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Sustainable Climate Change Response Measures under the Paris Agreement

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Reviews of emission reduction efforts of NDCs (Nationally Determined Contributions)

for sustainable climate change response measures

How to measure the comparability of efforts

The submitted NDCs include the targets of emissions reduction from different base years, CO_2 intensity, and CO_2 emission reductions from baseline (w/w.o. clear definition of baseline). We need to interpret them through comparable metrics to measure the efforts:

- **Simple metrics (easily measurable and replicable)**
  - Emissions reduction ratios from the same base year etc.
- **Advanced metrics (more comprehensive, but require forecasts)**
  - Emission reduction ratios from baseline emissions
  - Emissions per unit of GDP etc.
- **More advanced metrics (most comprehensive, but require modeling)**
  - Energy price impacts
  - Marginal abatement cost (per ton of CO_2)
  - Abatement costs as a share of GDP etc.

2030 Emission Target of Japan’s NDC

Under the situations after the Great East Japan Earthquake and the Fukushima nuclear power accident, in 2014 the Japanese Government decided a new strategic energy plan which seeks a better balance of S+3E (safety, energy security, economy, and environment) and to reduce dependency on nuclear power plants. The energy mix for 2030 was decided based on the strategic energy plan, and following the energy mix, the Japan’s NDC was decided in 2015.

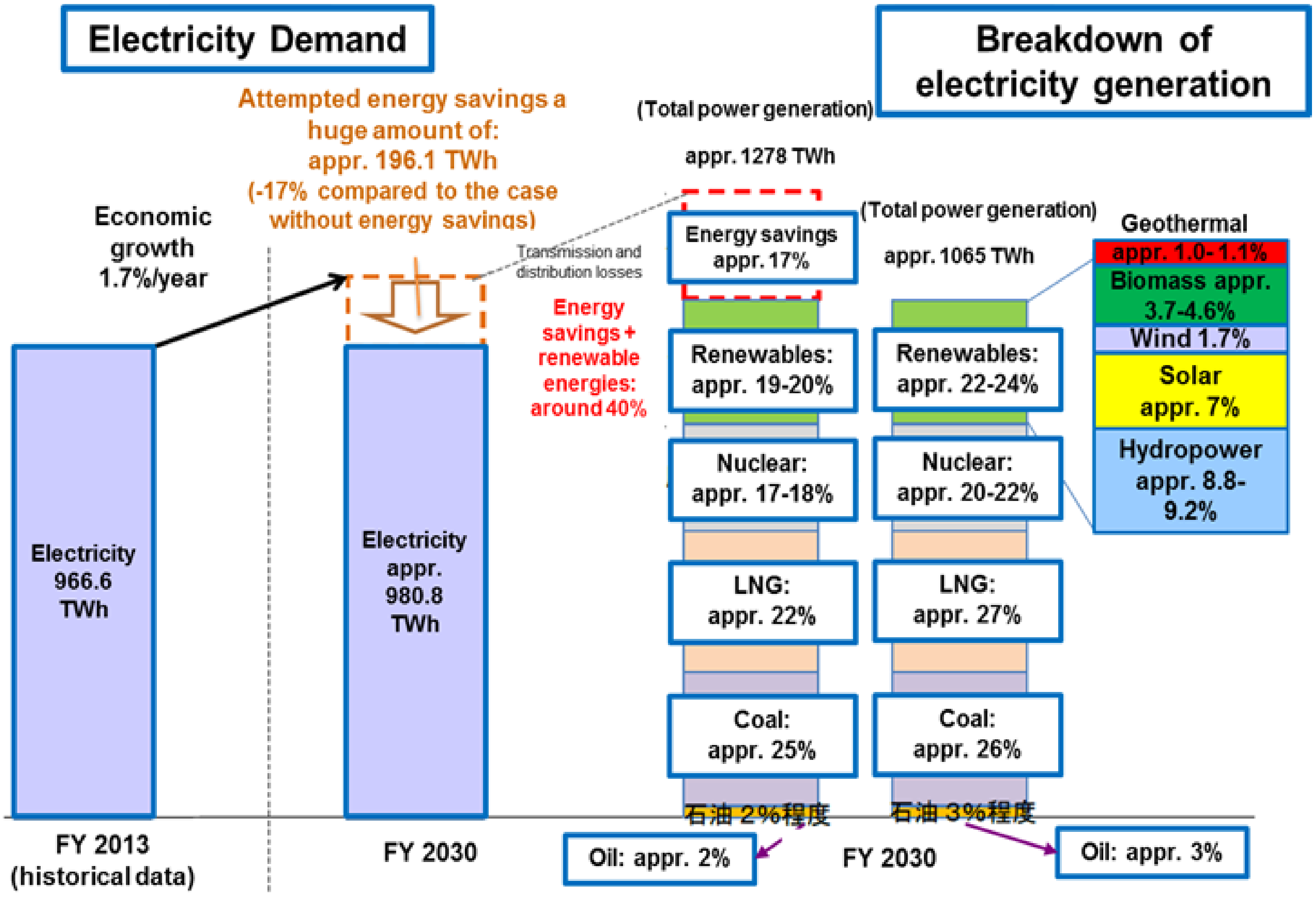
	2030; Compared to 2013（compared to 2005）
Energy-related CO_2	**-21.9%（-20.9%）**
Other GHGs	-1.5%（-1.8%）
Reduction by absorption	-2.6%（-2.6%）
Total GHGs	**-26.0%（-25.4%）**

Energy-related CO_2 by sector

Unit: Mt-CO_2

	2005	2013	2030
Industry	457	429	**401**
Commercial and other	239	279	**168**
Residential	180	201	**122**
Transport	240	225	**163**
Energy conversion	104	101	**73**
Energy-related CO2 Total	1219	1235	**927**

Japan's energy mix in 2030 – Electricity mix –



The Japanese government, July 2015

- The government intends to reduce the dependence on nuclear power as compared with that before the accident. However, the government had to also take the 3E: energy security, economic efficiency, environment into account, and consequently the share of nuclear power is decided to be 20-22% of total electricity in 2030.
- We believe that this maintains a good balance of electricity mix in Japan. On the other hand, it is not easy to achieve the electricity saving target given historical trends and the nuclear power share target from the current restarting conditions of nuclear plants.

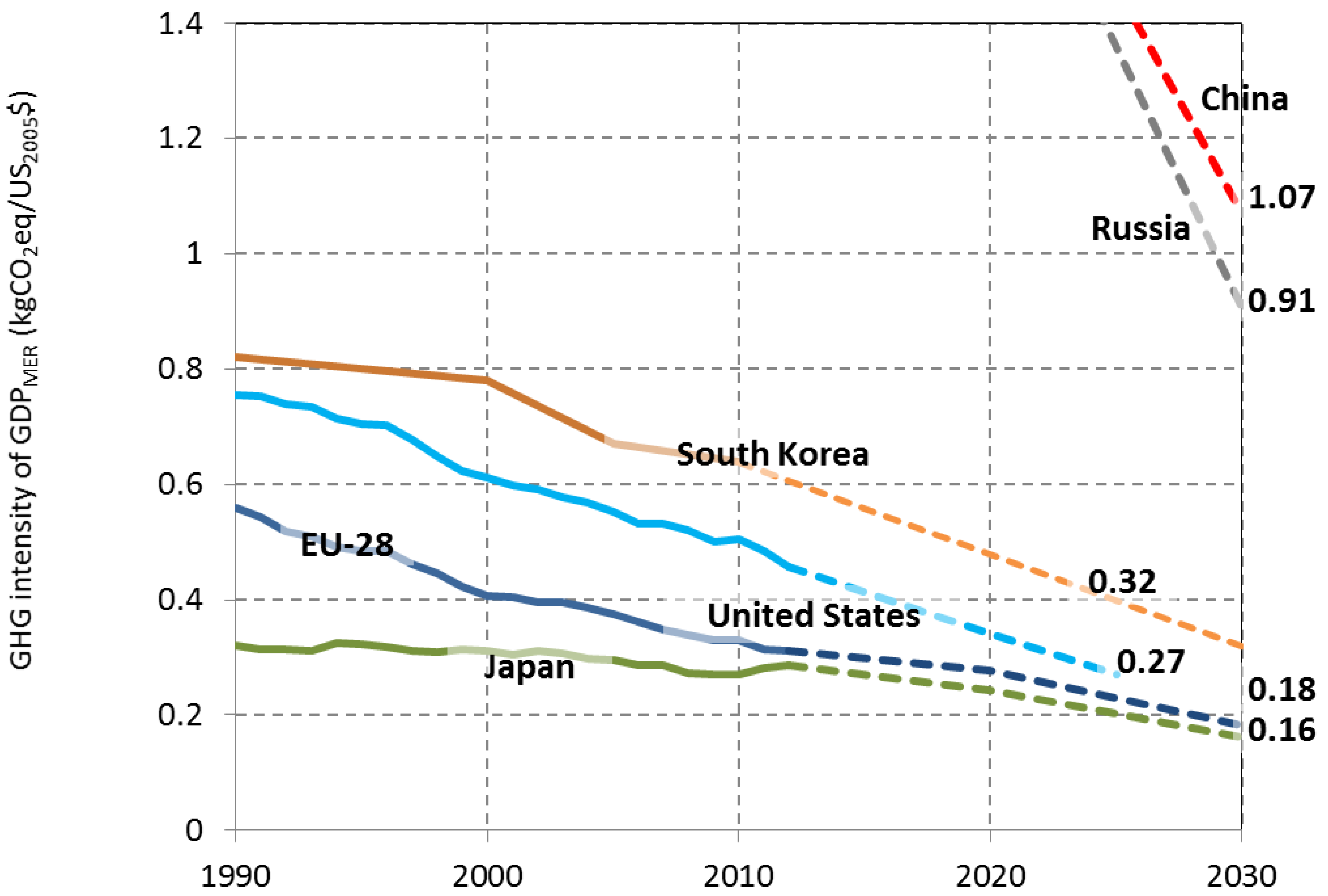
Emissions reduction ratio from base year for Japan and other major countries

	Emissions reduction ratio from base year		
	From 1990	From 2005	From 2013
Japan：in 2030, -26% from 2013 levels	-18.0%	-25.4%	**-26.0%**
US： in 2025, about -26 to -28% from 2005 levels	-14 to -16%	**-26 to -28%**	-18 to -21%
EU28： in 2030, -40% from 1990 levels	**-40%**	-35%	-24%
Russia： in 2030, -25% to -30% from 1990 levels	**-25 to -30%**	+10 to +18%	—
China： in 2030, CO2 intensity of -60% to -65% from 2005 levels	+379 to +329%	**+129 to +105%**	—

Underlined: official NDCs, Others: estimated by RITE

The reduction ratios can be seen differently across nations according to the adopted base year. If we take 2013 as the base year, Japan's target looks more ambitious in the emissions reduction ratio than the US's or the EU's.

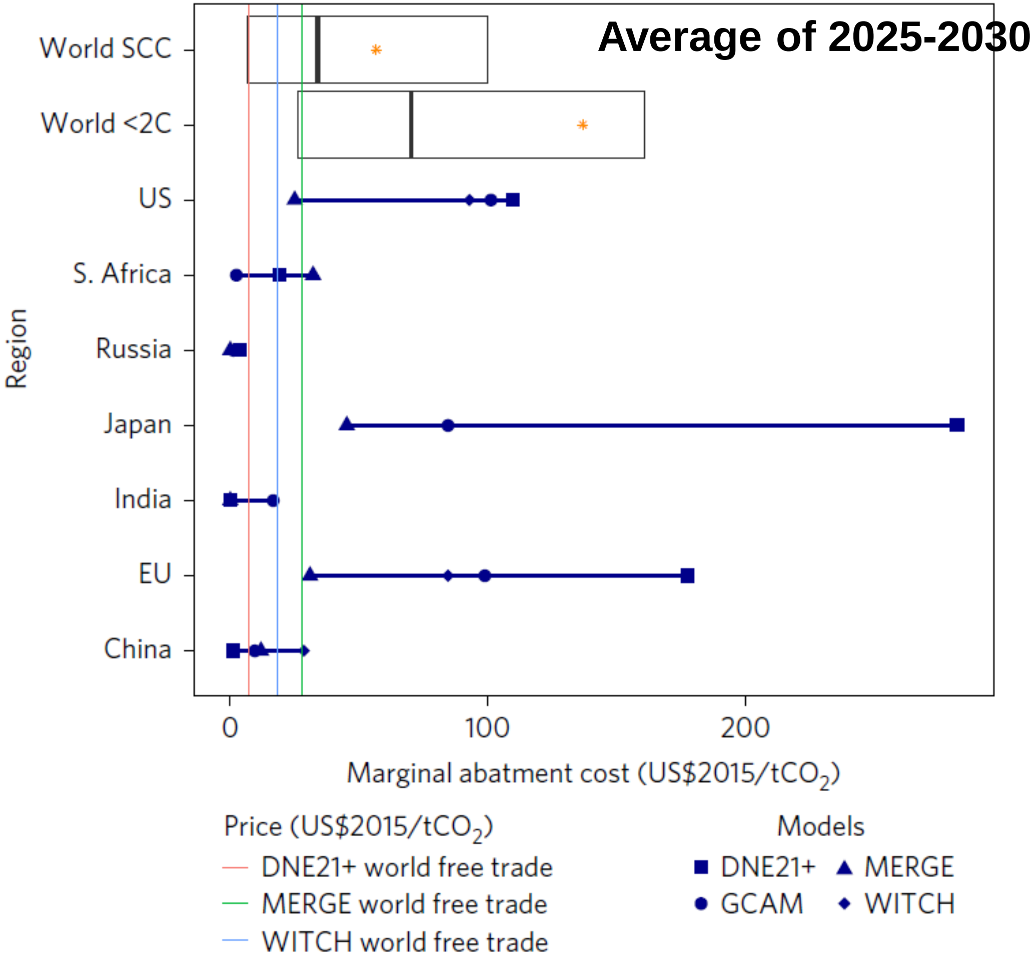
GHG intensity of GDP (MER)



