An Analysis on the PV and Battery Installation Connecting the Commercial and Residential Sectors

by

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Abstract

Recently, the progress of ICT such as cloud computing and bidirectional communication system is very marvellous. The battery system such as lithium ion, NAS and redox flow batteries is also being made a great progress. Therefore, in this study, we would like to analyze the PV (Photovoltaic cell) and battery installation connecting the commercial and residential (household) sectors under various capacity conditions. We also would like to discuss the present problems and future subjects of this activity.

The special environment brought by the much preferable purchased price of PV electricity by FIT makes quite large distortion to the decision making of investments for the installation of PV and battery. We need to reconsider desirable and sustainable FIT system, particularly to solar, more carefully.

For the installation of PV and battery connecting the commercial and residential (household) sectors, the cost reduction will be quite essential. Of these, especially, the cost reduction of various batteries would play a crucial role. Thus, technology innovation of battery will be desired earnestly from now on.

The "absolutely zero" purchased electricity at any time is often pursued as an achievable target. But the realization of this target is not reasonable. Instead of this strict target, the balancing between the purchased electricity and the sold PV electricity ("net zero") would be pursued.

Introduction

Japanese Government has determined the new target of GHGs reduction to achieve 26% reduction from the emission level in 2013 up to 2030 as Japanese INDC (Intended Nationally Determined Contributions). The discussions on the GHGs reduction measures to achieve this target are still wandering. However, in the long-run, Japan must intensify her GHGs reduction measures basically, because she already committed 50% (or 80%) reduction of GHGs in 2050 in the past several Summits etc. In addition, the rule of Paris Agreement has been finally adopted in COP24 which was held at Katowice in Poland on December 2018.

The GHGs emissions of Japan in 2016 recorded to the 3.6% up from the 1990 level (the base level in Kyoto Protocol) [1], though the first commitment period of Kyoto Protocol finished in 2012. Because of the East Japan great earthquake and Fukushima nuclear accident in 2011, the thermal power generations was increased sharply instead of nuclear power generations. In the long-run, especially, the continuous increases in GHGs emission in the commercial and residential (household) sectors were largely influenced to the whole GHGs increases in Japan.

Recently, the progress of ICT (information and communication technologies) such as cloud computing and bidirectional communication system is very marvellous. The battery system of electricity such as lithium ion battery, NAS battery and redox flow battery is also being made a great progress. Therefore, in this study, we would like to analyze the PV (Photovoltaic cell) and battery installation connecting the commercial and residential (household) sectors under various capacity conditions. We also would like to discuss the present problems and future subjects of this activity.

Methods

In this study, we made economics simulations on the installation of PV and battery connecting the commercial and residential (household) sectors. The average electricity demand pattern in the commercial and residential (household) sectors was estimated based on the METI survey report [2], EDMC survey data [3] and Cogeneration Comprehensive Manual [4]. We also surveyed past and present situations on PV and battery on the basis of NEDO and METI reports [5, 6]. The average daily pattern of solar power output was also estimated using NEDO Sunshine Database [7].

