An Analysis on Changes in Economics of Smart House Using Photovoltaic Cell and Electricity Storage System

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Abstract

In recent years, the progress of information and communication technologies is remarkable and the electricity storage system is also realized. The introduction of the smart house has been paid great attention. The smart house is composed of the photovoltaic cell (PV), the home energy management system (HEMS) and the electricity storage system (ESS). Judging from global environmental problems, the introduction of smart house to the existing houses will be a crucial issue in the future.

In the preceding study [1], the analyses on economics of smart house introduced to the existing houses were made under present cost conditions and the expansion feasibility of smart house was discussed. In this study, we would like to analyze changes in economics of smart house under various future cost conditions prospected to the photovoltaic cell (PV), the home energy management system (HEMS) and the electricity storage system (ESS) and we would like to discuss future subjects for introducing and expanding smart houses.

It was also pointed out that (1) the fixed price for receiving PV electricity by the power company should be lowered to the average level of residential electricity charge in the earlier stage and (2) the cost reduction of the electricity storage system would play a key role particularly from the viewpoint of technology because the electricity storage system caused the largest problems in the economics of smart house.

Contents

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1) She was a student in the Master course of the graduate school of economics during from April, 2012 through March, 2014.

1. Introduction

Though Japan internationally committed 25% reduction target of GHGs from the 1990 emission level in 2020 at the New York UN Conference in 2009, this target commitment was withdrawn because of the East Japan great earthquake and Fukushima nuclear accident and the revised temporal target under no nuclear plants restarted was announced recently. However, 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.

The first commitment period of Kyoto Protocol finished in 2012. We must say that Japan could not achieve 6% reduction target in the first commitment period except in 2009 after the Lehman Shock. Specially speaking, the continuous increases in GHGs emission in the residential sector were largely influenced to the nonattainment of Kyoto target. Therefore, the reduction measures in the residential sector will be quite crucial in the future.

In recent years, the progress of information and communication technologies is remarkable and the storage system of electricity is also realized. The introduction of the smart house to newly constructed houses has been paid great attention. The smart house is composed of the photovoltaic cell (PV), the home energy management system (HEMS) and the electricity storage system (ESS) as its functions. Based on above discussions, the introduction of smart house to the existing houses will be a crucial issue in the future.

In the preceding study [1], the analyses on economics of smart house introduced to the existing houses were made under present cost conditions and the expansion feasibility of smart house under those conditions was discussed. In this study, we would like to analyze changes in economics of smart house under various future cost conditions prospected to the photovoltaic cell (PV), the home energy management system (HEMS) and the electricity storage system (ESS) and we would like to discuss future subjects for introducing and expanding smart houses.

2. Method

In this study, first, we made survey on present situations and future prospects on PV [2-4], ESS [5-7] and HEMS [8, 9]. Based on surveyed information, the future cost down of PV, ESS and HEMS was assumed for the simulation analyses of changes in economics of smart house made in this study.

Next, we made economics simulations on the introduction of smart appliances such as photovoltaic cell, electricity storage system and HEMS as important functions of smart house, with the same method as made in the preceding study [1]. First of all, the average electricity demand pattern in a house was estimated by month based on the METI survey report [10] and Cogeneration Comprehensive Manual [11].

The capacity of electricity storage system was changed from 4 kWh to 12 kWh every 1 kWh in the simulation. The charging of electricity storage system is made from 0:00 to 7:00 for cheap purchased electricity in midnight and from 7:00 to 18:00 for surplus PV electricity, and the electricity from the storage system is discharged in necessary hours judging from electricity consumption and PV electricity supply.

The capacity of photovoltaic (PV) cell was assumed at 4 kW as standard installation capacity. The average daily pattern of solar power generation was estimated by month using NEDO Sunshine Database [12]. The final remaining of surplus PV electricity was assumed to be sold at FIT (Feed in tariff) price of 38 Yen/kWh (actual value in fiscal 2012). As for the HEMS (Home energy management system), 15% reduction of total electricity consumption was estimated by the demonstration project up to now.

Several combinations of the electricity charges different between daytime and night 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 considered plural combinations. We made the economics simulation which aims to reduce electricity purchased in higher electricity charge time as much as possible by using smart house appliances such as PV system, electricity storage system and HEMS in order to fulfill necessary electricity consumption.

The economics of the introduction of smart house functions is judged from the simple payback years which is calculated by dividing the net initial cost (excluding cost covered by the subsidy) of necessary appliances by the annual profit brought by the reduction of purchased electricity.