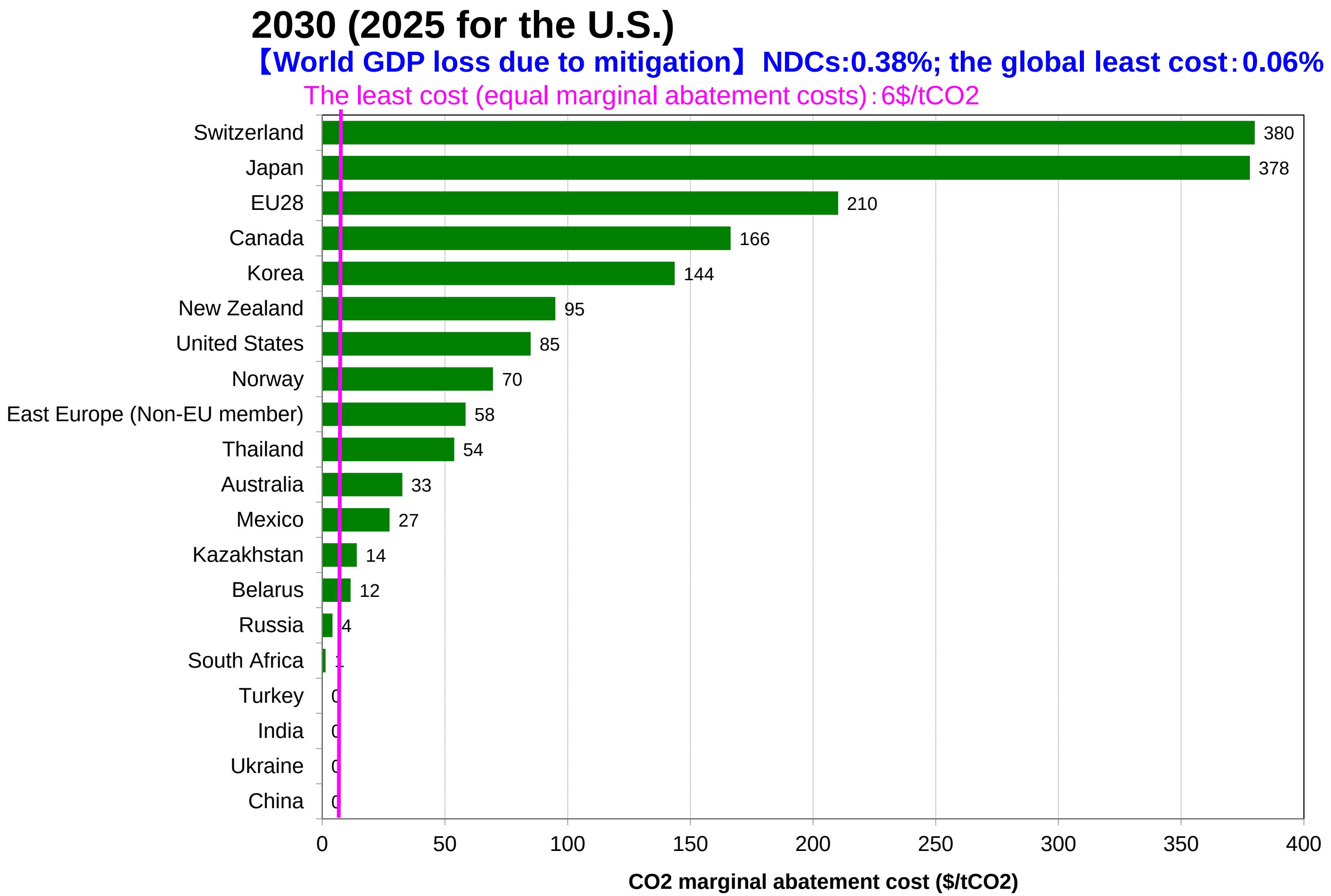
Note) For countries submitting their NDCs with ranges, the lower range of emission targets is shown.
Source) estimated by RITE

Even from the GHG intensity, the Japan's NDC sets a more demanding target than the US and the EU.

CO2 marginal abatement costs



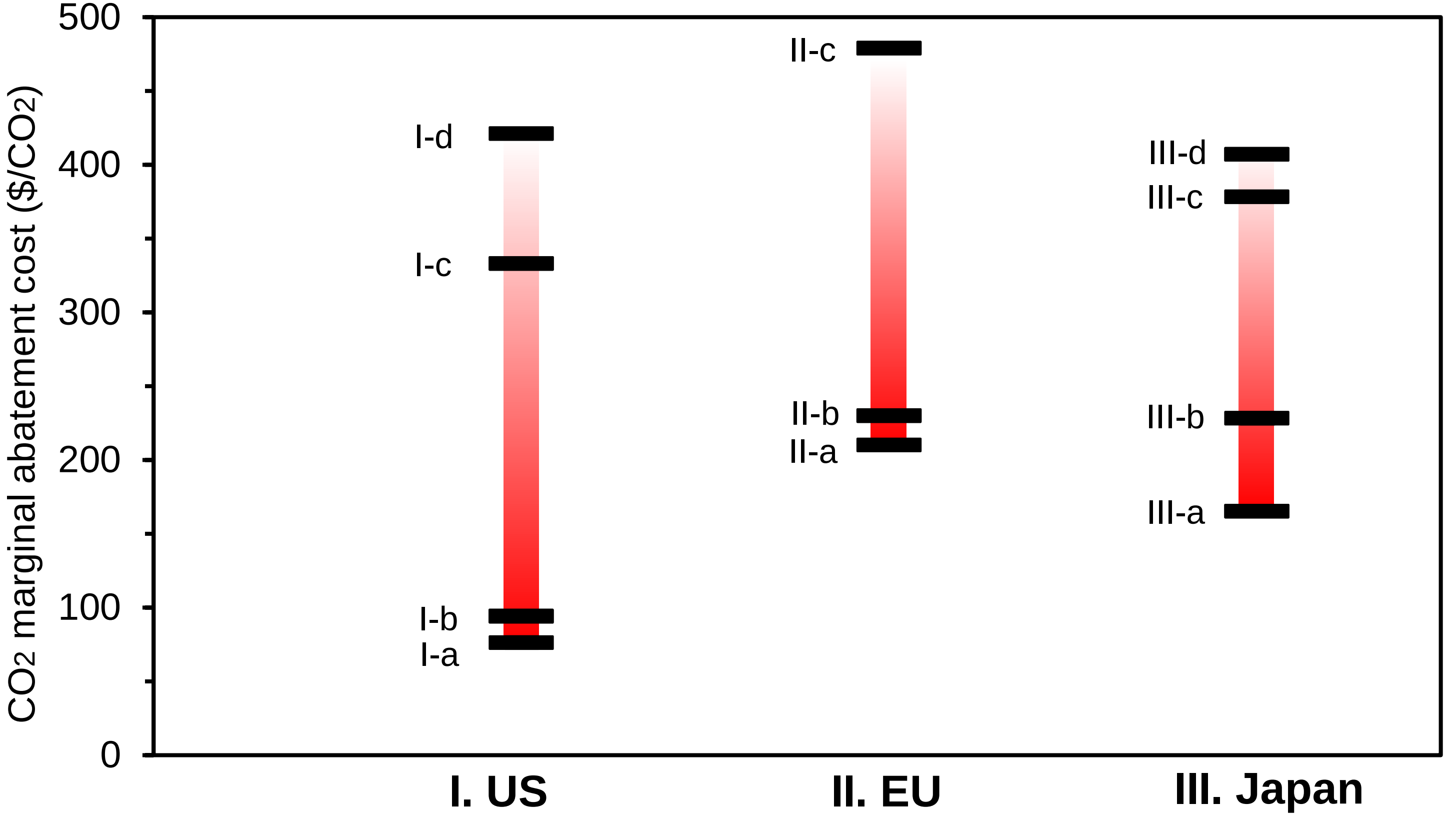
Source: J. Aldy et al., Nature Climate Change, 2016



Source: K. Akimoto et al., Evol. Inst. Econ. Rev., 2016

- Emission reduction costs are an important indicator for measuring emission reduction efforts.
- The estimated marginal abatement costs of NDCs are largely different among countries, and the mitigation costs are much larger than those under the least cost measures due to such large difference in marginal abatement costs.
- The difference will induce carbon leakages, and the leakages will reduce the effectiveness of global emission reductions.

CO_2 marginal abatement cost for the U.S, EU and Japan considering several kinds of policy constraints



I. US

I-a: -26%; the least cost
I-b: -28%; the least cost
I-c: -26%; power sector according to CPP
I-d: -28%; power sector according to CPP

* CPP: Clean Power Plan

II. EU

II-a: the least cost
II-b: Brexit (-40% for UK)
II-c: splitting into ETS and non-ETS sectors

III. Japan

III-a: the least cost under nuclear of maximum 20%
III-b: the least cost under nuclear of maximum 15%
III-c: following the NDC including the energy mix (nuclear of 20%)
III-d: following the NDC including the energy mix but nuclear of 15%

- It is not easy to achieve the least cost measures because there are several kinds of social and political constraints in each nation.
- The mitigation costs constrained by other policies can be much higher than those under the least cost measures.

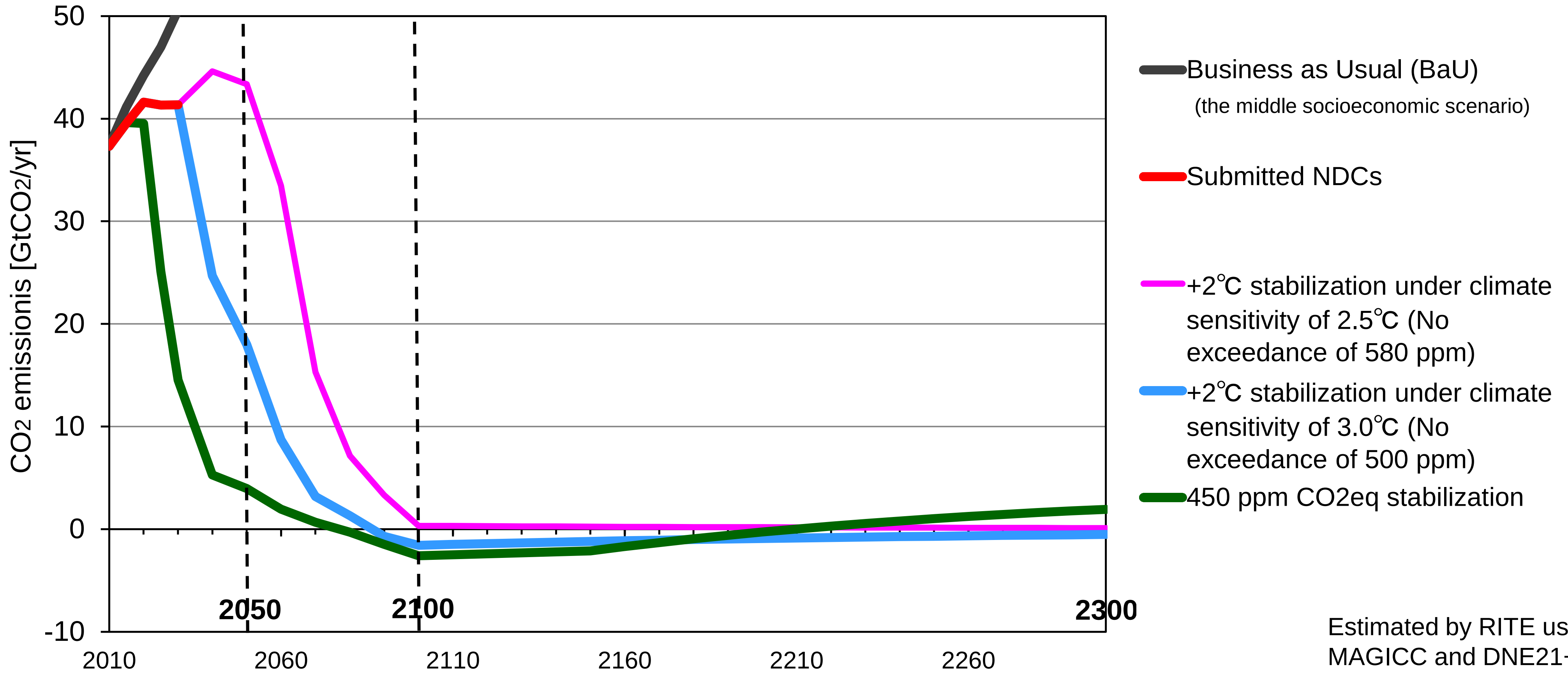
Source: estimated by RITE DNE21+

Long-term target

for sustainable climate change response measures

- considering uncertainties and role of innovation -

Global CO2 emission profiles toward 2300 for the 2 °C targets



Estimated by RITE using MAGICC and DNE21+

- The global CO_2 emissions should be nearly zero for a long-term period in the far future in any pathway to achieve temperature stabilization.
- On the other hand, the allowable global CO_2 emissions toward the middle of this century have a wide range according to the uncertainties in climate sensitivity (or achieving probability) even when the temperature target level is determined as a 2 °C. We should use this flexibility to develop several kinds of innovative technologies and societies.

