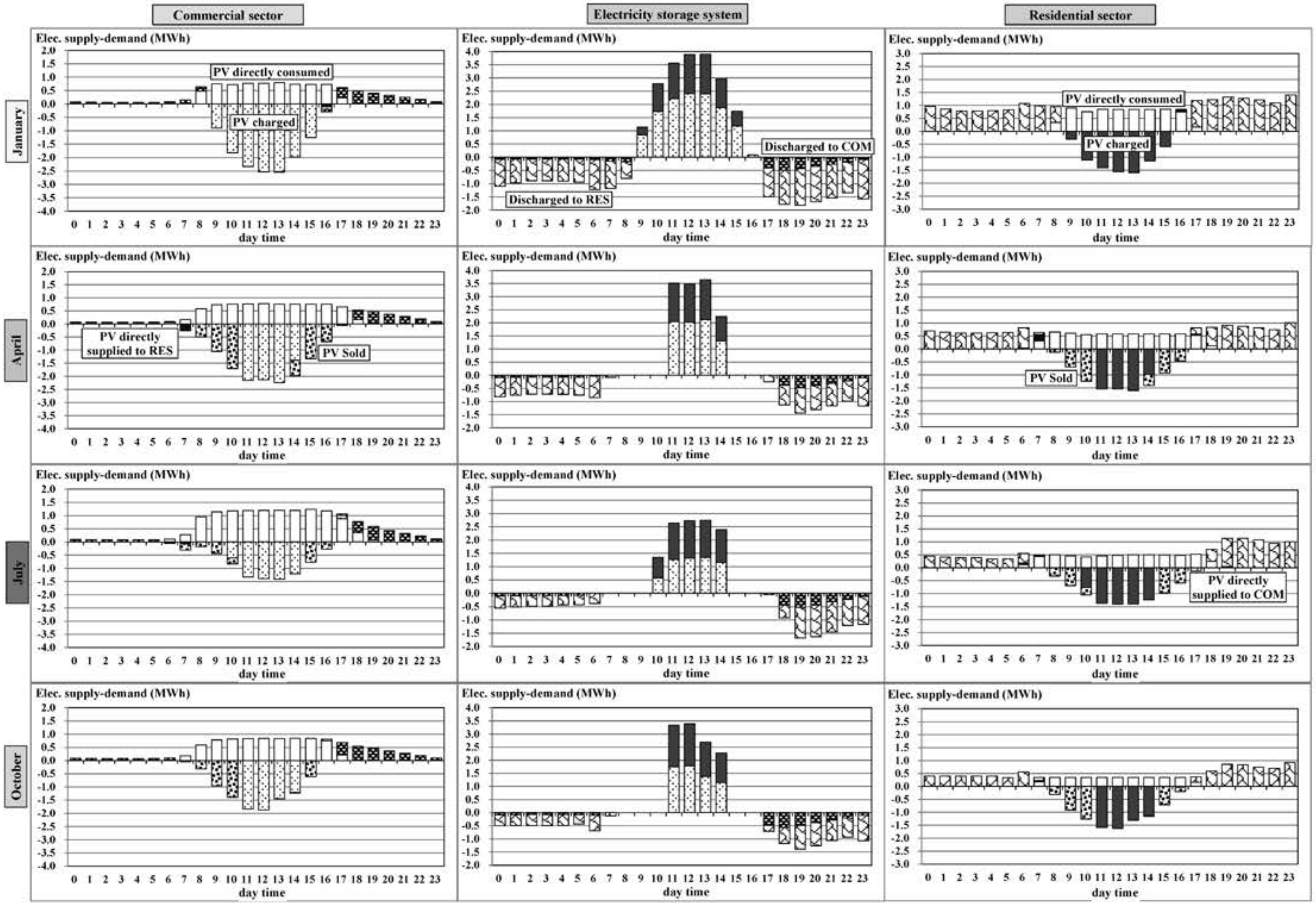
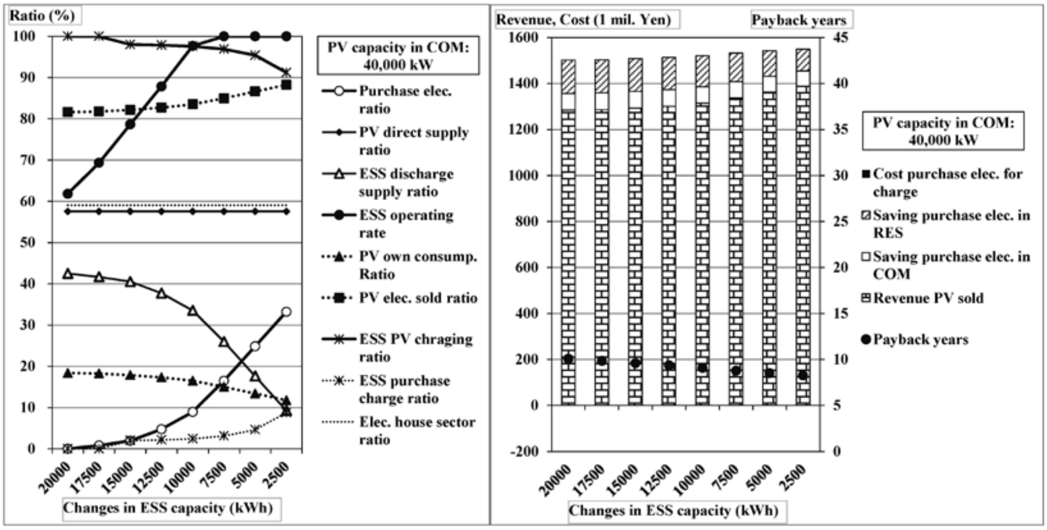


