Economic and Technological Evaluation for Zero Carbon Electric Power System Considering System Stability (Vol. 2):

Scenario Analysis for the Development of Zero Carbon Electric Power System in 2050

Summary

Low carbon and zero carbon electric power (ZC electricity) supply configurations were examined by way of simulating a power supply configuration model, aiming for the economical supply of electricity in 2030 and in 2050. The simulation result showed that it may be possible to supply electricity, at a level below current electricity costs, to meet demand of about 1,700 TWh/y when CO_2 emissions derived from electricity generation fuel in 2030 are reduced by 50% compared to 2013, and of about 1,400 TWh/y when the CO_2 emissions are reduced by 70%. Furthermore, even if for an electricity demand of 1,600 TWh/y in 2050, it may be feasible to construct economical ZC electricity generation configurations. Moreover, an analysis of capital investments showed that, by increasing the reduction of fossil-fuel CO_2 emissions in 2030, the total amount of new capital investments from 2021 through 2029 may be increased by about 20,000 to 40,000 billion JPY.

Proposals for Policy Development

- Towards the achievement of ZC electricity in the future, photovoltaic (PV) and wind power will become the mainstay, and their market sizes will increase. It is important to develop PV and wind power industries strategically considering the expansion of domestic markets in the future.
- While a high demand for storage batteries is expected, the cost of lithium-ion battery is estimated to rise due to depletion of lithium resource. Therefore, an inexpensive and efficient technology that can recycle lithium and promote new power storage technology, and the policy to realize large-scale power storage systems are required.

1. Power supply configuration and power cost calculation

Linear programming method was used to determine a power supply configuration that minimizes the generation cost by using input data of electricity demand per hour in a typical day for every season at every region in Japan. Table 1 shows the parameters for the power supply configuration model. Table 2 shows the power supply configuration breakdowns and costs for typical cases of power demand. For the 2030 cases of A, C, and D, the electricity cost was lower than the electricity cost in 2018 (13.9 JPY/kWh [1]). For the 2050 case of E, the electricity cost was 15 JPY/kWh including the transmission cost for the electricity demand of 1,000 TWh/y, about the same as in 2018.

Table 1 Parameters used for the electricity generation configuration model in this proposal

Case	A	B	C	D	E
Year	2030				2050
Cost level [year]	2025				2030
Reduction of fossil-fuel CO_2 emissions [%] compared to 2013	36		50	70	100
Lower limit of inertial force ratio [%]	25	50	25		25
Upper limit of electricity demand [TWh/y]*	2,125	2,055	1,705	1,385	2,770
LNG electricity generation	Yes				No
Nuclear power generation	Yes**		No		No
Coal fired power generation	Yes		No		No
PV potential [GW]	693				1,386
Onshore wind power generation potential [GW]	262				262
Fixed-bottom offshore wind power generation potential [GW]	0				95
Floating offshore wind power generation potential [GW]	0				538
Biomass power generation endowment [TWh/y]	34				40
New pumped storage power generation potential [GW]	0				282
Hot dry rock geothermal power generation potential [GW]	0				21.7
NH_3 turbine	No				Yes
Reinforcement of inter-region transmission network	No				Yes

*Upper limit of electricity demand that can be achieved with CO_2 reduction and inertia constraints in each case (confirmed in increments of 5 TWh/h)
**Some were calculated with "No".

Table 2 Electricity generation capacity and electricity cost for typical electricity generation configurations

