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Analysis and assessment of 1.5℃ target

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Long-term target decided at the Paris Agreement (COP21)

- **To hold the increase in the global average temperature to well below 2℃ above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5℃ . (Article 2, Para. 1 (a)) (=> At the COP21, COP invited IPCC to provide a special report in 2018 on the impacts of global warming of 1.5℃ and related global greenhouse gas emissions pathways. IPCC decided to provide a special report at the plenary session in Apr. 2016)**
- **In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, and to undertake rapid reductions thereafter so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century. (Article 4, Para. 1)**
- **All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies (Article 4, Para. 19) (COP21 decision clearly indicates its time period as 2020)**
- **COP shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals every five years (“global stocktake”, to be started from 2023)**

1. Evaluation on 1.5℃ target by IPCC AR5

Long-term scenarios for the global emissions reduction in IPCC AR5

CO2eq concentration in 2100 (ppm CO2eq)	Subcategories	RCP	CO2eq emissions in 2050 relative to 2010	2100 temperature (°C, relative to 1850-1900)	Probability of exceeding the target temperatures		
					1.5°C	2.0°C	3.0°C
<430	Only a limited number of analyses reported (no registration to AR5 scenario D/B)						
450 (430-480)	—	RCP2.6	-72 to -41%	1.5 - 1.7°C (1.0 - 2.8)	49-86%	12-37%	1-3%
500 (480-530)	No exceedance of 530 ppm CO2eq		-57 to -42%	1.7 - 1.9°C (1.2 - 2.9)	80-87%	32-40%	3-4%
	Once exceed 530 ppm CO2eq by 2100		-55 to -25%	1.8 - 2.0°C (1.2 - 3.3)	88-96%	39-61%	4-10%
550 (530-580)	No exceedance of 580 ppm CO2eq		-47 to -19%	2.0 - 2.2°C (1.4 - 3.6)	93-95%	54-70%	8-13%
	Once exceed 580 ppm CO2eq by 2100		-16 to +7%	2.1 - 2.3°C (1.4 - .6)	95-99%	66-84%	8-19%
(580-650)	—	RCP4.5	-38 to +24%	2.3 - 2.6°C (1.5 - 4.2)	96-100%	74-93%	14-35%
(650-720)	—		-11 to +17%	2.6 - 2.9°C (1.8 - 4.5)	99-100%	88-95%	26-43%
(720-1000)	—	RCP6.0	+18 to +54%	3.1 - 3.7°C (2.1 - 5.8)	100-100%	97-100%	55-83%
>1000	—	RCP8.5	+52 to +95%	4.1 - 4.8°C (2.8 - 7.8)	100-100%	100-100%	92-98%

The 1.5℃ target and the Allowable cumulative emissions expected (IPCC AR5)

Estimates of climate sensitivity based on CMIP5 : 2 ~ 4.5℃ (mean: 3.2℃)

Cumulative CO_2 emissions from 1870 in $GtCO_2$									
Net anthropogenic warming [a]		<1.5°C		<2°C			<3°C		
Fraction of simulations meeting goal [b]	66%	50%	33%	66%	50%	33%	66%	50%	33%
Complex models, RCP scenarios only [c]	2250	2250	2550	2900	3000	3300	4200	4500	4850
Simple model, WGIII scenarios [d]	No data	2300 to 2350	2400 to 2950	2550 to 3150	2900 to 3200	2950 to 3800	n.a. [e]	4150 to 5750	5250 to 6000
Cumulative CO_2 emissions from 2011 in $GtCO_2$									
Complex models, RCP scenarios only [c]	400	550	850	1000	1300	1500	2400	2800	3250
Simple model, WGIII scenarios [d]	No data	550 to 600	600 to 1150	750 to 1400	1150 to 1400	1150 to 2050	n.a. [e]	2350 to 4000	3500 to 4250
Total fossil carbon available in 2011 [f]: 3670 to 7100 $GtCO_2$ (reserves) and 31300 to 50050 $GtCO_2$ (resources)									

IPCC Synthesis report, Table 2.2

Estimates of climate sensitivity by MAGICC : likely 2.0 ~ 4.5℃ (mode: 3.0℃)

Note: The ranges in the table are generated by differences in non-CO2 GHG emission scenarios.

2. Uncertainties regarding the temperature targets and the assumed temperature trajectories for the 1.5℃ target

Political and Scientific Uncertainties

- **When should the temperature goal be achieved below +1.5 ℃ under the Paris Agreement?**
- **How high probability should be assigned to achieve the 1.5 ℃ target under the Paris Agreement? (How shall “well below” be scientifically interpreted?)**
- **The climate sensitivity and its probability density function is still uncertain scientifically.**

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 “median”)
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 estimates in the IPCC WG3 scenarios (employing MAGICC)	**2.0-4.5°C（3.0°C） [Based on the AR4]**

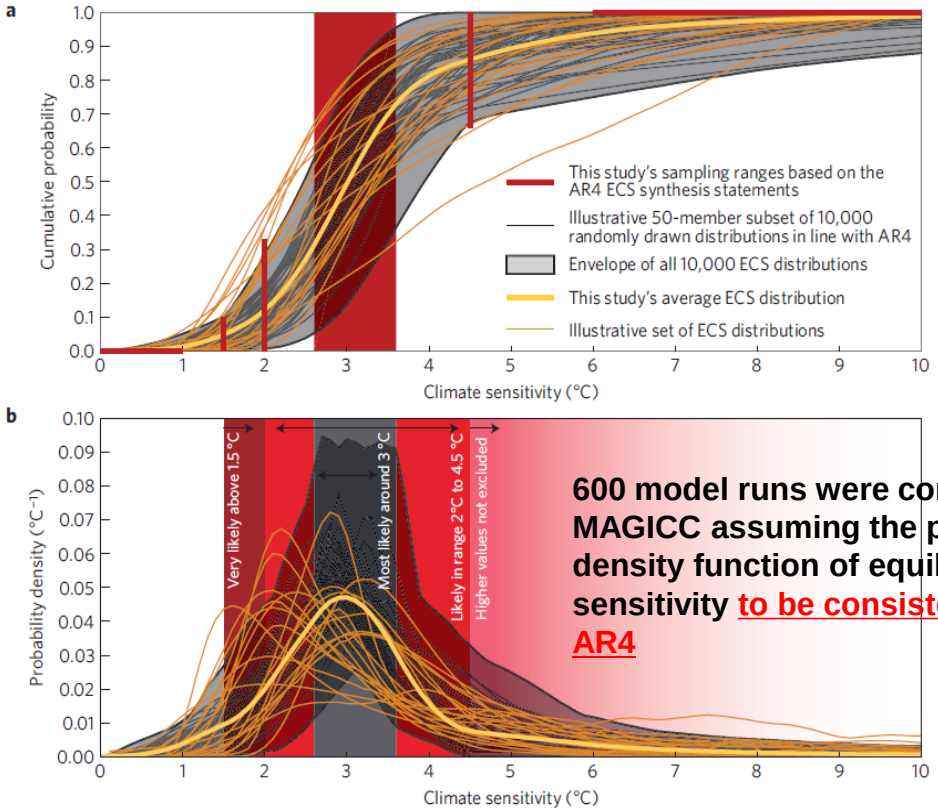
[Related descriptions of the SPM of WG1 AR5]