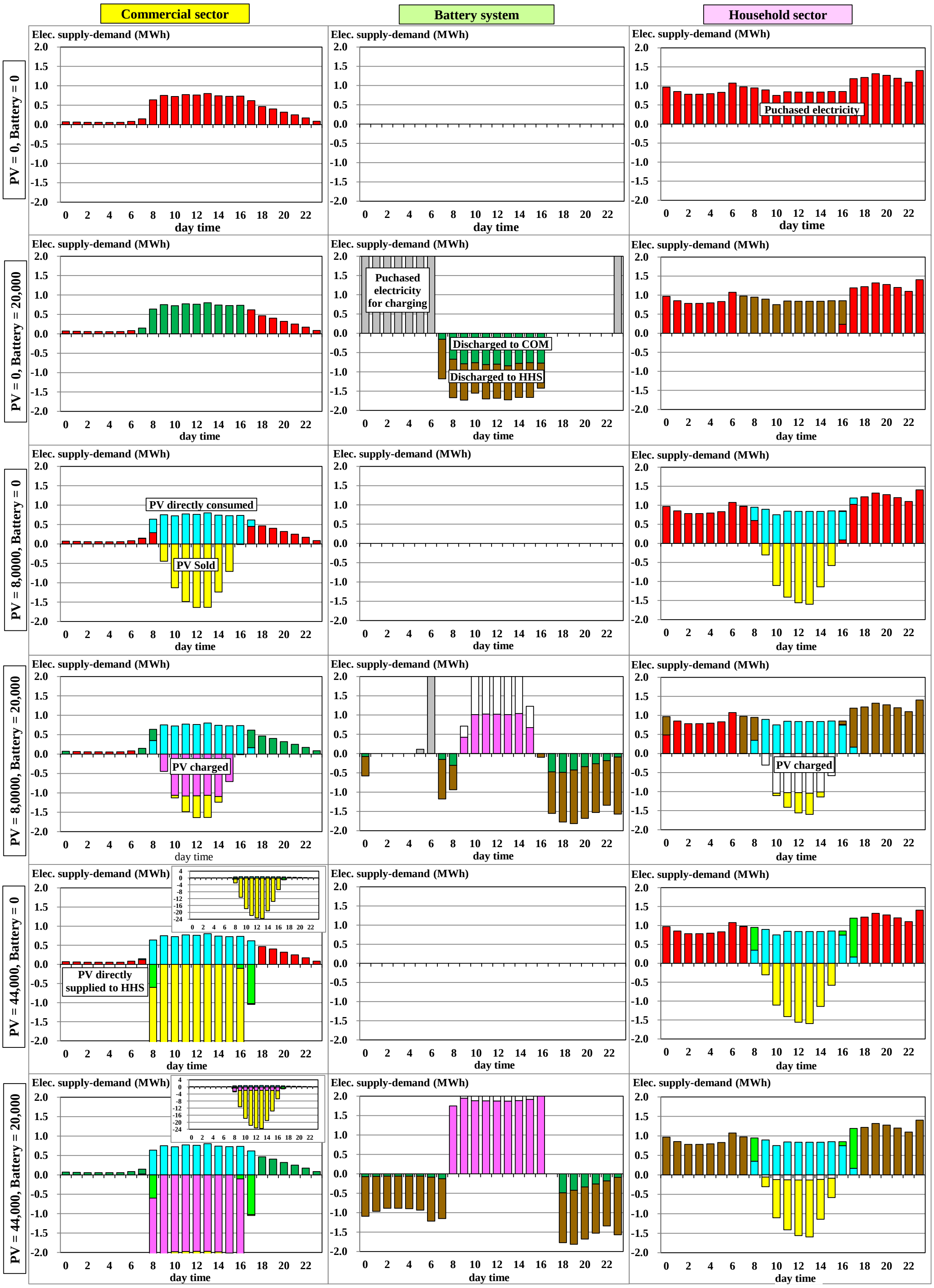
The economics is judged from the simple payback period which is calculated by dividing the total investment (deducting cost covered by the subsidy) of necessary equipment by the annual net profit (the reduction of purchased electricity and the revenue of PV electricity sold by using FIT). In the simulation, first, the starting point where purchased electricity from the power company outside could be made absolutely zero (a kind of extreme case) is determined. This starting point is the PV maximum (Case (vi): PV capacity 44,000 kW and battery capacity 20,000 kWh).

We also make the following several simulations: Case (i): PV capacity zero and battery capacity zero, Case (ii): PV capacity zero and battery capacity 20,000 kWh, Case (iii): PV capacity 8,000 kW and battery capacity zero, Case (iv): PV capacity 8,000 kW and battery capacity 20,000 kWh and Case (v): PV capacity 44,000 kW and battery capacity zero. As for the Case (iv), the electricity purchased from the power company outside is well balanced with the surplus PV electricity sold to the power company outside. Therefore, this case is positioned as “net zero” but not “absolutely zero.”