Case			A					C			D			E		
Year		2018	2030											2050		
Rate of reduction of CO_2 emissions from power generation fuel compared to 2013			36%					50%			70%			100%		
Electricity demand [TWh/y]		1,107	1,000	1,200	1,600	1,900	1,900**	1,000	1,200	1,600	1,000	1,200	1,385	1,000	1,600	2,000
Electricity generation capacity [TWh/y]	Nuclear Power	62	0	0	0	149	–	–	–	–	–	–	–	–	–	–
	Coal	924*	237	138	0	0	0	–	–	–	–	–	–	–	–	–
	Existing LNG		110	277	376	355	356	285	292	251	238	230	199	–	–	–
	Newly-established LNG	–	273	337	559	580	580	443	440	480	204	210	240	–	–	–
	Hydropower	78	92	92	92	92	92	92	92	92	92	92	92	92	92	92
	PV Power	65	299	373	536	636	656	214	393	648	401	579	671	491	1,142	1,363
	Wind power (onshore)	11	29	35	119	186	296	0	36	221	119	165	284	443	558	558
	Wind power (offshore)	–	–	–	–	–	–	–	–	–	–	–	–	66	214	569
	Geothermal power	2	11	11	11	11	11	11	11	11	11	11	11	111	111	111
	Woody biomass power	20	0	0	0	0	21	0	0	0	0	0	28	53	50	35
	Total	1,162	1,050	1,262	1,693	2,008	2,010	1,044	1,263	1,702	1,064	1,287	1,525	1,256	2,166	2,727
Usage [TWh/y]	Storage battery	–	72	90	132	177	209	10	83	240	140	249	297	176	385	423
	Pumping-up power	10	0	0	0	0	2	0	0	1	0	1	8	93	247	370
	NH_3 Turbine	–	–	–	–	–	–	–	–	–	–	–	–	11	32	35
Storage battery facility capacity [GWh]		–	265	316	463	618	822	141	313	865	500	889	1,145	521	1,211	1,357
Electric generation cost [JPY/kWh]		13.9	10.0	10.3	10.9	11.4	11.6	10.7	10.7	11.6	11.4	12.0	13.0	13.0	15.0	16.6
Electricity transmission cost [JPY/kWh]		1.0	0.6	0.7	0.6	0.6	0.7	0.5	0.6	0.7	0.7	0.8	0.8	1.6	2.0	1.9

*Including petroleum, etc.
** Calculated assuming no nuclear power operation

Table 3 Six scenarios of electricity generation configuration until 2050

Scenario	Case		Electricity demand [TWh/y]		Reduction of fossil-fuel CO_2 emissions [%-2013]	
	2030	2050	2030	2050	2030	2050
1	A	E	1,000	1,000	36	100
2	C				50	
3	D				70	
4	A		1,200	1,600	36	
5	C				50	
6	D				70	

Table 4 Amounts of new capital investments from 2021 through 2049 [1,000 billion JPY]

Scenario		1	2	3	4	5	6
2021 - 2029	LNG	12	14	9	15	15	12
	PV	20	14	28	26	27	41
	Wind Power	2	0	12	3	3	18
	Storage Battery	6	3	11	7	7	19
	Others	0	0	0	0	0	0
	Subtotal	41	31	60	51	53	91
2030 - 2049	LNG	0	0	0	0	0	0
	PV	24	24	24	56	56	56
	Wind Power	40	40	40	64	64	64
	Storage Battery	10	9	11	22	22	25
	Others	31	31	31	53	53	53
	Subtotal	104	104	105	194	194	197
Total		145	135	166	245	247	288

2. Changes in capital investments and CO_2 emissions

Based on the electricity power supply configuration given in Table 2, the amounts of new capital investments and CO_2 emissions until 2050 were calculated for each scenario assuming a combination of electricity demand and fuel CO_2 emission reduction rate (Table 3). Comparing the total amounts of capital investments until 2049 (Table 4), the total amounts of capital investments for scenarios 3 and 6 in which the fossil-fuel CO_2 emissions are reduced by 70% in 2030, were about 1.1 to 1.2 times those for the scenarios of 1 and 4, in which the fossil-fuel CO_2 emissions are reduced by 36%, respectively. This means that related markets may be highly activated by increasing the reduction of CO_2 emissions. Although the fossil-fuel CO_2 emissions are assumed to be zero in 2050 in these scenarios, CO_2 emissions associated with facility construction remain, suggesting that it becomes more important to develop technologies to suppress facility construction CO_2 emissions in the industrial fields towards the realization of ZC electricity.

[1] LCS, Proposal Paper for Policy Making and Governmental Action toward Low Carbon Societies, "Economic and Technological Evaluation for Zero Carbon Electric Power System Considering System Stability (Vol. 1)," Center for Low Carbon Society Strategy, Japan Science and Technology Agency, March 2020.