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 modified the likely range of climate sensitivity to be smaller than that in AR4 (1.5–4.5 °C), based on the synthetic judgement on various analyses including climate sensitivity assessment of observational data.**
- **However, 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.**

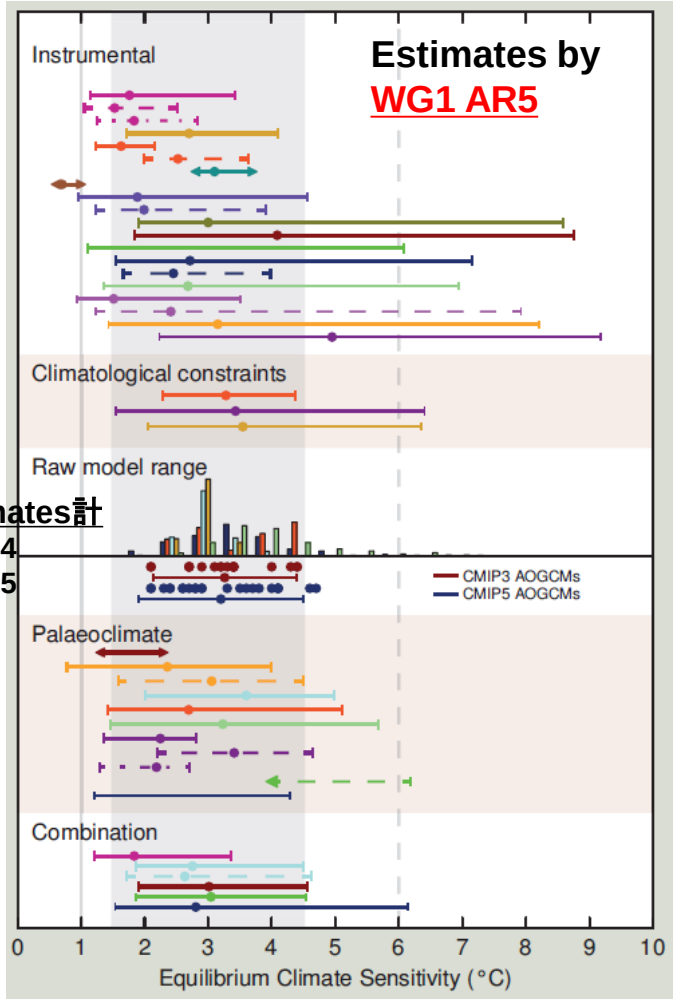
Climate sensitivity of MAGICC model which was employed for the temperature change estimates in the long term scenarios of IPCC WG3 AR5

WG3 AR5 employed a simple climate change model MAGICC for the temperature estimates for the long-term scenarios



600 model runs were conducted in MAGICC assuming the probability density function of equilibrium climate sensitivity to be consistent with the AR4

Source：J. Rogelj et al., 2012



GCM estimates計
CMIP3→AR4
CMIP5→AR5

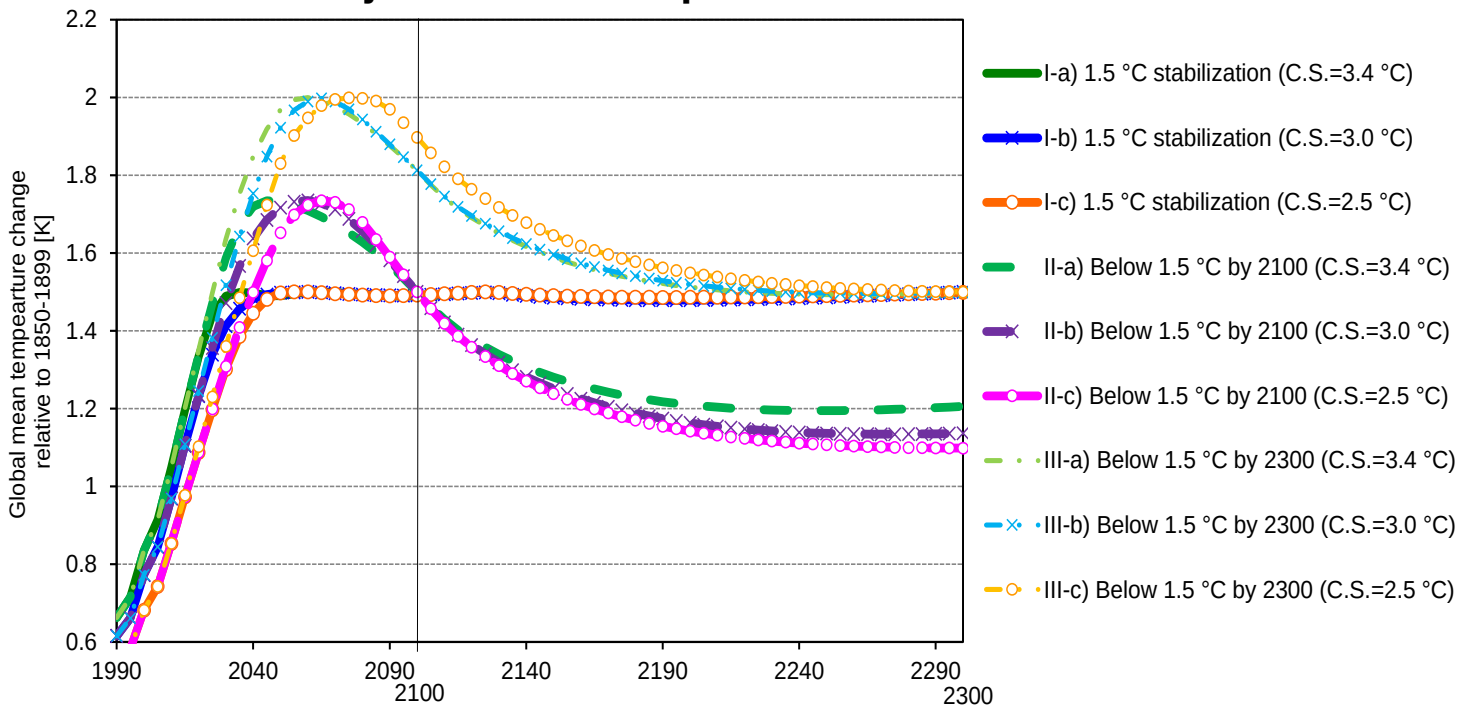
出典：IPCC WG1 AR5, 2013

- **WG3 AR5 employed the climate sensitivity of AR4 (likely range: 2.0−4.5 °C, best estimate: 3.0 °C) for estimating the temperature of long-term scenarios. This is almost consistent with the CMIP5 results but is inconsistent with the new synthetic judgment of WG1 AR5 considering other studies (shown in a gray zone in the right figure).**
- **Therefore, when compared with the latest judgment by WG1 AR5, the temperature rise estimates can be greater.**