Results

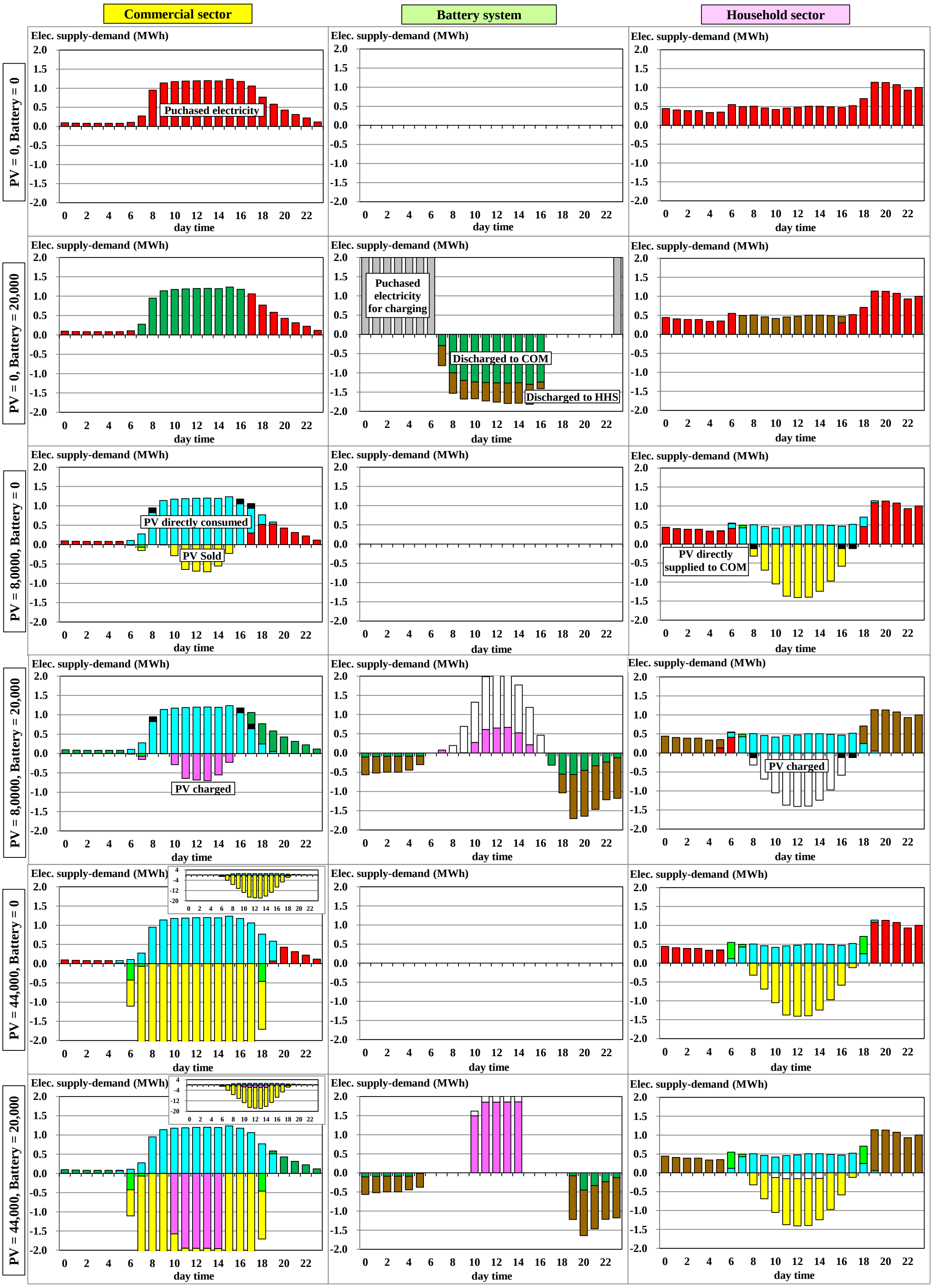
(1) Electricity supply and demand patterns in cases analyzed in this study

The electricity supply and demand patterns of the commercial and household (residential) sectors and the electricity storage system on Cases (i) to (vi) are shown in Fig. 1 (the winter season: January), Fig. 2 (the summer season: July) and in Fig. 3 (the intermediate season: October). The first (top) shelf of three figures shows the electricity supply and demand pattern of Case (i): PV capacity zero and battery capacity zero. In this case, all the electricity demands in both sectors are supplied by the electricity purchased from the power company outside.