The information on costs and subsides of photovoltaic cell (PV), electricity storage system (ESS) and HEMS in the present will be described in Section 4, together with future prospects on the corresponding items.

3. Analyses on the economics of smart house under present cost conditions

In Section 3, we would like to summarize the analyzed results on the economics of smart house composed of photovoltaic cell (PV), electricity storage system (ESS) or HEMS by assuming present situations of costs and subsidies, which were made in the preceding study [1]. Figure 1 shows changes in daily electricity supply-demand and electricity purchased by the introduction of PV system (4 kW) and electricity storage system (4 kWh and 12 kWh) as for January, May and August.

In the case of PV (4 kW) without electricity storage system, the electricity purchased from the power company becomes zero in the daytime due to enough rich electricity generated by PV. But more than half of PV electricity is sold to the power company especially in May and August, because the electricity demand in the house in the daytime is not so large, as shown in the upper part of Fig. 1.

If the small electricity storage system 4 kWh is installed additionally, the amount of PV electricity charged into the electricity storage system in the daytime is not so much, and the large amount of remaining surplus PV electricity is also sold to the power company. In this case, especially in January, the cheap electricity purchased from the power company from the midnight through the early morning is also charged into the electricity storage system, as shown in the middle part of Fig. 1.

On the other hand, if the large electricity storage system 12 kWh is installed additionally, the amount of PV electricity charged into the storage system in the daytime is quite large, and the remaining surplus PV electricity sold to the power company is very small in the corresponding three months. Except January, the purchasing of cheap electricity from the power company from the midnight through the early morning is not required for the additional charging into the storage system, as shown in the lower part of Fig. 1.

On the other hand, if the large electricity storage system 12 kWh is installed additionally, the amount of PV electricity charged into the storage system in the daytime is quite large, and the remaining surplus PV electricity sold to the power company is very small in the corresponding three months. Except January, the purchasing of cheap electricity from the power company from the midnight through the early morning is not required for the additional charging into the storage system, as shown in the lower part of Fig. 1.

Based on above-described results, the economics of smart house was analyzed using the calculation of payback year of investment costs required for the introduction of smart appliances. Figure 2 shows the estimated results on changes in electricity supply-demand pattern of house by introducing smart appliances such as photovoltaic cell, HEMS and electricity storage system. Figure 3 shows the estimated results on changes in revenues and costs related to electricity by introducing these smart appliances and the payback years in each case.

Judging from the payback year obtained under various cost conditions in the present situations, as shown in Fig. 3, we can conclude that the introduction and expansion of smart house to the existing houses would be quite difficult. Especially speaking, the purchased electricity could be largely reduced if the size of electricity storage system becomes larger, but the economics of smart house become worse rapidly, judging from the payback years. It is considered that the infiltration of smart houses would be quite difficult in the present stage, because the cost burden of introducing smart appliances, especially in the case that the capacity