Fig. 2 Electricity supply patterns in the ESS maximum case (ESS capacity 39,000 kWh and PV capacity 5,500 kW)



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

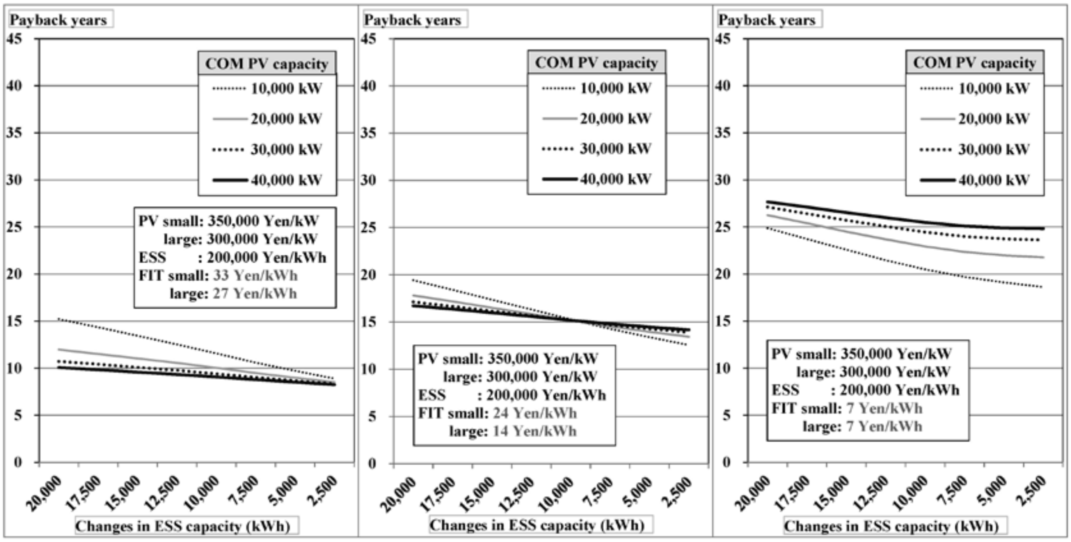
Fig. 3 Changes in specific indicators of electricity supply, revenue and saving costs, and payback years of smart community in PV maximum case

that the starting point pursuing absolutely zero purchased electricity would not be the most suitable solution.

The special treatments using the higher FIT prices have some distortion to the economics of smart community, as mentioned above. Therefore, we made the economics simulations by reducing the FIT price to (1) 24 Yen/kWh in the residential sector (the same level of electricity charge to the house) and 14 Yen/kWh in the commercial sector (the same level of electricity charge to the office building), and (2) 7 Yen/kWh in both sectors (the same level of generating cost in the power company).