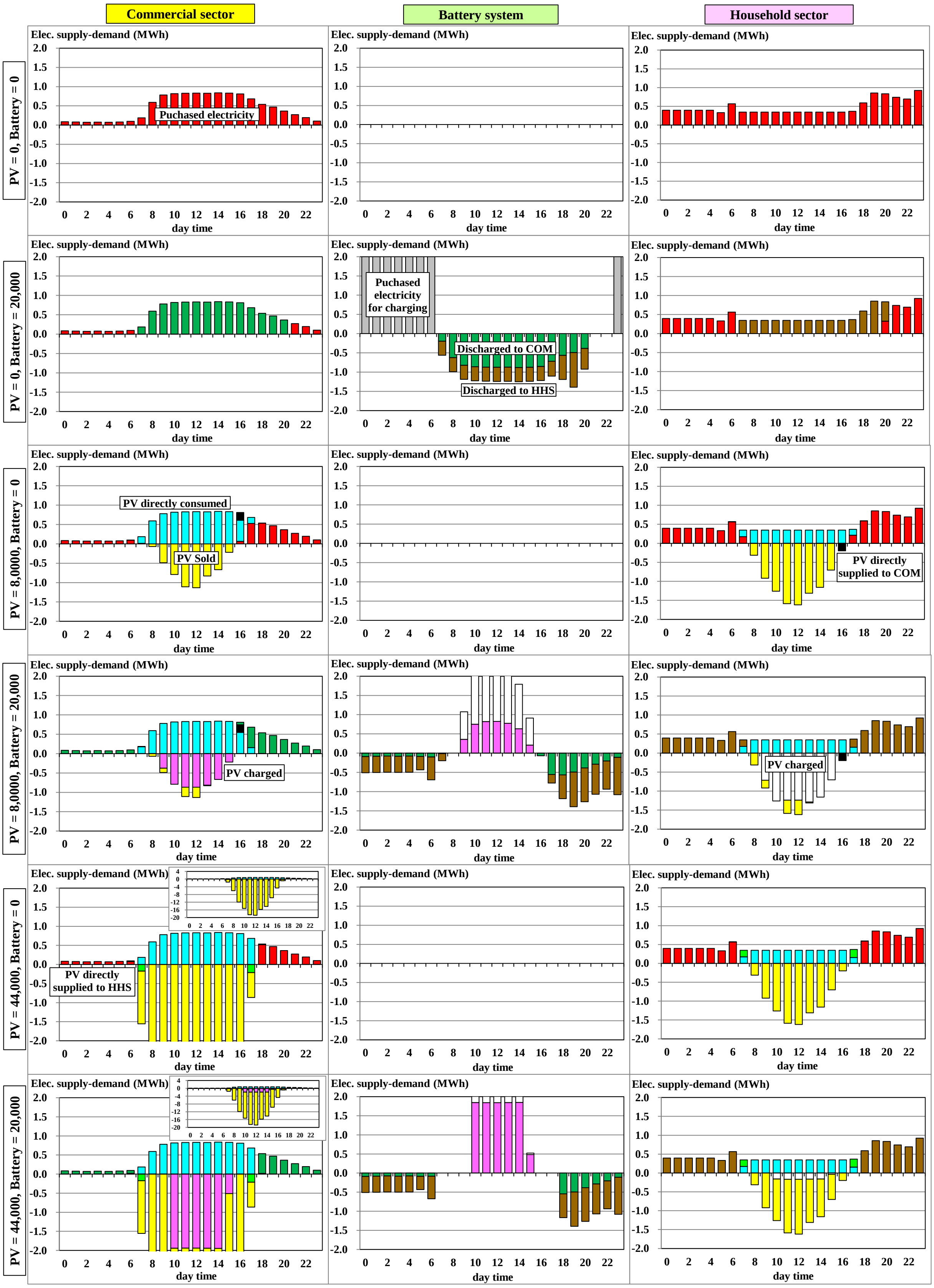
(Note) HHS: Household sector

Fig. 1 Changes in Electricity Supply Pattern in Winter Season (January) by the Installation of PV and Battery



(Note) COM: Commercial sector

Fig. 2 Changes in Electricity Supply Pattern in Summer Season (July) by the Installation of PV and Battery



(Note) COM: Commercial sector and HHS: Household sector

Fig. 3 Changes in Electricity Supply Pattern in Intermediate Season (October) by the Installation of PV and Battery

The second shelf of Figs. 1-3 shows the electricity supply and demand pattern of Case (ii): PV capacity zero and battery capacity 20,000 kWh. In this case, the cheap electricity in the midnight is purchased and charged to the battery, and discharged to the commercial and household sectors in the daylight. The electricity consumed in the night is also purchased from the outside power company.

The third shelf of Figs. 1-3 shows the electricity supply and demand pattern of Case (iii): PV capacity 8,000 kW (commercial sector 4,000 kW and household sector 4,000 kW) and battery capacity zero. In this case, the electricity consumed in the daylight is directly supplied by PV and the surplus PV electricity is sold to the outside power company by using the FIT system. In this case, the electricity consumed in the night is also purchased from the outside power company, as well as Case (ii).

The forth shelf of Figs. 1-3 shows the electricity supply and demand pattern of Case (iv): PV capacity 8,000 kW and battery capacity 20,000 kWh. In this case, the PV electricity generated charged in to the battery in the daylight in addition the PV electricity is directly supplied to the commercial and household sectors in the daylight. In this case, the