Pragmatic approach towards climate change - a long-term analysis using an integrated assessment model

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1. Actions against climate change

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INTERGOVERNMENTAL PANEL ON climate change

Scenarios reaching atmospheric concentration levels of about 450 ppm CO_2eq by 2100

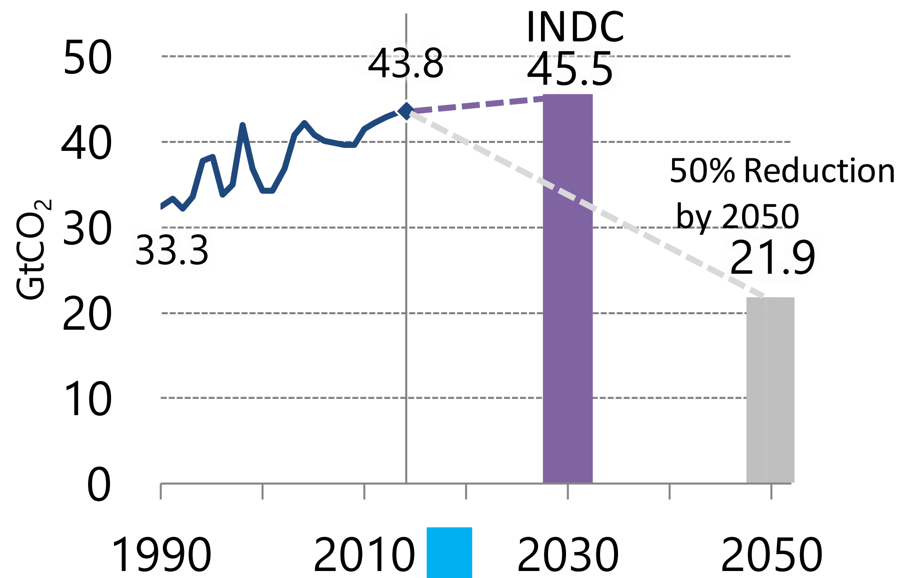
Lower global GHG emissions in 2050 than in 2010, 40 % to 70 % lower globally.