The assumed scenarios for the 1.5 °C target and the temperature trajectories

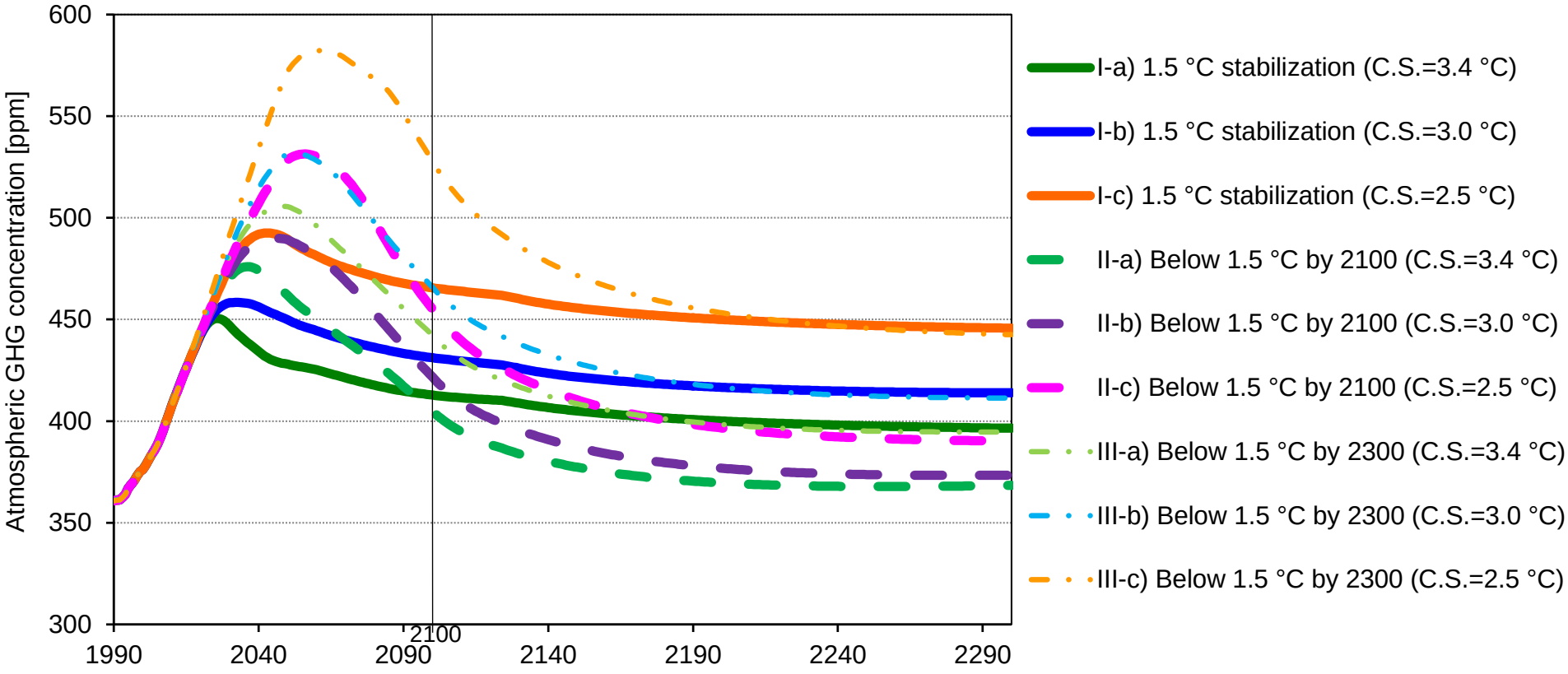
Temperature trajectories	Equilibrium climate sensitivity		
	a) 3.4 °C	b) 3.0 °C	c) 2.5 °C
I) 1.5 °C stabilization (below 1.5 °C over time)	I-a	I-b	I-c
II) Below 1.5 °C by 2100 (temperature overshoot; peak temperature: around 1.75 °C)	II-a	II-b	II-c
III) Below 1.5 °C by 2300 (temperature overshoot; peak temperature: around 2.0 °C)	III-a	III-b	III-c

The assumed trajectories of temperature rise



3. Emission pathways for the 1.5 °C target

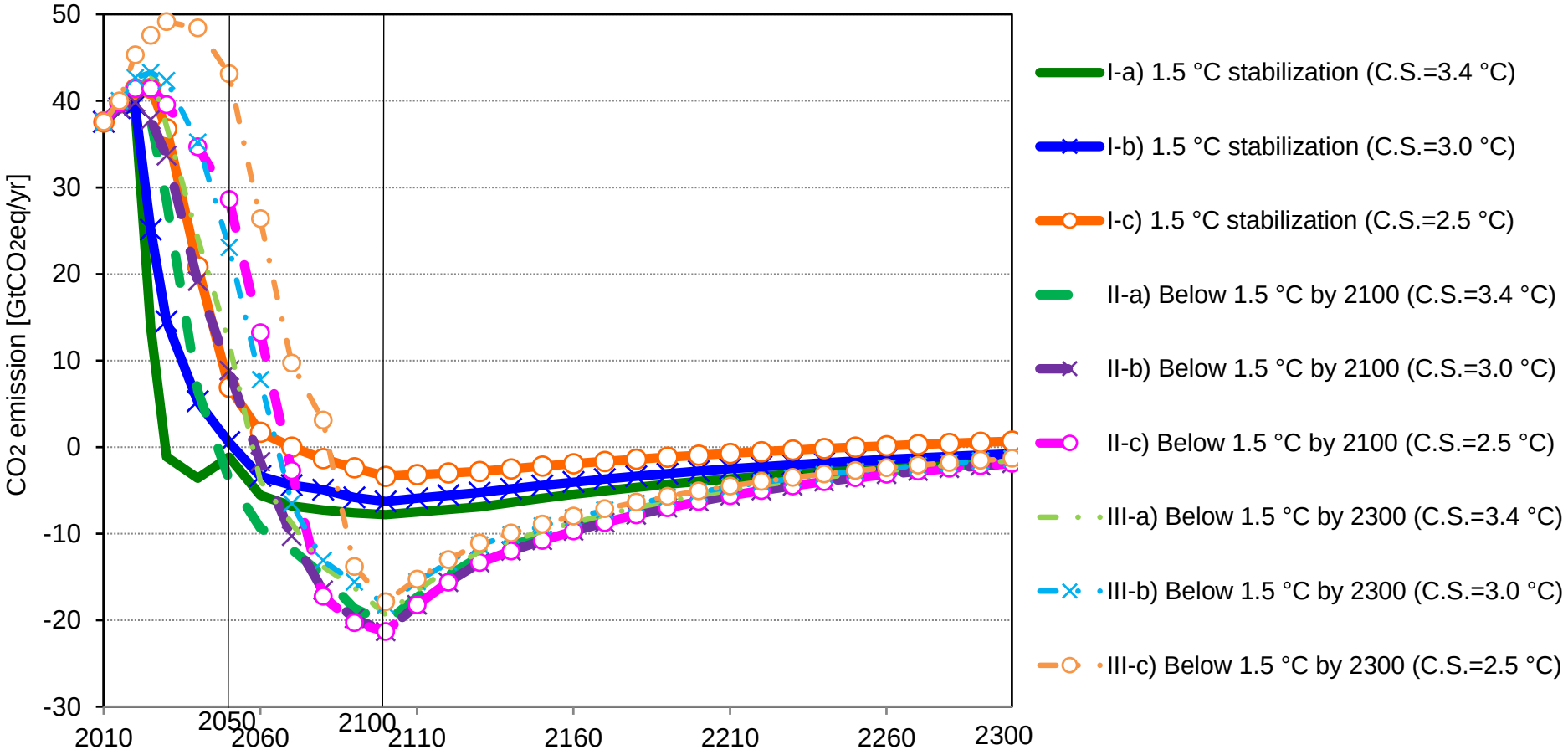
Atmospheric GHG concentration pathways for the 1.5 °C target scenario



Source: estimated by RITE using MAGICC

The atmospheric GHG concentration peaks at each level and thereafter declines for all of the assumed scenarios. The concentration levels in 2300 for the 1.5 °C stabilization scenarios are 400-450 ppm CO2eq. (The range depends on climate sensitivity.) The temperatures of the scenarios below 1.5 °C in 2100 decrease and the concentration levels reach about 370-400 ppm CO2eq.