small remaining surplus of PV electricity is also sold the outside company as well as Case (iii). The electricity charged into the battery is discharged to the commercial and household sectors in the night. The small shortage of electricity in the night is finally covered by the electricity purchased from the outside power company depending on the season (or month). In this case, the PV electricity sold and the electricity purchased from the outside power company are both small and are almost balanced mutually. Thus, the Case (iv) is recognized as “net zero.”

The fifth shelf of Figs. 1-3 shows the electricity supply and demand pattern of Case (v): PV capacity 44,000 kW (commercial sector 40,000 kW and household sector 4,000 kW) and battery capacity zero. In this case, of course, the electricity consumed in the daylight is all supplied from the PV installed. The enormously large surplus PV electricity is sold to the outside power company by using the FIT system. In this case, the electricity consumed in the night is also purchased from the outside power company, as well as Cases (ii) and (iv).

The last (bottom) shelf of Figs. 1-3 shows the electricity supply and demand pattern of Case (vi): PV capacity 44,000 kW and battery capacity 20,000 kWh. In this case, the electricity consumed in the daylight is also all supplied from the PV installed as well as Case (v). In addition, the PV electricity generated is also charged into the battery in the daylight. The still remaining enormously large surplus PV electricity is also sold to the outside power company by using the FIT system as well as Case (v). In this case, there is no electricity purchased from the outside power company. Thus, Case (vi) is recognized as “absolutely zero.”