Emissions levels near zero $GtCO_2$eq or below in 2100

Excessive actions generate costs extremely

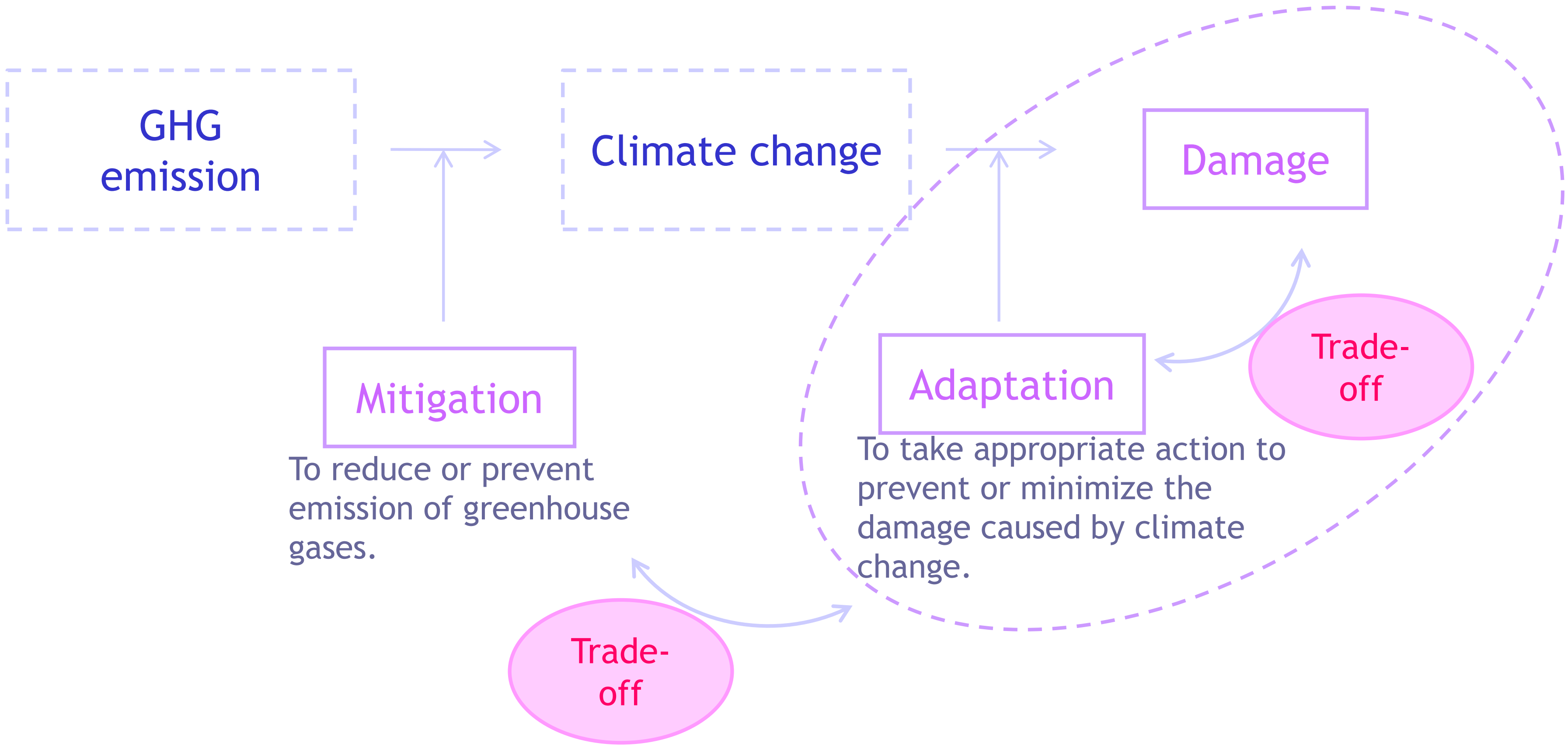
Paris Agreement

All nations into a common cause to combat climate change and adapt to its effects



Stronger energy and environmental policies are expected in the future.

1. Mitigation, damage costs and adaptation



-There is a trade-off relationship among the mitigation, damage costs, adaptation. It is impossible to reduce all three costs at the same time.
- It would be realistic to expect a balance among the three, while minimizing the total cost.

1.Objective and Scenarios

Objective

- Estimating CO_2 emissions, CO_2 concentration, Temperature rise, and total costs up to 2150 in four scenarios using an IEEJ Integrated Assessment model.

Scenarios

Reference Scenario reflects past trends as well as energy and environment policies that have been introduced so far.

50% reduction by 2050 Scenario assumes global GHG emissions decrease 50% from 2014 by 2050 and the trend continues afterwards.

Standard Scenario assumes that abatement costs decrease with technological progress under current model assumption

Technology Innovation Scenario assumes a future technological innovation moderates a sharp increase of marginal abatement cost at the range of high CO_2 reduction rate.

2.IEEJ Integrated Assessment Model

Major assumptions

GDP, population, energy prices, exchange rates, international trade, etc.

Macroeconomic model

Calculate GDP-related indices, price indices, activity indices including material production, etc. consistently.

Technology assessment model

Use a bottom-up approach to calculate future efficiencies of appliances, vehicles, etc.

Optimal power generation planning model

Calculate the cost-optimal power generation mix to meet the projected future electricity demand.

Energy supply-demand model

Econometric model to forecast future energy supply and demand by regression analysis of historical trends based on the energy balance tables data of the International Energy Agency (IEA).
This model calculates energy demand, supply and transformation as well as related indices including CO_2 emissions, CO_2 intensities and energy self sufficiency ratios.

Experts' opinions

MAC Curve

Climate change model

Calculate future GHG concentration in the atmosphere, temperature rise, damage caused by climate change, etc.

2.Climate change model(Mitigation Cost)

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Investment cost for a CO_2 abatement
up to 2050 applying Technology Assessment Model

- Energy-saving for each sector
- Efficiency of fossil-fuel power generation
- Nuclear
- Renewable
- Energy transmission and distribution
- Fossil fuel production and transportation
- CCS

