LIVE WEBINAR

ENERGY OUTLOOK TOWARD 2050 AND POST CORONA SCENARIO

25 FEBRUARY 2021 (THURSDAY)

10.30 AM – 11.30 AM (GMT+8KL)

SCAN ME

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PROF. DR. KEN KOYAMA
Chair in Energy Economics of Energy Commission at UNITEN

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SPEAKER

PROF DR. KEN KOYAMA

- CHAIR IN ENERGY ECONOMICS OF ENERGY COMISSION AT UNITEN
- CHIEF ECONOMIST/ MANAGING DIRECTOR, INSTITUTE OF ENERGY ECONOMICS, JAPAN (IIEJ)

A Japanese View on World Energy Future
IEEJ Outlook 2021

Energy Talk Webinar

February 25th, 2021

Prof. Dr. Ken Koyama

Chair in Energy Economics of Energy Commission at UNITEN
Chief Economist & Senior Managing Director, Institute of Energy Economics, Japan

Emerging global energy landscape

- **Unprecedented impact of COVID-19 pandemic**
- **Emerging over-supply and lower energy prices**
- **Impact of US "Shale Revolution"**
- **Impact of the next US Administration?**
- **Asia as a gravity center of world energy demand**
- **Energy Geopolitics revisited**
- **Waves of carbon neutral target**
- **Expectation for advanced and innovative technology**

Scenarios of IEEJ Outlook 2021

■ Regular scenarios

- **Reference Scenario (RS): Business-as-usual future**
- **Advanced Technology Scenario (ATS): Maximum introduction of energy related technologies (Bottom-up approach)**

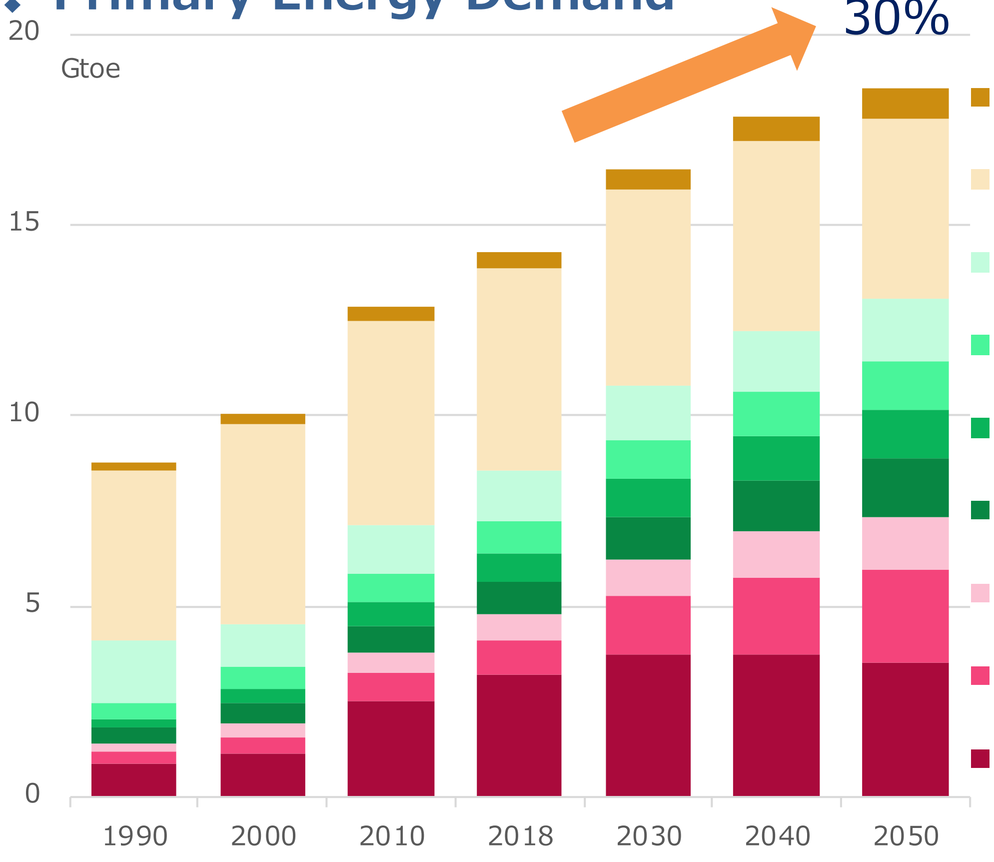
■ This year's highlight

- **Post-Corona World Transformation Scenario (PCS)**
- **Circular Carbon Economy/4R Scenario: (CCE)**
- **Update of Cost-Benefit (Total Cost Minimization) Analysis of Climate Change**

Reference

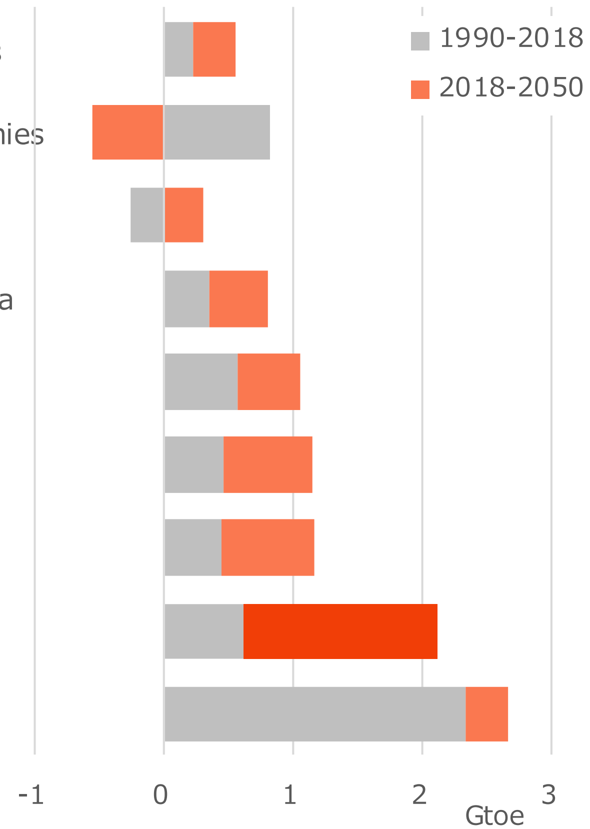
Demand growth shifts from China to India

Primary Energy Demand



*EDE: Emerging and Developing Economies

Growth (1990-2050)



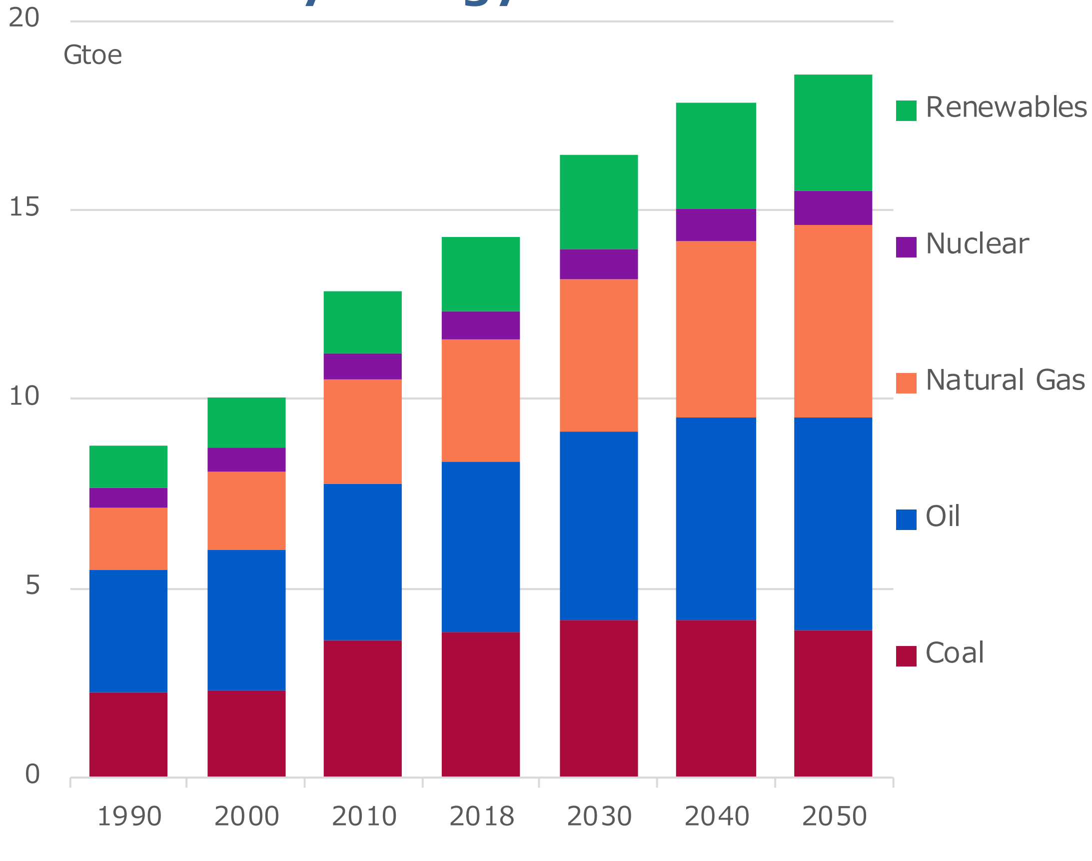
Energy demand in emerging and developing countries increases by more than 50%, while that in advanced economies decreases by about 10%.

The global energy demand growth changes from China to India. More than one-third of the global demand growth comes from India, while China's demand peaks in the late 2030s.