CO2 emissions pathways until 2300 for the 1.5 °C target

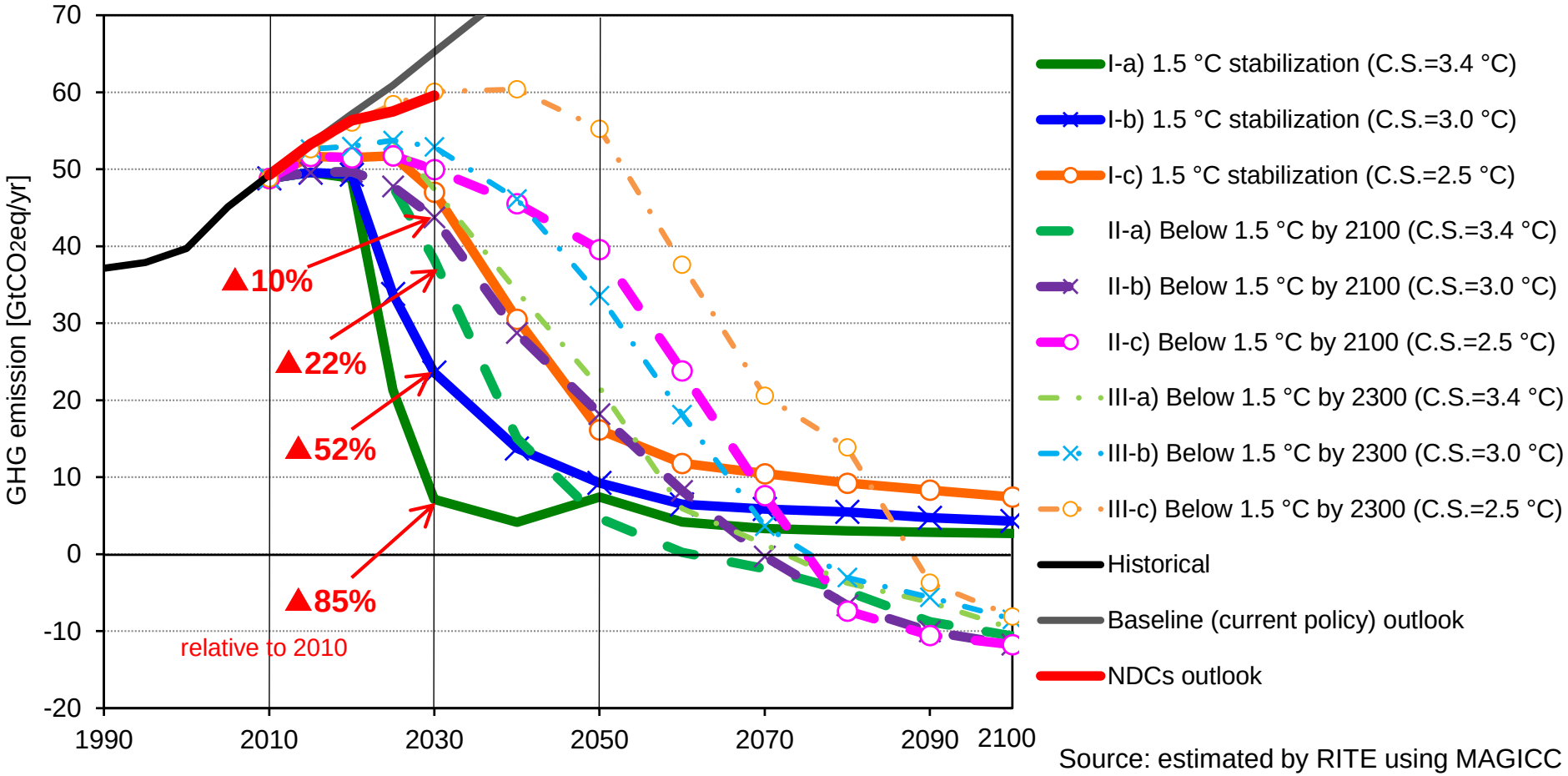


Source: estimated by RITE using MAGICC

- All of the scenarios require global net negative emissions. Especially, every scenario of temperature overshoot (case II and III) requires large amounts of net negative emissions (around 20 GtCO2/yr) in 2100.

- All of the scenarios require negative emissions for long terms to stabilize temperature.

GHG emissions pathways until 2100 for the 1.5 °C target

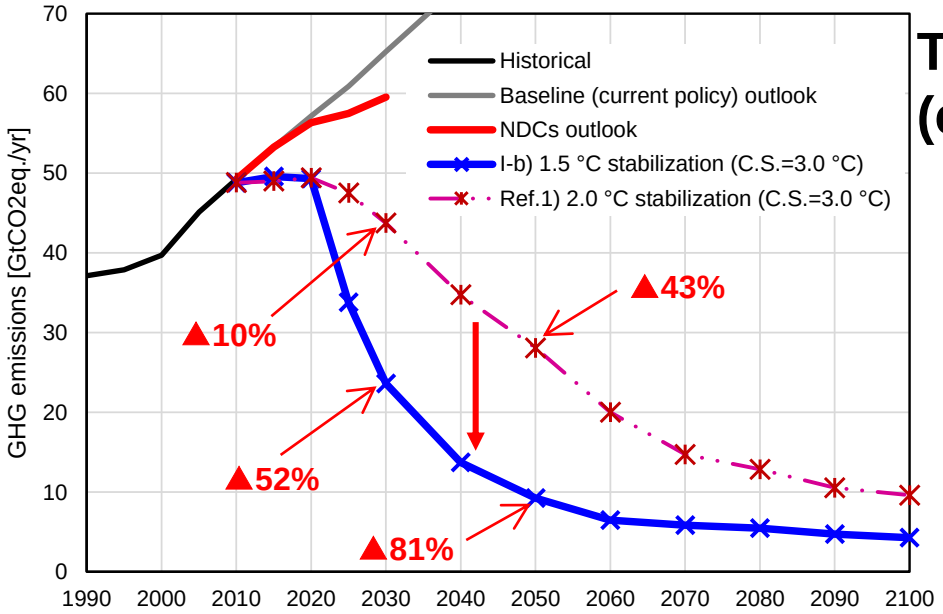


Source: estimated by RITE using MAGICC

- The GHG emission pathways for stabilizing below 1.5 °C with over 66% probabilities (equivalent to C.S. of 3.4 °C) requires 85% reduction compared with 2010 by 2030. Even for over 50% probabilities, 52% reduction is required. (in the case of best estimates for C.S. is 3 °C and likely range is 2.0 to 4.5 °C)

