Suitable Combination of Photovoltaic Cell and Electricity Storage System in the Smart Community Connecting the Commercial and Residential Sectors

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Purpose of this study

- The Paris agreement was finally approved in December 2015. Last year, Japanese Government also determined the new target of GHGs to achieve 26% reduction from the emission level in 2013 up to 2030. This new target is somewhat mild.

- Up to 2014, GHGs emissions in Japan has increased largely from 1990 level (the base level in Kyoto Protocol). Especially, the continuous increases in GHGs emission in the commercial and residential sectors were remarkable.

- On the other hand, Japan was committed to the 50% (or 80%) reduction target of GHGs in 2050 already, and thus Japan must strengthen GHGs reduction measures in the long run.

- For this achievement, the introduction of smart community connecting both sectors is an important option in Japan. The purpose of this study is to analyze the suitable combination of smart facilities for both sectors and to discuss their issues.
Assumed Conditions for Sectors and Facilities

<Characteristics in commercial and residential sectors>
- Commercial sector/ total floor area: 25,000 m²  Referred Yokohama and Kitakyushu.
- Residential sector/ total household number: 1,000, PV capacity: 4 kW/house, PV is assumed to be introduced in all houses. Total PV capacity is 4 MW in the RES.

<Electricity storage system (ESS)>
- Cost: 200,000 Yen/kWh, Subsidy: 1/3 of initial cost. Charged for 6 hours from 0:00 to 6:00 for purchased electricity with minimum necessity and from 7:00 to 17:00 for PV electricity, and discharged in other hours without charging.

<Photovoltaic (PV) cell>
- (For house) Cost: 350,000 Yen/kW, Subsidy: 40,000 Yen/kW (Local). Surplus electricity is sold at FIT price of 33 Yen/kWh.
- (For building and mega solar) Cost: 300,000 Yen/kW, Subsidy: 20,000 Yen/kW (Local). Surplus electricity is sold at FIT price of 27 Yen/kWh.

<Electricity rate>
- Several cases of the electricity rates different from hour by hour were assumed under the condition that the total electricity charge revenues to base electricity consumption would be the same (neutral)
# Electricity Supply Pattern without Smart Facilities

<table>
<thead>
<tr>
<th>Month</th>
<th>Commercial sector</th>
<th>Electricity storage system</th>
<th>Residential sector</th>
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<tbody>
<tr>
<td>January</td>
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<tr>
<td>April</td>
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<td>July</td>
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<tr>
<td>October</td>
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### Electricity Supply Demand (MWh)

<table>
<thead>
<tr>
<th>Day Time</th>
<th>Elec. supply-demand (MWh)</th>
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<tbody>
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-2.0 \[ \quad \] -1.5 \[ \quad \] -1.0 \[ \quad \] -0.5 \[ \quad \] 0.0 \[ \quad \] 0.5 \[ \quad \] 1.0 \[ \quad \] 1.5 \[ \quad \] 2.0 \[ \quad \]

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

### Purchased Electricity

Purchased electricity consumption varies throughout the day, reflecting peak times and off-peak periods.

### Commercial Sector

The commercial sector shows high demand during the day, peaking in the afternoon.

### Residential Sector

Residential sector demand is lower overall, with a slight rise in the evening.

### Electricity Storage System

The electricity storage system balances supply and demand, absorbing excess energy during off-peak hours and releasing it during peak times.
PV: COM 3 MW, RES: 700 houses (2.8 MW) / ESS: 30 MWh
Methods of Economics Simulation

<Determination of starting points (Extreme case)>

- The starting points at which the purchased electricity becomes absolutely zero was determined (a kind of extreme case). The following two cases were obtained.

- PV maximum case: PV capacity 40 MW and ESS capacity 20 MWh.

- ESS maximum case: ESS capacity 39 MWh and PV capacity 5.5 MW

<Economic simulations by changing PV and ESS capacities>

- The economic and performance simulations were made by reducing PV and ESS capacities step by step as for above-mentioned two extreme cases.

- Several indicators which can give the performance of smart community were also calculated.
Electricity Supply Pattern in PV Max case

Elec. supply-demand (MWh)

day time

January

Elec. supply-demand (MWh)

May

Elec. supply-demand (MWh)

October

PV: COM 40 MW, RES: 1,000 houses (4 MW) / ESS: 20 MWh
Checking of Performance Indicators and Payback Years by Reducing ESS Capacity

The following performance indicators were checked.