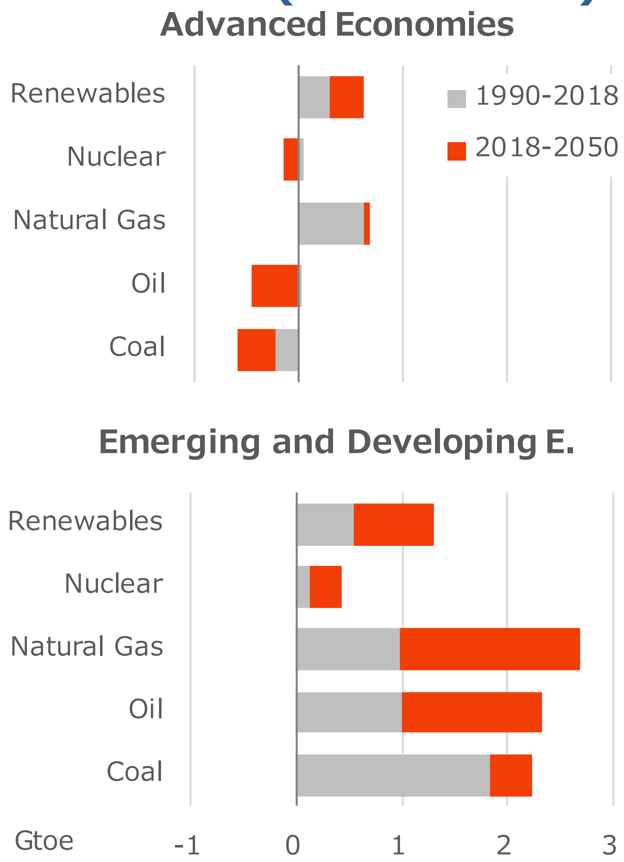
Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Coal peaks out, NG increases significantly, Oil continues to gradually increase

❖ Primary Energy Demand



❖ Growth (1990-2050)



Natural gas increases the most, especially in the power generation sector, making it the second largest energy source after oil. The growth in oil consumption in emerging and developing countries by far counter-balances the decrease in advanced economies. Coal demand peaks in the mid-2030s due to a decline in advanced economies and China.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

"Post Corona World Transformation Scenario (PCS)"

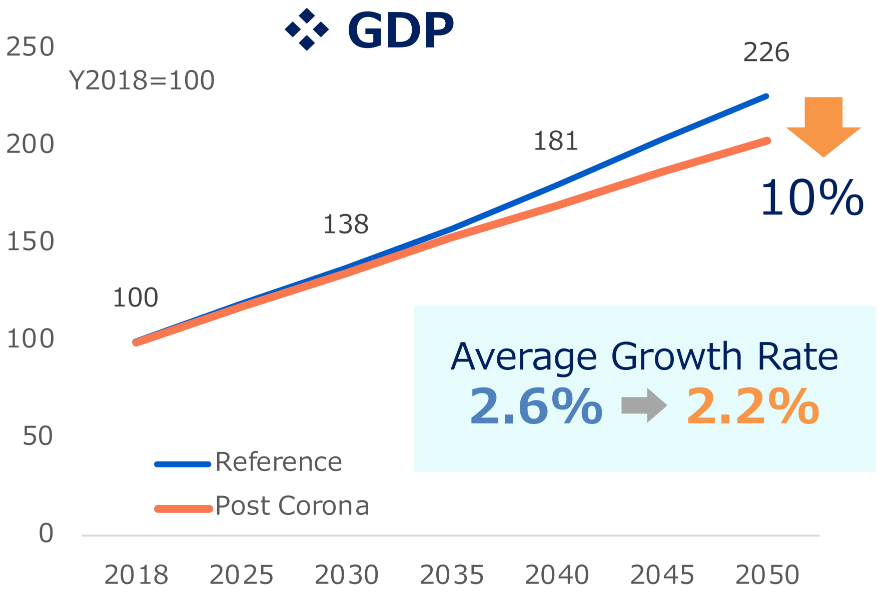
Reference Scenario	Business-as-usual future. Ongoing trends continue for technology progress and energy/environment policies.	
Post Corona World Transformation Scenario	A world in which the coronavirus pandemic causes transformation and changes in politics, economy and society. Strengthening climate measures continues, but the extent of efforts differs in each country/region.	
	Emphasis on security	**Progress of digitization**
Changes in consciousness and behavior	・Ensuring the safety and health of people, including measures against infection. ・Reviewing global supply chains, based on the emphasis on security.	・Increase in remote activities to reduce/avoid people's movements and personal contacts. ・Decentralization from large cities is emerging.
Changes are accelerating	・The worsening of US-China relations drives high political tensions between nations. ・Me-first and Nationalism leading to deviation from the free trade system.	・Accelerating ICT to support and establish remote/online economic activities. ・Reduced movement of people lead to stagnation in transportation demand.
Consequences of the changes	・Global economy slows down. Manufacturing base shifts from China to India /ASEAN. ・Strengthening efforts to diversify energy supply and improve self-sufficiency. Competition for technology hegemony.	・As society becomes more digital, electricity demand increases. ・Reduction in oil demand, especially for transportation fuels .

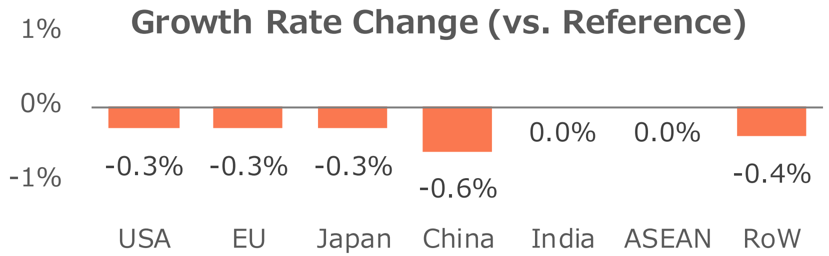
Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Post-Corona

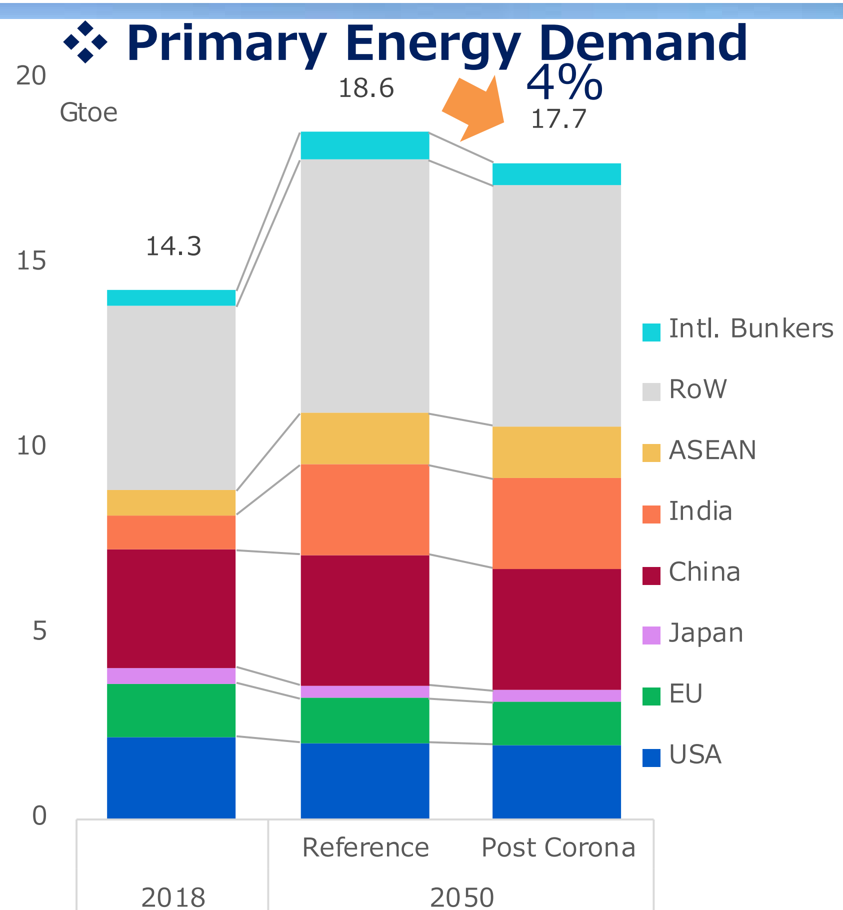
IEE JAPAN

Economic growth slows and energy demand curtails





Ref.) During the Great Depression of 1929, about 10% of GDP was lost in three years.



Note) The EU (European Union) does not include the United Kingdom. The same shall apply hereafter. RoW: Rest of the world

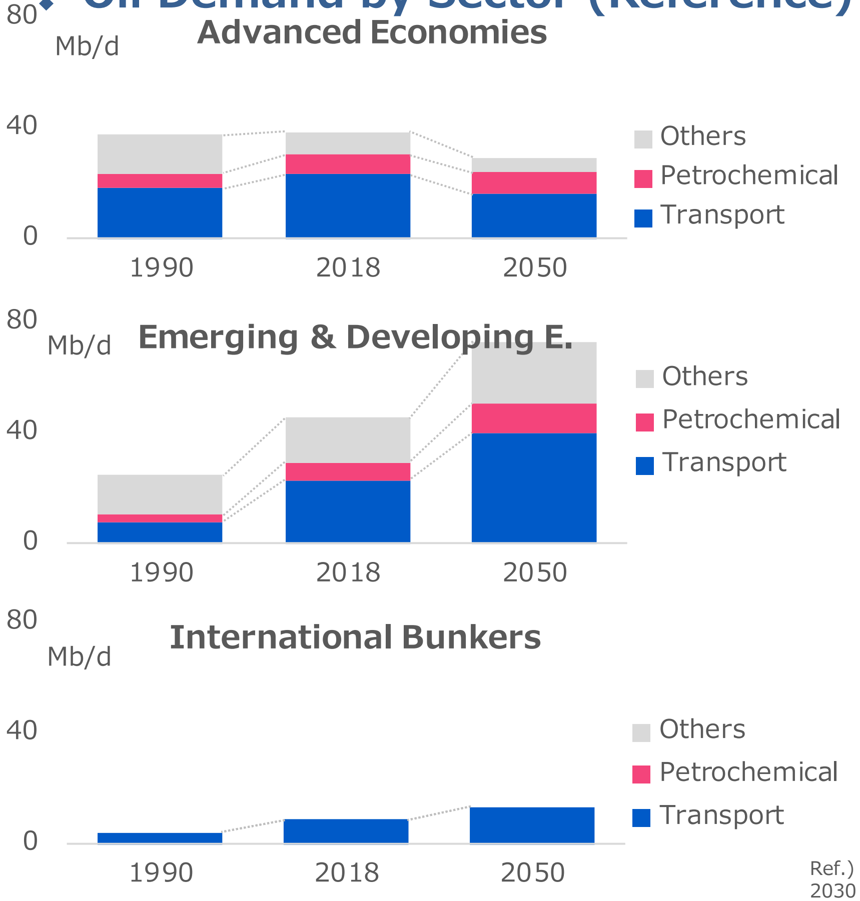
In the Reference scenario (RS), energy demand increases by 30%, with more than 60% of the increase coming from the Asian region.

In the Post Corona scenario (PCS), stagnation in free trade causes the world economy to shrink 10% by 2050. With leakages in production bases, China's economy significantly slows down. Global energy demand shrinks by 4%, but concentration in Asia remains unchanged.