Based on the seasonal comparison among Figs. 1-3, we can easily point out the following specific characteristics.

a) As shown in Fig. 1, in the winter season (January), the electricity demand increases both in the commercial and household sectors. Especially, the electricity demand in the household sector increases throughout the day, as compared with other season. The electricity demand in the commercial sector increases mainly in the daylight. In the Case (vi) only, the electricity purchased from the outside power company becomes zero.

b) As shown in Fig. 2, in the summer season (July), the electricity demand also increases both in the commercial and household sectors. Especially, the electricity demand in the commercial sector increases largely in the daylight. The electricity demand in the household sector increases mainly from the evening to the mid night. In the Case (vi), the electricity purchased from the outside power company also becomes zero and in the Case (iv), the electricity purchased from the outside power company becomes almost zero.

c) As shown in Fig. 3, in the intermediate season (October), the electricity demand decreases both in the commercial and household sectors, compared with the winter and summer seasons. Not only in the Case (vi) but also in the Case (iv), the electricity purchased from the outside power company becomes zero.

d) The PV installation plays a powerful role on covering the electricity demand in the daylight of the commercial sector directly. The PV installation also plays a certain role on covering the electricity demand in the daylight of the household sector directly. However, the combination of PV and battery plays a crucial role on covering the electricity demand in the night of the household sector.

(2) Changes in annual electricity supply and demand balances by cases

Figure 4 shows the annual electricity demand and supply balances in sectors, PV and battery. The base case is Case (i): PV zero and battery zero. In this case, all electricity demand in residential (household) and commercial sectors is supplied by the purchased electricity from the power company outside. In Case(ii): PV zero and battery 20,000 kWh, more than half of the elcericity demand is covered by the electricity supply from the battery which is charged by the puchase of cheap electricity in the night from the power company outside.

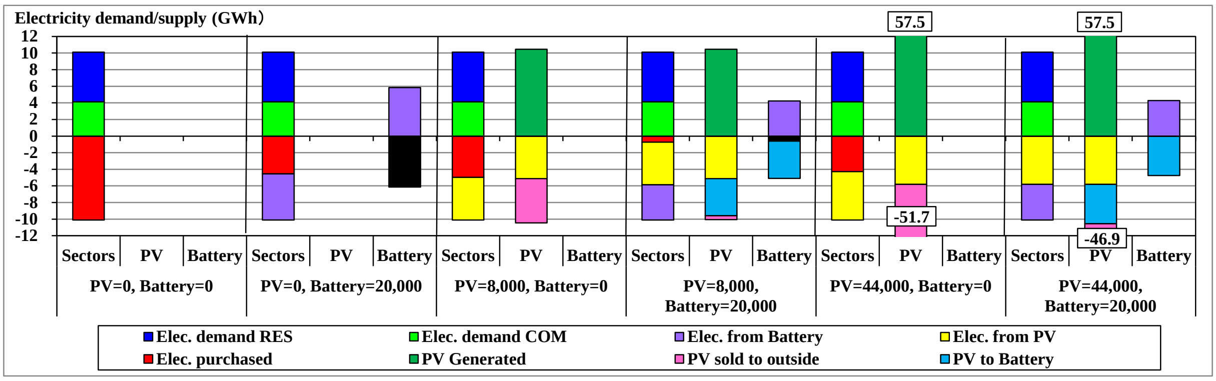


Fig. 4 Annual electricity demand and supply balances in sectors, PV and battery

In Case (iii): PV 8,000 kWh and battery zero, almost half of the electricity demand is supplied by the PV electricity generated, but the surplus of PV electricity (almost half of PV electricity generated) is sold to the power company outside because of no battery. Also in Case (v): PV 44,000 kWh and battery zero, more than half of the electricity demand is covered by the PV electricity generated, but the enormously large remaining surplus of PV electricity is sold to the power company outside also because of no battery. In Cases: (ii), (iii) and (v), almost half of the electricity demand is finally covered by the purchased electricity from the power company outside.

Different from the three cases mentioned above, in Case (iv): PV 8,000 kWh and battery 20,000 kWh, almost half of the electricity demand is firstly supplied by the PV electricity generated as well as Case (iii). Almost all of the remaining PV electricity is charged into the battery and then is discharged to the electricity demand in the night. Only the small remaining surplus of PV electricity is finally sold to the power company outside. The quite small part of the electricity demand is fulfilled by the purchase of electricity from the power company outside. The small part of PV electricity sold by FIT is almost well-balanced with the small part of electricity purchased from outside. Therefore, we can recognize Case (iv) as an example of “net zero” state.

