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Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread, and irreversible impacts globally *(high confidence). Mitigation involves some level of co-benefits and of risks due to adverse side-effects, but these risks do not involve the same possibility of severe, widespread, and irreversible impacts as risks from climate change, increasing the benefits from near-term mitigation efforts. {3.2, 3.4}*

Post-AR5 examination of the CO_2 emissions scenario Z650

Junichi Tsutsui
Central Research Institute of Electric Power Industry, Japan

Climate stabilization concept

Traditional emissions-keeping stabilization (UNFCCC, until AR4)

Increasing CO_2 concentration levels off in a century or two and is then fixed at a constant level, in which low level CO_2 emissions continue over a millennial-long period.

New zero-emissions stabilization (Matsuno et al 2012)

CO_2 emissions are reduced to zero at some time, typically in the next century, and thereafter CO_2 concentration is decreased by natural removal processes, eventually reaching an equilibrated stable state.

Carbon budget:

anthropogenic emissions = increase in atmospheric concentration
+ natural uptake by ocean
+ natural uptake by terrestrial ecosystem

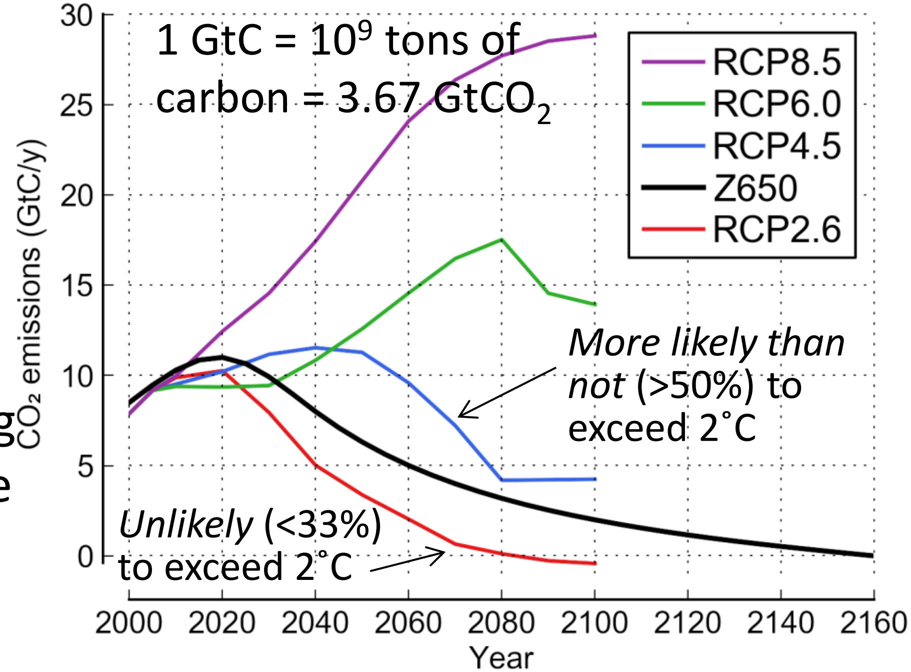
Units of carbon:

emissions: GtC (billion tons of carbon), $GtCO_2$ = 44/12 x GtC

concentration: ppm (parts per million), 1 ppm ~ 2.1 GtC

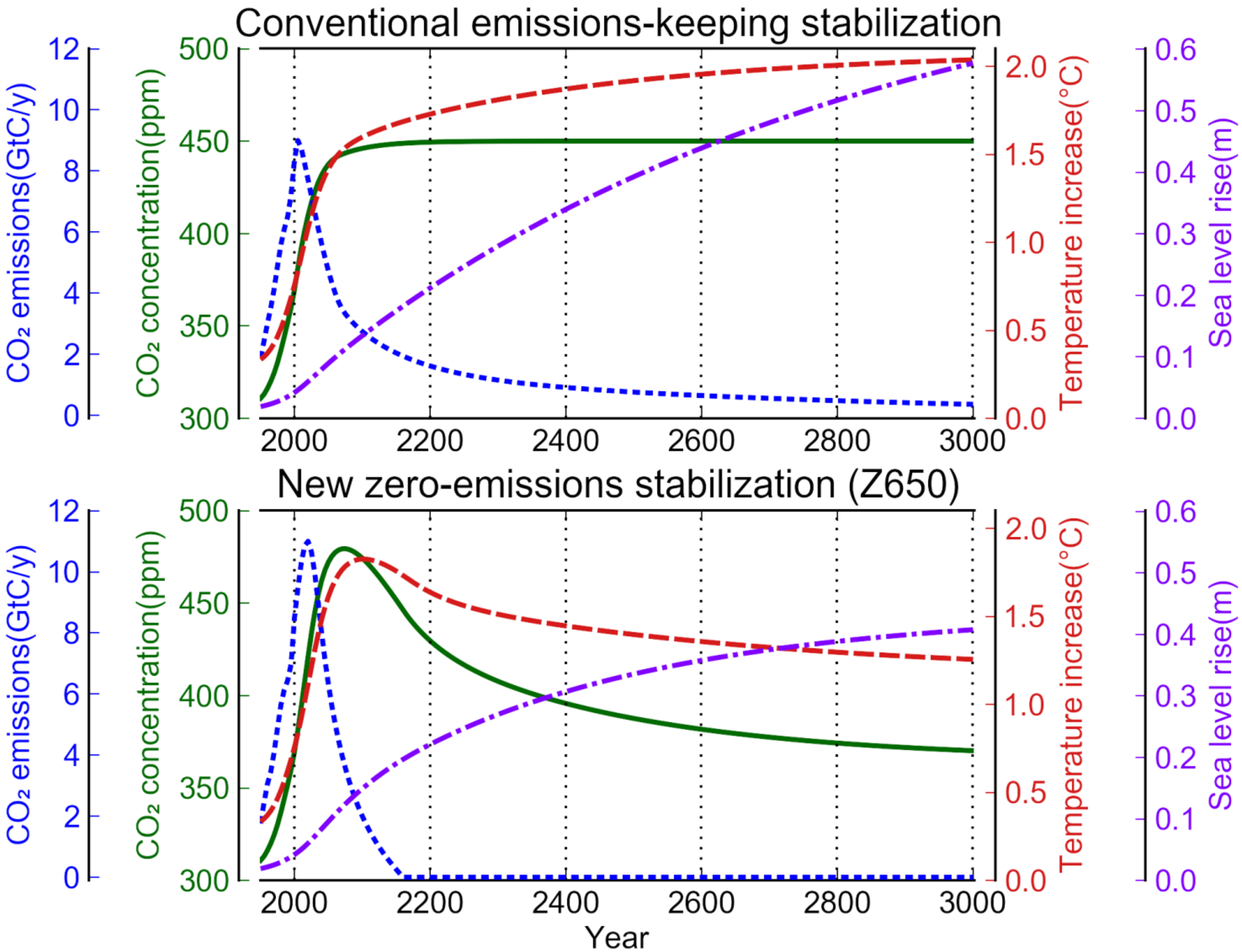
Z650 Scenario

- Allow more emissions than in a typical 450 ppm-eq path based on the new climate stabilization concept
- Premise temporal exceeding (overshoot) of a target CO_2 concentration in a near term while attain zero emissions in a long term, resulting in concentration decrease due to natural CO_2 uptake



Design of Z650 CO_2 emissions		Remark
Cumulative total during 21C	650 GtC	420 GtC for RCP2.6; 850 GtC for RCP4.5
Year of peak annual emissions	2020	Consistent with the current increase
Annual reduction in 2030–2050	2.3%	3% or more is not feasible
Year of zero emissions achievement	2160	Expectations of innovative technologies

Comparison of stabilization pathways



Idealized exp with CO_2-only forcing (Matsuno et al., 2012a)
Sea level rise considers thermal expansion of sea water alone.