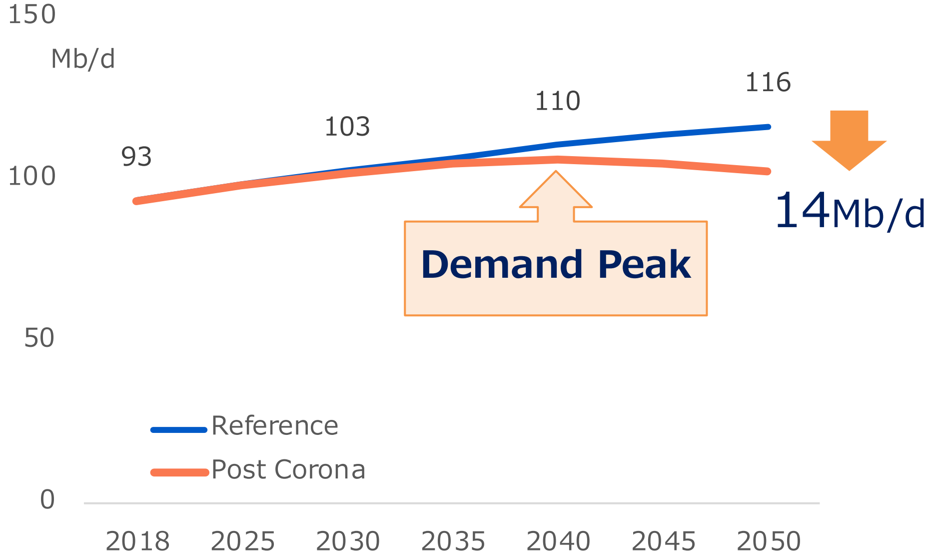
Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

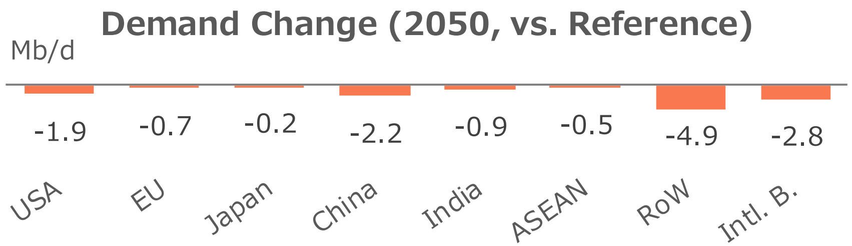
Oil demand peaks due to stagnation in transportation

Oil Demand by Sector (Reference)



Oil Demand in Post-Corona





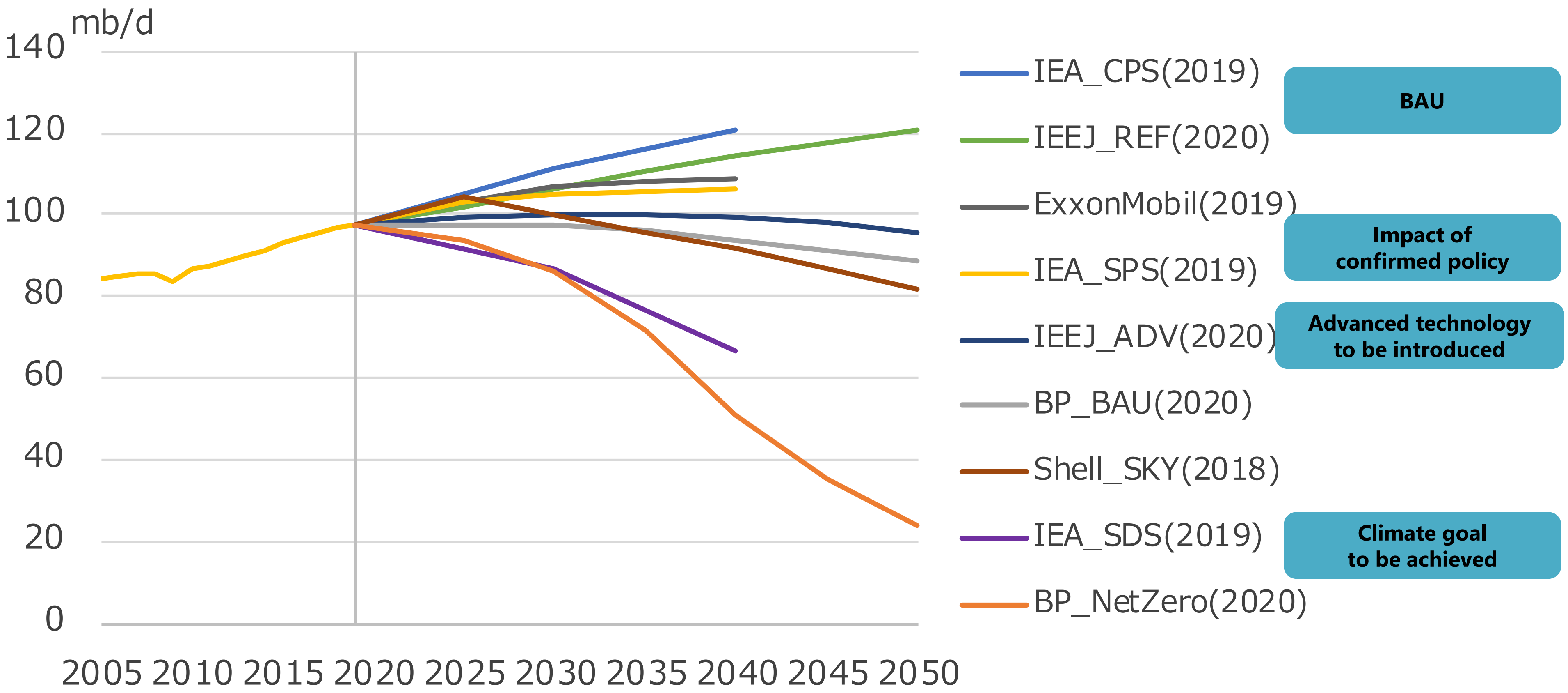
Ref.) It is estimated that if the electrification of automobiles progresses rapidly, it will reach its peak around 2030 (IEEJ Outlook 2018).

In the RS, global oil demand grows primarily because of transportation fuels and petrochemical feedstocks. In advanced economies, however, demand for transportation fuels is declining.

In the PCS, oil demand peaks around 2040. Fuel demand for automobiles, aviation, and ships declines due to economic slowdown and associated lower transportation requirements.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Comparison of oil demand outlook

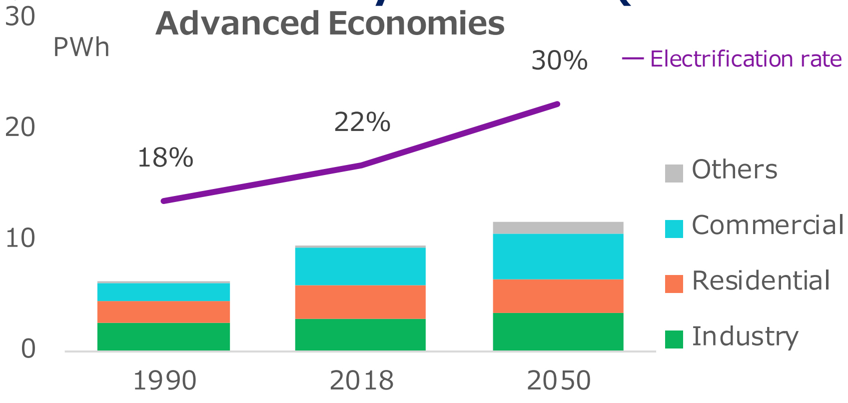


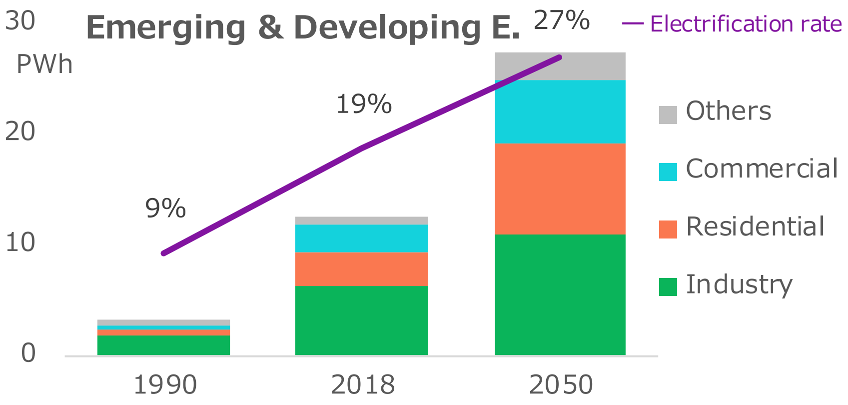
Source: Yasuaki Kawakami(IEEJ, October 2020) with some additions by the author

Post-Corona

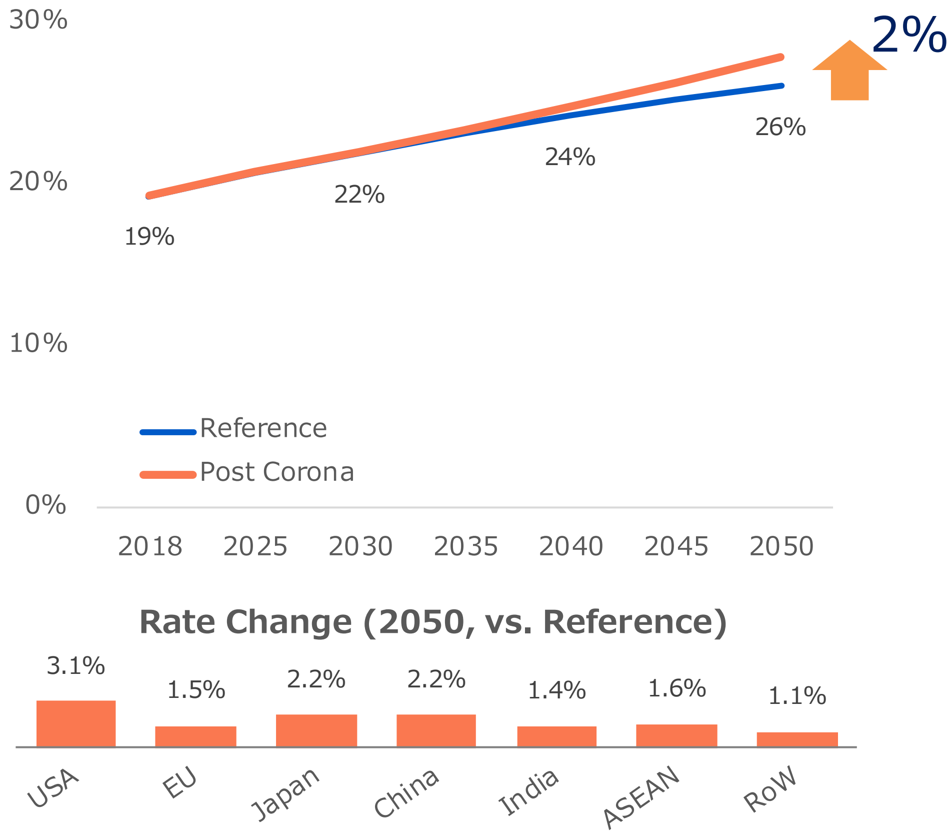
Digital transformation(DX) raises electrification rate

Final Electricity Demand (Reference)





Electrification Rate in Post-Corona



In the RS, electricity demand in the industry and building sectors surged along with the economic development of developing countries. Energy demand becomes more electrified.