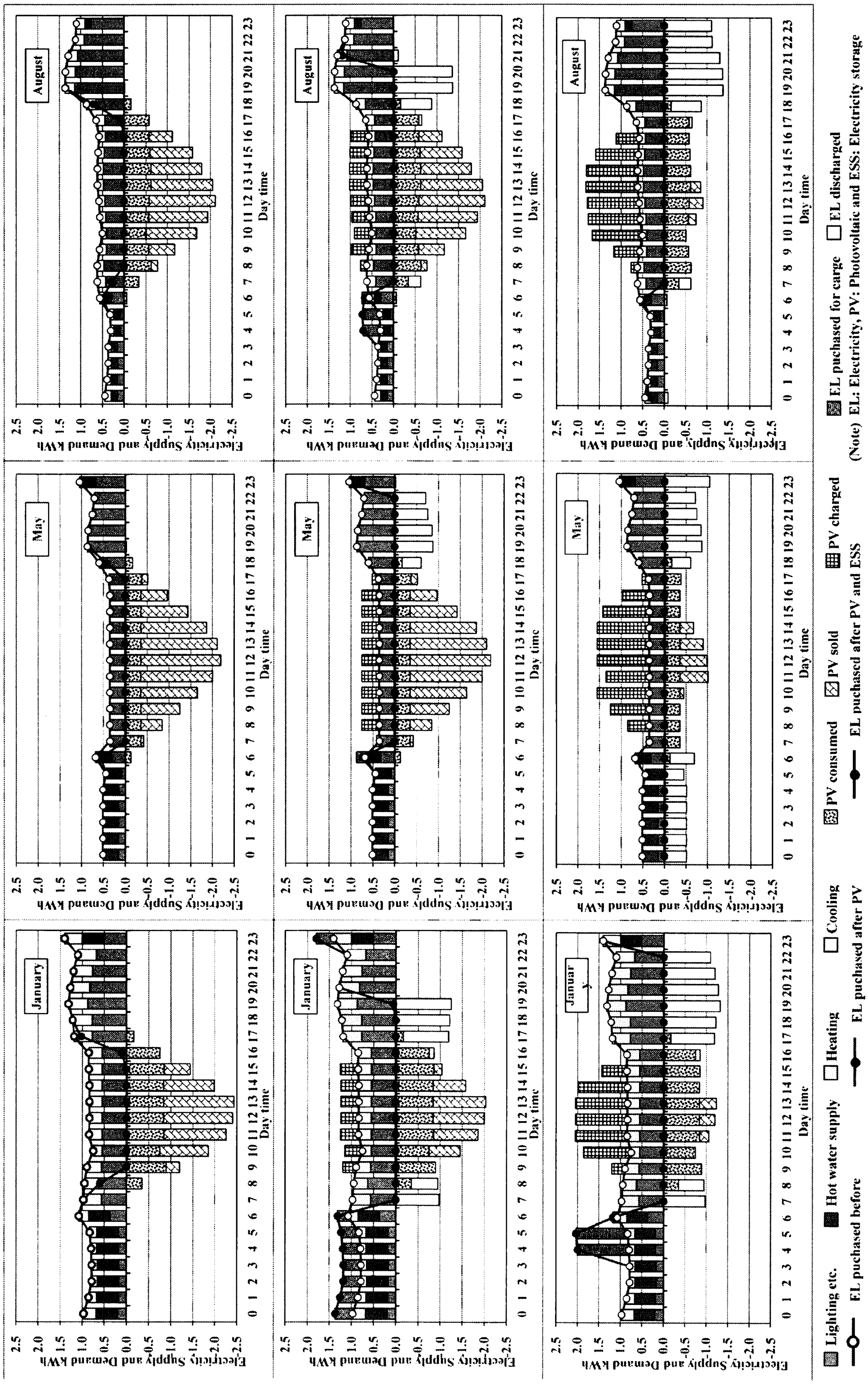

Fig. 1 changes in daily electricity supply-demand and electricity purchased by the introduction of PV and electricity storage system

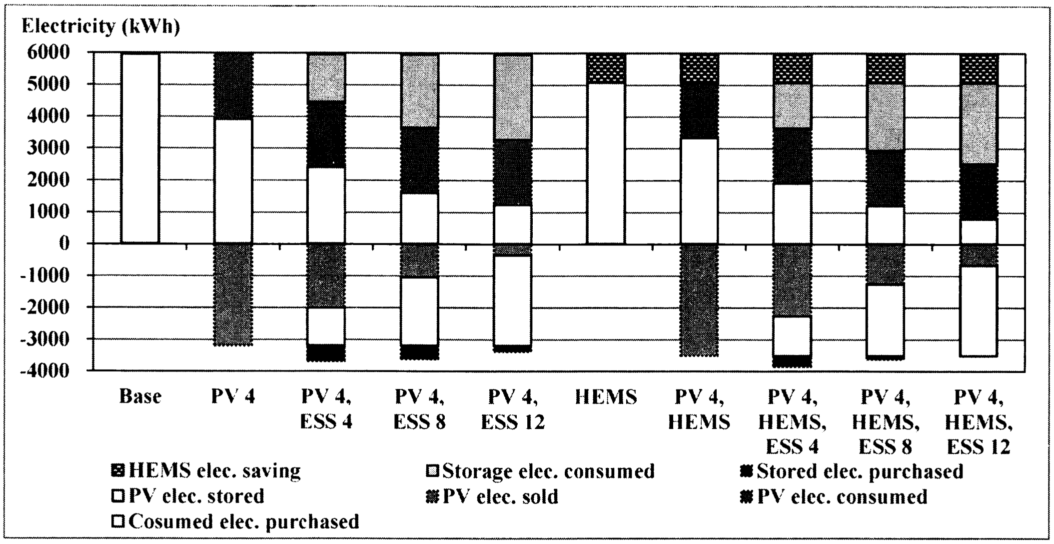

Fig. 2 Changes in electricity supply-demand pattern of house by introducing smart appliances

(Note) The following abbreviations are used in this figure, HEMS: home energy management system, PV: photovoltaic cell, ESS: electricity storage system and elec.: electricity. The number following "PV" or "ESS" shows the capacity size of corresponding equipment.

of electricity storage system becomes larger.