- For the achievement of below 1.5 °C with over 66% in 2100 while allowing temperature overshoot, 22% reduction compared with 2010 by 2030 is required. For over 50%, 10% reduction by 2030 is required. (NDC outlook: +21%)

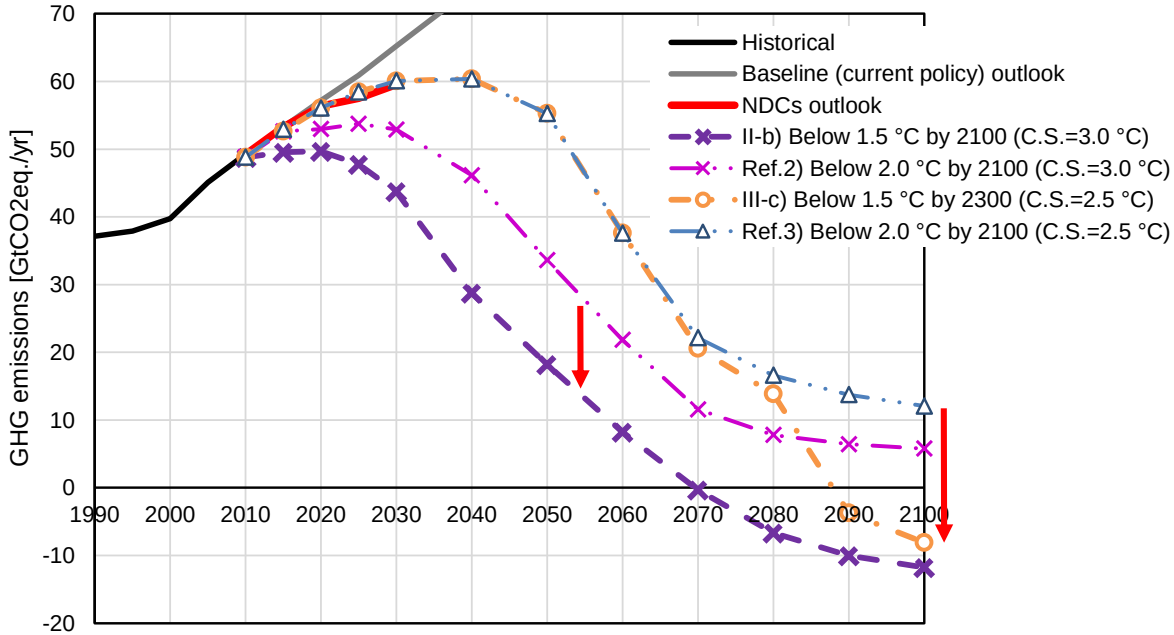
GHG Emissions Pathways －2 °C vs 1.5 °C targets－



Temperature stabilization scenarios (climate sensitivity: 3.0 °C)

Source: estimated by RITE

Temperature overshoot scenarios (climate sensitivity: 3.0 °C and 2.5 °C)



- The emission pathway for below 1.5 °C by 2300 under climate sensitivity of 2.5 °C is similar by around 2070 to that for below 2 °C by 2300, and both of them are consistent with aggregated NDCs.

- However, the scenario for below 1.5 °C by 2300 requires deep emission reductions after about 2070, and negative emissions of about 10GtCO2eq/yr in 2100.

Required emission reductions and cumulative emissions for the 1.5 °C targets

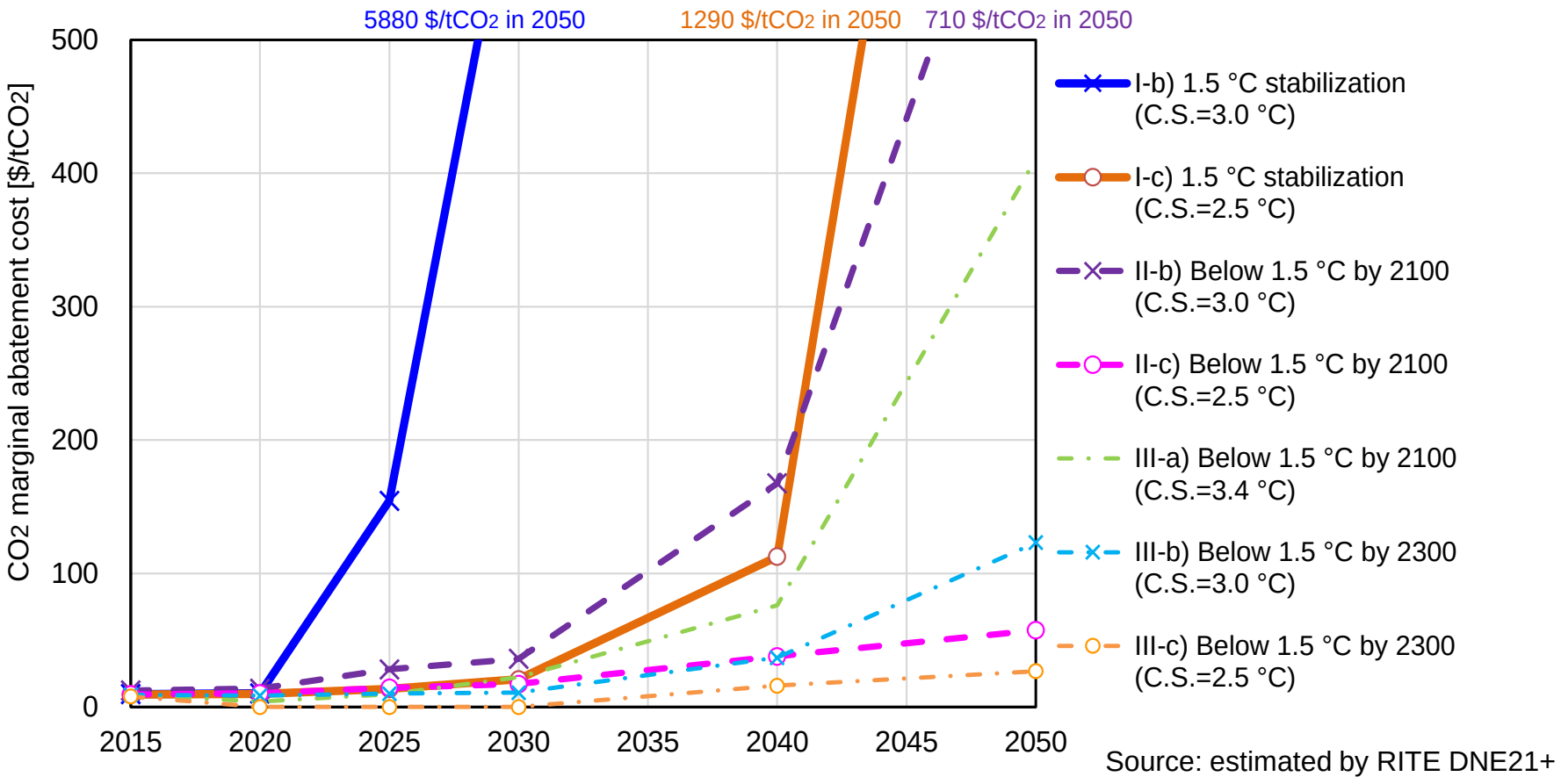
	Global mean temperature relative to 1850-1900			Required GHG emission reductions in 2030 (GtCO2eq./yr)		Required GHG emissions compared with 2010 (%)		Cumulative net CO2 emissions (GtCO2)		Cumulative net negative CO2 emissions (GtCO2)*
	2100	2300	Peak temp.	From baseline	From NDCs	2030	2050	2016-2100	2016-2300	2016-2300
I-a	1.5 °C	1.5 °C	1.5 °C	58.1	52.4	-85%	-85%	230	-210	-615
I-b				41.6	35.9	-52%	-81%	469	154	-414
I-c				18.2	12.5	-4%	-67%	873	756	-148
II-a		1.1–1.2 °C	1.75 °C	27.0	21.3	-22%	-90%	394	-360	-1069
II-b				21.5	15.8	-10%	-63%	577	-221	-1065
II-c				15.3	9.6	+2%	-19%	919	121	-1024
III-a	1.8–1.9 °C	1.5 °C	2.0 °C	17.8	12.1	-3%	-56%	711	-3	-950
III-b				12.3	6.6	+8%	-31%	926	261	-862
III-c				5.2	-0.5	+23%	+13%	1427	777	-738