In the PCS, digital transformation (DX) supports remote economic activities and further promotes electrification. The issue is the balance between privacy protection and information management by governments. There are two patterns, “centralized” and “distributed”, and there are various differences.

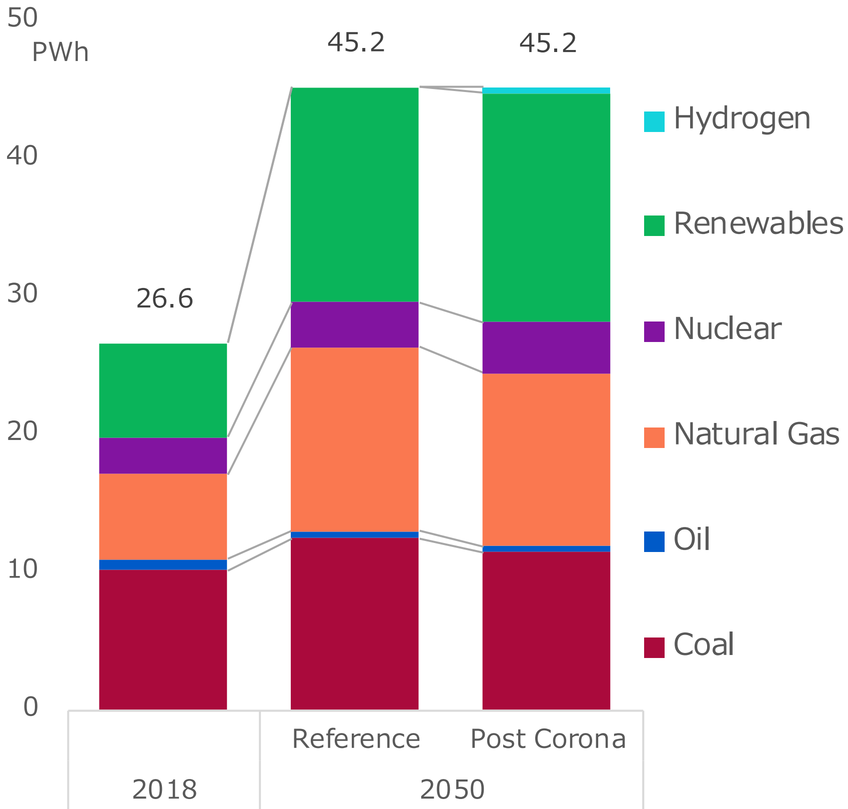
Source: “IEEJ Outlook 2021” (IEEJ, October 2020)

"4D challenges" in the electricity sector

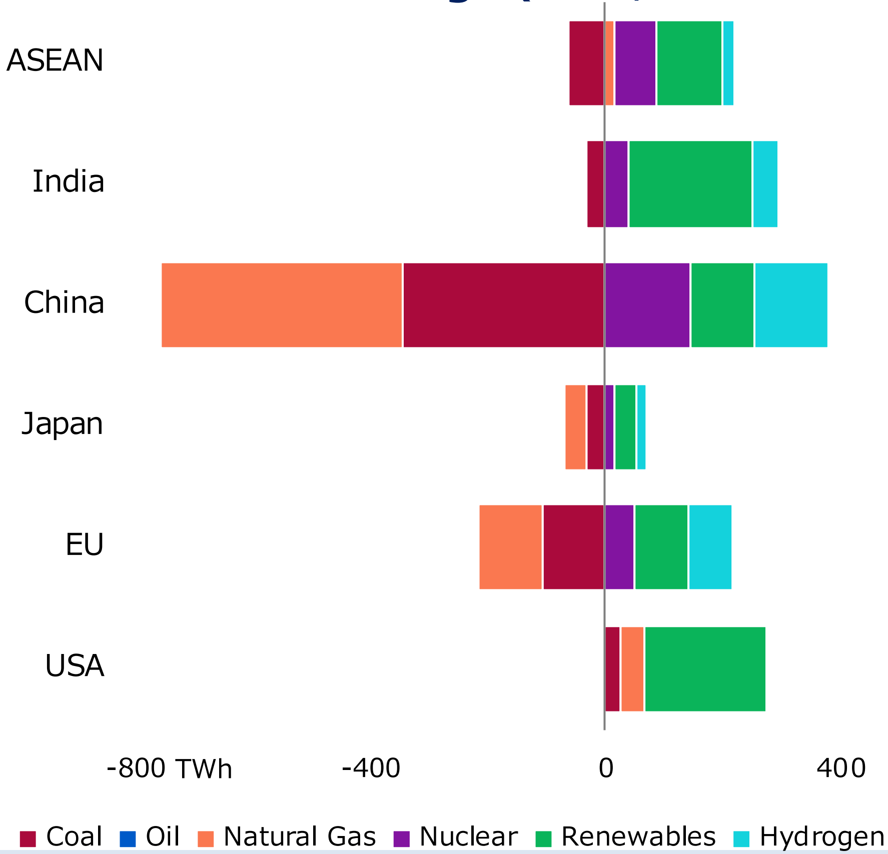
- **Decarbonization : How to tackle with ambitious GHG reduction**
- **Deregulation : Response to changes caused by market reform/liberalization**
- **Digitalization : Electricity as increasingly important in digital society, but...**
- **Decentralization : Need to respond to shift to decentralized society**
- **Complicated relations among "4D challenges", including "trade-off" relations**
- **At the same time, price affordability and supply stability/security in electricity continue to be a top priority**
- **Large scale increase in VRE, implications of market reform (reduced supply surplus/cussion), cyber security, extreme weather, etc. have emerged as new risks/threats to electricity security of supply**

Power generation shifts to non-fossil power sources, including hydrogen

❖ Power Generation Mix



❖ Generation Change (2050, vs. Reference)



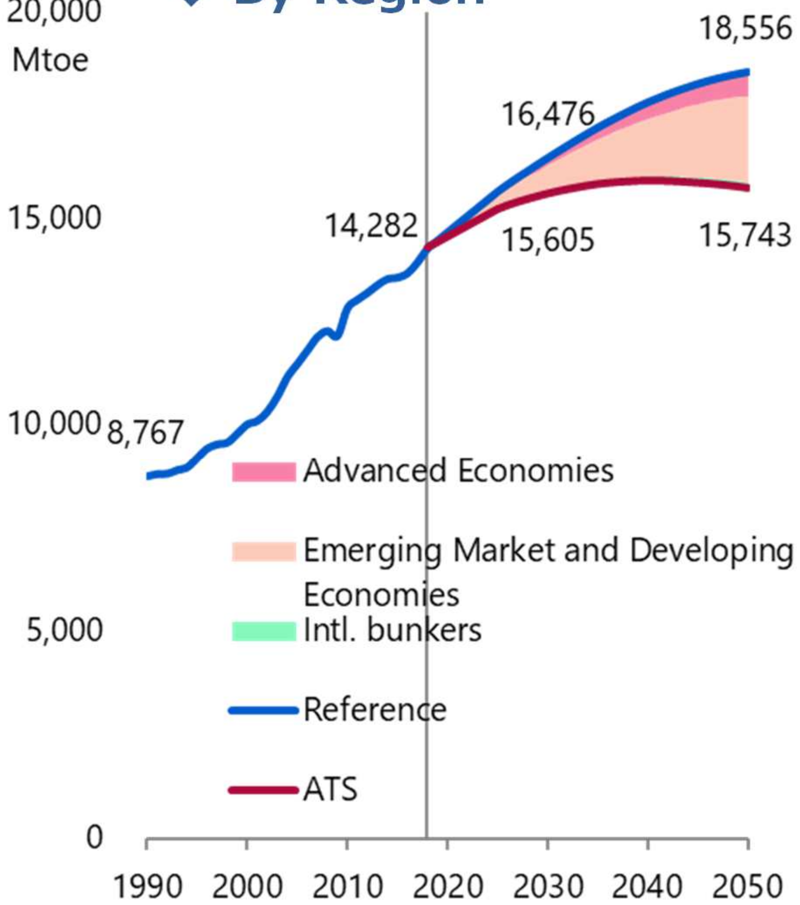
In the RS, gas-fired power and renewable energy support the rapidly increasing electricity demand. Coal-fired power is still needed in developing countries.

In the PCS, the shift to nuclear and renewable energy sources progresses, while the use of natural gas, which is highly dependent on imports, is curtailed. As competition for the development of innovative technologies progresses, hydrogen begins to be used for power generation. For more on hydrogen introduction, see "Circular Carbon Economy / 4R Scenario".

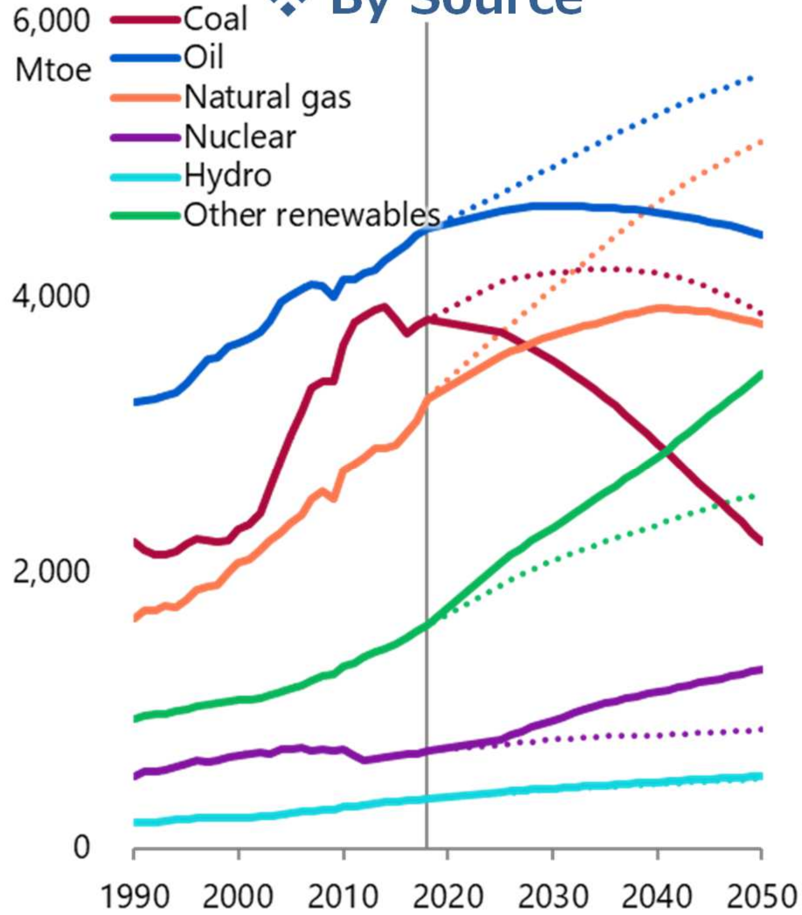
Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Total Primary Energy demand (World)