As well as Case (iv) discussed avobe, in Case (vi): PV 44,000 kWh and battery 20,000 kWh, almost half of the electricity demand is also firstly supplied by the PV electricity generated and all the remaining electricity demand is covered by the electricity discharged from the battery which is stored by charging PV electricity in the daylight. The still enormously large remaining PV electricity due to the huge PV capacity installed is sold to the power company outside as well as Case (v). In this case, there is no purchased electricity from the power company outside at all. Therefore, we can recognize Case (vi) as an example of “absolutely zero” state.

(3) Changes in economics of PV and battery installation by cases

Figure 5 shows the components of net profits and the payback period to total investment under the past cost and FIT purchased price conditions in 2015. In this simulation, based on the preceding study [8], the cost of PV is assumed to be 350,000 Yen/kW for the house use (small scale) and 300,000 Yen/kW for the mega solar use (large scale). The cost of battery is also assumed to be 200,000 Yen/kWh. The FIT (Feed in tariff) purchase price is assumed to be 33 Yen/kWh for the residential (household) sector and to be 27 Yen/kWh for the commercial sector.

Figure 6 shows the components of net profits and the payback period to total investment under the present cost and FIT purchased price conditions in 2019. In this simulation, based on the survey results in this study [9], the cost of PV is assumed to be 250,000 Yen/kW for the house use (small scale) and 200,000 Yen/kW for the mega solar use (large scale). The cost of battery is also assumed to be 150,000 Yen/kWh. The FIT (Feed in tariff) purchase price is assumed to be 24 Yen/kWh for the residential (household) sector and to be 14 Yen/kWh for the commercial sector. Entering 2019, the FIT purchased price in the commercial sector has just announced by METI [10].

As shown in Fig.5, under the past conditions in 2015, the payback period of total investment is less than or around 10 years as for the following three cases: Case (iii): PV 8,000 kW and battery zero, Case (v): PV 44,000 kW and battery zero and Case (vi): PV 44,000 kW and battery 20,000 kWh (“absolutely zero”) because of no battery or the preferable FIT purchased price for PV. The payback period of total investment remains still high owing to the expensive battery cost in Case (ii): PV zero and battery 20,000 kWh and case (vi): PV 8,000 kW and battery 20,000 kWh (“net zero”).

As shown in Fig. 6, under the present conditions in 2019, the payback period of total investment in Case (ii): PV zero and battery 20,000 kWh is improved from 47.6 years (2015) to 35.7 years (2019) and the payback period in Case (iv) : PV 8,000 kW and battery 20,000 kWh (“net zero”) is also improved from

21.8 years (2015) to 16.4 years (2019) mainly due to the cost reduction of battery. The cost reduction of PV also influences the latter improvement of the payback period.

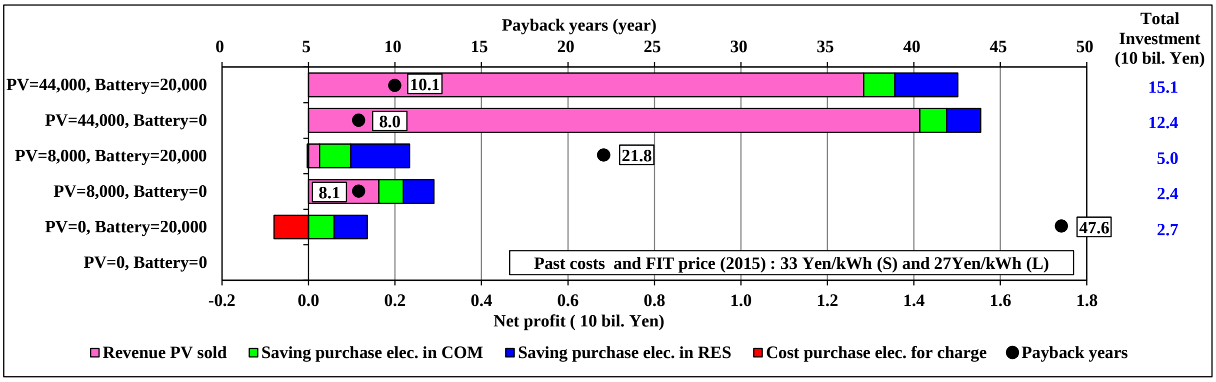


Fig. 5 Components of net profits and payback period of total investment (cost and FIT purchased price conditions in 2015)