Global warming and sea level rise continue over a millennium timescale under a constant concentration.

Zero emissions result in concentration decrease and subsequent reduced warming and sea level rise.

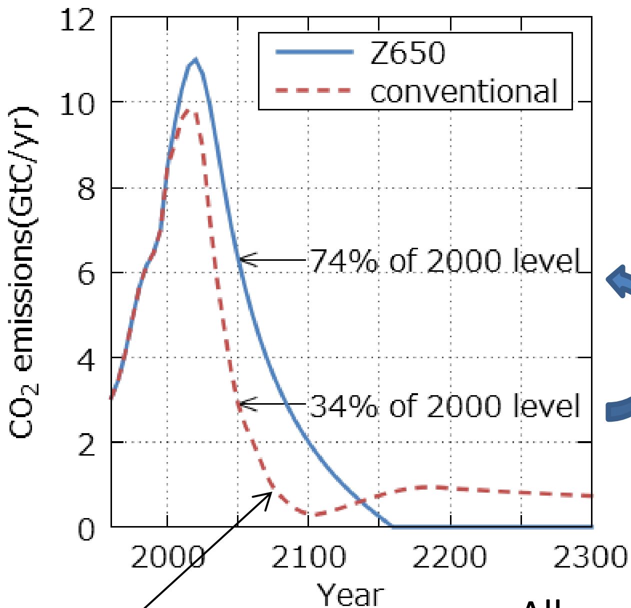
Based on Matsuno et al. (2012a) Fig. 3
https://www.jstage.jst.go.jp/article/pjab/88/7/88_PJA8807B-05/_article

Comparison between Z650 and conventional “2˚C” pathways

More realistic exp including non-CO_2 forcing (Matsuno et al., 2012b)

(https://www.jstage.jst.go.jp/article/pjab/88/7/88_PJA8807B-06/_article)

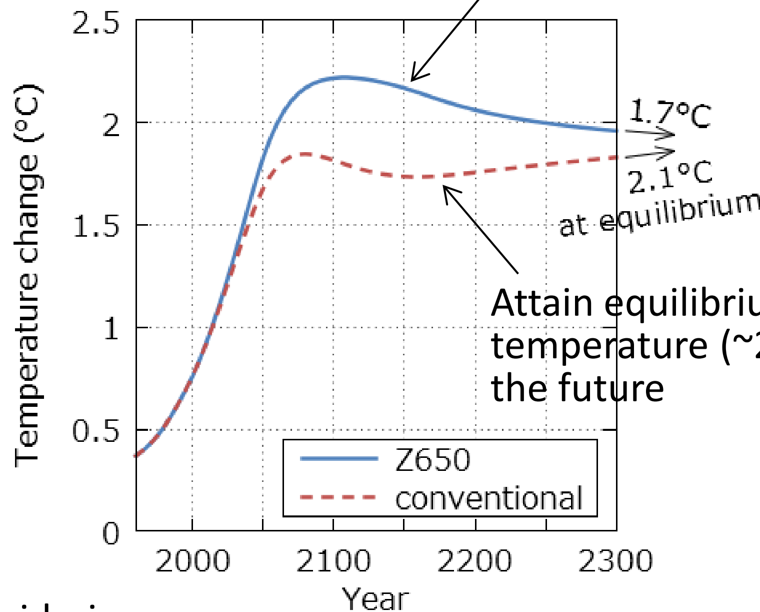
(AR5 findings have not been incorporated.)