❖ By Region



❖ By Source

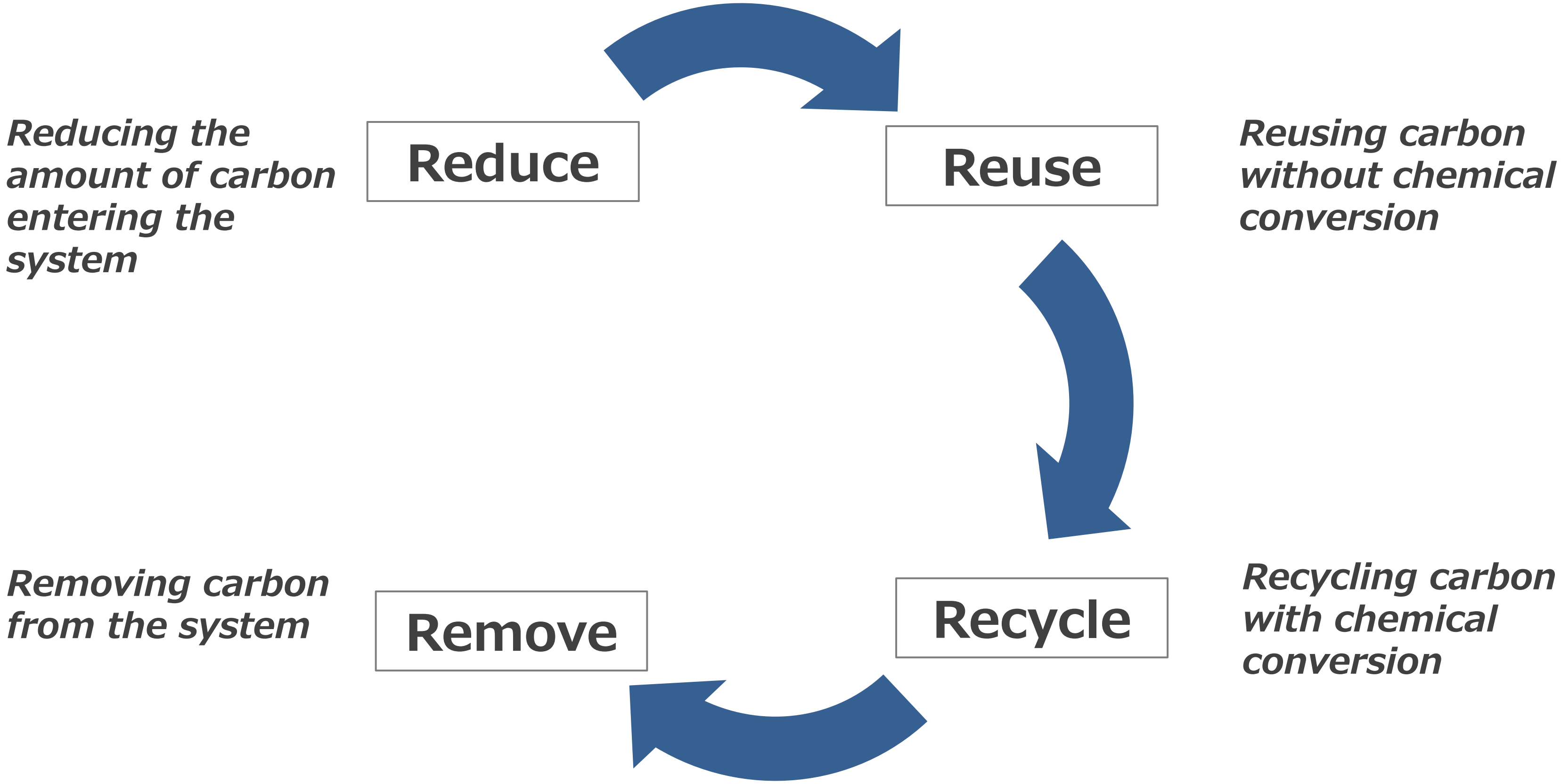


The world's energy demand in ATS is lower by 15% compared to Reference largely because of the energy saving by emerging countries.

The world will remain dependent on fossil fuels for 67% of the total demand as of 2050.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Circular Carbon Economy: CCE



Circular Carbon Economy (CCE) is a holistic approach to manage carbon emissions as a closed circular system.

CCE aims to utilize all available emissions reduction technologies by the "4R" steps (Reduce, Reuse, Recycle, and Remove).

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Assumptions of CCE Scenario

Assumed adoptions of 4R technologies in CCE scenario

4R	Technology	Assumption
Reduce	Blue hydrogen* for power generation	Adopt blue hydrogen power generation (including ammonia produced from blue hydrogen) for 50% of coal-fired power plants without CCS facility as of 2050 in Advanced Technology Scenario (ATS)
	Blue hydrogen for transportation	Adopt blue hydrogen (mainly as fuel cell vehicle) to 20% of road transportation demand as of 2050
	Direct reduction in steel making by blue hydrogen	Adopt direct reduction technology utilizing blue hydrogen to 25% of crude steel production in OECD, China, and India as of 2050
	Reduction of cement production	Reduction of cement production by 25% utilizing coal ash and limestone and calcined clay as of 2050
Reuse	Algae synthesis to produce biofuel	Increase algae-based bio-diesel by 50% from ATS
Recycle	Concrete curing capturing CO_2	Adopt concrete curing capturing CO_2 technology to 50% of the world concrete production as of 2050
	Synthetic methane	Replace natural gas with synthetic methane (produced from blue hydrogen and green hydrogen**) for 50% of gas-fired power plants without CCS facility as of 2050 in ATS
Remove	Carbon capture and storage	CCS for blue hydrogen production

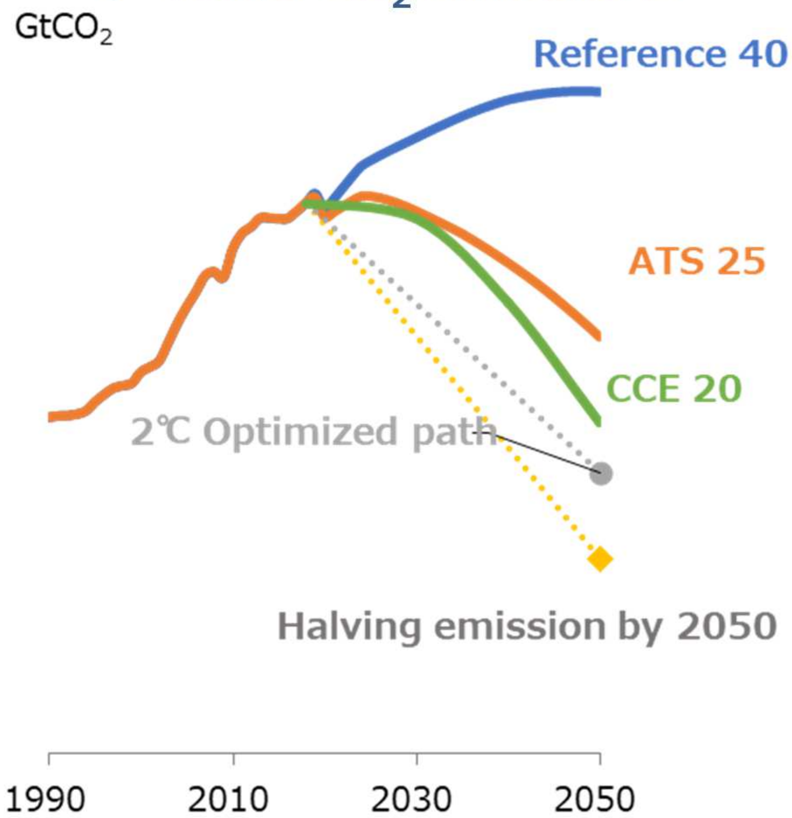
*Blue hydrogen : Hydrogen produced from fossil fuels with CCS
**Green hydrogen : Hydrogen produced by electrolysis utilizing electricity from renewable power generation

CCE scenario assumes the utmost adoptions of 4R technologies for carbon-neutral use of fossil fuels with all other assumptions based on Advance Technology Scenario.

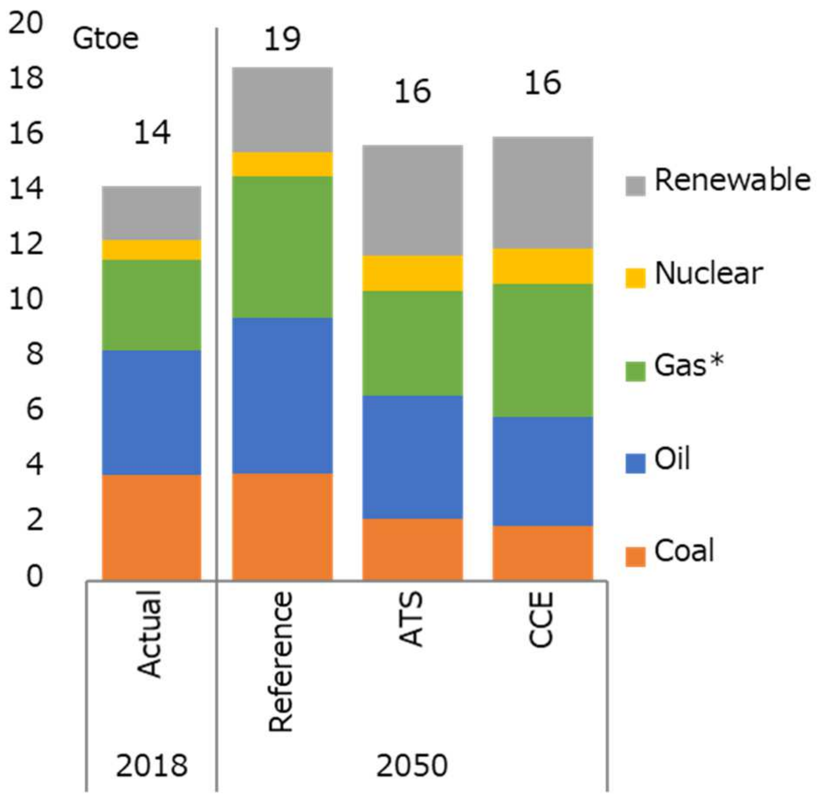
Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Emissions reduced while using fossil fuels

World CO_2 Emissions



World Primary Energy Demand



*Gas in CCE scenario includes synthetic methane

CO_2 emissions are reduced by 5Gt from ATS and approaches 2℃ optimized path.