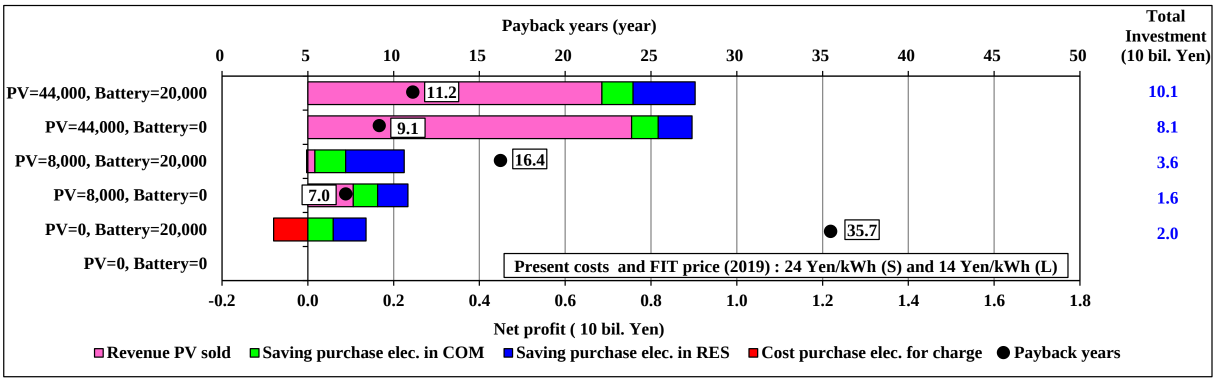


Fig. 6 Components of net profits and payback period of total investment (cost and FIT purchased price conditions in 2019)

Also as shown in Fig. 6, the payback period of total investment in Case (iii): PV 8,000 kW and battery zero is slightly improved from 8.1 years (2015) to 7.0 years (2019) mainly due to the cost reduction of PV. On the contrary, the payback period of total investment in Case (v): PV 44,000 kW and battery zero is slightly worsened from 8.0 (2015) to 9.1 (2019) and the payback period in Case (vi): PV 44,000 kW and battery 20,000 kWh ("absolutely zero") is also slightly worsened from 10.1 years (2015) to 11.2 years (2019) maily due to the lowering of FIT purchase prices to PV electricity.

Acoording to the obtained results on the economics of PV and battery installation, we can point out the following issues.

a) The reduction of battery cost is quite crucial for the effective use of PV and battery in the commercial and residential (household) sectors.
b) The reduction of PV cost is also important for the purpose mentioned above.
c) The lowering of FIT purchase price has a bad influence on the effective use of PV and battery in the commercial and residential (household) sectors.
d) However, too preferable FIT purchase price bring a kind of distortion on the effective use of PV and battery in the commercial and residential (household) sectors.

Conclusions

The special environment brought by the much preferable purchased price of PV electricity by FIT makes quite large distortion to the decision making of investments for the installation of PV and battery. We need to reconsider desirable and sustainable FIT system, particularly to solar, more carefully.

For the installation of PV and battery connecting the commercial and residential sectors, the cost reduction will be quite essential. Of these, especially, the cost reduction of various batteries would play a crucial role. Thus, technology innovation of battery will be desired earnestly from now on.

The "absolutely zero" purchased electricity at any time is often pursued as an achievable target. But the realization of this target is not reasonable. Instead of this strict target, the balancing between the purchased electricity and the sold PV electricity ("net zero") would be pursued.

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