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Economic Analyses on CCS by using an Energy Systems and Climate Change Mitigation Model

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Overview of Analyses on CCS in Japan

- Cost effectiveness of CCS is explored by using the DNE+ model, which is able to evaluate various technologies precisely in a bottom-up way considering regional differences.
- Cost effectiveness of CCS depends on various conditions, such as long-term CO_2 emission reduction level and the costs of other global warming mitigating technologies as well as CCS (related technologies). Those uncertainties are taken into account in the analyses.

Overview of DNE21+ (Dynamic New Earth 21+)

- Systemic cost evaluation on energy and CO_2 reduction technologies is possible, not intending to cover the whole economy.
- Linear programming model (minimizing world energy system cost)
- Evaluation time period: 2000-2100

  Representative time points: 2005, 2010, 2015, 2020, 2025, 2030, 2040, 2050, 2070 and 2100
- World divided into 54 regions

  Large area countries, e.g. US and China, are further disaggregated, totaling 77 world regions.
- Interregional trade: coal, crude oil/oil products, natural gas, electricity, ethanol, hydrogen, CO_2 (provided that external transfer of CO_2 is not assumed in the baseline), and CO_2 credit
- Bottom-up modeling for technologies in energy supply side (e.g. power generation sector) and CCS
- For energy demand side, bottom-up modeling conducted for industry sector including steel, cement, paper, chemicals and aluminum, transport sector, and a part of residential & commercial sector.
- Around 400 specific technologies are modeled.

Assumed Costs and Potentials for CO_2 transportation and Storage

	CO2 storage potentials (GtCO2)		【References】 IPCC SRCCS (2005) (GtCO2)	Storage costs ($/tCO2)*1
	Japan	World		
Depl. oil well (EOR)	0.0	112.4	675–900	57 – 69*2
Depl. gas well	0.0	147.3 – 241.5		9 – 59
Deep saline aquifer	11.3	3140.1	10^3–10^4	5 – 38
Coalbed (ECBM)	0.0	148.2	3–200	27 – 122*2

Note 1: It is assumed that the CO2 storage potentials of depl. gas well could be expanded to the upper limit in the table with the increase of future mining volume.

Note 2: It is assumed that the storage costs could rise within the range in the table with the increase of accumulated storage amount.

*1 The costs for CO2 capture is not included.

*2 The costs do not include the payoffs of obtained oil or gas.

The constraint on CO2 storage expansion is assumed considering the difficulties of its rapid expansion, e.g. limited number of drilling rigs; it can be expanded by 0.02%/yr until 2030 and afterwards by 0.04%/yr for domestic/regional total storage implementation.

(The maximum storage potential in 2050 is 91MtCO2/yr in Japan's case, where CCS is assumed to be available after 2030.)

CO2 transportation cost

- **The CO2 transportation costs from the sources to the reservoirs are assumed separately as 1.36$/tCO2 (per 100km) and 300km for average transport distance in Japan's case.**
- **For large area countries which are disaggregated in the models (US, Russia, China and Australia), the interregional CO2 transportation costs are estimated according to the transportation distance.**
- **The case of cross-border CO2 transportation, which might cause CO2 leakage, is not analyzed although it is possible to be done in the models.**

Emission Reduction and Technology Scenarios

【Emission reduction scenarios】

	Temperature targets	Emissions in 2050
B2DS-D	**2 °C, >66% achievability**	**World: -70% × Japan: -80%**
2DS	**2 °C, >50% achievability**	**World: -40% (Equal marginal abatement costs among countries)**