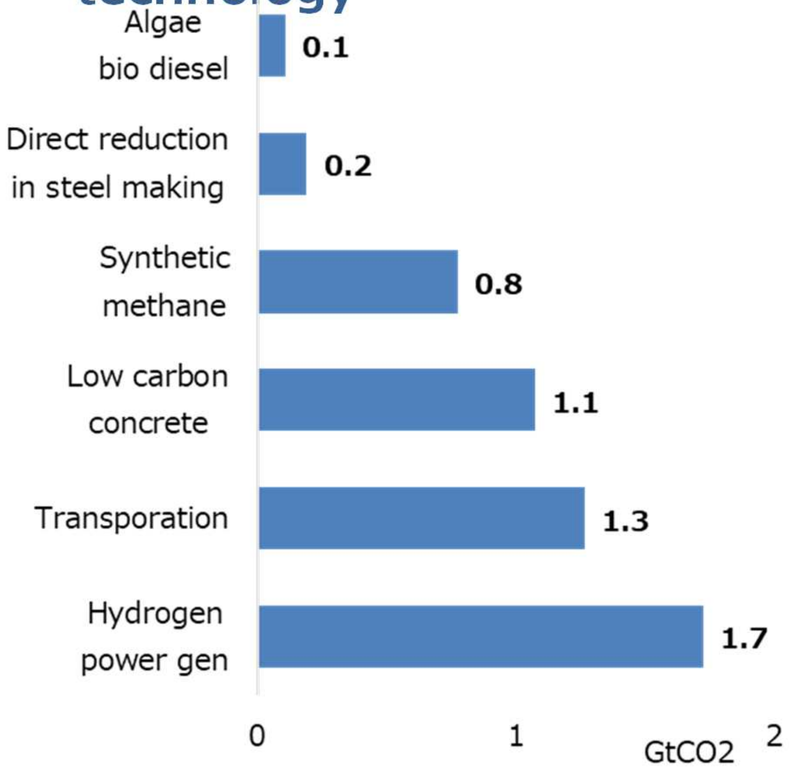
While the share of fossil fuels of CCE scenario is almost same as ATS', the mix of fossil fuel shifts from coal and oil to natural gas as a primary feedstock of blue hydrogen.

CO_2 emissions significantly reduced while the consumption of fossil fuel unchanged.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

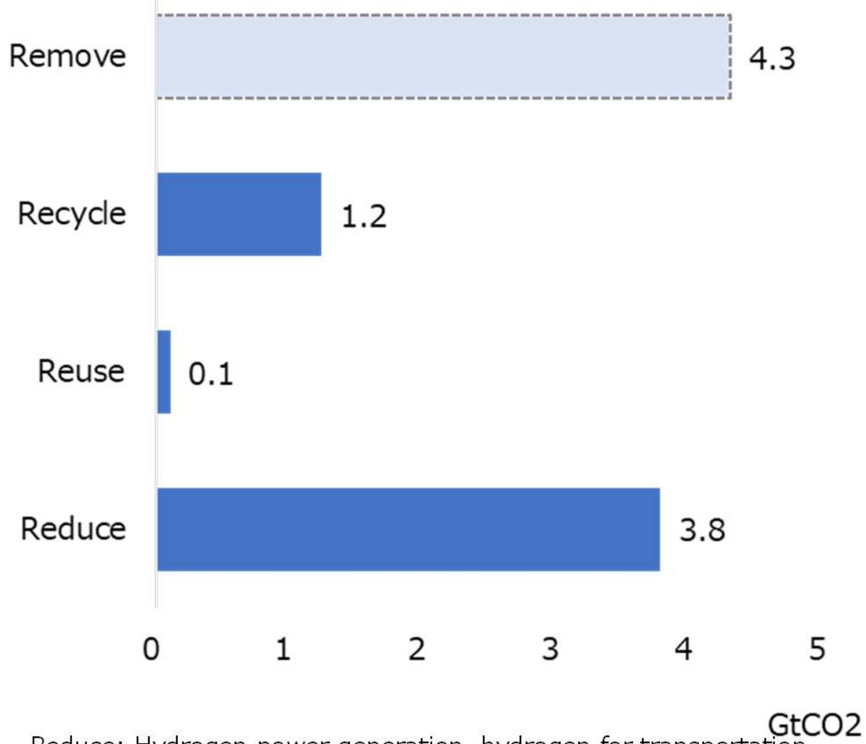
Power and transport have large reduction potential.

❖ CO_2 emissions reduction by technology



＊ The amount of Low carbon concrete is the sum of reduced volume of cement production reduction and concrete curing absorbing CO_2.

❖ CO_2 emissions reduction by 4R



Reduce: Hydrogen power generation, hydrogen for transportation, cement production reduction, direct reduction of steel making
Reuse : Algae biodiesel
Recycle : CO_2 absorbing concrete, synthetic methane
Remove: CCS（also counted in Reduce and Recycle technologies）

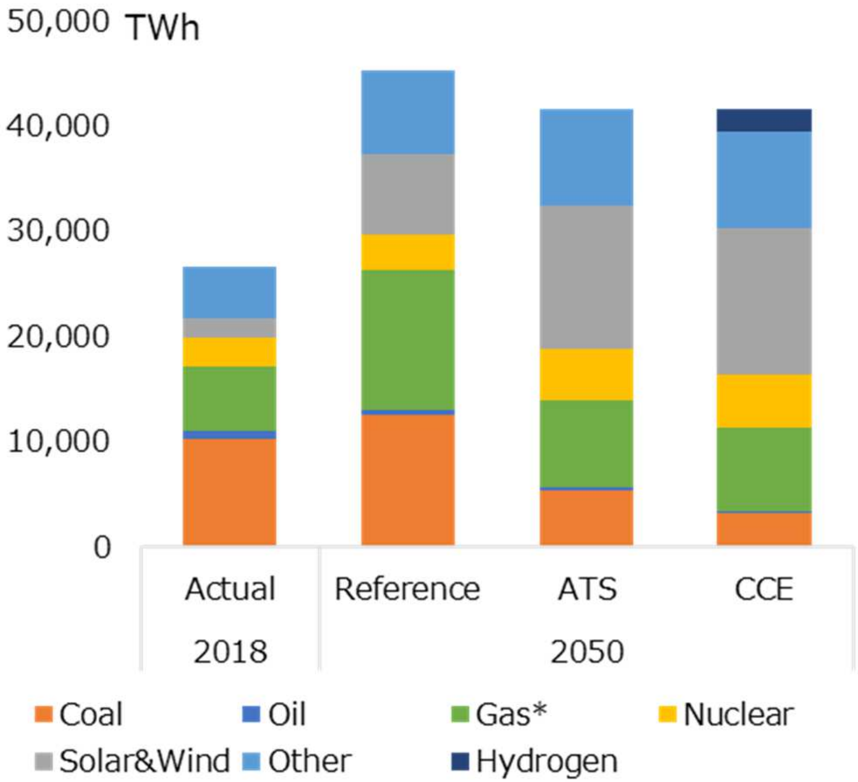
Power and Transportation sectors have high potential of emissions reduction in CCE scenario. Blue hydrogen plays a significant role in both sectors.

Reduce technologies contributes major reduction while contribution of Reuse and Recycle is small.

Source: “IEEJ Outlook 2021” (IEEJ, October 2020)

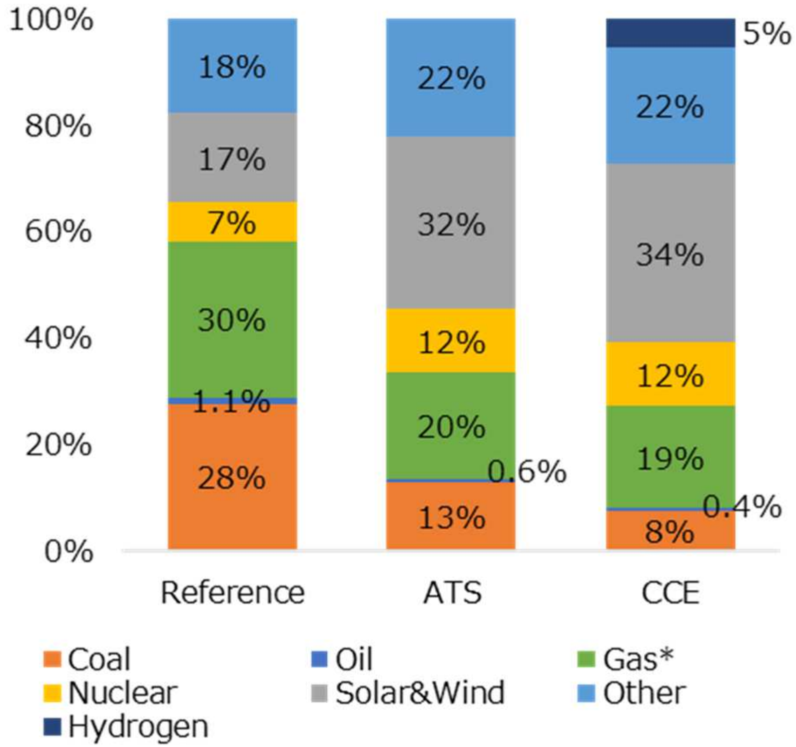
Coal power will be partially replaced with H_2.

❖ Electricity generation (World)



*CCE scenario includes synthetic methane.

❖ Power generation mix (World as of 2050)



*CCE scenario includes synthetic methane.

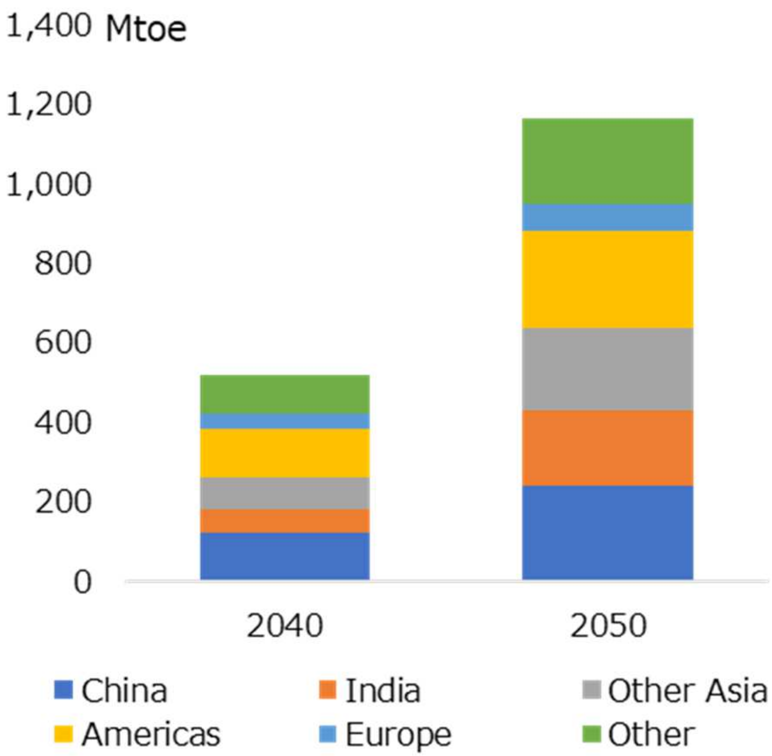
Share of fossil fuels will decline from 34% to 27% in CCE scenario.