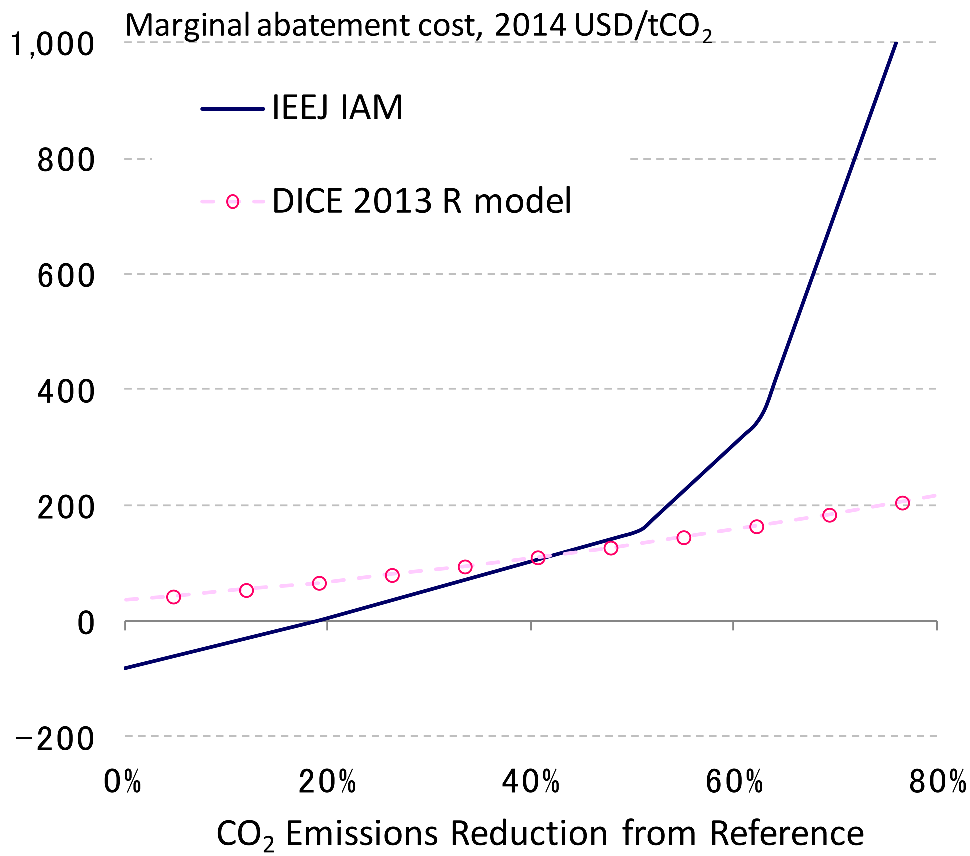
Estimated marginal abatement cost includes limitation of actual penetration rate of technologies

$$\Lambda(\mu) = I(\mu) - EC(\mu) \quad (1)$$

Λ:Abatement cost, I:Investment cost for a CO_2 abatement,
EC:Energy cost saving from the Reference Scenario, μ: Emissions reduction rate from the Reference Scenario

2.Marginal abatement cost in 2050

•Estimated marginal abatement costs increase sharply at the range of high CO_2 reduction rate.
•To moderate this sharp increase, future technological innovation is required