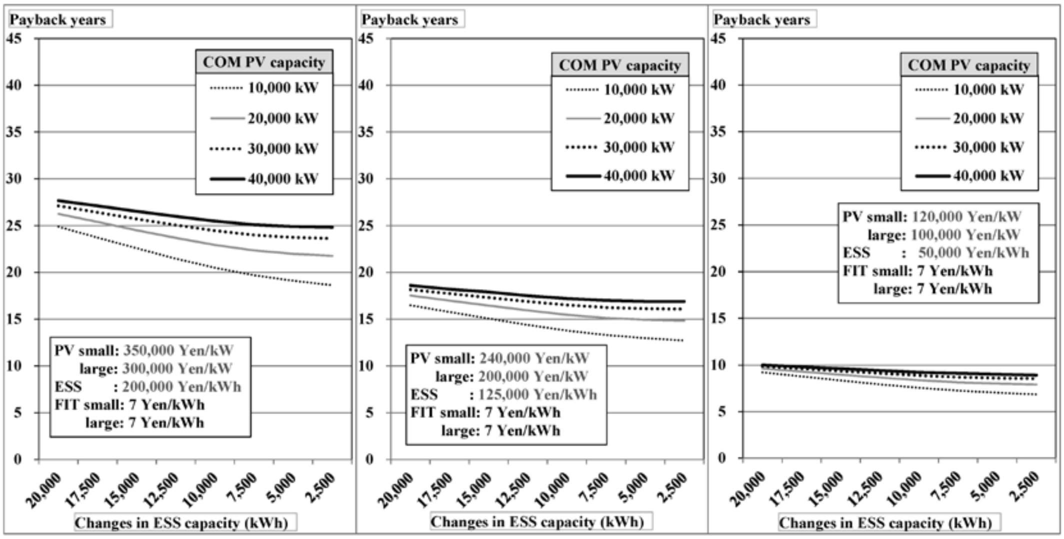
Figure 4 shows changes in economics of smart community by reducing FIT prices. If the acceptance PV electricity price by FIT is lowered to 7 Yen/kWh, the economics of this case will become worse (more than 20 payback years) rapidly, as shown in Fig. 4. The FIT price started from 48 Yen/kWh in 2009 has been already reduced and reached to 33 Yen/kWh for the smaller size and 27 Yen/kWh for the larger size. This reducing movements of FIT prices will also continue in the future.

Next, we analyzed on necessary cost reductions of PV and ESS required if the FIT price is lowered to 7 Yen/kWh. Figure 5 shows changes in the economics of smart community by reducing the investment costs of PV and ESS to about two-third or one-third of the present cost level. If the investment cost of PV and ESS is lowered to one-third of the present cost level, the payback years of smart community would be less than 10 years. In addition, the payback years of smart community is not different so largely by the installed PV and ESS capacities, as shown in Fig. 5.



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

Fig. 4 Changes in the economics of smart community by reducing the FIT prices in PV maximum case



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

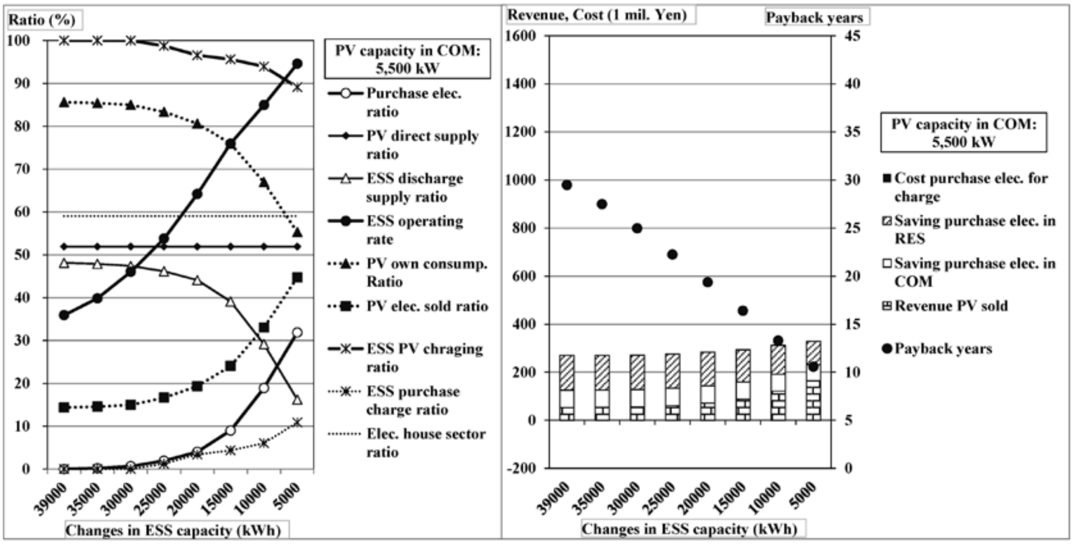
Fig. 5 Cost reductions on PV and ESS required by the reduced FIT price of 7 Yen/kWh In PV maximum case