Marginal CO2 abatement costs (Carbon prices) for the 2 °C target

SSP: "Shared Socioeconomic Pathways"

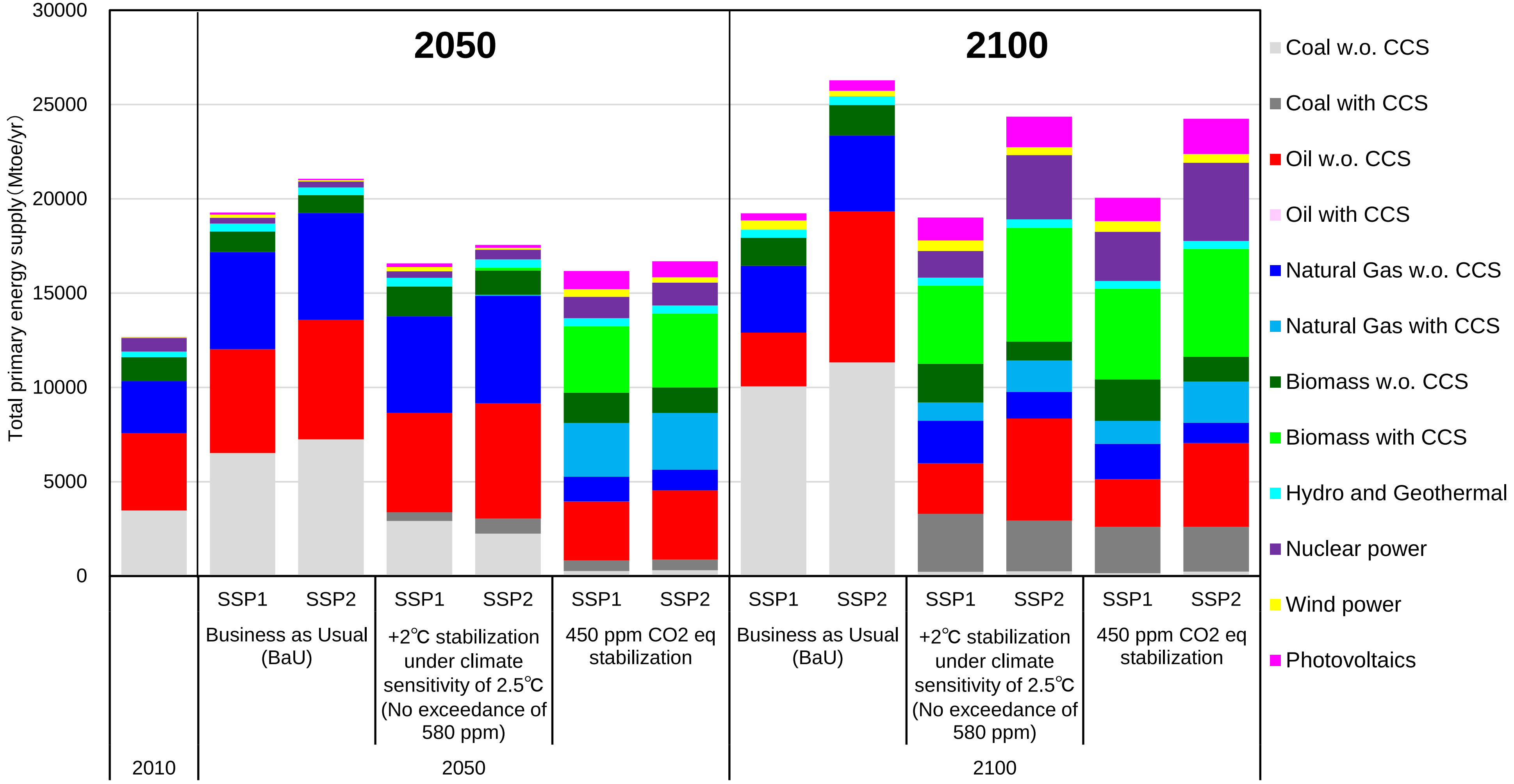
	SSP2 (Middle of the Road)			SSP1 (Sustainability)		
	+2°C stab. under climate sensitivity of 2.5°C	+2°C stab. under climate sensitivity of 3.0°C	450 ppm CO2eq stab. (climate sensitivity of 3.4°C)	+2°C stab. under climate sensitivity of 2.5°C	+2°C stab. under climate sensitivity of 3.0°C	450 ppm CO2eq stab. (climate sensitivity of 3.4°C)
2050	12	135	604	14	117	518
2100	408	427	457	134	140	143

Unit: \$/tCO2 (real price); Uniform carbon prices among all nations are assumed.

Source) estimated by RITE DNE21+

- **The marginal abatement costs (carbon prices) for the 2 °C target are huge even under the global least cost measures (uniform carbon prices) except in the case of low climate sensitivity (2.5 °C) and by 2050.**
- **The carbon price in SSP1 that energy demands in the end-use sectors are much smaller than in SSP2 is much lower than that in SSP2.**
- **Technological and social innovations are definitely required for the 2 °C target to be achieved in harmony with other SDGs. (Newly emerging technologies such as AI, IoT etc. will induce social changes which may lower the energy demand.)**

Global primary energy supply



Source) estimated by RITE DNE21+

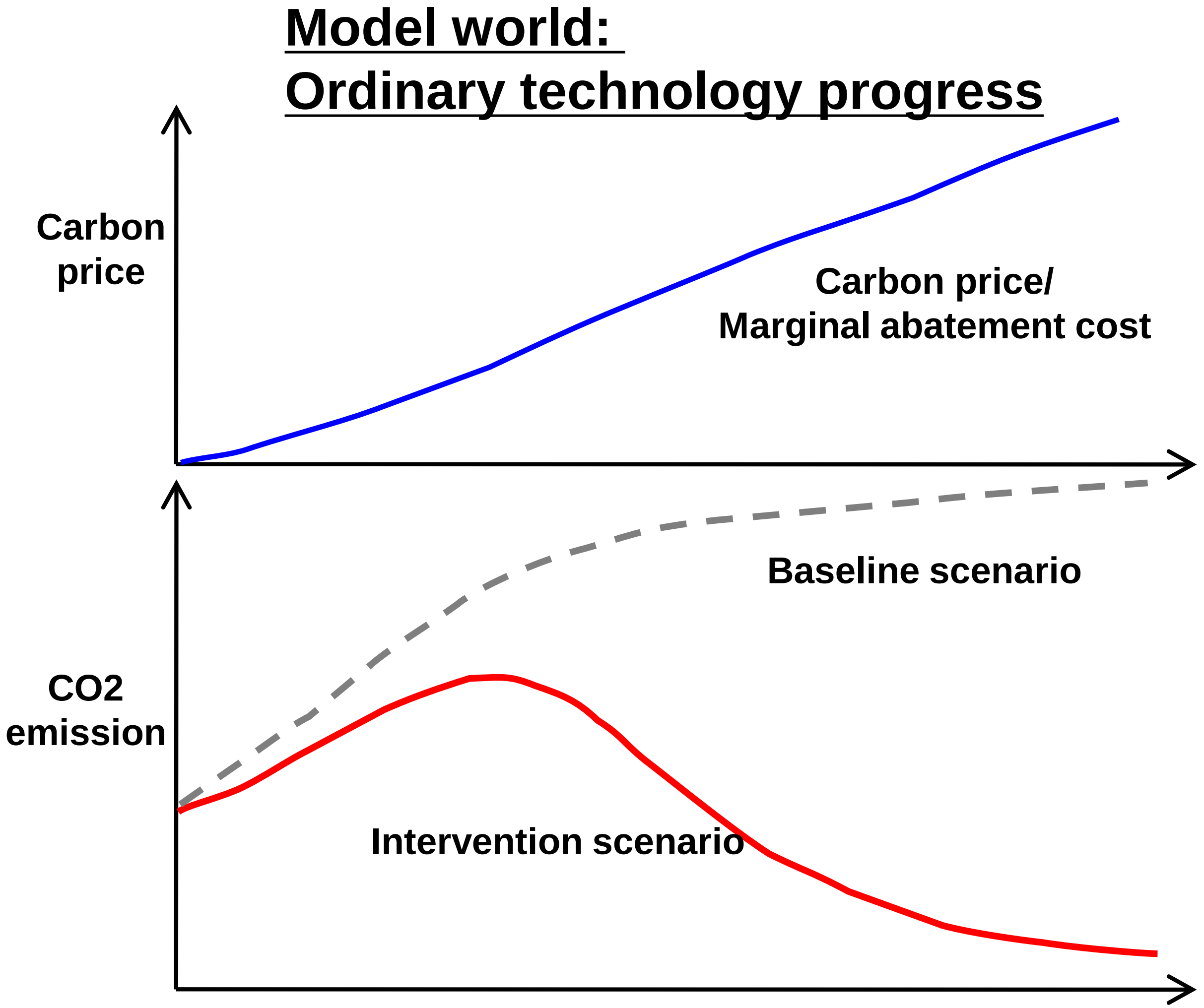
SSP (Shared Socioeconomic Pathways)
SSP1: Sustainability SSP2: Middle of the Road

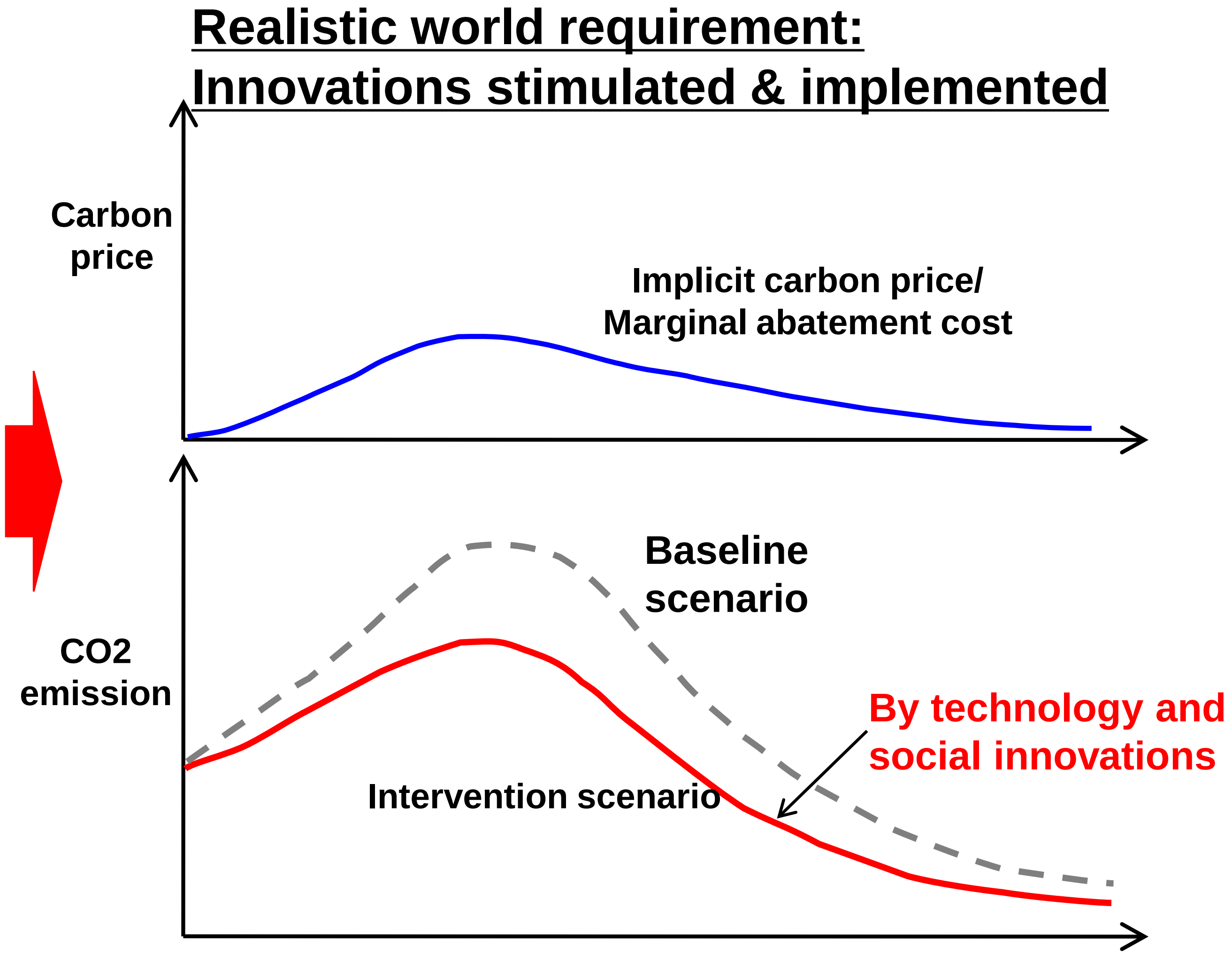
- The energy supply is very different in 2050 according to the uncertainty in the climate sensitivity and different socioeconomic scenarios.
- The total amount of energy supply in the SSP1 world is much smaller than that in the SSP2 world.
- But in any scenarios for the 2 °C target as the IPCC also showed, a large amount of BECCS is employed by 2100. This is technologically feasible, but will be very difficult to be achieved in the real world.