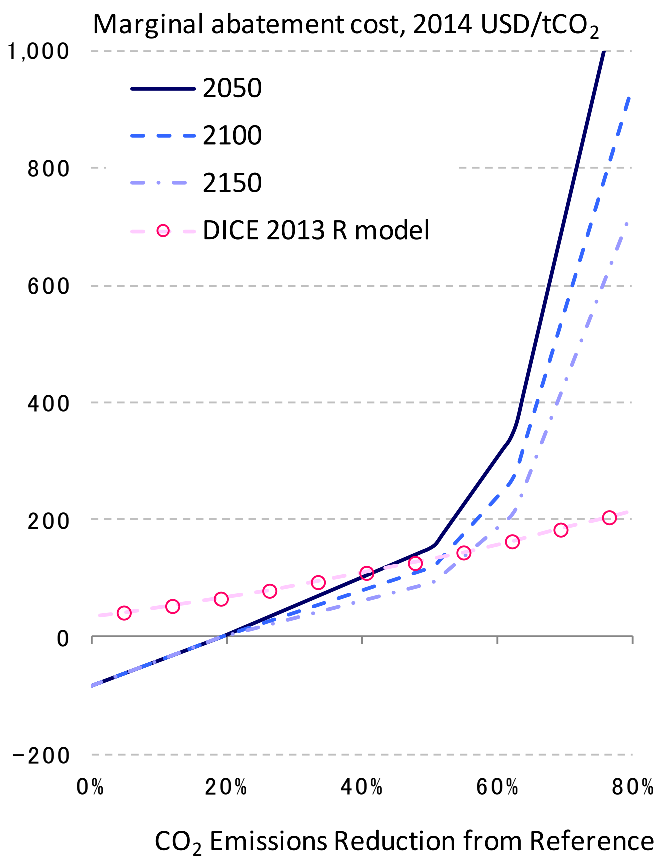
「DICE 2013R model by Prof. W. Nordhaus」

2.Marginal abatement cost after 2100

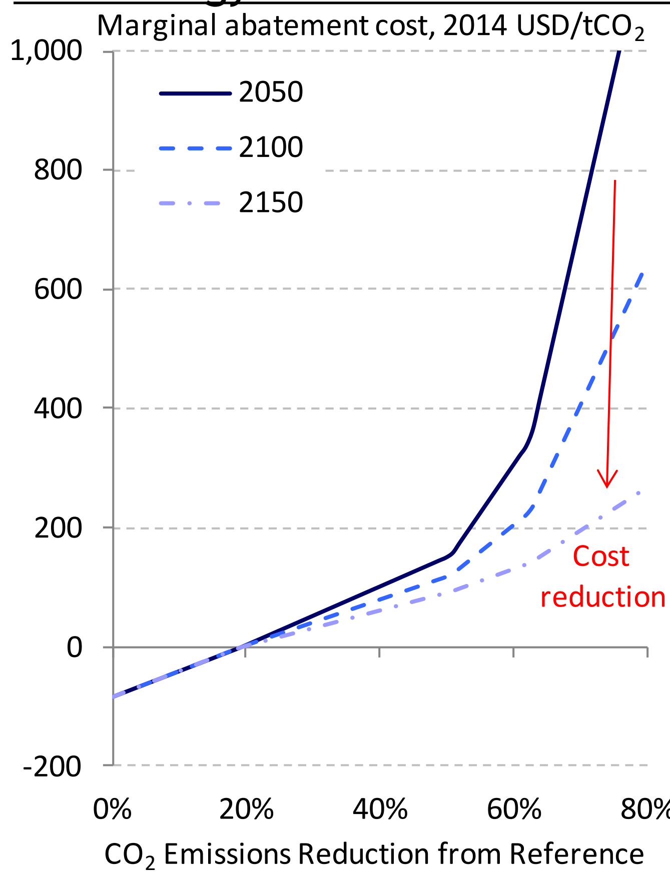
Mitigation cost decreases 0.5% per year by a technological progress

Further technological innovation is assumed at the range of high CO_2 reduction rate

Standard Scenario

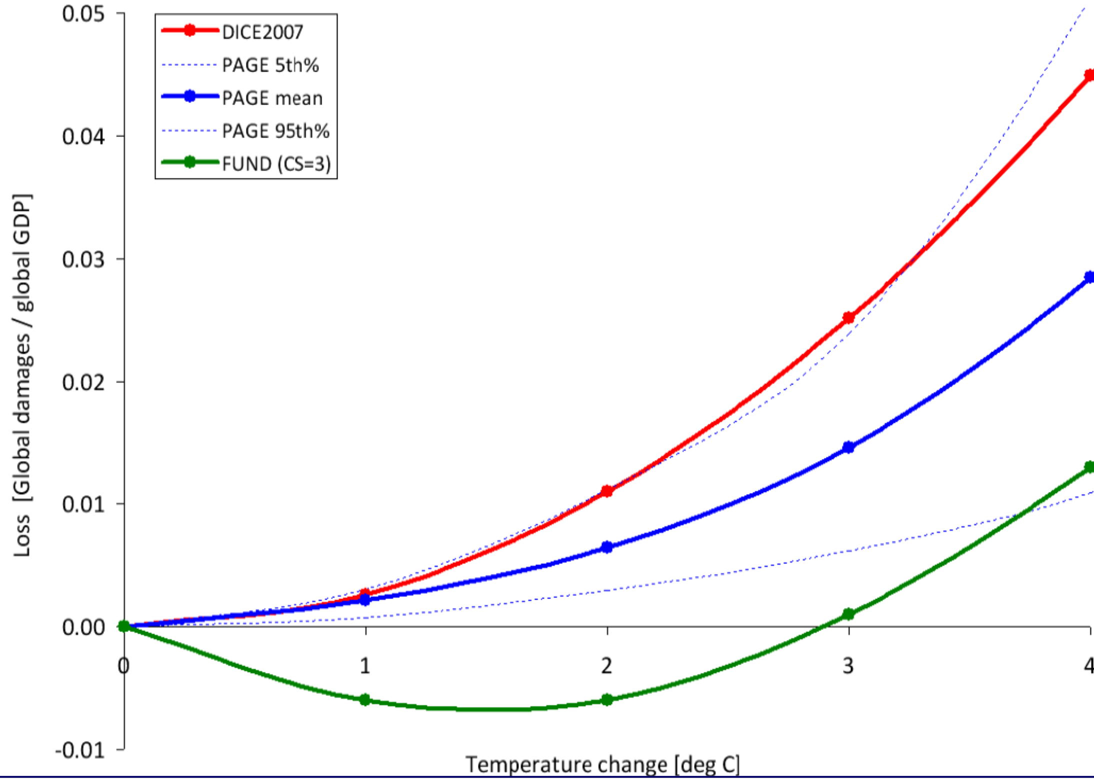


Technology Innovation Scenario



2.Climate change model（Damage and adaptation cost）

- The U.S. Interagency Working Group on Social Cost of Carbon compared climate change damage projections based on three comprehensive assessment models



- We apply the equations of DICE 2013 developed by Prof. W. Nordhaus to estimate adaptation costs and damage

2.Climate change model(Damage and adaptation cost)

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Damage and adaptation cost

- Agriculture
- Diseases and pollution
- Coastal area by sea level rise
- Ecosystems
- Energy use change
- Fewer chances for outdoor recreation (skiing and golfing)

$$R(t)/Q(t) = \frac{\Omega(t)}{\left[1+\Omega(t)^{\theta}\right]} \quad (2)$$

$$\Omega(t) = 0.0026\,T_{AT}(t)^{2} \quad (3)$$

R: Damage and adaptation cost, Q:Total Production, Ω:Damage function, θ:Adjustment factor of adaptation cost and damage, t:Time, T_{AT}: Temperature rise