* * Only annual net negative CO2 emissions are summed up

Required emission reductions in II-c, III-b and III-c from NDCs are relatively small compared with other scenarios. However, these cases require cumulative net negative emissions only by summing up annual net negative emissions.

4. Emission reduction costs and measures for the 1.5 °C target

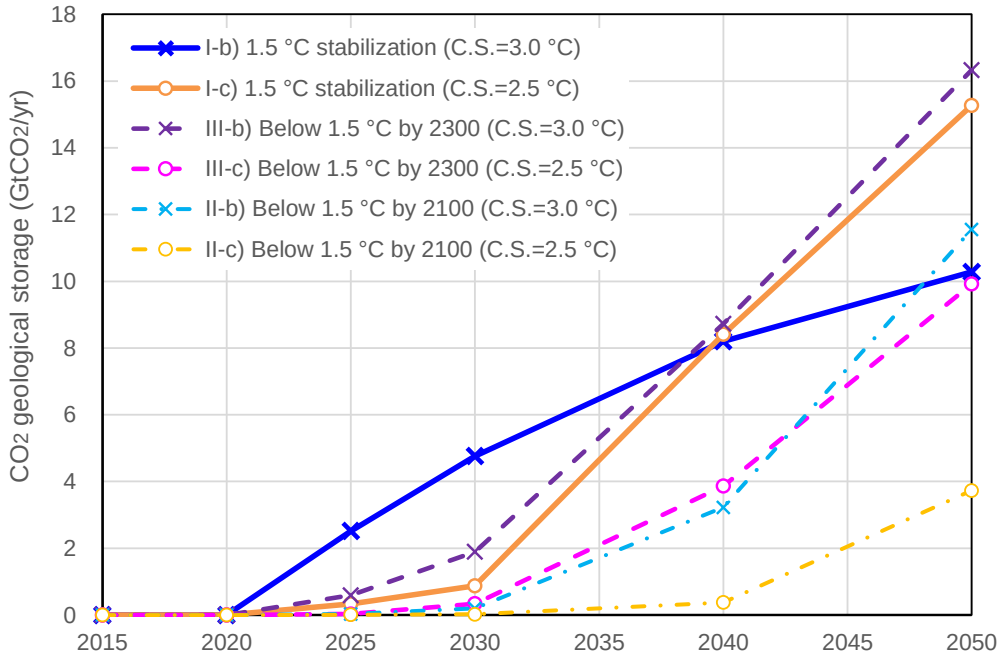
CO_2 marginal abatement costs for the 1.5 °C target



Source: estimated by RITE DNE21+

- There were no feasible solutions by DNE21+ in Cases I-a and II-a(C.S = 3.4 °C for both).
- While there are feasible solutions for emission trajectories for 1.5 °C target with C.S. of 3.0 °C (cases I-b and II-b) at least by 2050, marginal abatement cost in 2050 would be 710$tCO2 for the 1.5 °C convergence in 2100 (overshoot) case, and 5900$/tCO2 for the 1.5 °C stabilization case (cost minimization for both cases).

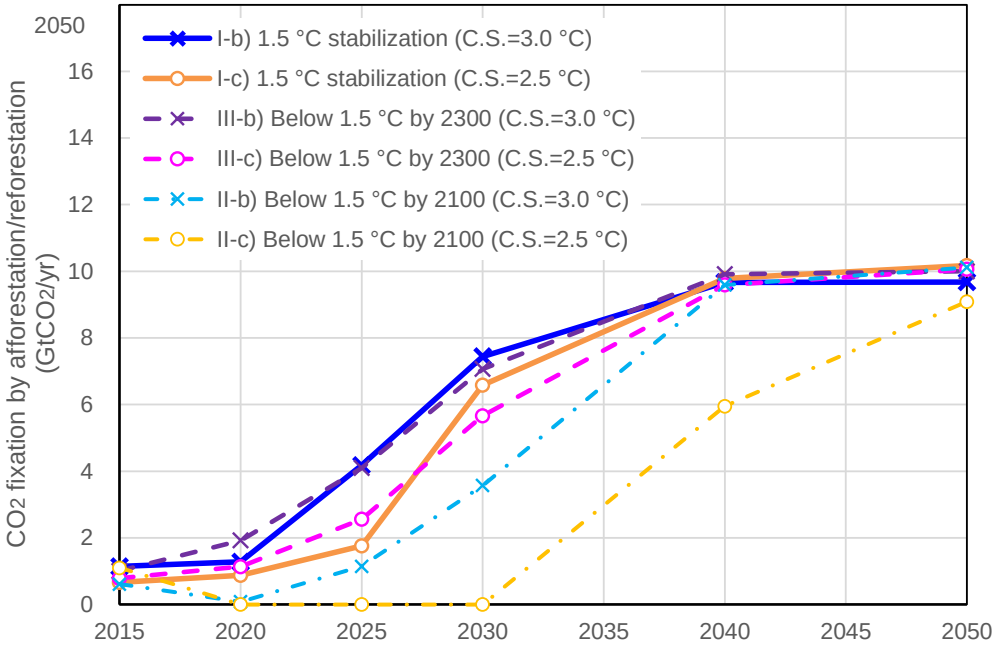
Amounts of CCS and CO2 fixation by reforestation/afforestation for the 1.5 °C target