(3) Economics simulations on ESS maximum case by changing capacity and cost conditions

The results of PV maximum case discussed in the preceding section is brought especially by the special favourable treatments using higher FIT prices. Because the required size of PV capacity to generate PV electricity sold to the outside electricity company is quite large, the risks on the investment recovery are also expected from various viewpoints widely. If we pursue the sound developments of smart community connecting the residential and commercial sectors, the large dependence on investment recovery to the FIT revenue is not always desirable.

Thus, next, as for ESS maximum case (the starting point: ESS capacity 39,000 kWh and PV capacity 5,500 kW), the economics simulations were made by reducing the PV and ESS capacity from the sarting point, and also made by changing the FIT prices and the investment costs and subsidies of PV and ESS. Figure 6 shows changes in specific indicators of electricity supply, revenue and saving costs, and paybak years as for the smart community. In this case, the simple payback years is estimated about 30 years at the staring point because of large ESS capacity.

If ESS capacity is lowered, the economics of this case would be improved rapidly, as shown in Fig. 6. This fact also suggests that the investment cost of ESS would largely influence to the economics of smart community. If the capacity of ESS is lowered to 20,000 kWh, the specific indicators such as purchased electricity ratio, ESS discharge supply ratio and PV own consumption ratio are not changed drastically from those in the starting point and the ESS operating rate is improved largely. This result also means that the starting point pursuing absolutely zero purchased electricity would not be the most suitable solution in the ESS maximum case.



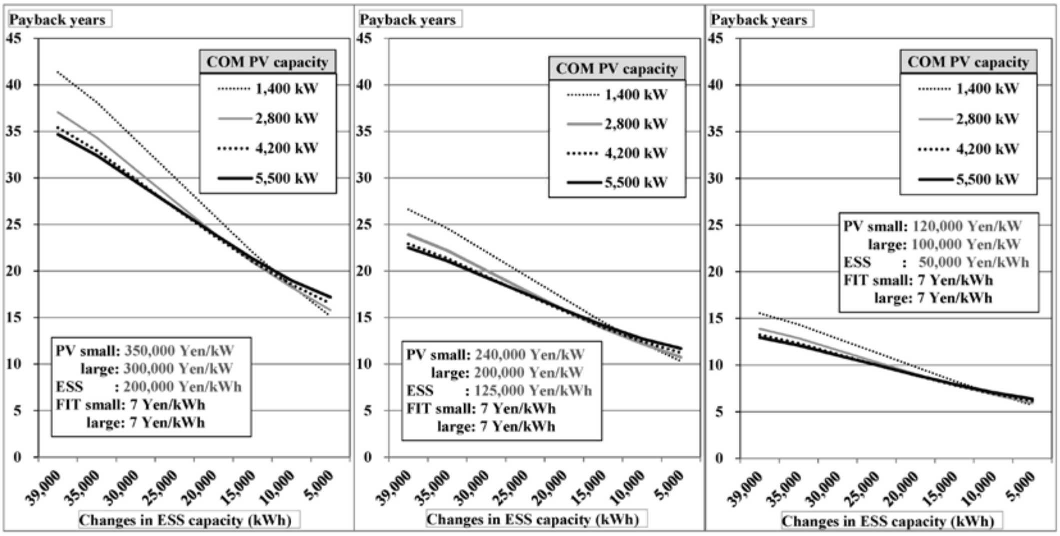
(Note) COM: Commercial sector, EL: Electricity, PV: Photovoltaic cell and ESS: Electricity storage system.

Fig. 6 Changes in specific indicators of electricity supply, revenue and saving costs, and payback years of smart community in ESS maximum case

As for the ESS maximum case, we also made the economics simulations by reducing the FIT price to (1) 24 Yen/kWh in the residential sector (the same level of electricity charge to the house) and 14 Yen/kWh in the commercial sector (the same level of electricity charge to the office building), and (2) 7 Yen/kWh in both sectors (the same level of generating cost in the power company). Figure 7 shows changes in economics of smart community by reducing FIT prices.