2.Climate change model（Total Cost）

Total Cost

$$TC = \sum_{t=1}^{Tmax} \left(\frac{R(t) + \Lambda(\mu)}{(1 + \delta + \eta g)^t} \right) \quad (4)$$

TC:Total cost

δ:Pure rate of time preference

η:Elasticity of marginal utility with respect to consumption

g growth rate of total production

→δ+ηg: discount rate

Pure rate of time preference:1.5%

Elasticity of marginal utility with respect to consumption :1.45

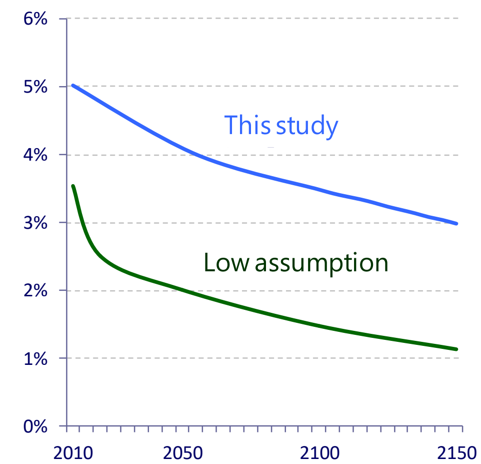
2.Uncertainty related to climate change model

Mitigation, adaptation and damage costs

- The estimation of these costs and damages are still at a very early stage. The uncertainty is extremely large.

Discount rate (social discount rate)

-With higher discount rates, future climate damages are valued less, resulting in smaller mitigation being optimal.
-This study assumes "normal" discount rates at around 4% in 2050, whereas the Stern Review assumes "low" discount rates at around 2% in 2050.



Equilibrium Climate Sensitivity (ECS)

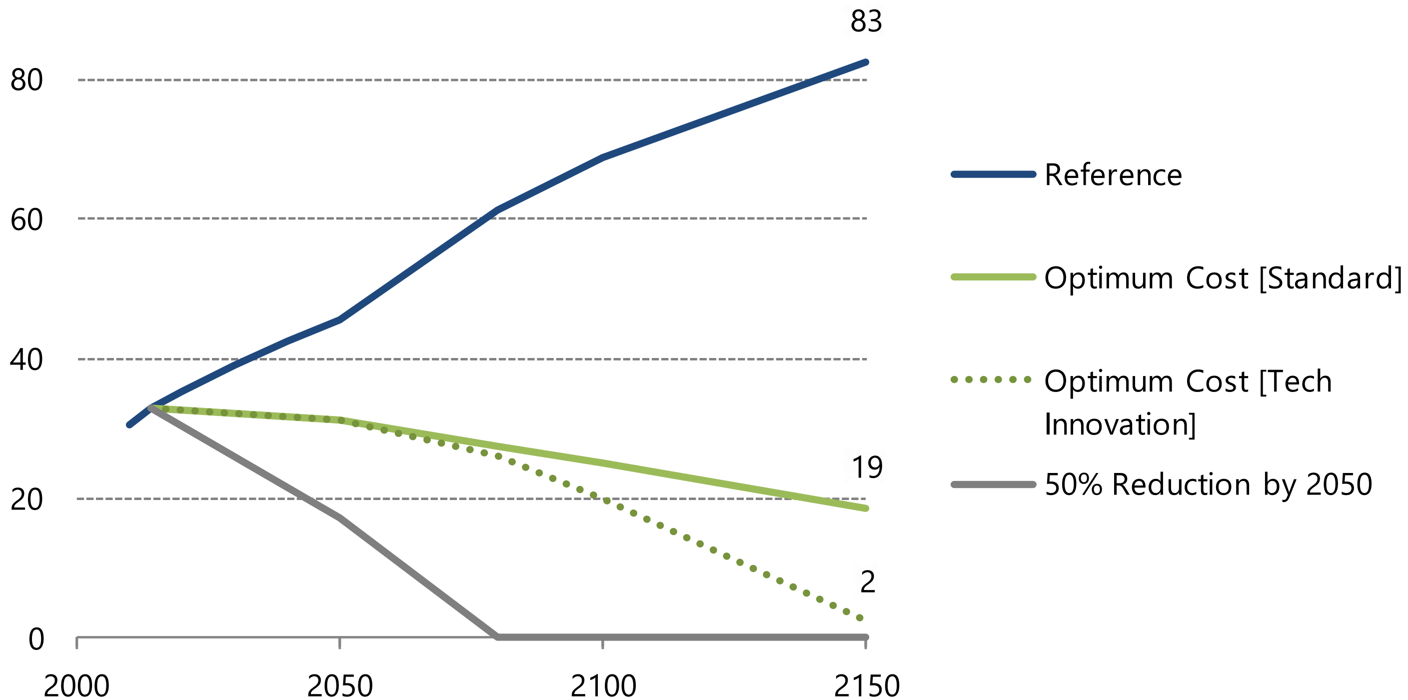
-The temperature change in response to the changes in the radiative forcing is called the Equilibrium Climate Sensitivity (ECS).
- In IPCC AR4, it was estimated at 2.0 – 4.5° C with the best estimate at 3.0° C. However, recent studies tend to estimate ECS lower. In IPCC AR5, it was estimated at 2.0 – 4.5° C without any agreement on the best estimate.
-With lower ECS, damage caused by climate change becomes smaller, resulting in a less ambitious mitigation path being optimal.