Harmonization among climate change issues and other SDGs needed

- We have multiple agendas to tackle. Harmonization among climate change issues and other SDGs is necessary.

Image of standard scenario by models and real world scenarios for deep cuts

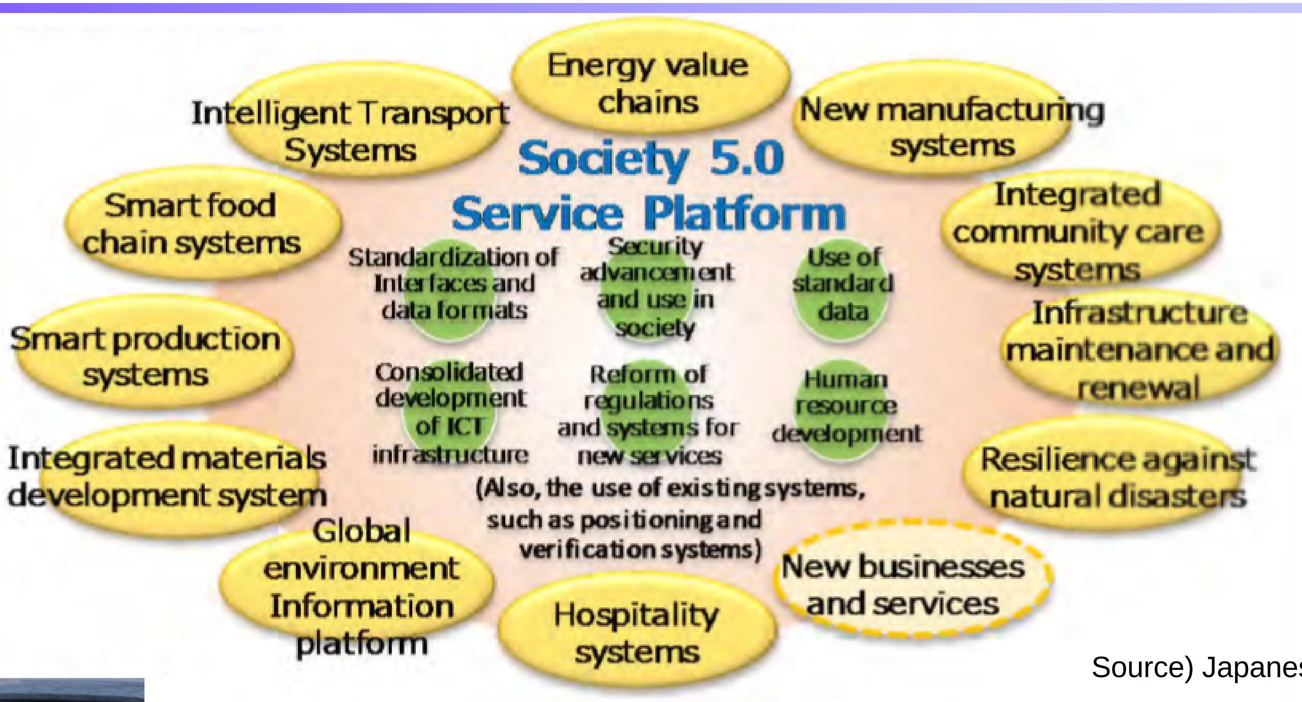




Explicit high carbon prices such as over 100$/t$CO_2$ in real price are unlikely in a real world. Technology and social innovations resulting in low (implicit or explicit) carbon prices (including coordination of secondary energy prices) are key for deep emission cuts to be implemented.

5th Science and Technology Basic Plan of Japan
- "Society 5.0" ("Super Smart Society") -

What is Society5.0?
It is a society that can be expected to facilitate human prosperity. Such a society is capable of providing the necessary goods and services to the people who need them at the required time and in just the right amount; a society that is able to respond precisely to a wide variety of social needs; a society in which all kinds of people can readily obtain high-quality services, overcome differences of age, gender, region, and language, and live vigorous and comfortable lives.



Source) Japanese Government

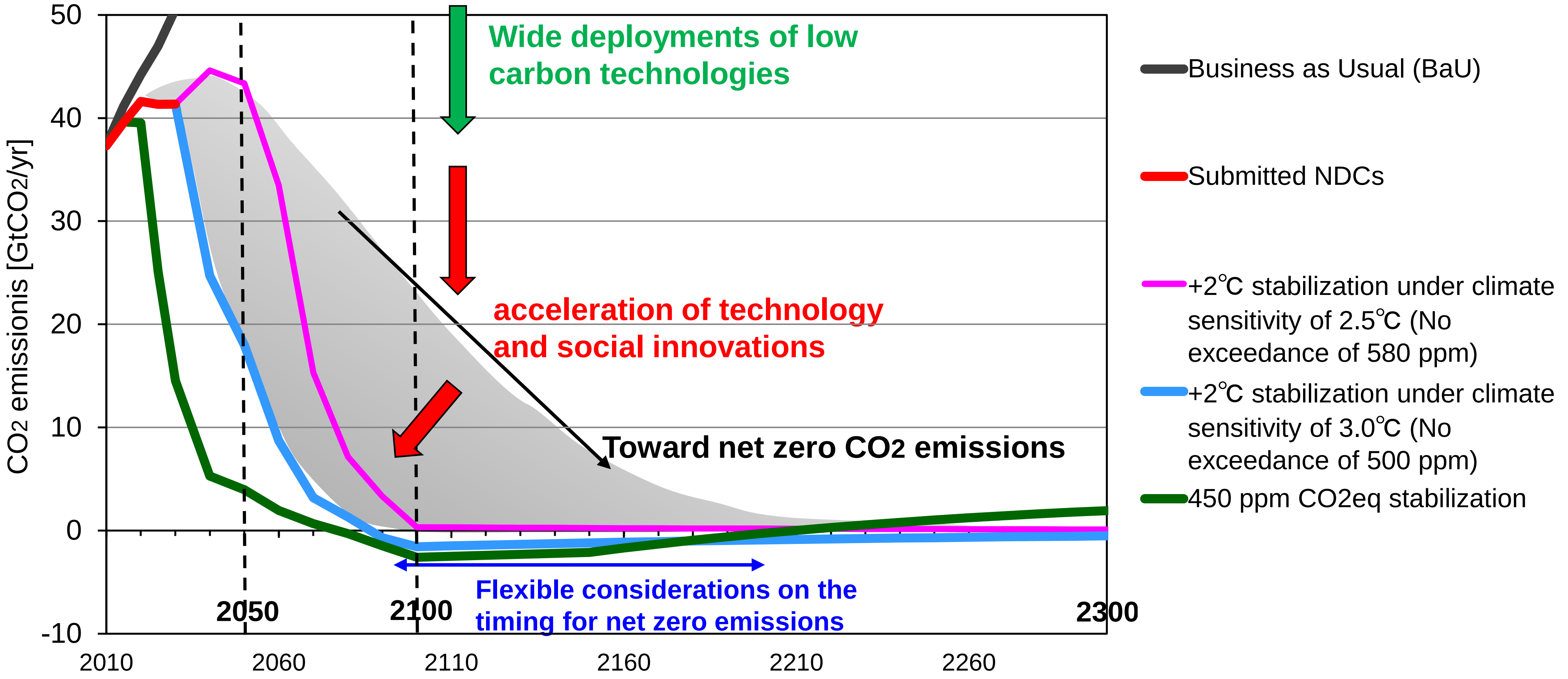
Source) Gendai Business "http://gendai.ismedia.jp/articles/-/50859"

AI + IoT + big data + ….

Operation ratio of automobiles is about 4%, for example. The large room for the improvement in energy efficiency by sharing economy exists.

- Wide range of innovations of technologies and their integrations are required for improving our welfare and sustainable development.
- AI, IoT, big data etc. will be able to stimulate such innovations.

We should have some flexibilities in emission pathways while keeping the goal of net zero CO_2 emissions



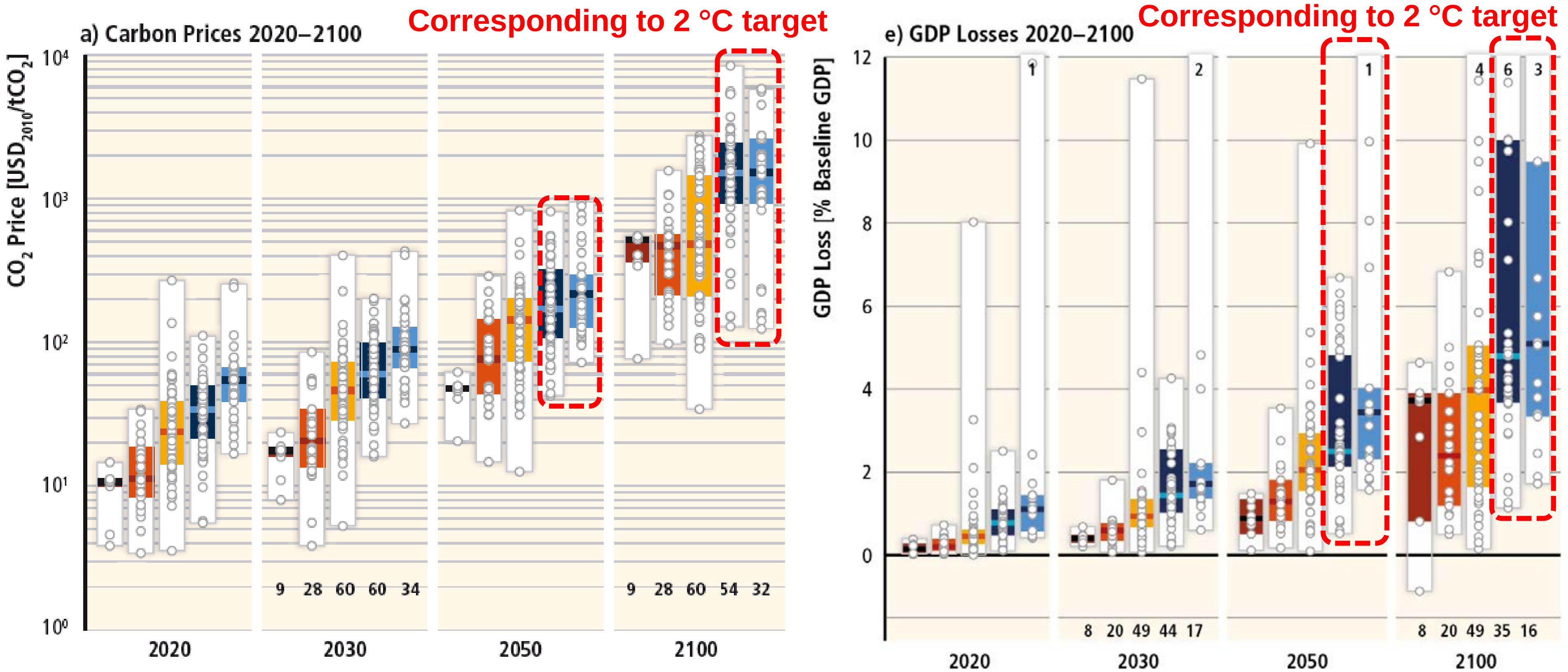
- Many of the studies show the difficulty in meeting net zero emissions by 2100.
- More reasonable and realistic targets will have more flexibility in terms of the timing to achieve net CO_2 zero emissions.
- Having the flexibility, technology and social innovations (social innovations will be also induced by technologies) should be accelerated harmonizing with sustainable development.