Amounts of CO_2 storage by CCS

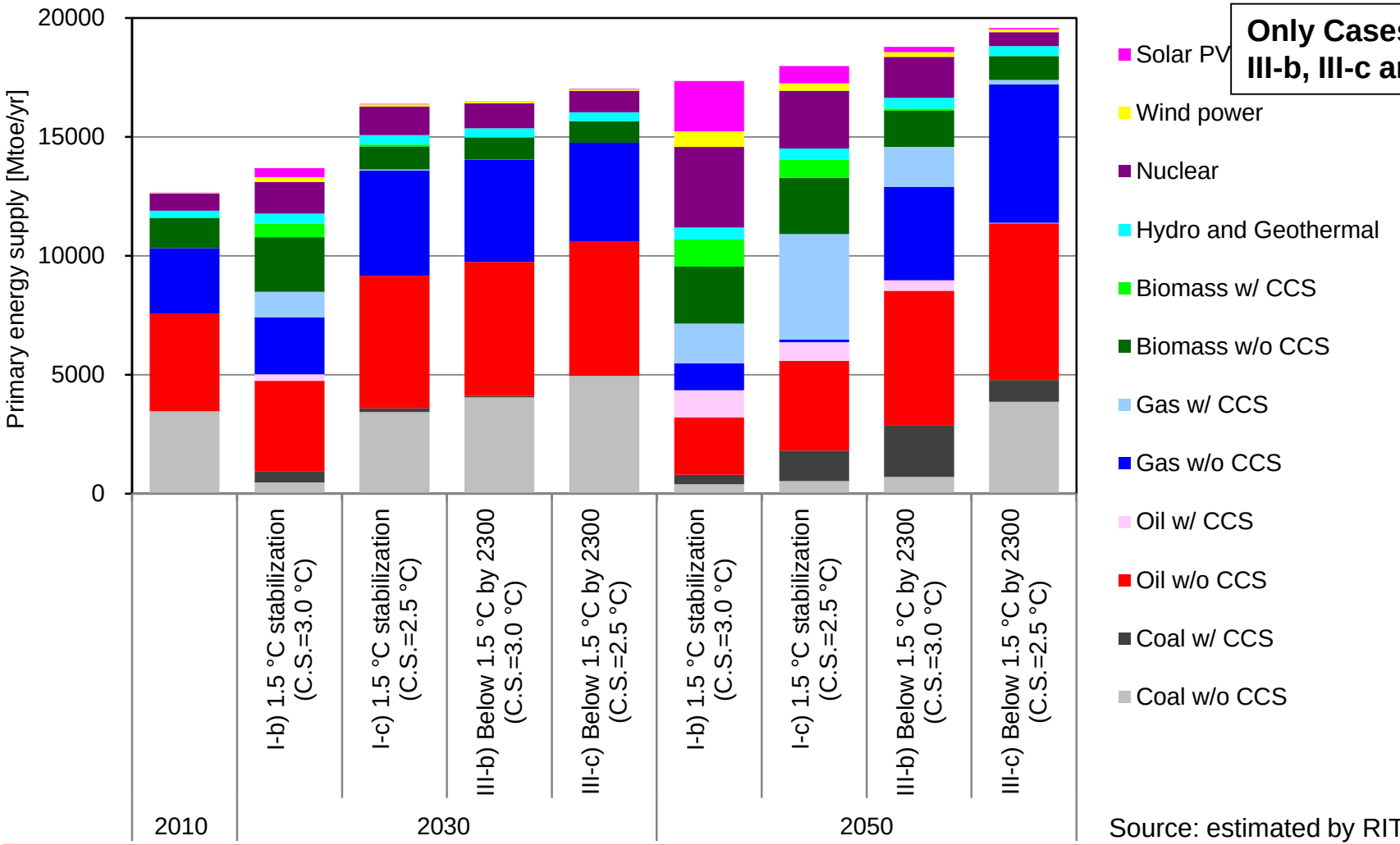
Source: estimated by RITE DNE21+

CO_2 fixation by reforestation/afforestation



- According to the model calculation, more than 20GtCO2 fixation by reforestation/afforestation is forecasted in 2050.
- To achieve global net negative emissions of 20GtCO2 around 2100 indicates requiring both 20GtCO2 fixation of positive emissions and 20GtCO2 negative emissions.

Global Primary Energy Supply for the 1.5 °C Target



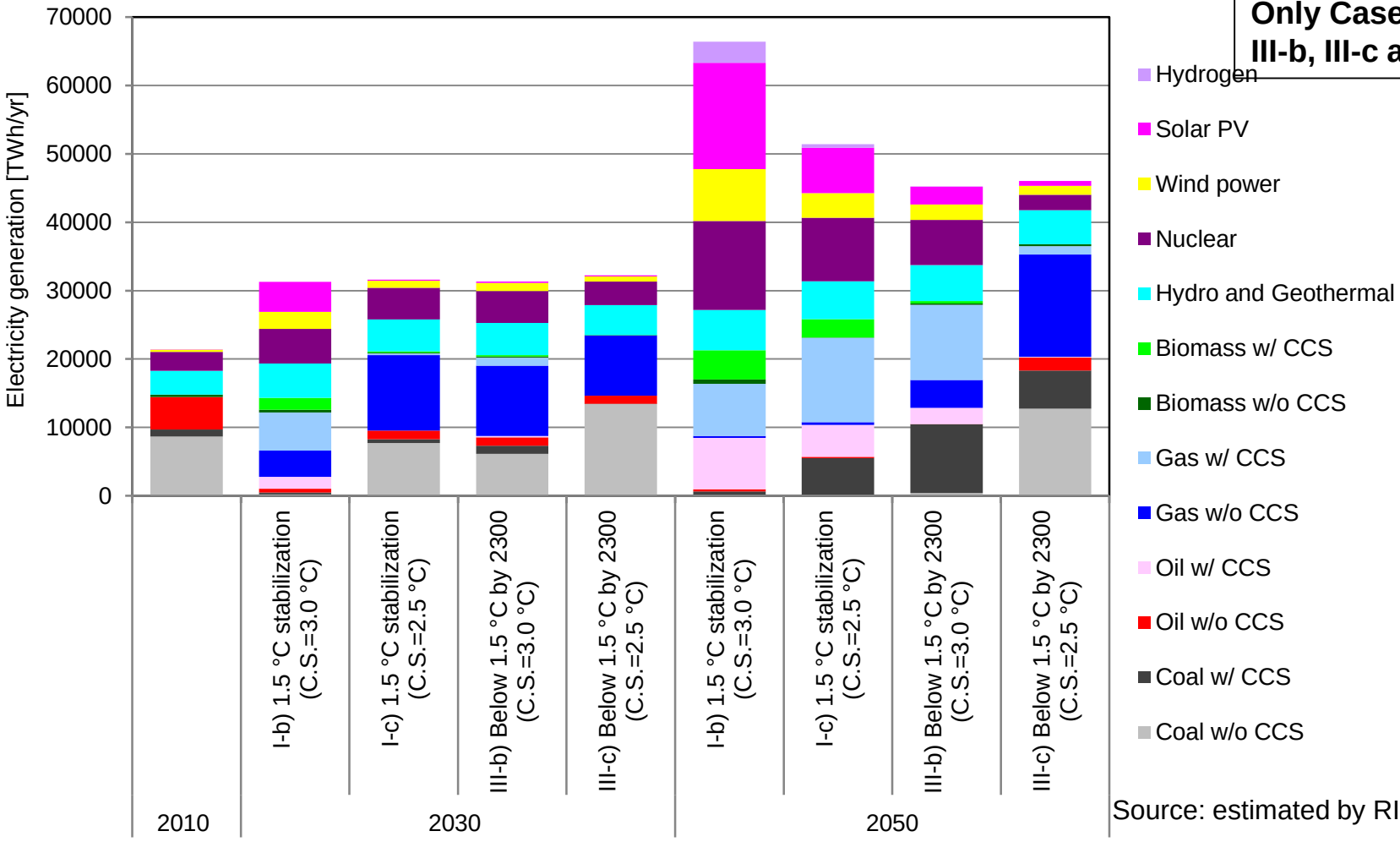
Only Cases I-b, I-c, III-b, III-c are shown