Share of hydrogen power will be 5% as of 2050.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Hydrogen demand will grow in Asia.

World hydrogen demand



Hydrogen balance (2050)

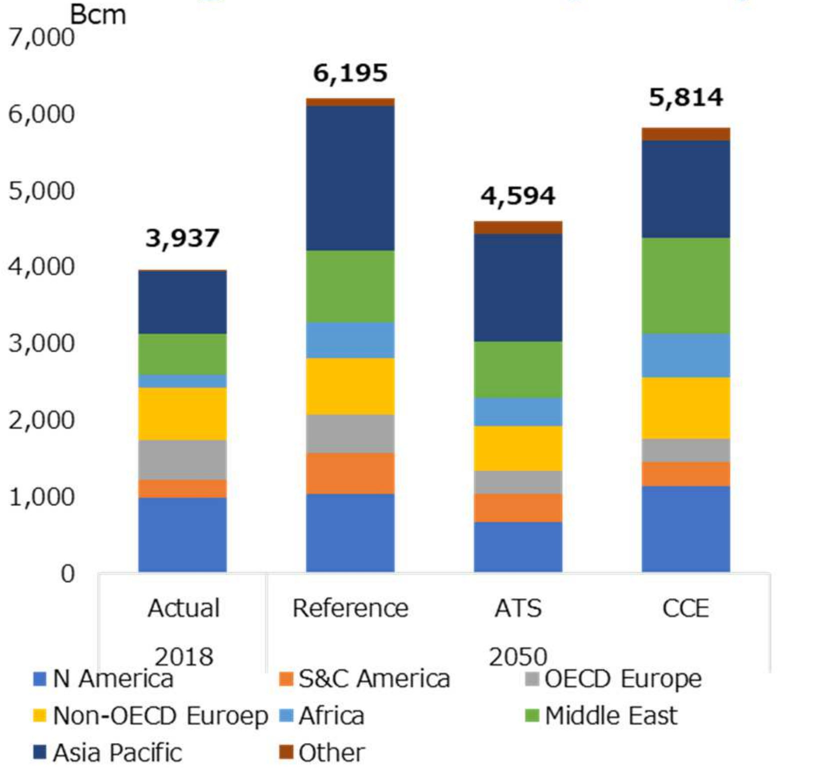
World hydrogen demand is expected to grow mainly in Asia in CCE scenario.

Countries without blue hydrogen production capability will need to import blue hydrogen from countries with low cost and abundant fossil fuel resources with CCS capability.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

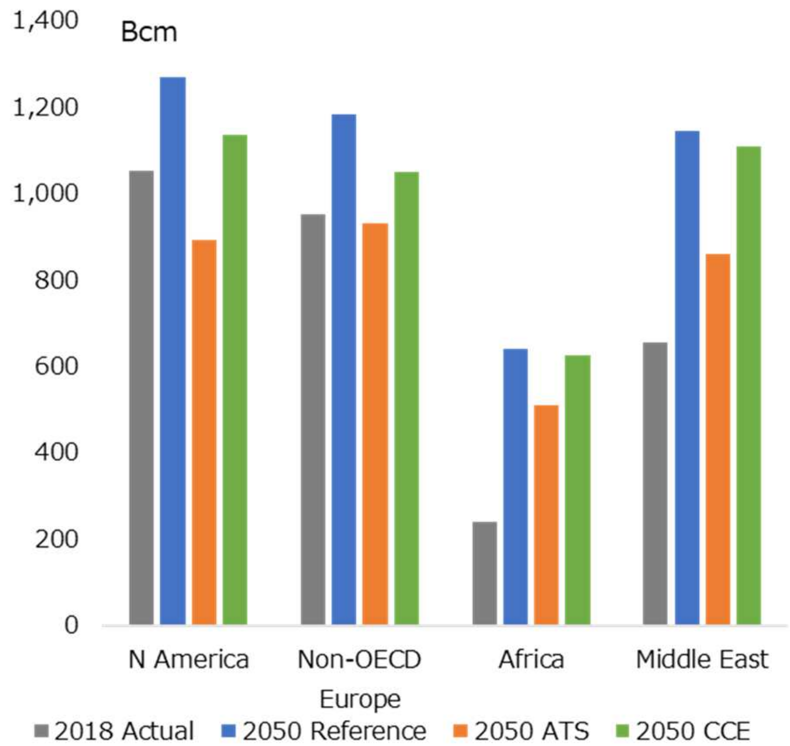
New natural gas demand will emerge.

❖ Natural gad demand* (World)



*Includes synthetic methane

❖ Natural gas production (as of 2050)



Natural gas demand will grow by 27% in CCE scenario as of 2050 because of the additional feedstock demand for blue hydrogen.*

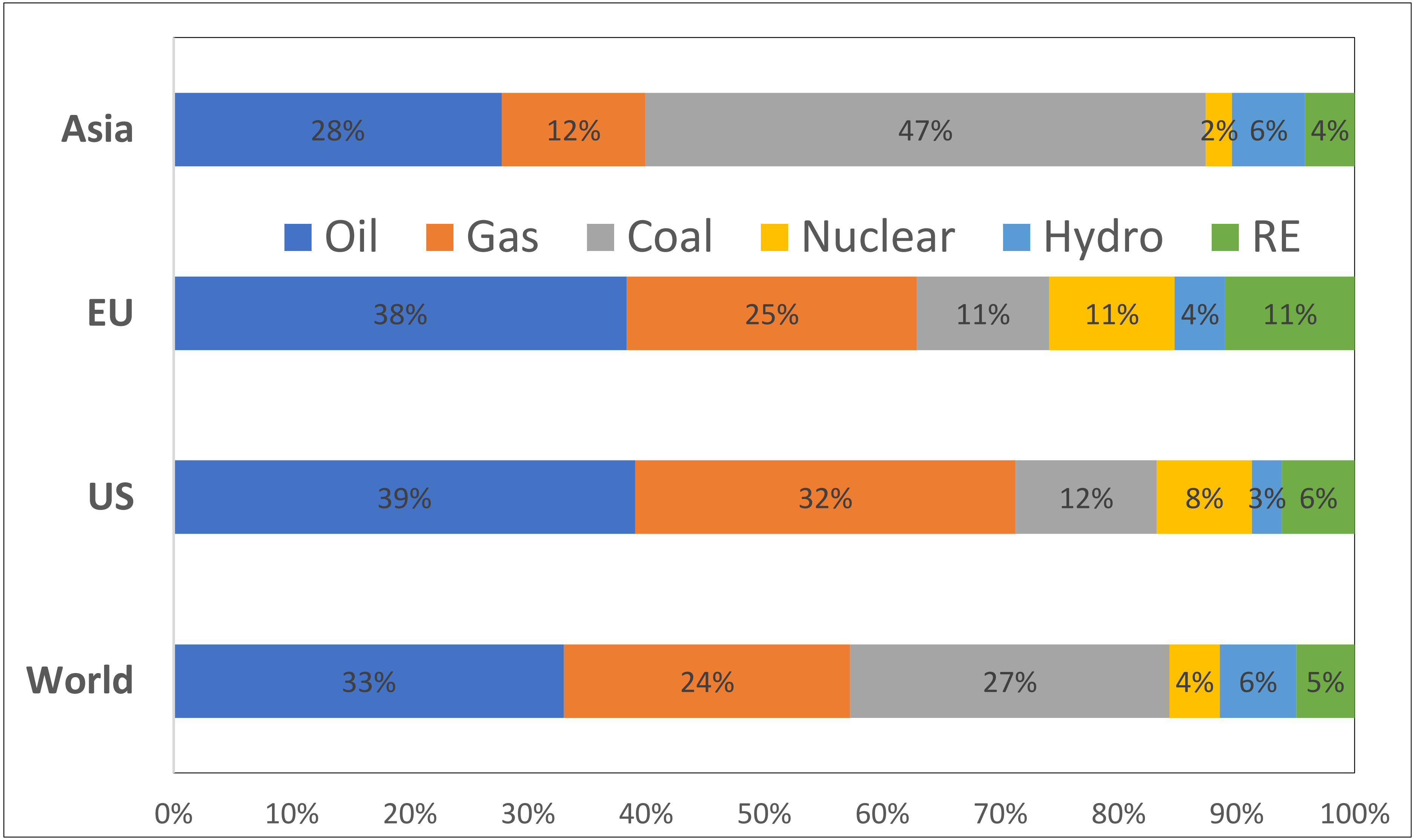
Major gas producing countries are required to increase their production although the volume of production will not exceed the reference scenario.

*This scenario assumes a major feedstock of blue hydrogen will be natural gas.

Waves of carbon neutrality target

- EU, as a front runner, targets Carbon Neutrality (CN) in 2050
- China announced CN target in 2060 (September 2020)
- Japan announced CN target in 2050 (October 2020) followed by Korea
- Biden administration has CN target in 2050
- The above CN waves will affect international momentum
- But, CN achievement is extremely challenging
- Promotion of EE and non-fossil energy plus electrification with zero emission power is essential
- Innovative technology/approach such as hydrogen is needed
- Minimization of “transition costs” to CN is critically important

Asia, heavily dependent on coal



Source: Prepared from "BP Statistical Review of World Energy 2020"

Cost-benefit analysis of climate change

❖ Mitigation+Adaptation+Damage=Total Cost

Mitigation

•Typical measures are GHG emissions reduction via energy efficiency and non-fossil energy use.
• Includes reduction of GHG release to the atmosphere via CCS
• These measures **mitigate** climate change.