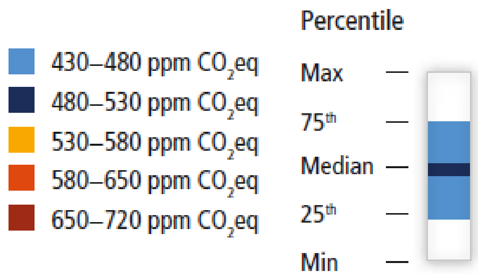
Conclusions

- Measuring the ‘emission reduction efforts (degree of ambition)’ of NDCs is key for effective emission reductions under the Paris Agreement.
- Measuring the efforts is a hard work but can be approached by employing multiple good indicators including the mitigation costs.
- Large differences in marginal abatement costs will hinder the sustainable measures by all nations, and the coordination of the NDCs through the review process will be important.
- Evaluations of the mitigation costs require comprehensive models and include uncertainties but using several models helps ensure comparability to some extent.
- A challenging issue on evaluations of the mitigation costs is what constraints are inevitable and should be considered in estimating the mitigation costs. Several social and political conditions hindering the least cost mitigation measures exist in each nation. Cheaper emission reduction measures should be pursued, but some of the realistic constraints should also be considered.
- The estimated mitigation costs for the 2 °C goals are large even under the assumptions of the least cost measures. For the sustainable measures by all nations pursuing the 2 °C goal, broad innovations harmonized with SDGs are necessary.

Appendix

Huge costs are estimated for achieving the 2 °C target

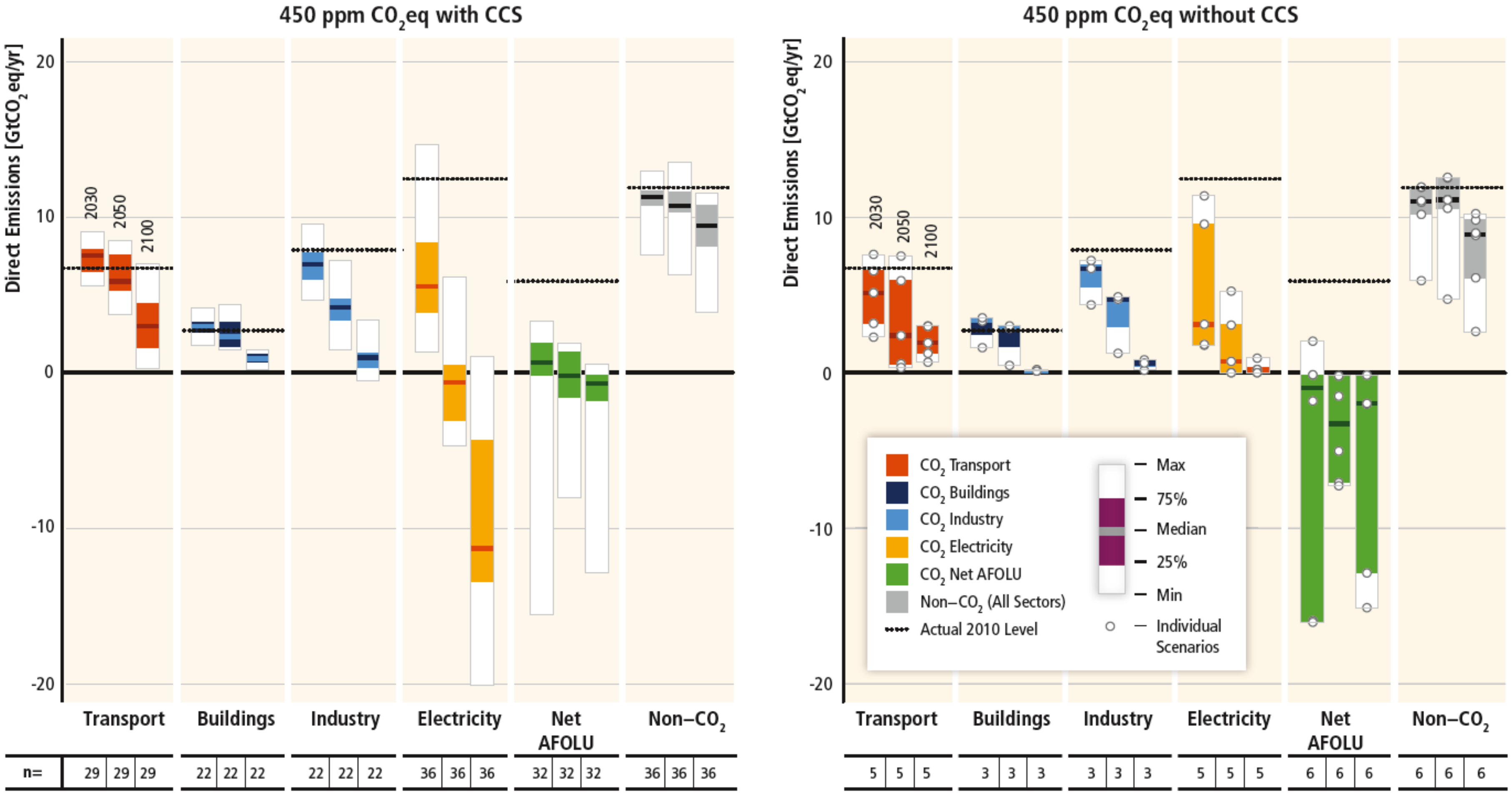




Source) IPCC WG3 AR5

- According to the IPCC AR5, the CO2 marginal abatement costs (carbon prices) for the 430-530 ppm CO2eq (which are consistent with the 2 °C target) are about 1000-3000 $/tCO2 (25-75 percentile) and 150-8000 $/tCO2 (full range) in 2100.
- About 25% of the analyzed scenarios estimate global GDP losses of over 10%.
- The feasibility of such scenarios should be carefully examined in terms of various real world constraints.

Global emissions by sector for the 450 ppm pathways



Source) IPCC WG3 AR5

- The IPCC 450 scenario assumes large amounts of bioenergy with CCS and negative emissions in power sector, or large amounts of afforestation. While BECCS and afforestation are important measures to reduce CO2 emissions , such scenarios are unrealistic in the real world.

Energy Assessment Model: DNE21+

- Linear programming model (minimizing world energy system cost)
- Evaluation time period: 2000-2100

  Representative time points: 2000, 2005, 2010, 2015, 2020, 2025, 2030, 2040, 2050, 2070, 2100

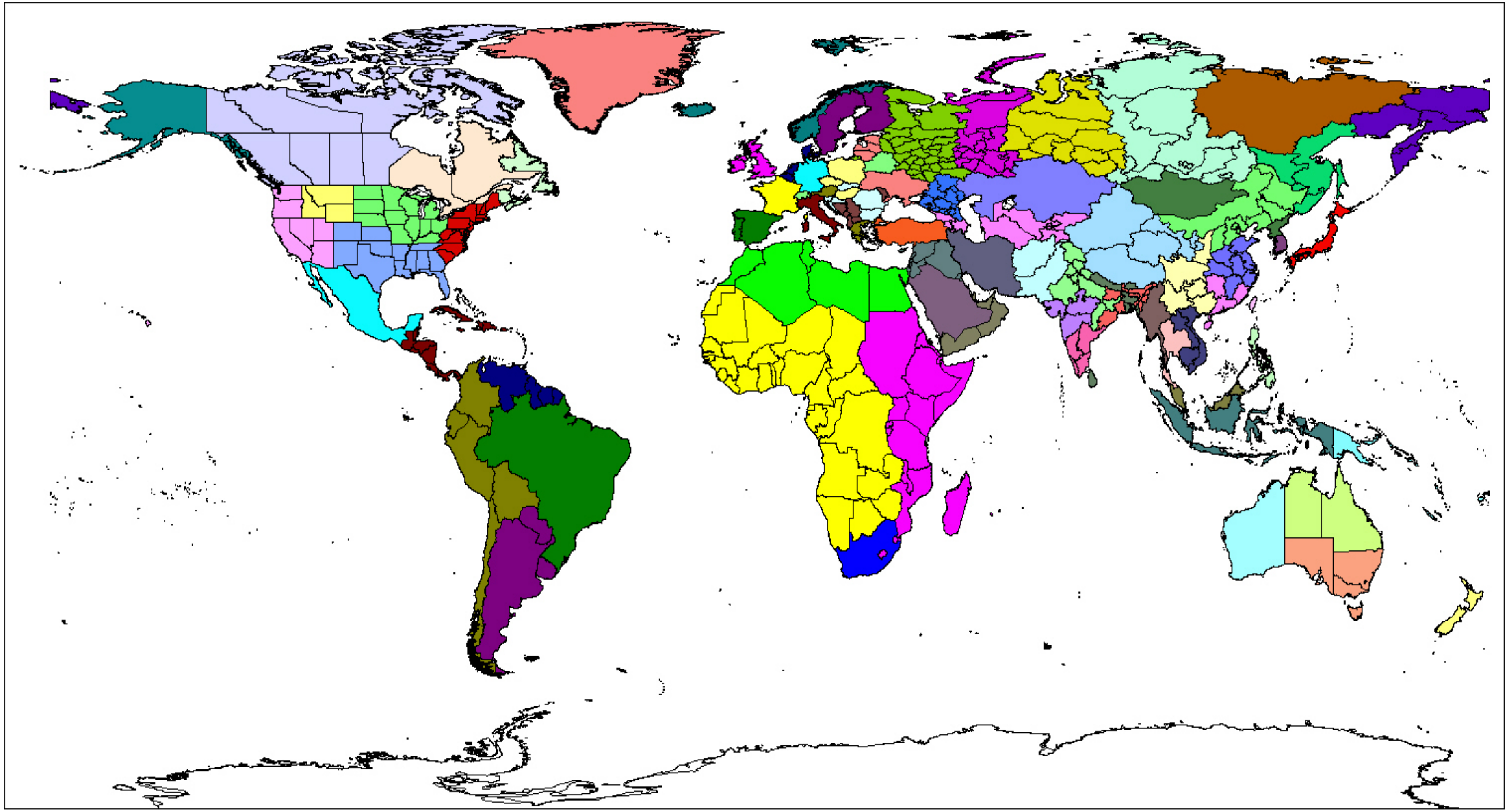
- World divided into 54 regions

  Large area countries are further divided into 3-8 regions, and the world is divided into 77 regions.

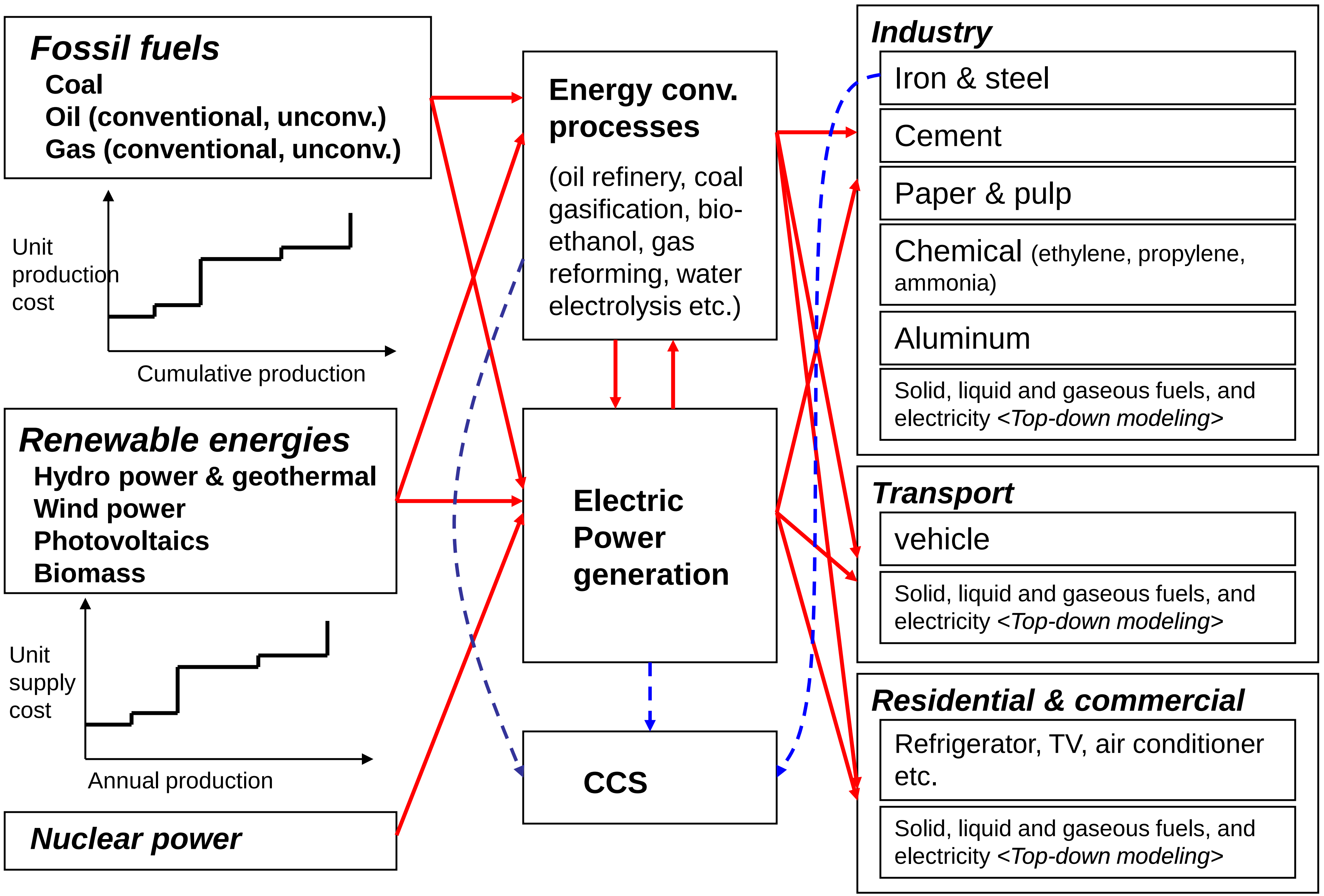
- Bottom-up modeling for technologies both in energy supply and demand sides (about 300 specific technologies are modeled.)
- Primary energy: coal, oil, natural gas, hydro&geothermal, wind, photovoltaics, biomass and nuclear power
- Electricity demand and supply are formulated for 4 time periods: instantaneous peak, peak, intermediate and off-peak periods
- Interregional trade: coal, crude oil, natural gas, syn. oil, ethanol, hydrogen, electricity and CO_2
- Existing facility vintages are explicitly modeled.