【Technology scenarios】

<table>
<tr><th colspan="2" rowspan="2">Constraint on CCS use</th><th rowspan="2"></th><th colspan="3">CO2 capture cost･CCS investment risk</th><th rowspan="2"></th><th rowspan="2">Renewable energy (photovoltaic) cost</th></tr>
<tr><th>2030</th><th>2050</th><th></th></tr>
<tr><td colspan="2">Standard case: Upper limit for annual expansion 0.02%/yr until 2030, afterwards 0.04%/yr</td><td rowspan="4">×</td><td colspan="2">Standard cost (Low)</td><td rowspan="4">×</td><td rowspan="2">Investment discount rate (Standard)</td><td rowspan="4">×</td><td rowspan="2">Standard cost (High)
[Ratio of total potential]
10 yen/kWh (1%)
12 -13 yen/kWh (20%)
15 -18 yen/kWh (79%)</td></tr>
<tr><td rowspan="3"></td><td>Without CCS</td><td rowspan="2">Capture costs around 1500 yen/tCO2</td><td rowspan="2">Capture costs around 1000 yen/tCO2</td></tr>
<tr><td rowspan="2">Accelerated expansion of CCS
Upper limit for annual expansion 0.04%/yr until 2030, afterwards 0.08%/yr</td><td rowspan="2">Investment discount rate (High)(large uncertainty in investment in environment): Standard +8% points</td><td rowspan="2">Cost (low)
2 yen/kWh (1%)
3 - 4 yen/kWh (20%)
6 - 9 yen/kWh (79%)</td></tr>
<tr><td colspan="2">High cost
Capture costs 2000 yen/tCO2 (2030)
Capture costs 1500 yen/tCO2 (2050)</td></tr>
</table>