4. Future prospects on cost reduction of appliances composed of smart house

4.1 Photovoltaic cell (PV) system

The price of PV system (including the costs of PV cell module, attached appliances and installation works) was 391,000 Yen/kW for newly constructed houses and 432,000 Yen/kW for existing houses (average 415,000 Yen/kW), respectively, in fiscal 2013 and the price for the latter was 10% higher than that for the former. Observing changes in the price of PV system since 1997 [3], the price of PV system has been lowered remarkably since 2009 when the feed-in-tariff system for PV surplus electricity started.

According to the Photovoltaic Expansion Center, the subsidy system to the photovoltaic cell in fiscal 2013 is as follows: (1) the subsidy from Japanese government is 20,000 Yen/kW if the cost of concerned PV system for subsidy is 410,000 Yen/kW or less and is 15,000 Yen/kW if the cost of concerned PV system for subsidy is 500,000 Yen/kW or less, and (2) as for the subsidy from the local government, in the case of the Metropolis of Tokyo, subsidy of average 50,000 Yen/kW with upper limit of average 200,000 Yen from the Ward.

Based on these data, in the analyses on the economics of smart house under present cost conditions already discussed in Section 3, the cost of photovoltaic cell (PV) was assumed to be 410,000 Yen/kW and the subsidy by the Government mentioned above was also assumed.

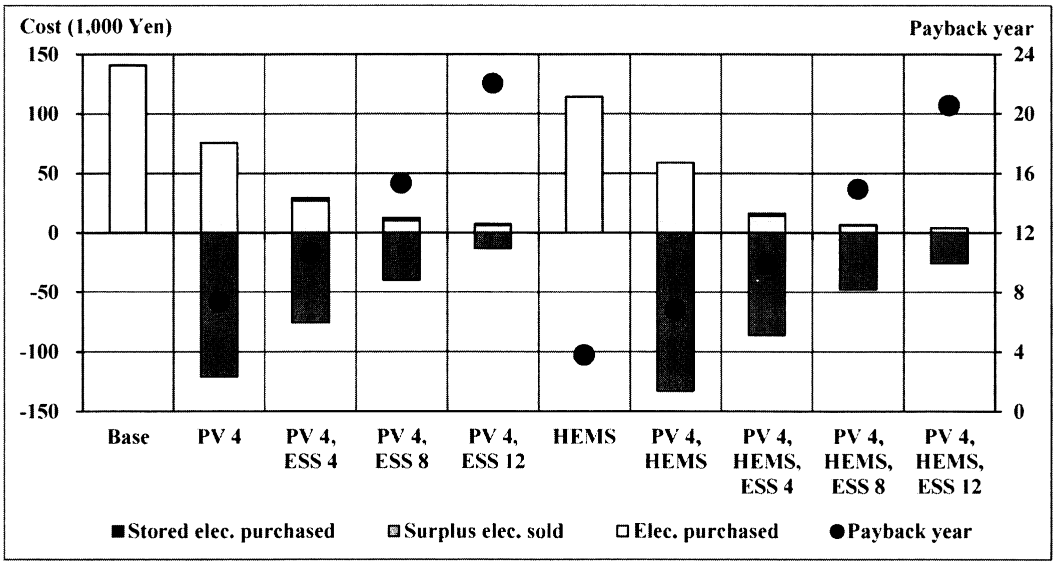

Fig. 3 Changes in revenues and costs related to electricity by introducing smart appliances and the economics based on the payback years

(Note) The abbreviations used in this figure are the same as those in Fig. 2.

The report on "PV Road Map 2030+" by NEDO [2] announced the future prospects on technology developments and the various targets of each technology including the cost reduction, as shown in Table 1. According to this road map, the generating cost of PV electricity is expected to be lowered from 30 Yen/kWh in 2007 to 23 Yen/kWh between 2010 and 2020, 14 Yen/kWh in 2020 and 7 Yen/kWh in 2030. These cost down prospects means the price of PV system of 410,000 Yen/kW would be possible to be lowered to 200,000 Yen/kW in 2020 and to 100,000 Yen/kW.

Therefore, in the analyses on the economics of smart house under the prospected future conditions made by this study, the lowering of the cost of photovoltaic cell (PV) was assumed to be 400,000 (almost the same as the present level), 300,000, 200,000 and 100,000 Yen/kW. As for subsidy, the ratio of subsidy to the PV system cost was assumed to be constant and this means that the amount of subsidy become smaller as the cost of PV system lowered larger.