Emissions pathway for 450 ppm-eq stabilization

Allow +40% considering the temperature target in a flexible way based on the new stabilization concept

Higher temperature is temporarily permissible because of slow response of sea level rise



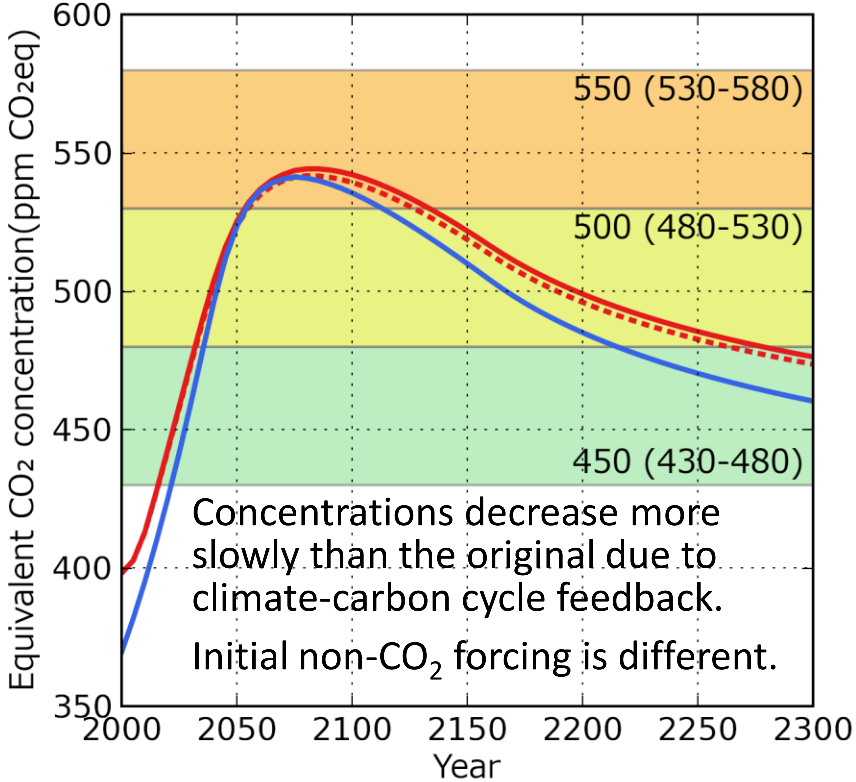
Attain equilibrium temperature (~2 ˚C) far in the future

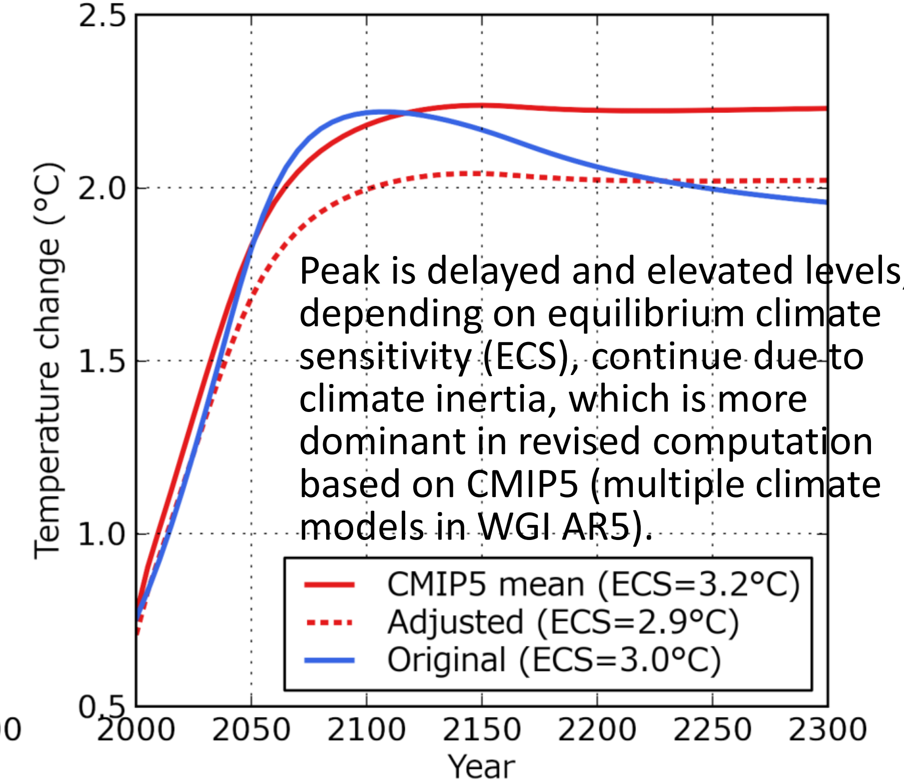
Based on Matsuno et al. (2012b) Figs. 4 and 6.