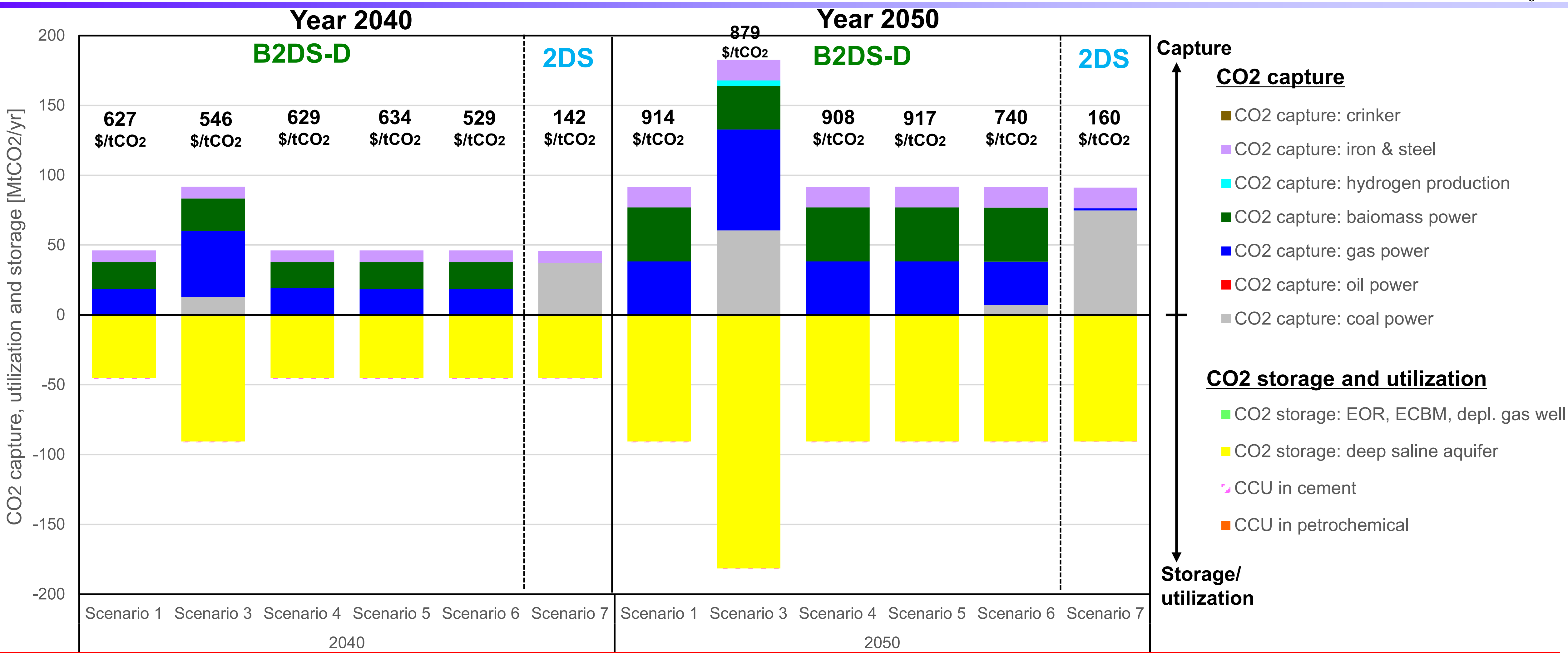
Assumed Scenarios

- For the economic evaluations on CCS considering several kinds of the related uncertainties, the results of seven scenarios below are shown in this presentation. (Much more scenarios are analyzed.)

Scenarios	Emission pathways	CO2 storage assumptions	CO2 capture costs			Discount rate of investment for CCS (return of investment)	Solar PV
				Year 2030	Year 2050		
1	B2DS-D	Standard	Standard	1500 JPY/tCO2	1000 JPY/tCO2	Standard	Standard
Infeasible 2	B2DS-D	Not available	Standard	1500 JPY/tCO2	1000 JPY/tCO2	Standard	Standard
3	B2DS-D	Acceleration	Standard	1500 JPY/tCO2	1000 JPY/tCO2	Standard	Standard
4	B2DS-D	Standard	High cost	2000 JPY/tCO2	1500 JPY/tCO2	Standard	Standard
5	B2DS-D	Standard	Standard	1500 JPY/tCO2	1000 JPY/tCO2	High	Standard
6	B2DS-D	Standard	High cost	2000 JPY/tCO2	1500 JPY/tCO2	High	Low cost
7	2DS	Standard	Standard	1500 JPY/tCO2	1000 JPY/tCO2	Standard	Standard