- The model has regional and technological information detailed enough to analyze sectoral measures. Consistent analyses among regions and sectors can be conducted.

Region divisions of DNE21+

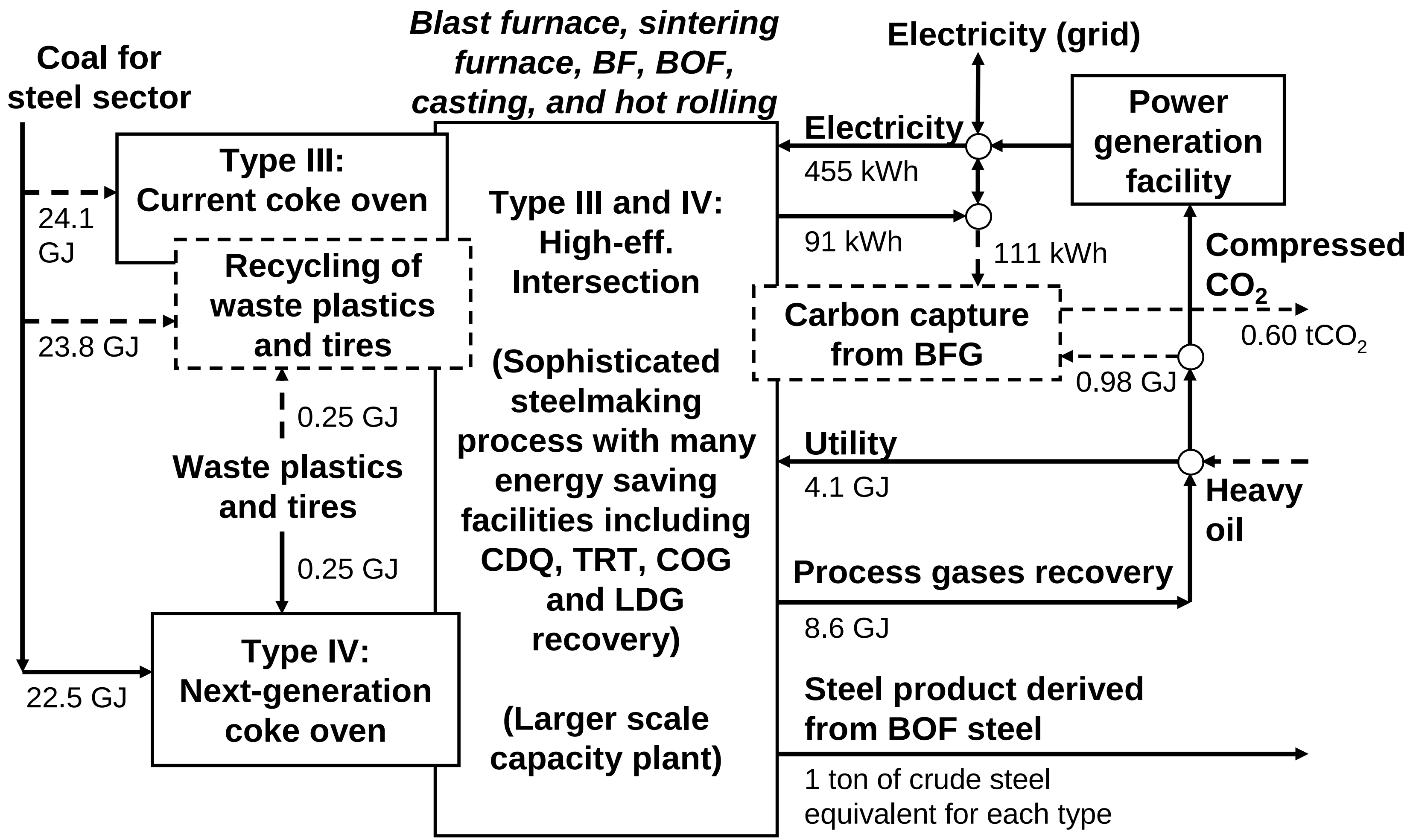


Technology Descriptions in DNE21+ (1/2)



Technology Descriptions in DNE21+ (2/2)

–An Example for High Energy Efficiency Process in Iron & Steel Sector–



BF: blast furnace, BOF: basic oxygen furnace, CDQ: Coke dry quenching,
TRT: top-pressure recovery turbine, COG: coke oven gas, LDG: oxygen furnace gas

History of climate sensitivity judgment by IPCC and the sensitivity employed in the scenario assessments of the IPCC WG3 AR5

	Equilibrium climate sensitivity Likely range ("best estimate" or "most likely value")
Before IPCC WG1 AR4	**1.5–4.5°C (2.5°C)**
IPCC WG1 AR4	**2.0–4.5°C (3.0°C)**
IPCC WG1 AR5	**1.5–4.5°C (no consensus)**
Global mean temperature estimations for the long-term scenarios in the IPCC WG3 AR5 (employing MAGICC)	**2.0–4.5°C（3.0°C）[Based on the AR4]**

Same "likely" range

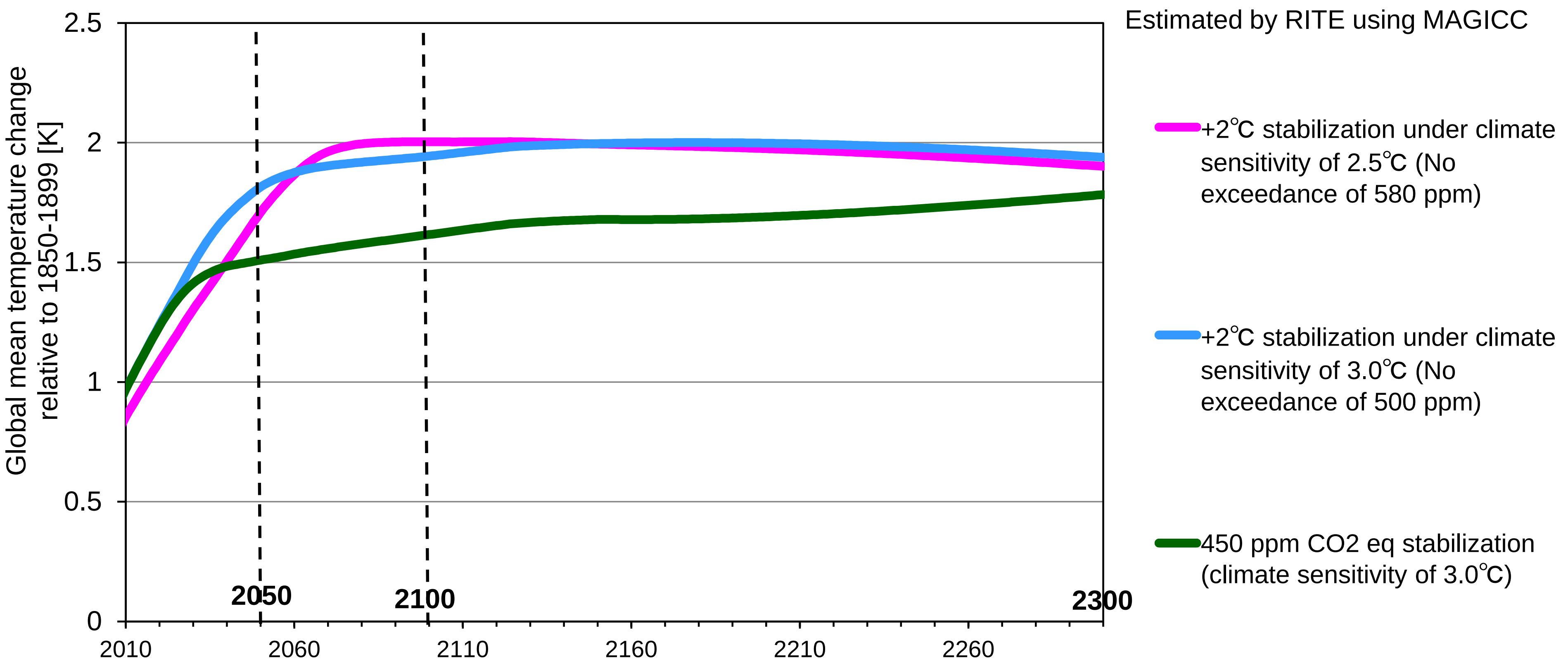
[The related descriptions of the SPM of WG1 AR5]

Likely in the range 1.5 °C to 4.5 °C (high confidence)
Extremely unlikely less than 1 °C (high confidence)
Very unlikely greater than 6 °C (medium confidence)
No best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies.

- **The equilibrium climate sensitivity, which corresponds to global mean temperature increase in equilibrium when GHG concentration doubles, is still greatly uncertain.**
- **AR5 WG1 judged the likely range of climate sensitivity to be 1.5–4.5 °C, in which the bottom range was changed to a smaller number than that in the AR4, based not only on CMIP5 (AOGCM) results but also other study results.**
- **AR5 WG3 adopted the climate sensitivity of AR4, which has the likely range of 2.0–4.5 °C with the best estimate of 3.0 °C, for temperature rise estimates of long-term emission scenarios.**