4.2 The electricity storage system

In the present, the cost of large scale lithium ion battery is about 100,000-300,000 Yen/kWh and its average is 200,000 Yen/kWh. The installation cost of electricity storage system is 23,000 Yen/kWh on average. The subsidy system to the electricity storage system by Sustainable Open Innovation Initiative (SII) is as follows: one third of the core body price is subsidized with upper limit of 1 million Yen and the installation cost is out

Table 1 Future prospects on technology developments and cost reductions of PV system

Item		Main development contents and targets
Module prodction	Module production cost	High efficiency of module, Lower cost and higher productivity process, Expansion of life Target (Completion of technology development): 75 Yen/W in 2017, 50 Yen/W in 2025, less 50 Yen/W in 2050
	Module high qualification	Technollogy innovation of existing PV (Developments on ultra thin type crystal Si cell, New materials with wide gap, Multi connected cell, Hetero connected cell and so on)
	Module life expansion	Investigations on module structure and module materials Target (Completion of technology development): Life time 25 yeras in 2017, Life time 30 years in 2025 (Technology for life time 40 years)
	Technology corresponding material issues 1)	Supply technology of high pure Si, Lowering of unit Si (3 g/W), Si saving ((Wafer + Kerf = 100μm) and Rare resources measures
System components	Power conditioner	Improvement of endurance, Diversificaation/High efficiency/Cost down/ Integration of IT functions Target (Completion of technology development): Production cost 15,000 Yen/kW, Life time more than 20 years (including parts change)
	Storage technology for PV 2)	Long life electricity battery, Lowering weight/Expansion of life, New type of electricity storage Target (Completion of technology development): Production cost 10,000 Yen/kW, Life time more than 20 years (including parts change)
	Installation cost, Sales cost	One third or one half of present cost (about 200 Yen/W)

1) The unit consumption of matrial Si will be fixed at the realistic value of about 3 g/W and the cost down will be achieved by the reduction of board production cost.

2) The endurance as system will be aimed at 40 years including parts exchange (prospecting one exchange for power conditioner).

(Source) NEDO, "PV Road Map 2030+"

of support subjects.

Based on these data, in the analyses on the economics of smart house under present cost conditions already discussed in Section 3, the cost of electricity storage system was assumed to be 200,000 Yen/kWh and the one third of initial cost of electricity storage system was also assumed to be subsidized by the Government.

The report on "Battery Road Map 2010," by NEDO [6] announced the future prospects on technology developments and various targets for cost reduction and expansion of life of the electricity storage system in the house, as shown in Fig. 4. According to this report, the cost of electricity storage system is expected to be lowered 100,000 – 200,000 Yen/kWh in the present to 40,000 Yen/kWh in 2015, 20,000 Yen/kWh in 2020 and 15,000 Yen/kWh in 2030.

Because the gap between the present cost and the prospected cost in 2015 is too large, in the analyses on the economics of smart house under the prospected future conditions made by this study, the lowering of the cost of electricity storage system was assumed to be 200,000 (the same as the present level), 150,000, 100,000

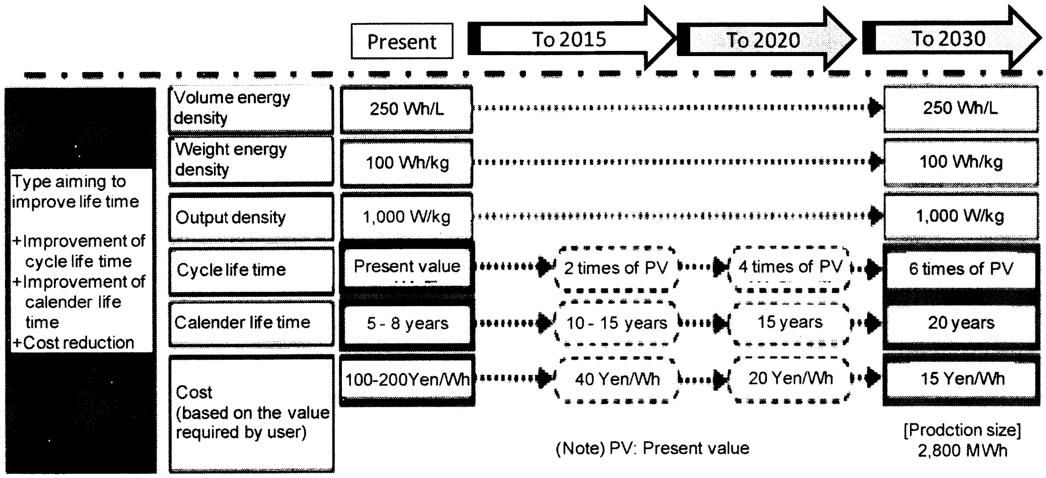

Fig. 4 Future prospects on technology developments and cost reduction of electricity storage system