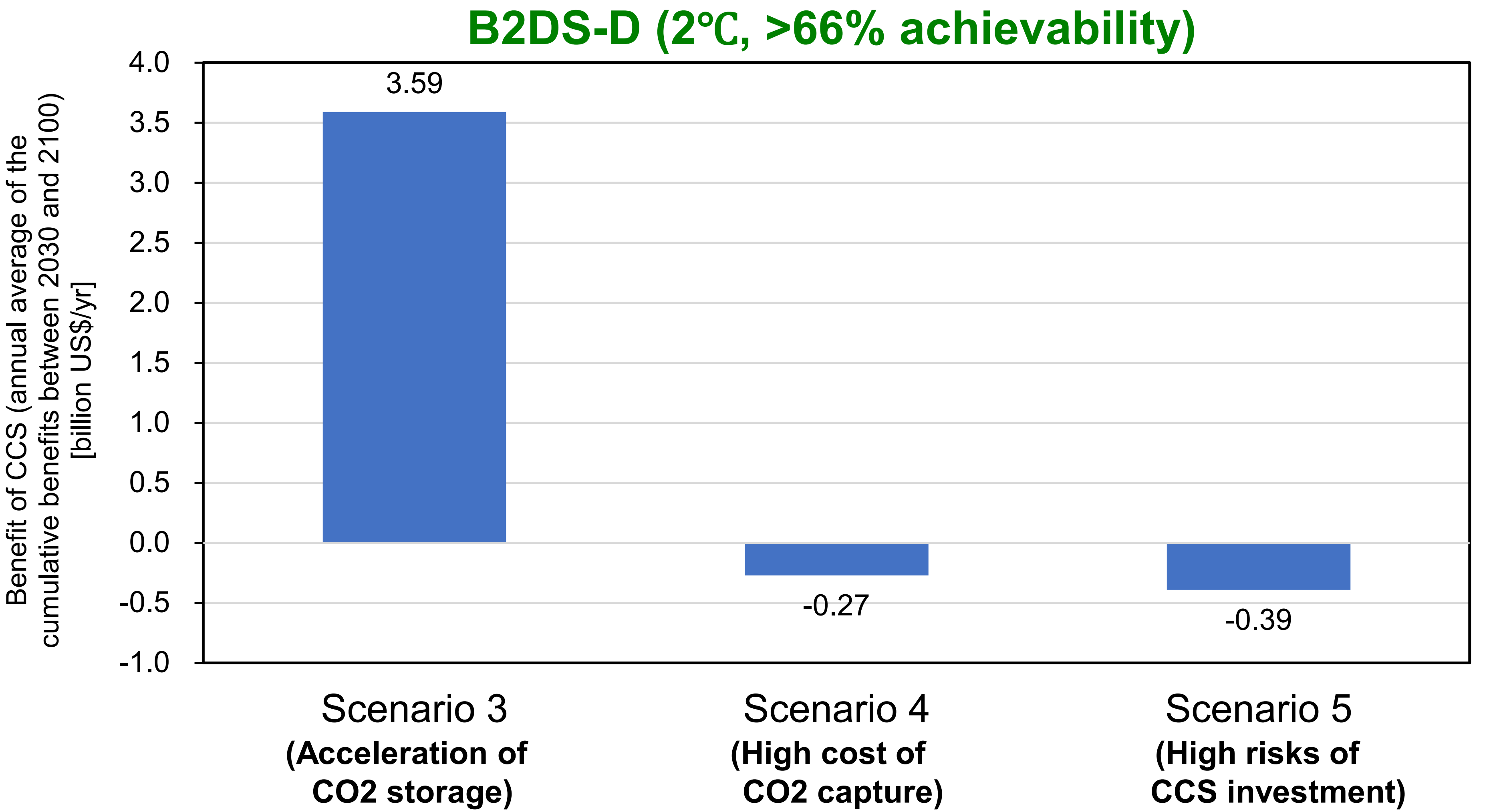
✓ There is no feasible solution for the 80% reduction by 2050 in Japan in the case of Scenario 2 which assumes that CCS is unavailable.

CO2 Marginal Abatement Costs, and the Balances of CO2 Capture, Utilization and Storage



- ✓ For the 2DS (Scenario 7), the amounts of CO2 capture from coal power are large, but for the B2DS scenarios, large amounts of CO2 captures from gas and biomass are economical in order to meet the deep emission reductions.
- ✓ In the case of the constraint on CO2 storage expansion, CO2 capture from coal power increases.
- ✓ All of the assumed maximum CO2 storage capacity are economical in Japan for all of the assumed scenarios due to high marginal abatement costs.