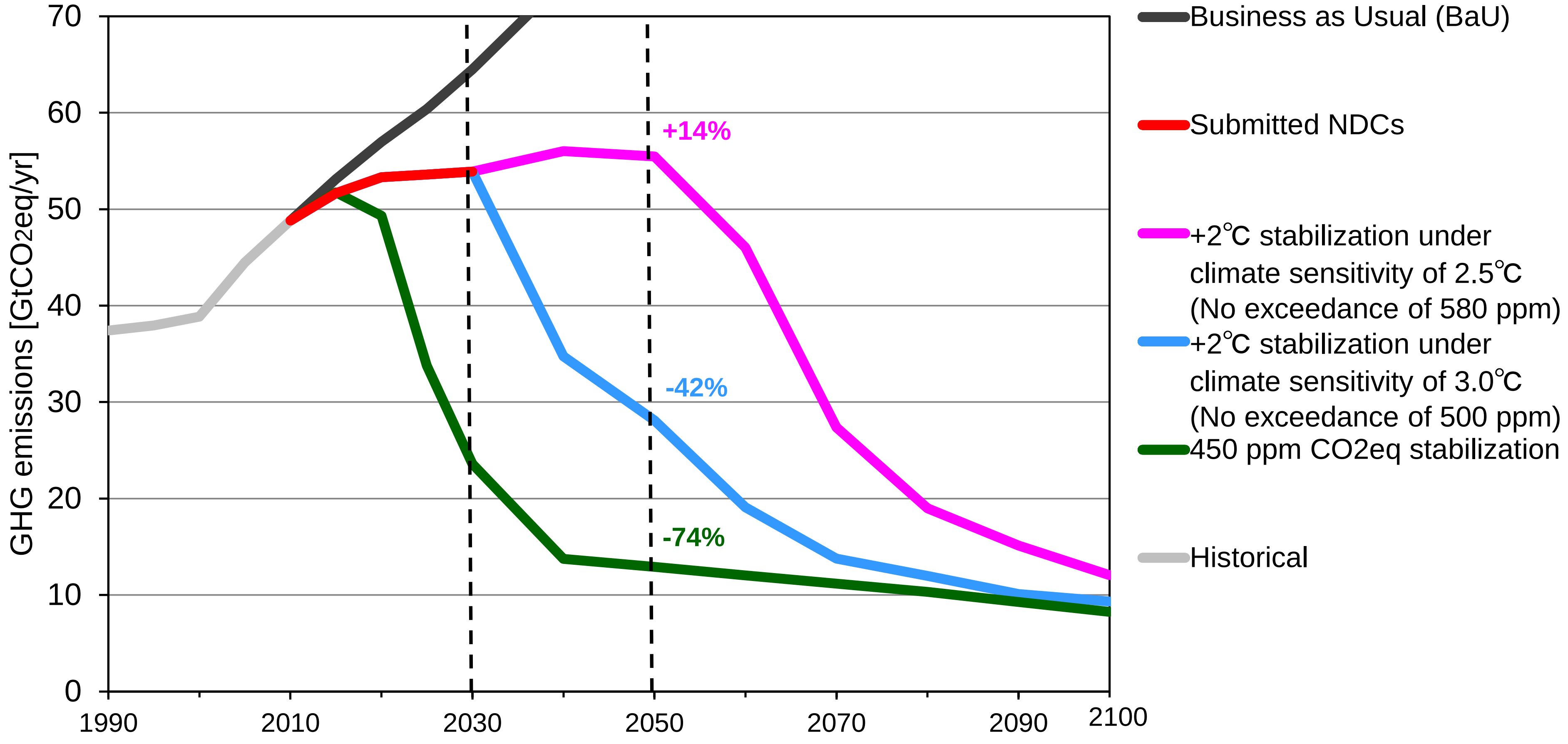
Assumed temperature trajectories for the 2 °C target

There are several uncertainties concerning the achievement timing and probability for the 2 °C target



The climate sensitivity assumes:
3.0 °C: according to the WG1 AR4 judgment, and
2.5 °C: according to the judgment before AR4 (the likely range is as same as the WG1 AR5)

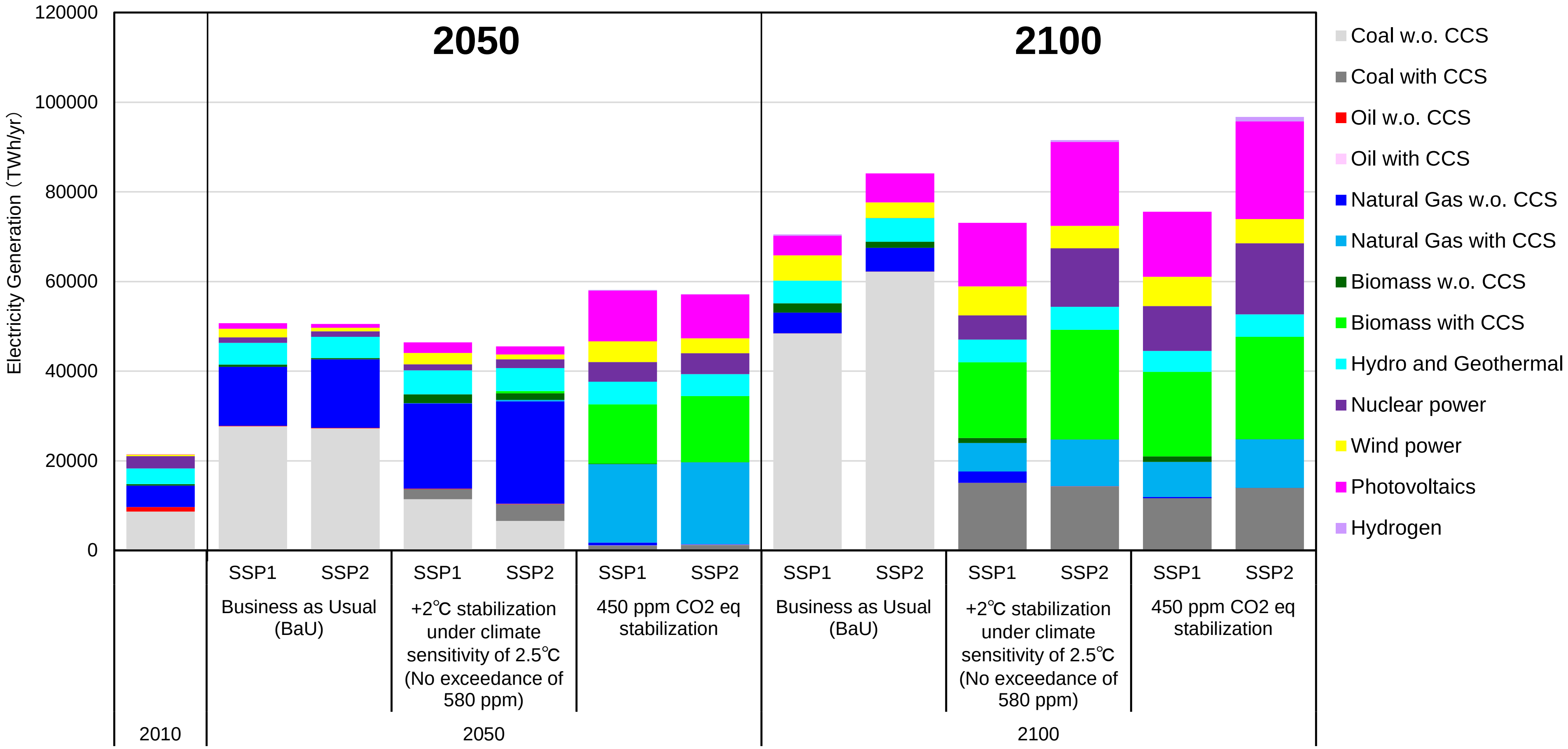
Global GHG emission profiles toward 2100 for the 2 °C target



Estimated by RITE using MAGICC, DNE21+ and non-CO2 GHG models

- The corresponding GHG emission trajectories for the 2 °C target vary widely particularly in 2050.
- There are large gaps between the expected emissions under the submitted NDCs and the 450 ppm CO_2eq pathway.

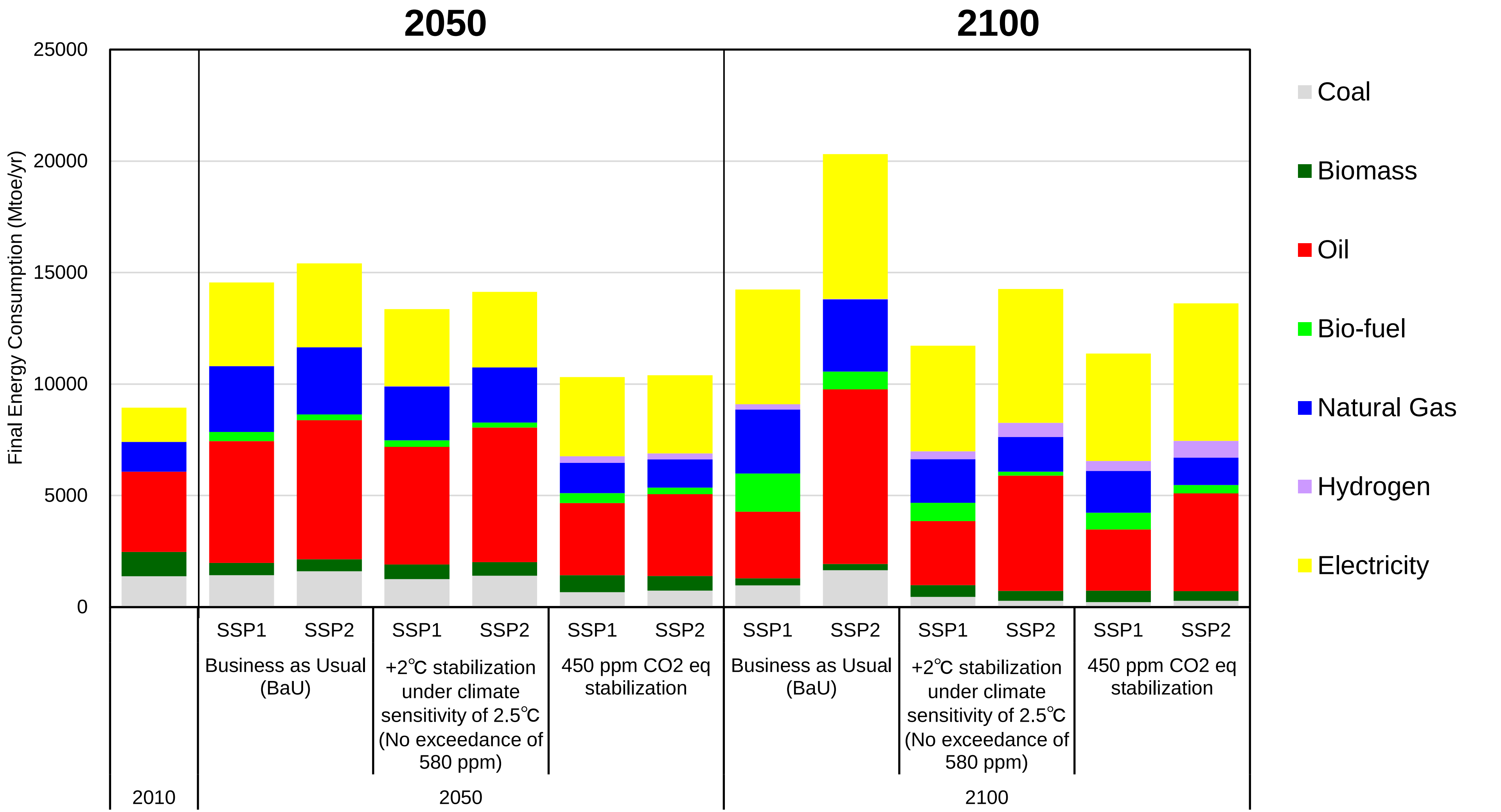
Global electricity generation



Source) estimated by RITE DNE21+

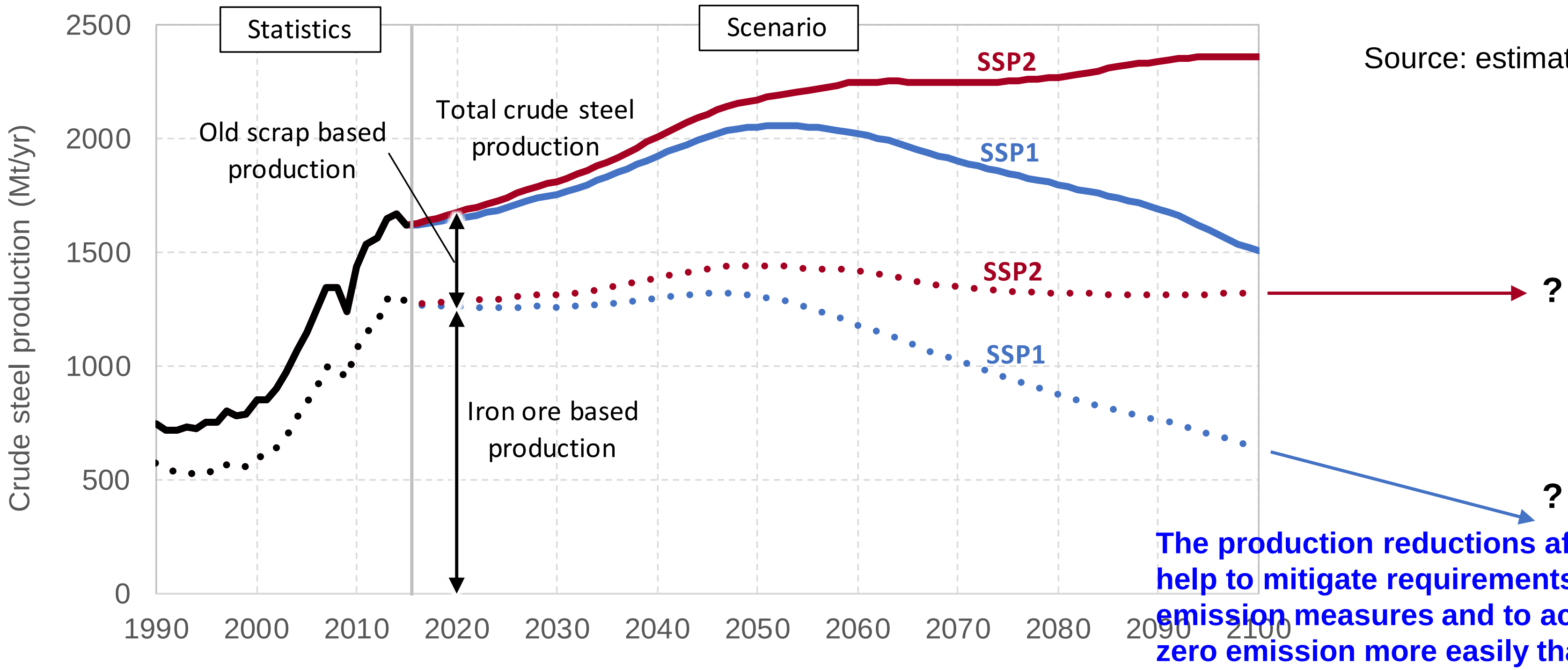
- CO2 emissions from power sector in most of the scenarios for the 2 °C target are nearly zero.
- The total amounts of electricity for the 2 °C target will increase with deeper emission reductions due to substitution for fossil fuel use in other sectors.