→ We apply 3.0° C in our analysis.

3.CO_2 emissions

In the Standard Scenario, CO_2 emissions gradually decrease and reach about 50% lower than the current level in 2150.

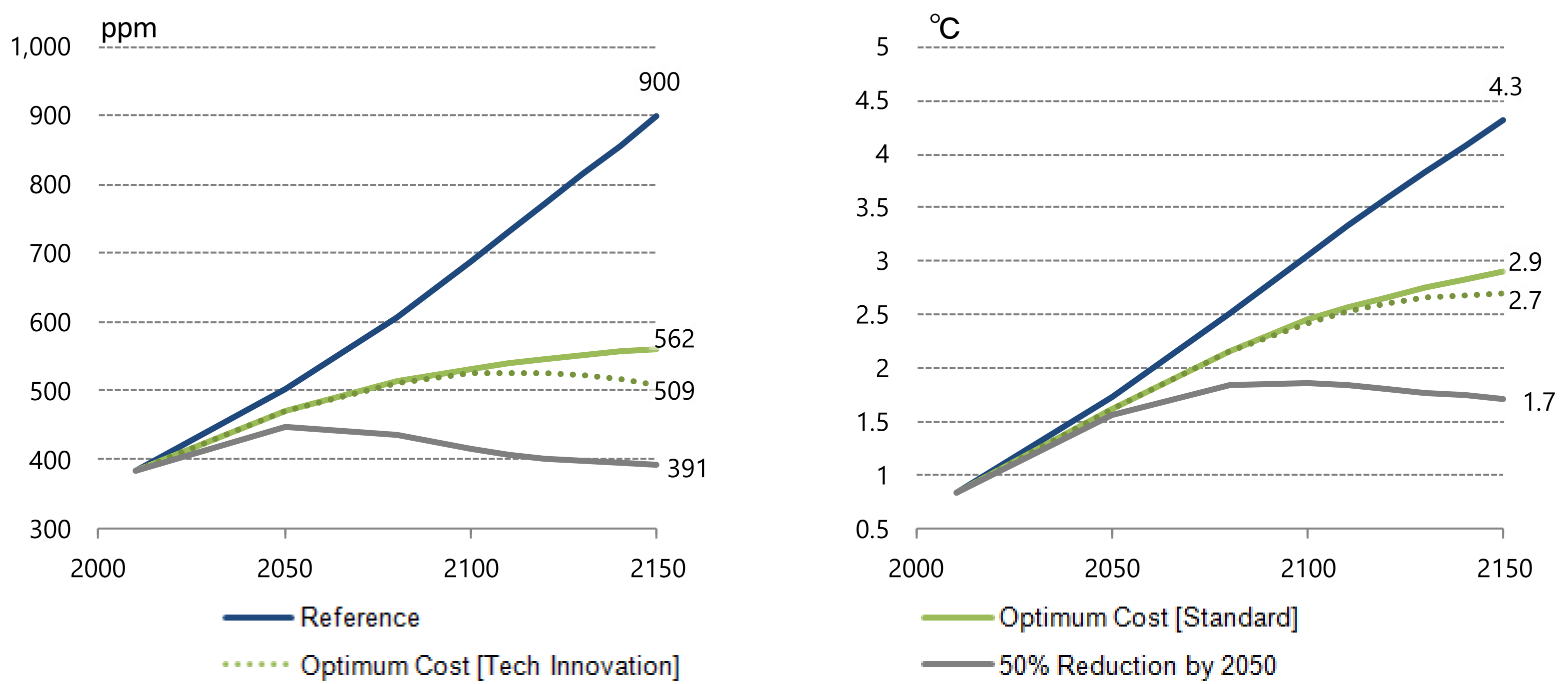
CO_2 emissions of the Technological Innovation Scenario rapidly decrease after 2100 and reach almost zero emissions in 2150.