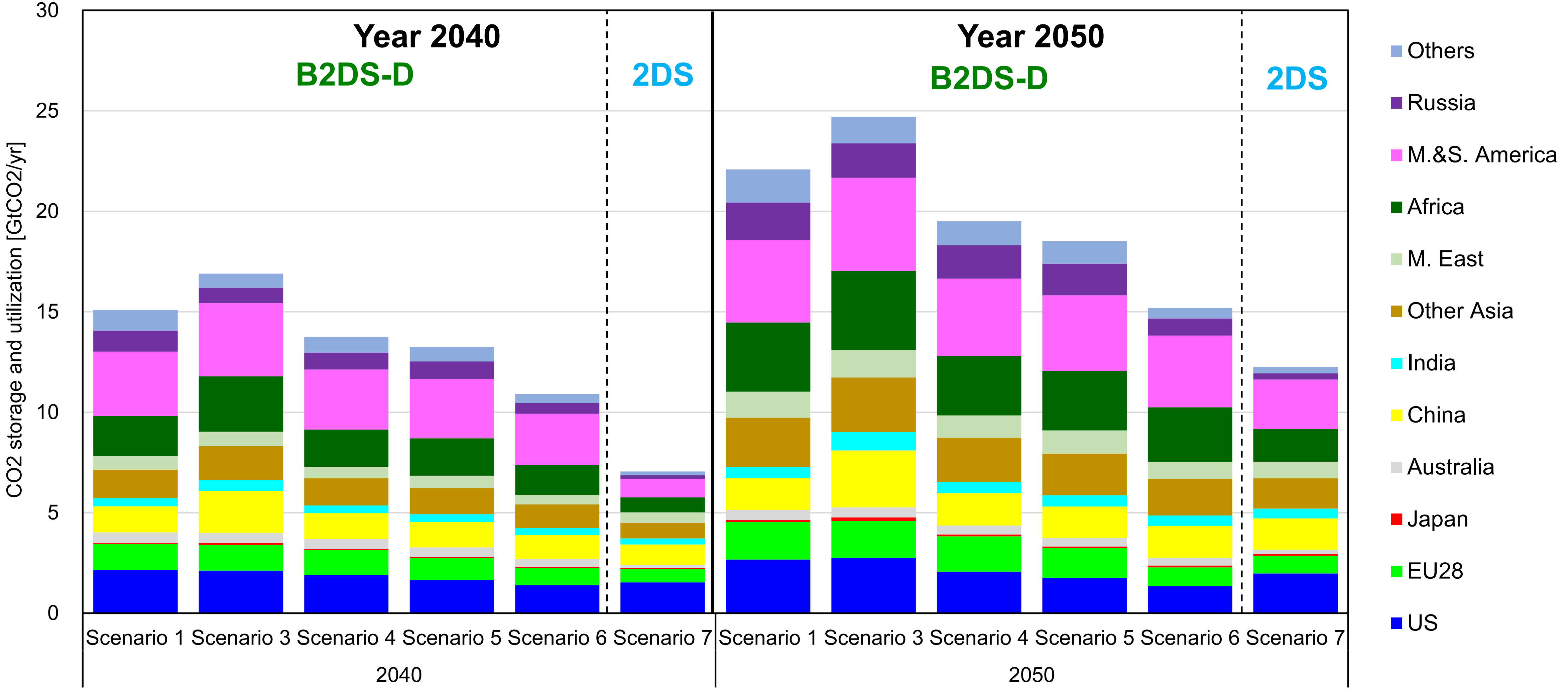
Benefits of CCS in Japan (annual average between 2030 and 2100)



※ **Emission reduction costs relative to those of Scenario 1** (These are converted to the price in 2030 adopting the discount rate of 5%/yr)

- ✓ **In the acceleration of CO_2 storage scenario, a large amounts of benefits, about 3.6 billion $/yr, are expected.**
- ✓ **The benefits by the reductions in CO_2 capture costs and discount rate of CCS investments (reductions in the investment risks) are expected to be about 0.3 and 0.4 billion $/yr, respectively, compared with the standard technology assumption.**

Global CO_2 Storage by Region/Country



The deployments of CCS is a cost-effective option even in Japan. However, the expected amounts of CCS deployments are relatively small compared to those in the world. Therefore, the deployments within Japan should be pursued, but the CCS contributions should also be considered over the world, particularly in Asian countries.

Conclusions

- According to the analyses using an energy systems model, CCS is one of the cost-effective measures after 2030 for the long-term emission reductions consistent with the Paris Agreement in Japan, even in consideration of the several kinds of uncertainties.
- Under the 80% reduction by 2050 in Japan, there is no feasible solution in the CCS unavailable case in this study.
- For the 80% reduction by 2050 in Japan, BECCS is an economical option because it will be able to reduce net emissions within the limited potentials of CO_2 storage. When the CO_2 storage potentials are expanded, CCS for coal power is also economical.
- CO_2 captures not only from power but also from iron and steel are cost-effective for the 2 °C target in Japan.
- For CCS, international collaboration and co-operative deployments will be also important from the global viewpoint.