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A TWO STAGE ENERGY PLANNING MODEL INTEGRATING POWER EXPANSION AND REGIONAL ENERGY SYSTEMS FOR THE ASSESSMENT OF SOLAR AND CGS

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Overview

Such distributed energy supply systems as solar power photo voltaics (PV), wind power and co-generation systems (CGS) are often expected to play main roles in the future energy systems, especially after the 3.11, 2011 gigantic earthquake in Japan. However, the following two points should be addressed: firstly, the decrease of the future PV cost is often assumed with the expansion of PV production. However, since PV's are basically employed by consumers based on the costs, it is still questionable whether "consumer's behavior on PV purchase" is compatible with the "future scenario on PV market". Second, when the above distributed energy systems are extensively employed by the consumers, then the power expansion planning should also be affected since the total power demand as well as the daily load patterns should change. Although many models hav been developed to assess the contribution of distributed energy systems (Danestig et.al.(2007)) or to generate power expansion plannings (Shiraki et.al.(2008)), the interactions between these two have not been well evaluated systematically.

We develope a two-stage model focusing on the Tokyo Electric Power Co. area in this study. In the first stage, we disaggregate the Kanto area into 38 regions and then develop an optimum energy system model including PV and CGS for the consumers by region. The electric power demand for the utility is transferred to the power expansion planning model of Tokyo Electric Power Company in the second stage. We can then observe how the results on the penetration of PV harmonizes with the cost and the market projection scenarios given by governmental plans. We also evaluate the effect of subsidy scenarios for PV.

Method

In this study we employ the simulation duration through 2010 to 2030 for every five years. Energy demand curves consist of four seasons, i.e. middle, winter, summer and peak three days, and 24 hourly periods.

Stage-1 Regional consumer behavior model: we firstly disaggregate the Tokyo Electric Power Company (TEPCO) supply area into 38 subregions. We categorize the consumers into four groups, say household(hs), office(of), shop(sh), hospital(ho). The power demand for industry and others is defined by the total power demand for utility minus the sum of the demand of consumers. We collect the floor area of the consumers by region based on the building statistics. Potential installation area of PVs and energy demand of consumers by end use are also estimated by region based on these estimates and existing statistics. We apply this model to the four consumers of 38 regions for four seasons, 24 hours and 6 periods for 2010-2030.

Stage-2 Power expansion model: The sum of the electric power demand of the consumers and other industry is then transfered to the power generation expansion in Stage-2. Power expansion model includes 6 conventional plants, i.e. coal fired plants (CLF), gas fired plants(GDF), oil fired plants (OLF), nuclear power (NCR), hydraulic power (HYD) and pumped storage hydraulic power (PmHD), and two new technologies, gas combined cycle (GCC) and coal gasification combined cycle plants (IGCC). Costs, conversion efficiencies, carbon emission rates and other parameters follow the existing literature.

For the costs and the installation area scenario on PV, we employ three cases following EPIA 2011 (NPU, 2011), say reference (RF), accelarated (AC) and paradigm shift (PS) scenarios.

Results

Figure 1 exhibits the PV installation results as well as the PV installation target in paradigm shift case. It is shown that only few PV is employed by consumers in the reference scenario (RF). Since the PV installation results in the accelerated scenario (AC) and paradigm shift scenario (PS) do not reach the target, subsidy will be needed when the policy maker would realize the target. We evaluate the subsidy by imposing the additional lower bound constraint on the PV installation. Comparing the optimal costs with and without this lower bound, one can evaluate the subsidy required to achieve the target as shown in Figure 2.

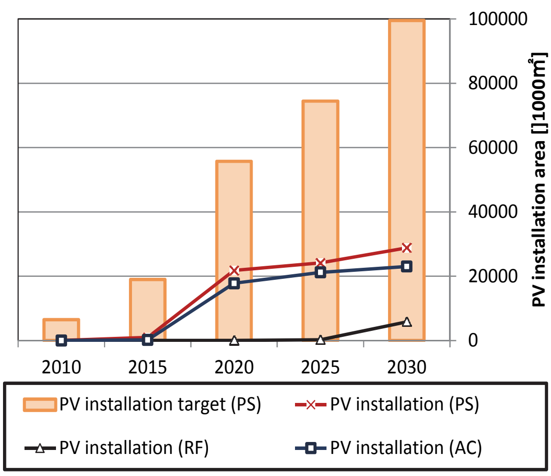

Figure 1 PV installation results in $1000m^2$

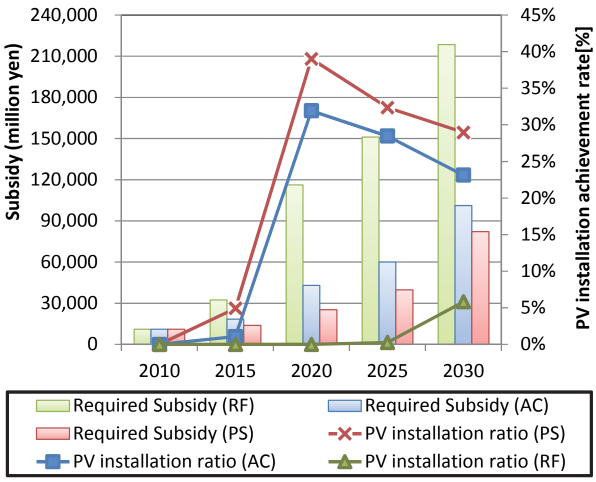

Figure 2 Estimated subsidy and installation ratio

Table 1 compares how power expansion planning is affected by the PV cost scenario in the reference (RF) and accelerated (AC) scenario. Since the daily load curve changes when PV is largely implemented, optimal power generation mix also changes. Table.1 also suggests that the changes in load pattern would increase the average power generation costs due to the lower capacity utilization rates.

Table 1 Comparison of nuclear power installation by PV scenario

	New Nuclear Power (GW)		CO_2 emission Mt-CO_2		Ave.cost[yen/kwh]	
	RF	AC	RF	AC	RF	AC
2010	31.25	24.72	103.07	79.35	9.03	9.31
2015	3.31	3.28	20.84	21.94	8.67	9.01
2020	1.51	1.85	21.09	22.57	8.00	8.23
2025	2.51	2.63	20.98	20.99	8.04	8.28
2030	0.00	0.00	21.04	21.04	7.91	8.12

Conclusion

In this study we develop a two-stage model approach to see how the consumer's behavior in terms of PV and CGS installation gives consistent installation targets and influences the power expansion planning. The results in stage-1 suggest that PV installation projection would not meet the installation target only by the consumer behavior unless additional PV penetration policy such as large scale PV plant (so called Mega-Solar) is promoted. The model also provides the subsidy needed to achieve the installation target. The power expansion model in stage-2 shows how the long term expansion is affected by the consumer's behavior and PV cost projection. It is also suggested that the changes in load curve would increase the power generation costs. Our approach would provide further information when EV and other distributed energy systems are broadly implemented as a part of SmartCity.

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