Developing innovative technologies much faster than current level is essential in order to achieve nearly zero emissions in the whole world.

3. CO_2 concentration and temperature rise

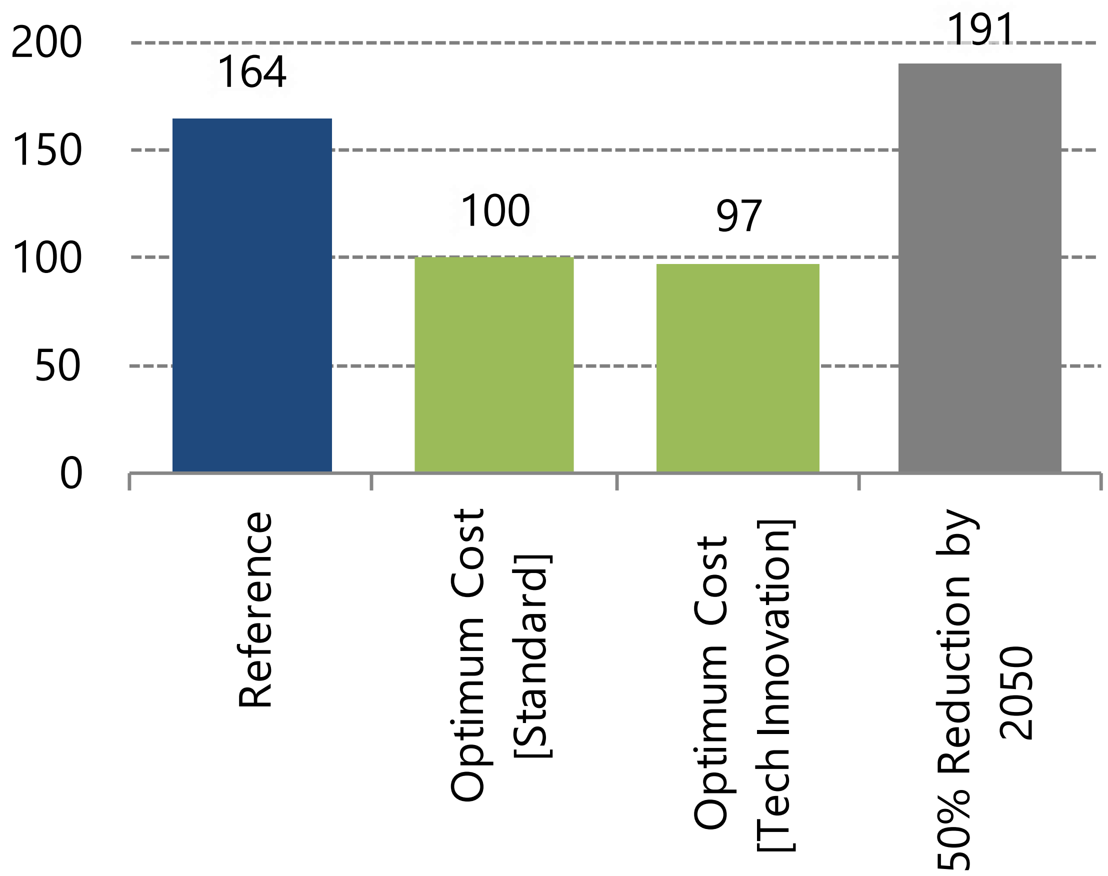
•In the Standard Scenario, CO_2 concentration and temperature rise continues at a longer term, that is "cost optimum" but not "sustainable".
•On the other hand, Temperature rise in the Technology Innovation Scenario reaches the peak of 2.7° C around 2150 and start to go down and reach about 2° C after 2150, that is "cost optimum" and also "sustainable".



Technological innovation is essential to achieve sustainable development.

3.Total cost

Total cost in the Standard Scenario and Technology Innovation Scenario is much lower than the Reference Scenario and 50% Reduction by 2050.