(Note) Intermediate target spec value in the development stage Spec value which further improvement is required Spec value required for infiltration (or target value of development towards infiltration)
(Source) NEDO, "Battery Road Map 2010"

and 50,000 Yen/kWh mildly. As for subsidy, one third of the core body price was assumed to be subsidized with upper limit of 1millions Yen and the installation cost was also assumed to be out of support subjects.

4.3 HEMS

In the present stage, the price of HEMS costs at 160,000-200,000 Yen/system. The future cost down of HEMS is largely anticipated, because the average growth rate of HEMS market is prospected to be 148% according to the market movement survey. The subsidy of HEMS is 100,000 Yen/system by Sustainable Open Innovation Initiative (SII).

Based on these data, in the analyses on the economics of smart house under present cost conditions already discussed in Section 3, the cost of HEMS was assumed to be 200,000 Yen/system and the subsidy of HEMS was assumed to be 100,000 Yen/system.

Because the future prospects on the cost of HEMS has not been yet published definitely, in the analyses on the economics of smart house under the prospected future conditions made by this study, the future cost of HEMS was assumed to be lowered to 100,000 Yen/system. As for the subsidy, the ratio of subsidy to the system cost was assumed to be constant. The electricity reduction rate of HEMS was also assumed at 15% which is the same as the present value but it will be possible to improve the electricity reduction rate of HEMS through technology developments.