Source: estimated by RITE DNE21+

- **In Case I-b, global coal supply should be small and BECCS will be required in 2030.**
- **On the other hand, in Cases I-c、III-b、III-c, no big changes in primary energy supply by 2030 are observed. In Case III-c, no big changes are observed even in 2050 (in this case, drastic reduction is required after 2050).**

Global Electricity Supply for the 1.5 °C Target

Only Cases I-b, I-c, III-b, III-c are shown



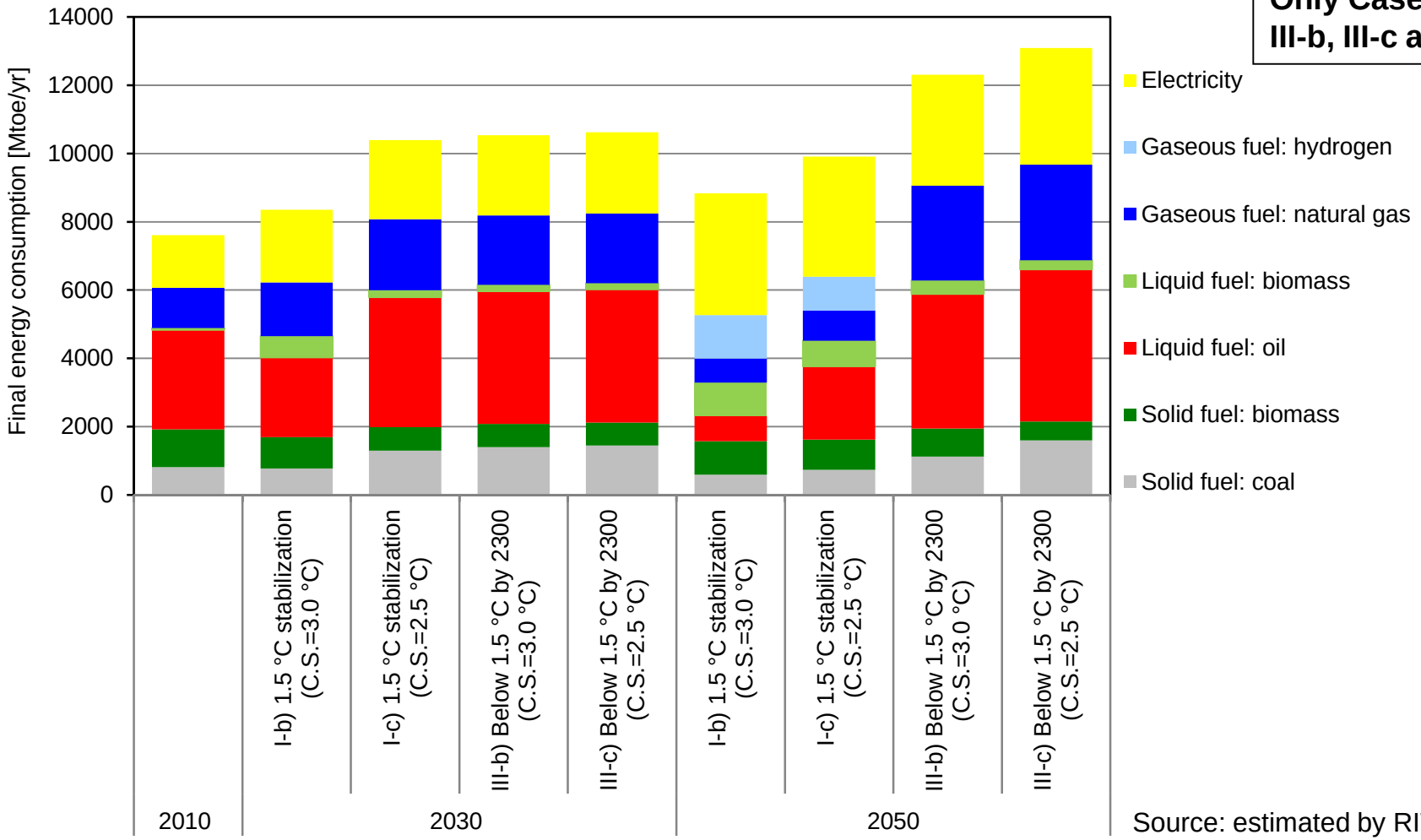
Source: estimated by RITE DNE21+

- In contrast to primary energy supply or final energy demand, amounts of electricity generation are observed to be larger for deeper emission reduction pathways while the total amounts of primary energy decrease.

- Composition rate of renewable energy (w/o hydrogen) in 2050 for Case I-b is approx. 51%

Global Final Energy Consumption for the 1.5 °C Target

Only Cases I-b, I-c, III-b, III-c are shown



Source: estimated by RITE DNE21+

- In accordance with a stringent target, final energy demand is significantly suppressed.
- More than half of gaseous fuel demand in 2050 is supplied with hydrogen in cases I-b and I-c
- Composition rate of electricity in Case III-c requiring comparatively moderate emission reduction is 26%; on the other hand, approx. 40% in Case I-b requiring stringent reduction.

5. Conclusions

Conclusions

- The Paris Agreement mentioned 2 °C and 1.5 °C as a temperature target. As there have been less evaluation examples for 1.5 °C target, IPCC has been invited to provide a special report on the impacts of 1.5 °C.
- However, emission pathways and intensities for the 1.5 °C target vary widely when considering political uncertainties in interpreting a description of the temperature target in the Paris Agreement, as well as scientific uncertainties in temperature estimates themselves.
- This analysis shows significant gap between most of the 1.5 °C target scenarios assumed here and NDCs in 2030.
- Meanwhile, in the case of climate sensitivity is 2.5 °C, a scenario with temperature peaking at 2 °C, then converging on +1.8 °C in 2100 and +1.5 °C by 2300 is consistent with NDCs in 2030.
- However, this scenario requires net negative emissions continuously from the late 21th century to 2300 (infeasible with afforestation due to the restriction of land area; geoengineering measures like large-scale BECCS or DAC (direct air capture) are required). Therefore, there seems to be very little possibilities for achieving the target. There also shall be a discuss whether achieving + 1.5 °C in a quite long term like 2300 shall be consistent with “to pursue efforts to limit the temperature increase to 1.5℃”.