AR5 findings

- WGI (climate science)
  - Approximately linear relationship between the global temperature and cumulative CO_2 emissions
  - Temperatures remain approximately constant at elevated levels for many centuries under zero emissions
  - Substantial uncertainties of equilibrium climate sensitivity
    - No best estimate; downward adjustment of lower bound
- WGIII (mitigation)
  - Scenarios categorized by GHG concentration in 2100
    - focusing on likelihood of staying below a specific temperature level over 21C
    - different from AR4, where stabilization levels of GHG concentration and temperature are considered

Revised Z650 path of CO_2 concentration and the global temperature





- Z650 corresponds to WGIII scenario category of 550 ppm-eq without overshoot, which is assessed as *more unlikely than likely* (<50%) for staying below 2 ˚C.
  - Considering AR5 ECS assessment (median of ECS is assumed to be 2.9 ˚C here), likelihood of staying below 2 ˚C is about 50%.
- Temperatures peak but unlikely to decrease under zero emissions.

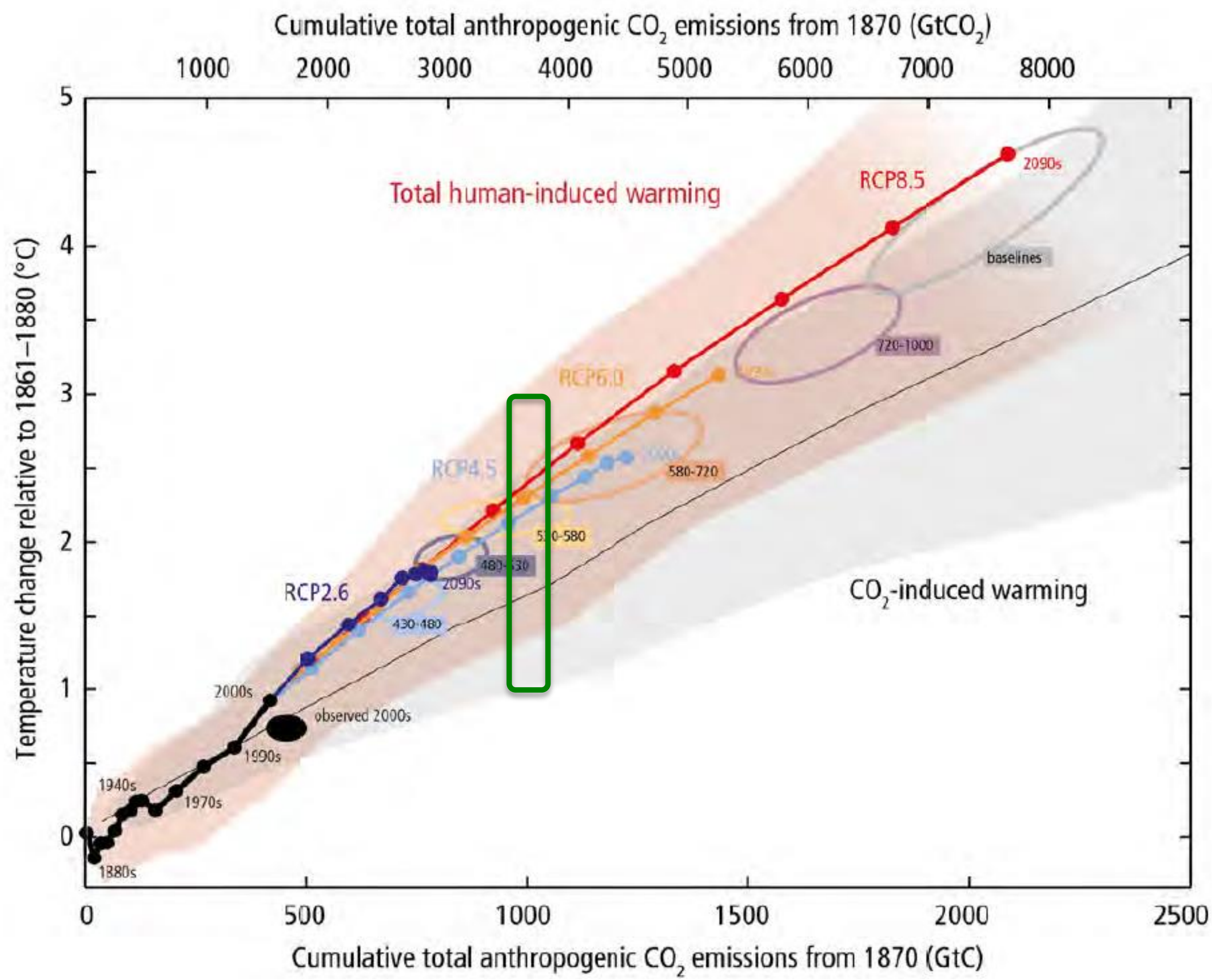
Z650 compared with AR5

Table 3.1 [TABLE SUBJECT TO FINAL COPYEDIT]

CO_2eq Concentrations in 2100 (CO_2eq)[6] Category label (conc. range)	Subcategories	Relative position of the RCPs[4]	Change in CO_2eq emissions compared to 2010 (in %)[3]		Likelihood of staying below a specific temperature level over the 21st century (relative to 1850-1900)[4,5]			
			2050	2100	1.5°C	2°C	3°C	4°C
< 430	*Only a limited number of individual model studies have explored levels below 430 ppm CO_2eq*[10]							