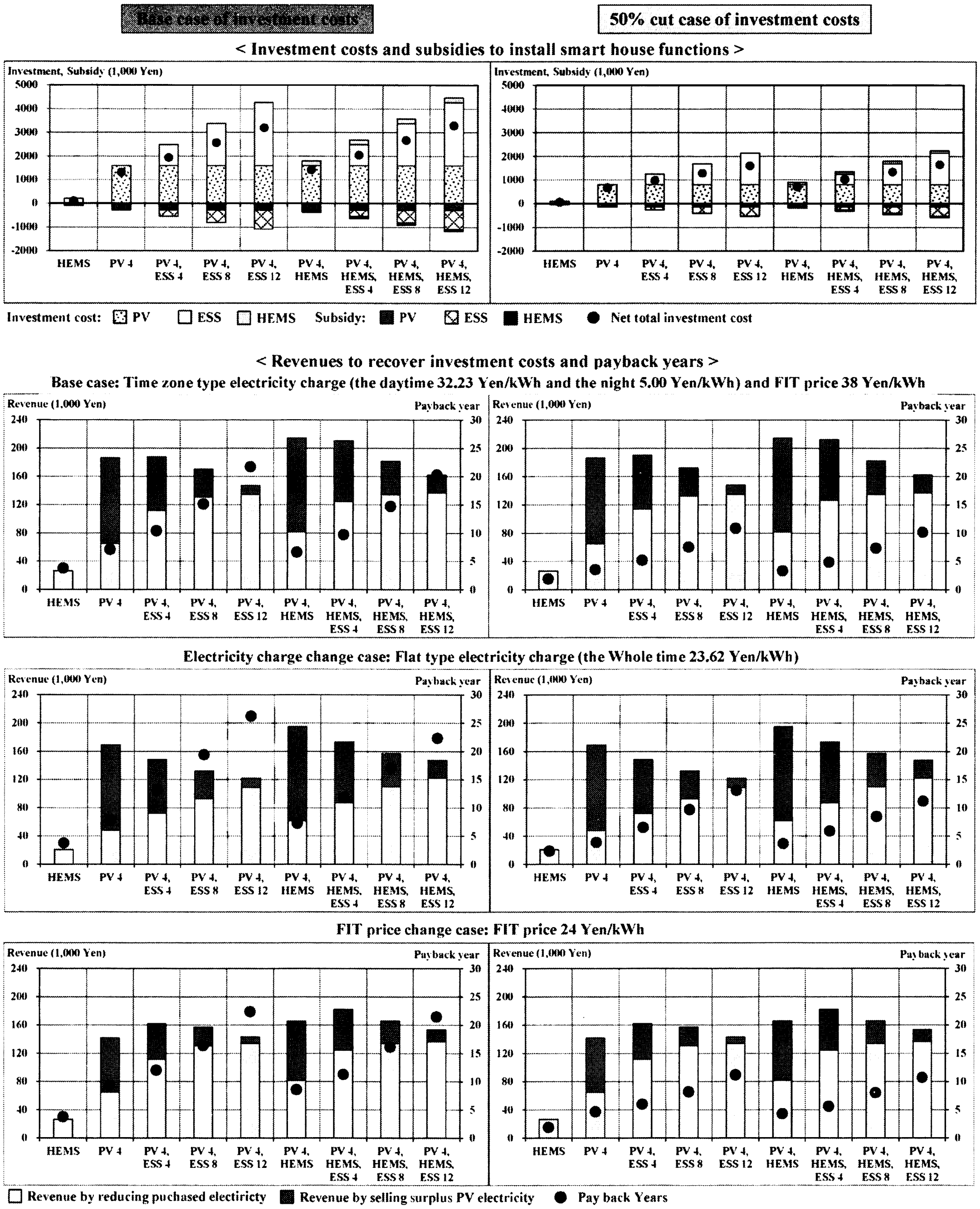

Fig. 5 Changes in the payback years of necessary investment costs to introduce smart house under various different conditions

(Note) The following abbreviations are used in this figure, HEMS: home energy management system, PV: photovoltaic cell, ESS: electricity storage system and FIT: feed in tariff. The number following "PV" or "ESS" shows the capacity size of corresponding equipment.

5. Analyses on the economics of smart house under prospected cost conditions

Figure 5 shows changes in the payback years of investment costs to install smart house functions such as Photovoltaic cell (PV), electricity storage system (ESS) and HEMS under various different conditions, that is, (1) the reduction of investment costs by technology developments, (2) the different pattern of electricity charge by time zone and (3) the different setting of FIT (Feed-in tariff) receiving price of PV electricity.

PV and electricity storage system have a large weight in necessary total costs of smart house, as shown in the upper part of Fig. 5. Especially speaking, the share of electricity storage system is increasing sharply if its capacity is expanded. The share of HEMS to total investment costs is quite small, and thus, the introduction of HEMS does not have large influences to the economics of smart house.

The direct reduction of investment costs by technology developments or by governmental subsidies drastically influences to the economics of smart house, as shown in the comparison between the base case of investment costs and the 50% cut case of investment cost in Fig. 5. In the base case of investment costs, the payback year reaches to more than 20 years if the capacity of electricity storage system is increased, but in the 50% cut case of investment costs, almost all values of the payback year are within 10 years.

Different from the direct reduction of investment cost, the changes in electricity charge pattern by time zone (the third part of Fig. 5) or the changes in FIT receiving price of PV electricity (the lower part of Fig. 5) does not influence to the economics of smart house so largely. We can easily find these results by comparing with the Base case (the second part of Fig. 5). The economics of smart house is made worse by the lowering of FIT receiving of PV electricity. This result means that the FIT system would be one of obstacles for the introduction and expansion of smart house.

As it was found that the direct reduction of total investment costs would be a crucial factor to improve the economics of smart house, detailed analyses on the economics of smart house was made under various cost conditions. Figure 6 shows the estimated results on changes in economics of smart house under various cost conditions of photovoltaic cell and electricity storage system.

The increase on the capacity of electricity storage system is quite important to reduce purchased electricity by using photovoltaic cell effectively in a house. 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 200,000 Yen/kWh, the economics of smart house become worse rapidly, judging from the payback years. It is considered that the infiltration of smart houses would be quite difficult in the present stage, because the cost burden of introducing smart appliances, especially the electricity system is too large.

If the cost of photovoltaic system decreased to less than 200,000 Yen/kWh and the cost of electricity