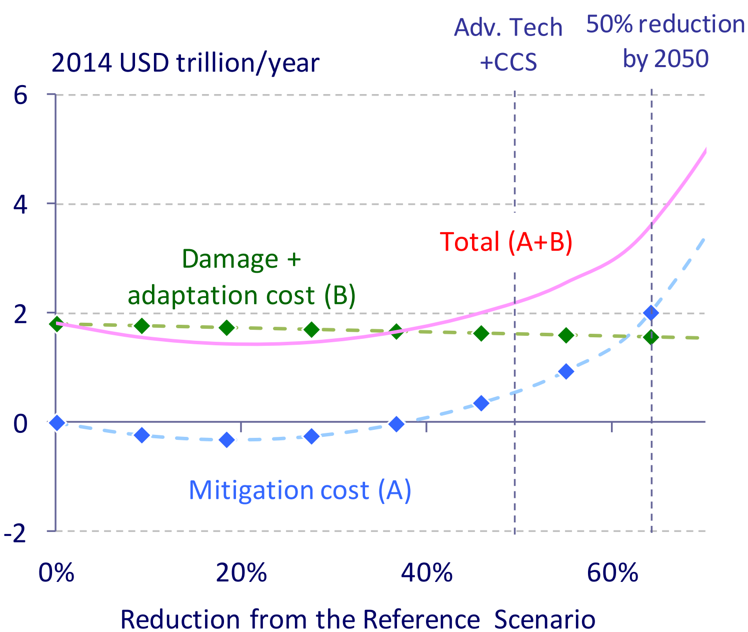
4.Conclusion

- Even though uncertainties such as mitigation, adaptation and damage costs, equilibrium climate sensitivity, and discount rate would affect optimum emissions path, we find that optical path is somewhere between the Reference Scenario and 50% reduction by 2050 Scenario.
- Human cannot control discount rate and equilibrium climate sensitivity, however, we can reduce mitigation costs by lowering current low carbon technologies' costs and developing innovative technologies.
- Developing innovative technologies including in both energy demand and supply side is essential to become sustainable. We need to encourage technology development in a long view as well as implementing appropriate climate policies continuously.

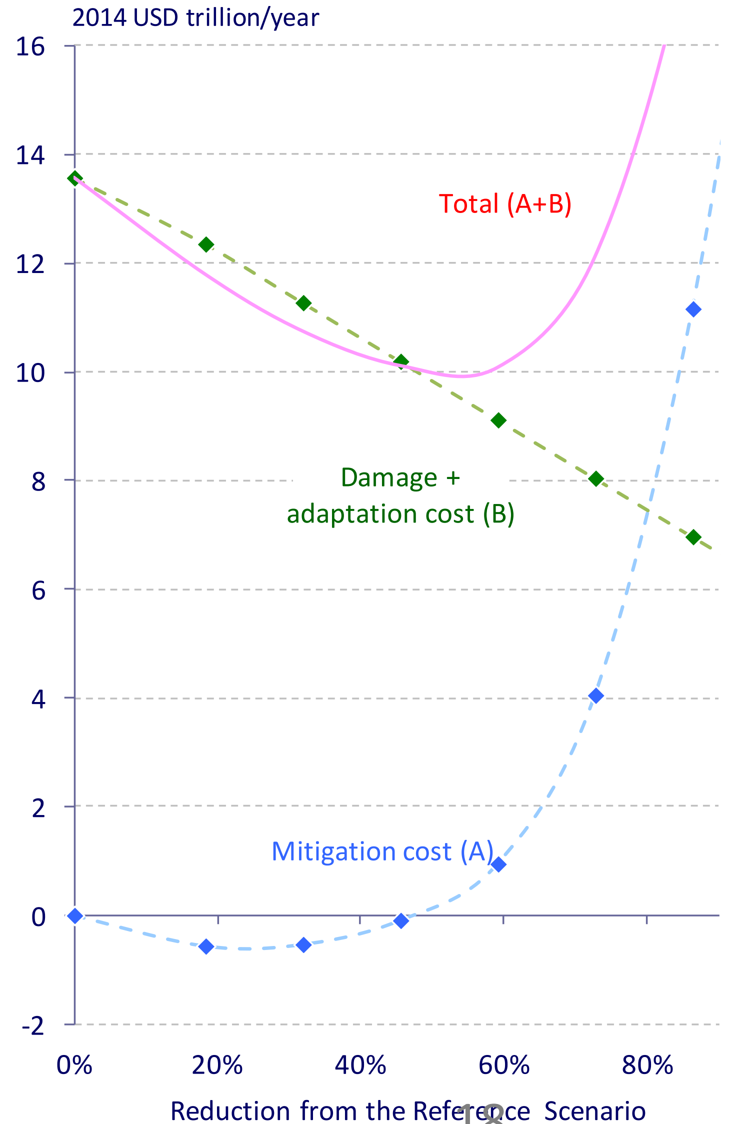
Mitigation vs. adaptation and damage

Mitigation cost: estimated by IEEJ
Damage + adaptation cost: calculated using the formula in the DICE 2013R model
Equilibrium Climate Sensitivity assumed at 3° C.

- In 2050 the temperature rise is relatively small (less than 2° C from the latter half of the 19th century), resulting in smaller damage.
- CO_2 reduction brings benefits (negative costs) to a certain extent due to the savings of fossil fuel consumption. If the reduction ratio exceeds that of the Advanced Technologies Scenario, however, the cost increases enormously.
- The damage costs also become tremendous after 2100. Thus a long-term perspective is indispensable to address the problem of climate change.



2050



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