450 (430 – 480)	Total range[1,7]	*RCP2.6*	-72 to -41	-118 to -78	*More unlikely than likely*	*Likely*	*Likely*	*Likely*
500 (480 – 530)	No overshoot of 530 ppm CO_2eq		-57 to -42	-107 to -73	*Unlikely*	*More likely than not*		
	Overshoot of 530 ppm CO_2eq		-55 to -25	-114 to -90		*About as likely as not*		
550 (530 – 580)	No overshoot of 580 ppm CO_2eq		-47 to -19	-81 to -59		*More unlikely than likely*[9]		
	Overshoot of 580 ppm CO_2eq		-16 to 7	-183 to -86				
(580 – 650)	Total range	*RCP4.5*	-38 to 24	-134 to -50				
(650 – 720)	Total range		-11 to 17	-54 to -21		*Unlikely*	*More likely than not*	
(720 – 1000)[2]	Total range	*RCP6.0*	18 to 54	-7 to 72	*Unlikely*[8]		*More unlikely than likely*	
>1000[2]	Total range	*RCP8.5*	52 to 95	74 to 178		*Unlikely*[8]	*Unlikely*	*More unlikely than likely*

Z650 and Cumulative Emissions

Figure 2.3 [FIGURE SUBJECT TO FINAL COPYEDIT AND QUALITY CONTROL]



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There are multiple mitigation pathways that are *likely to limit warming to below 2°C relative to pre-industrial levels. These pathways would require substantial emissions reductions over the next few decades and near zero emissions of CO2 and other long-lived GHGs by the end of the century. Implementing such reductions poses substantial technological, economic, social, and institutional challenges, which increase with delays in additional mitigation and if key technologies are not available. Limiting warming to lower or higher levels involves similar challenges, but on different timescales. {3.4}*