Global final energy consumption



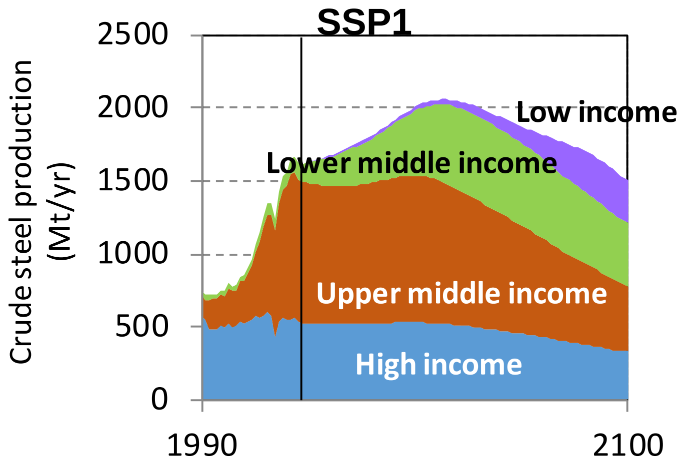
Source) estimated by RITE DNE21+

Outlook of steel productions
(primary and secondary productions)

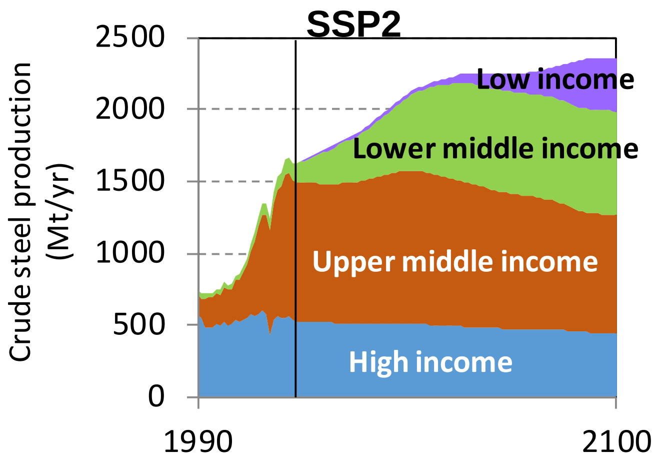


Source: estimated by RITE

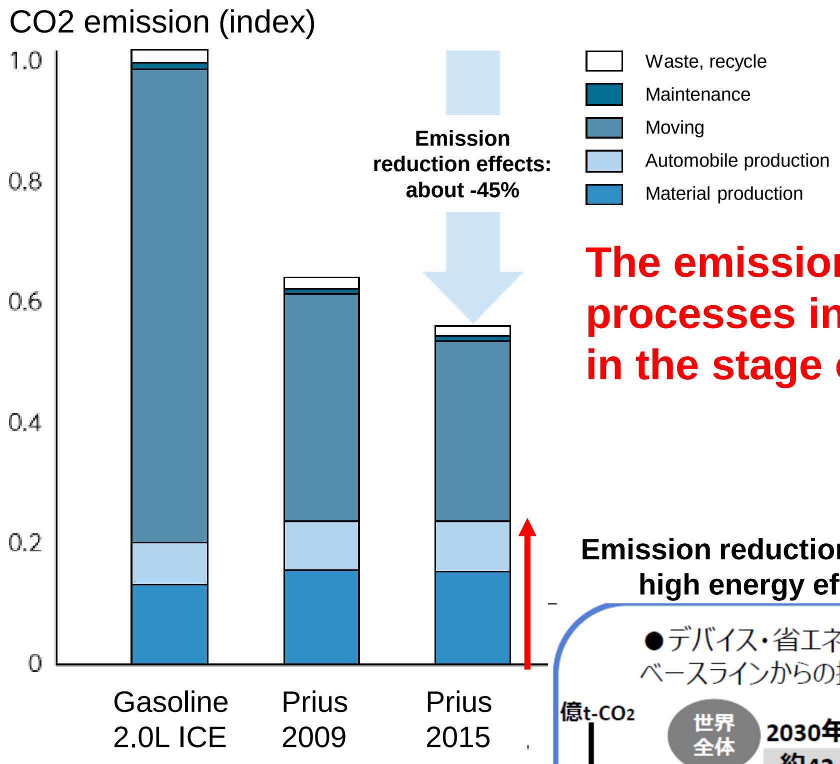
The production reductions after 2100 will help to mitigate requirements of negative emission measures and to achieve the net zero emission more easily than that by 2100.



Total crude steel production by region



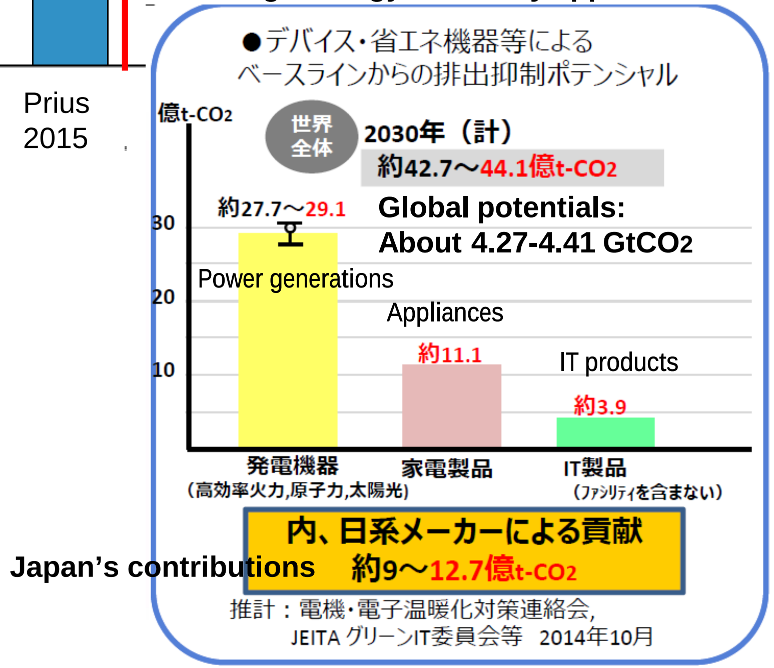
Importance of product innovation



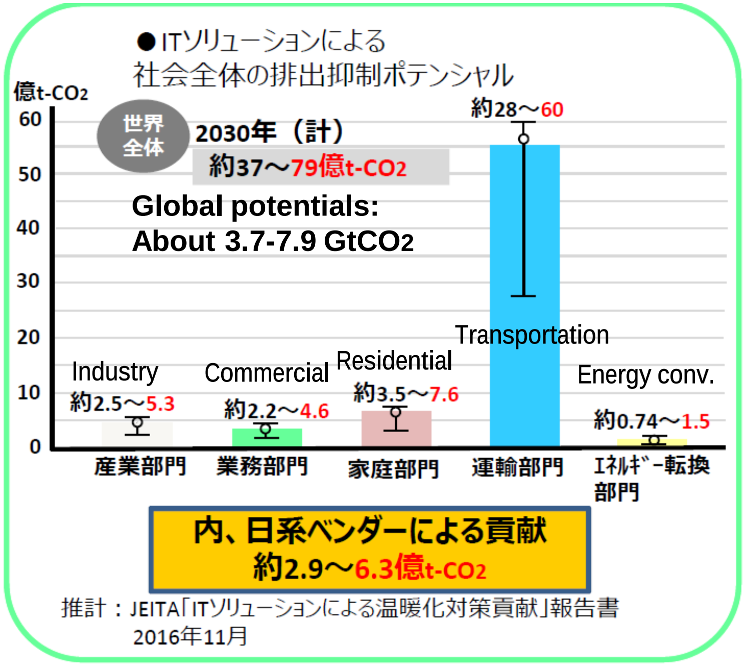
Source) Toyota

The emissions in the production processes increase slightly, but those in the stage of use decrease greatly.

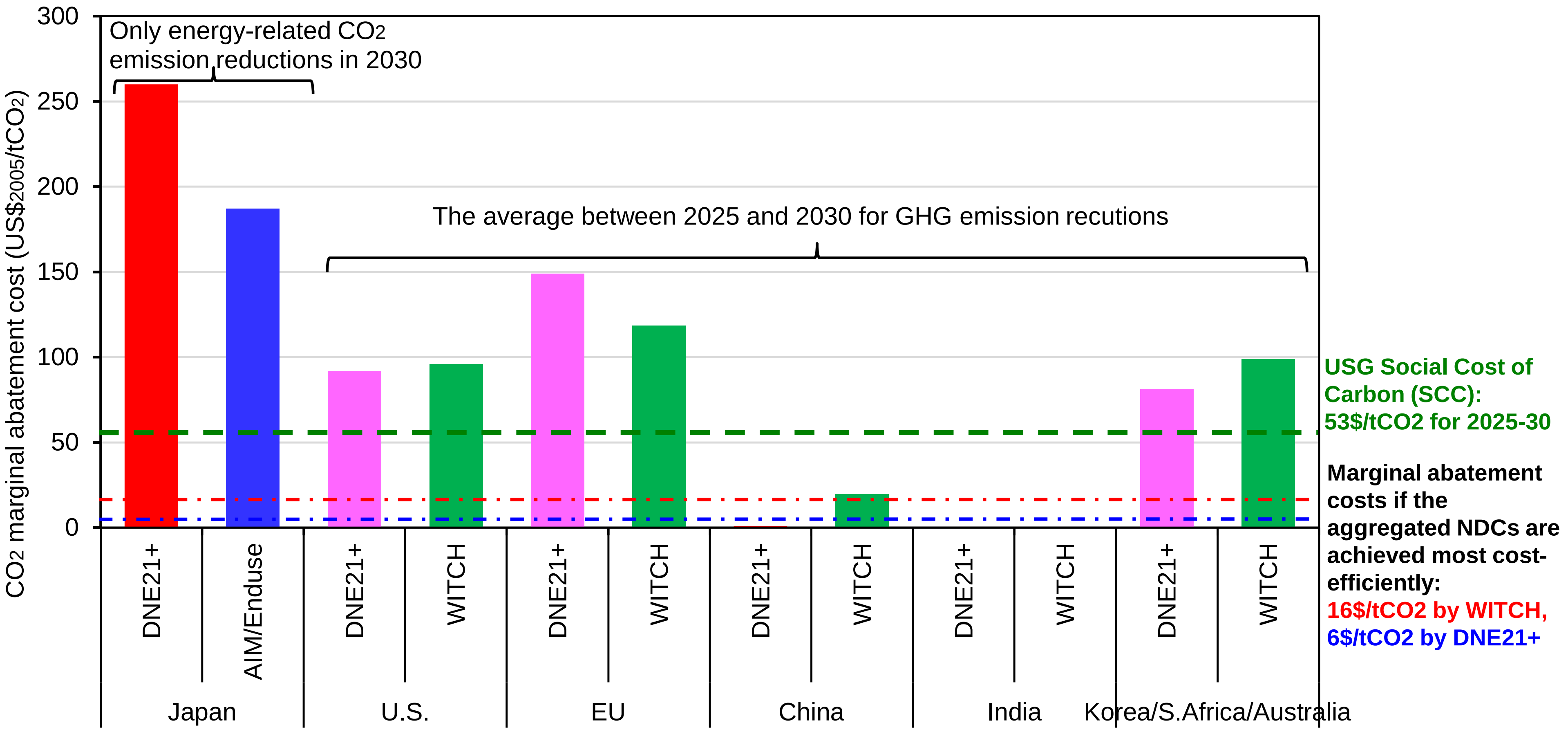
Emission reduction potentials by devices, high energy efficiency appliances



Emission reduction potentials in whole sectors by IT solutions



Marginal abatement costs estimations across models (RITE DNE21+, FEEM WITCH and NIES AIM)



Source: B. Pizer, J. Aldy, R. Kopp, K. Akimoto, F. Sano, M. Tavoni, COP21 side-event; MILES project report for Japan

- The marginal abatement costs vary across models for some countries, but can be comparable for many countries/regions.
- The CO_2 marginal abatement costs of the NDCs of OECD countries are much higher than the marginal cost for the case that the aggregated NDCs are achieved most cost-efficiently (globally uniform marginal abatement cost).