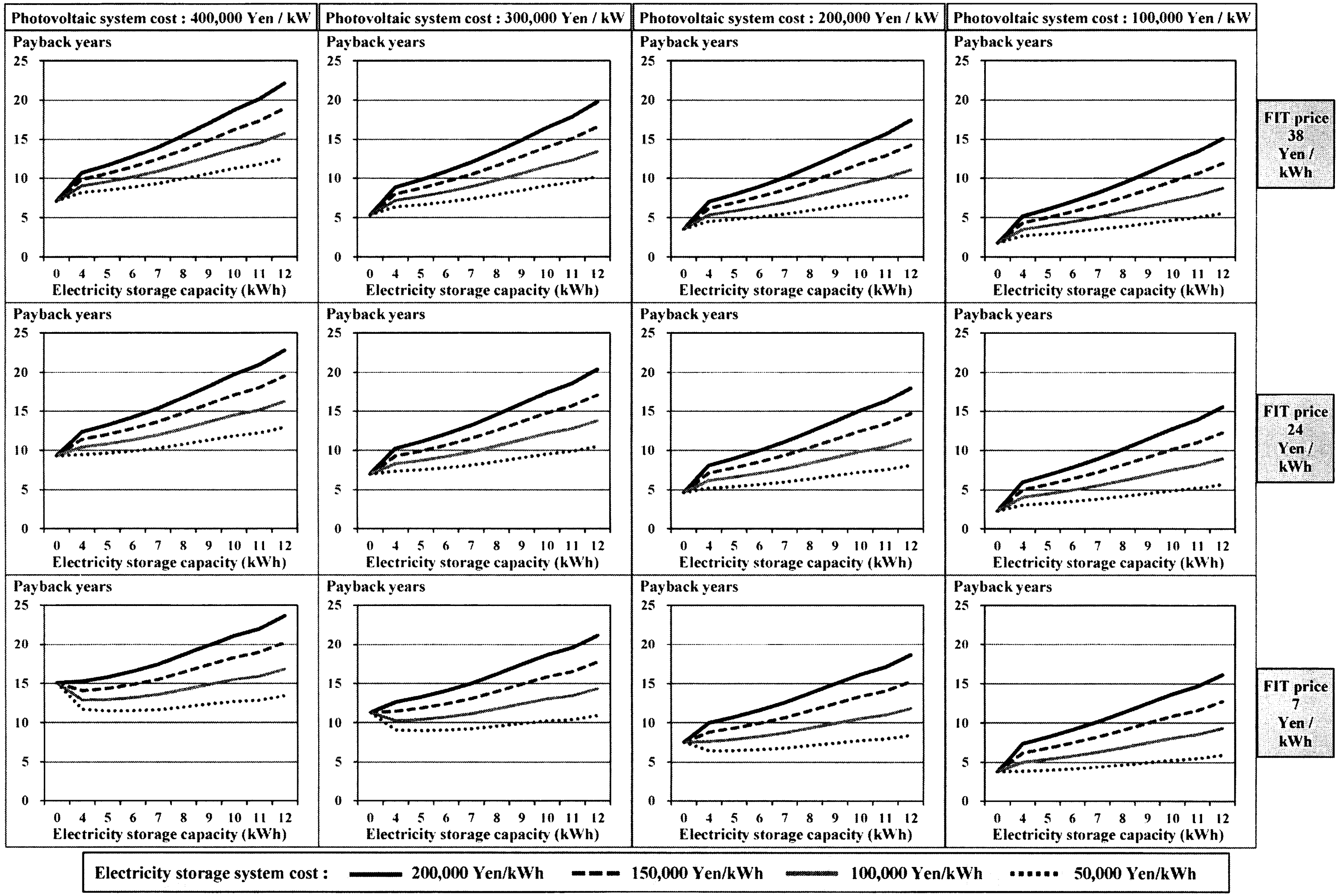

Fig. 6 changes in economics of smart house under various cost conditions of photovoltaic cell and electricity storage system storage system also decreased to less than 100,000 Yen/kWh, the economics of smart house will be improved drastically, as shown in Fig. 6.

6. Concluding Remarks

We would like to make the following concluding remarks finally through the analyzed results done by the preceding study [1] and this study.

First, the expansion of smart house functions to existing houses would be quite difficult under present conditions, because the payback year of total investment cost is more than 10 years.

Second, though the introduction of the photovoltaic cell (PV) becomes more reasonable owing to the feed-in-tariff (FIT) system, the cost up by the electricity storage system (ESS) disturbs the expansion of smart house due to the lowering economics.

Third, considering the payback year, the cost of the photovoltaic cell (PV) should be lowered at least to 200,000 Yen/kW and the cost of the electricity storage system (ESS) should be lowered at least to 100,000 Yen/kWh.

Forth, different from direct reduction of investment cost, changes in the pattern of electricity charge and the receiving price in the feed-in-tariff (FIT) system do not influence so largely.

Fifth, the role of the photovoltaic cell (PV) is to fulfill electricity in the house as much as possible. The feed-in-tariff (FIT) price to receive PV electricity should be lowered to at least the residential electricity rate earlier.

Sixth, the electricity storage system (ESS) has the largest problem of economics in smart house functions. Thus, the cost reduction of the electricity storage system (ESS) would be important particularly from the viewpoint of technology developments.

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