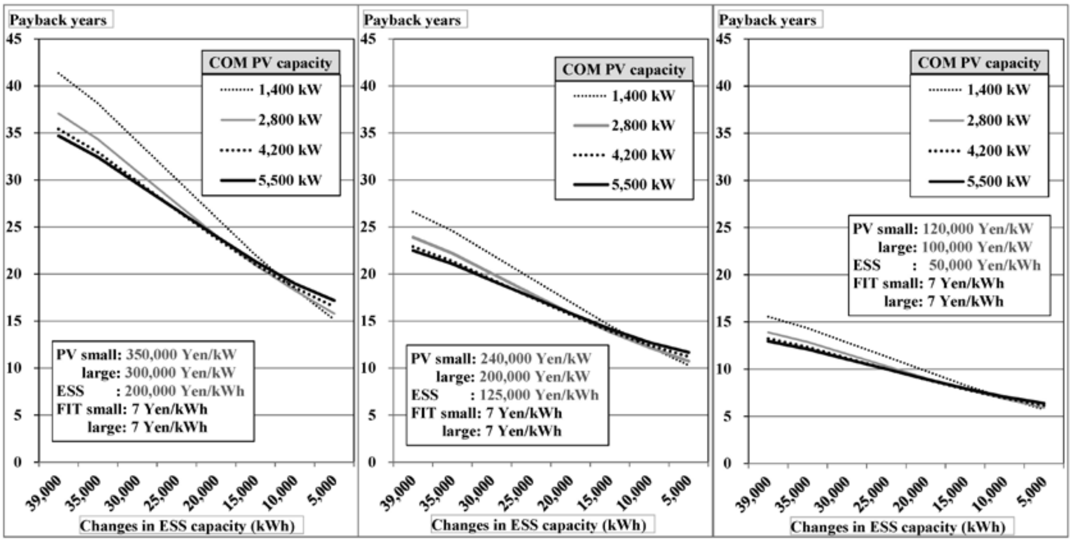
Different from the lowering of ESS capacity, if PV capacity is lowered, the economics of this case will become worse because of the sales revenue of PV electricity by FIT. If the acceptance PV electricity price by FIT is lowered to 7 Yen/kWh, the economics of this case will also become worse (more than 35 payback years) rapidly at the starting point, as shown in Fig. 7. Thus, the cost reduction of PV and ESS system will be also required.

Next, we analyzed on necessary cost reductions of PV and ESS required if the FIT price is lowered to 7 Yen/kWh. Figure 8 shows changes in the economics of smart community by reducing the investment costs of PV and ESS to about two-third or one-third of the present cost level. If the investment cost of PV and ESS is lowered to one-third of the present cost level, the payback years of smart community would be less than 15 years. In addition, the payback years of smart community is not different so largely by the installed PV and ESS capacities, as shown in Fig. 8



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

Fig. 7 Changes in the economics of smart community by reducing the FIT prices in ESS maximum case



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

Fig. 8 Cost reductions on PV and ESS required by the reduced FIT price of 7 Yen/kWh

Concluding remarks

The special environment brought by the preferable acceptance price of PV electricity by FIT makes large distortion to the decision making of investments to smart community. We need to reconsider desirable and sustainable FIT system more carefully. The special treatments by the FIT system are not suitable for the sound developments of smart community.

Judging from the results on both of the PV maximum case and the ESS maximum case, we can conclude that the starting point pursuing absolutely zero purchased electricity would not be the most suitable solution. We need to pursue the most suitable solution of PV and ESS capacity by using specific indicators on electricity supply pattern.

For the expansion of smart community connecting the commercial and residential sectors, the cost reduction of smart facilities are quite important as a future subject. Of these, the cost reduction of the electricity storage system would play a essential role particularly. The quite lower price of electricity storage system announced by TESLA is a gratifying information for smart community.

It is essential to strengthen peoples' incentives to smart community connecting the commercial and residential sectors from the viewpoints of policy. The smart community would be expected to influence to peoples' life style in the future. We need to pursue self-sufficiency of electricity supply using smart community more profoundly.

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