1. Purchased electricity ratio,
2. Electricity in house sector ratio,
3. PV directly supply ratio,
4. PV own consumption ratio,
5. PV electricity sold ratio,
6. ESS operating rate,
7. ESS discharged supply ratio,
8. ESS PV charging ratio,
9. ESS purchased charging ratio

The following simple payback years was checked.

Payback years = (Total investment cost required) / {((Saving purchased electricity expenses in RES and COM) + (Revenue of PV electricity sold) + (Cost of purchased electricity for charging))}
In this case, the simple payback years is estimated 10 or lower than 10.

The revenue by selling PV electricity using FIT system play a quite important role for the improvement of economics.

Even if the capacity of ESS is lowered to 10,000 kWh, the specific indicators are not changed drastically and the ESS operating rate is improved largely.

This result means that the starting point would not be most suitable.
Problems in PV Max Case

- The results of PV maximum case explained by the previous slides is brought especially by the special favorable treatments using higher FIT prices.

- Because the required size of PV capacity to generate PV electricity sold to the outside 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, we would like to consider ESS maximum case in the next step.
PV: COM 5.5 MW, RES: 1,000 houses (4 MW) / ESS: 39 MWh
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 would be improved rapidly.

Even if the capacity of ESS is lowered to 20,000 kWh, the specific indicators are not changed drastically and the ESS operating rate is improved largely.

This result also means that the starting point would not be most suitable.
Indicators for Pursuing Suitable Combination of Smart Facilities (1)

a. **Balancing ratio of purchased electricity and sold electricity**
   \[(\text{purchased electricity} - \text{sold electricity})/\text{(electricity demand)}\times 100\]
   Largely related to PV capacity

b. **Ratio of purchased electricity**
   \[(\text{purchased electricity})/\text{(electricity demand)}\times 100\]
   Related to both of PV and ESS capacity

c. **Ratio of sold PV electricity**
   \[(\text{sold PV electricity})/\text{(generated PV electricity)}\times 100\]
   Related to both of PV and ESS capacity
In the case of PV capacity at 4.1 MW, purchased and sold electricity has a well balanced relation.

If ESS capacity reaches to less than 20 MWh, the ratio of purchased elec. and the ratio of sold PV elec. increases drastically.
Indicators for Pursuing Suitable Combination of Smart Facilities (2)

d. Operation rate of ESS
   \[(\text{charged electricity to ESS})/(\text{ESS capacity}) \times 100\]
   Largely related to ESS capacity

e. Ratio of discharged electricity from ESS
   \[(\text{discharged electricity from ESS})/(\text{electricity demand}) \times 100\]
   Related to both of PV and ESS capacity

f. Ratio of purchased electricity for ESS
   \[(\text{charged electricity to ESS by purchasing})/(\text{total charged electricity to ESS}) \times 100\]
   Related to both of PV and ESS capacity
If ESS capacity reaches to more than 25 MWh, the operation rate of ESS falls down to less than 60%. As PV capacity down, it is also sharply down.

If ESS capacity reaches to less than 20 MWh, the ratio of discharged elec. decreases sharply and the ratio of purchased elec. for ESS increases.
PV: COM 4.1 MW, RES: 1,000 houses (4 MW) / ESS: 20 MWh
First, 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 FIT is not suitable for the sound developments of smart community.

Second, although the always absolutely zero purchased electricity is pursued in the smart community as an achievable target, the realization of this target is quite difficult and extremely inefficient.

Instead of this target, the balancing between the purchased electricity and the sold PV electricity would be an important target should be considered.
Third, we also need to consider the balancing between the economics of smart community and the role of installed ESS capacity.

In order to reduce purchased electricity more, the larger ESS capacity would be required. However the economics of smart community becomes worse rapidly as the ESS capacity become larger.

Fourth, under the present cost conditions, the economics of smart community would not be so preferable. For the expansion of smart community, the cost reduction of smart facilities, especially for ESS, would be quite important.

The quite lower price of ESS announced by TESLA is a gratifying information for smart community. As for the large-scale ESS, Japanese companies also have advanced technologies such as NAS (Nihon Gaishi) and redox flow (Sumitomo Denki) batteries.