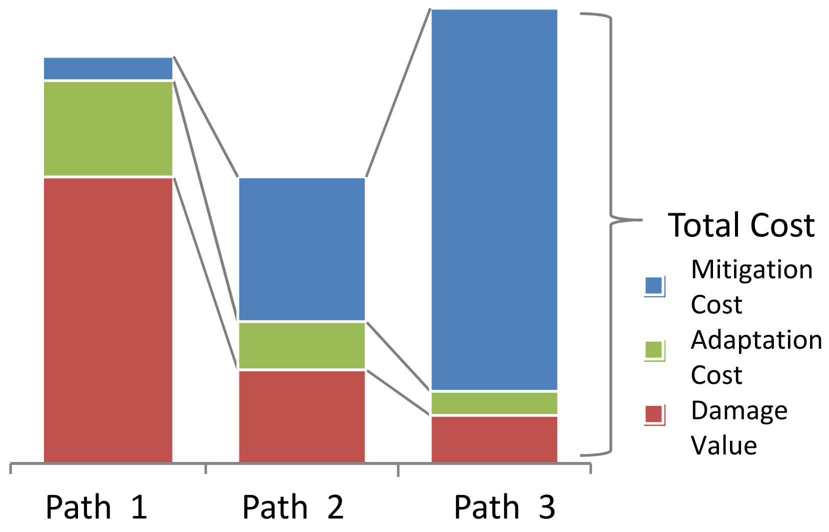
Adaptation

•Temperature rise may cause sea-level rise, agricultural crop drought, disease pandemic, etc.
• **Adaptation** includes counter measures such as building banks/reservoir, agricultural research and disease preventive actions.

Damage

If mitigation and adaptation cannot reduce the climate change effects enough to stop sea-level rise, draught and pandemics, **damage** will take place.

❖ Illustration of the Total Cost



	Path 1	Path 2	Path 3
Mitigation	Too Small	Reasonable	Too Big
Adaptation	Big	Medium	Small
Damage	Big	Medium	Small

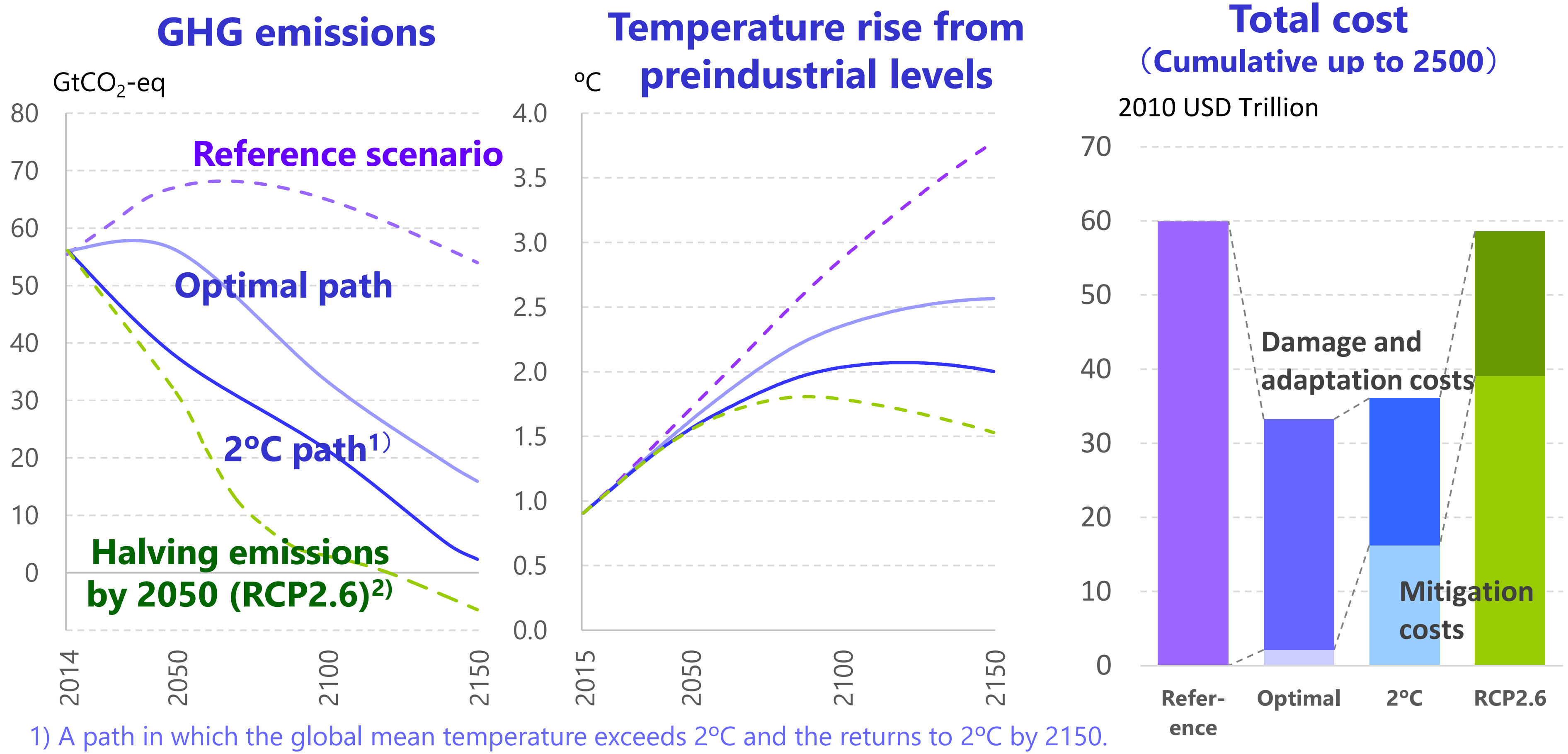
Note: In the actual simulation, the optimal path is calculated by maximizing the utility.

Without measures against climate change, the mitigation cost is small, while the adaptation and damage costs become substantial. Aggressive mitigation measures on the other hand, would reduce the adaptation and damage costs but the mitigation costs would be notably colossal.

The climate change issue is a long-term challenge influencing vast areas over many generations. As such, and from a sustainability point of view, the combination (or the mix) of different approaches to reduce the total cost of mitigation, adaptation and damage is important.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Optimal and 2°C paths



1) A path in which the global mean temperature exceeds 2°C and the returns to 2°C by 2150.

2) A path roughly equivalent to IPCC's RCP2.6.

- The temperature rise in the optimal path exceeds 2.5°C by 2150, although the results vary strongly depending on the assumptions.
- At the same time, an overshooting path, in which the temperature rise returns to 2.0°C by 2150, may also be achievable without large cost increases. 6

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Challenges for the cost-benefit analysis

Accuracy of the damage function

- Estimation of the damages caused by climate change involves great uncertainties. Although research is progressing around the world, sufficient knowledge has not been accumulated.
- It is important to refine the damage function (relationship between temperature rise and damage value) based on the latest scientific knowledge.

Effects of “tipping elements”

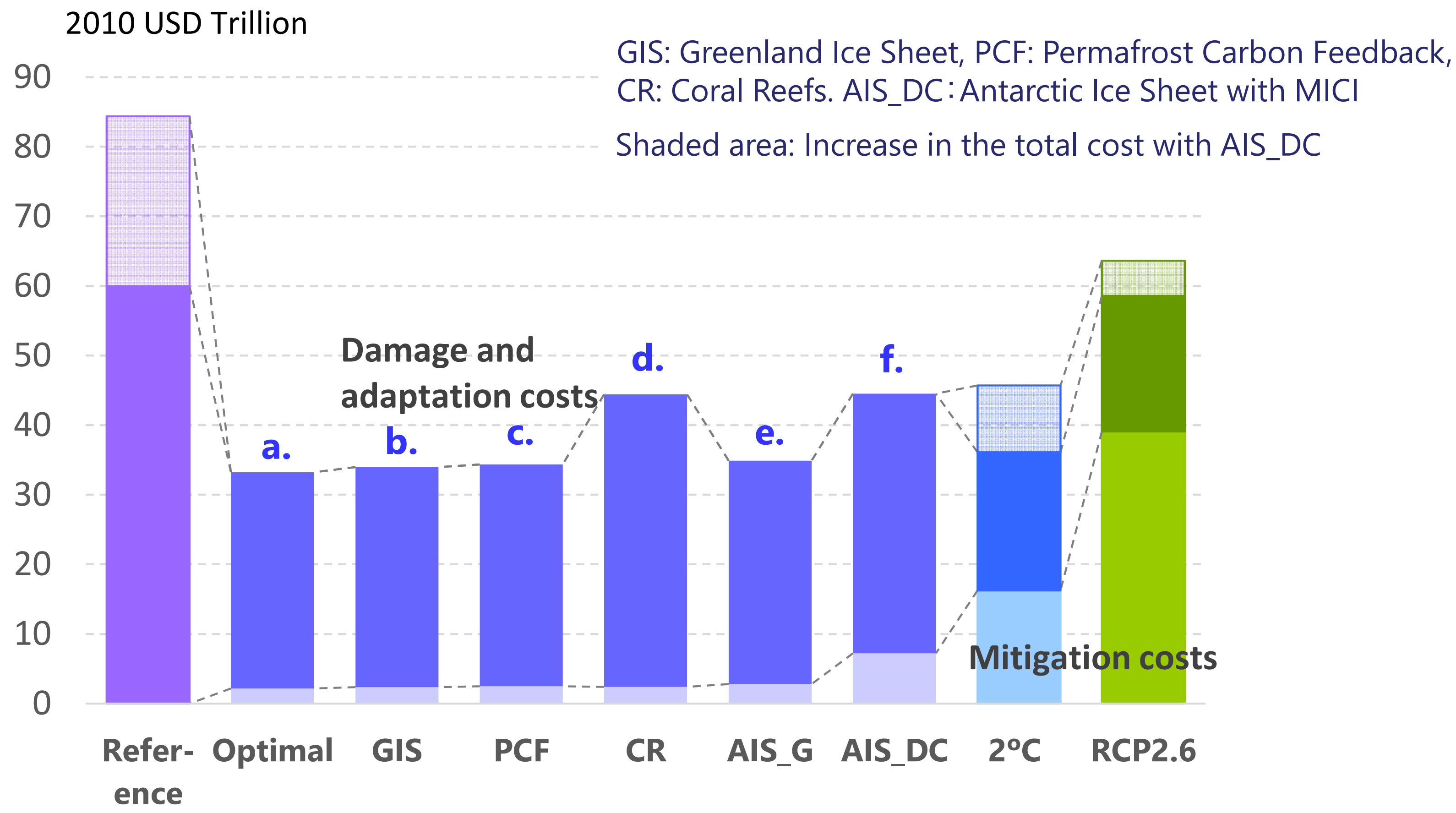
- If the progress of an event exceeds the critical point, negative feedbacks of the Earth system may stop functioning, and the change may be accelerated.
- For example, as Siberian permafrost melting progresses due to global warming, underground methane and CO_2 are released into the atmosphere. The release itself contributes to global warming, further thawing the frozen soil.
- They point out that there is a risk of shifting to a different equilibrium state, for example, “Hothouse Earth” where the temperature is higher by several degrees or more than before as a result.

Other theoretical issues

- Issues related long-term discount rates, “fat tails, etc.
- Discussions continue, and no consensus has been found among researchers at present.

Source: “IEEJ Outlook 2021” (IEEJ, October 2020)

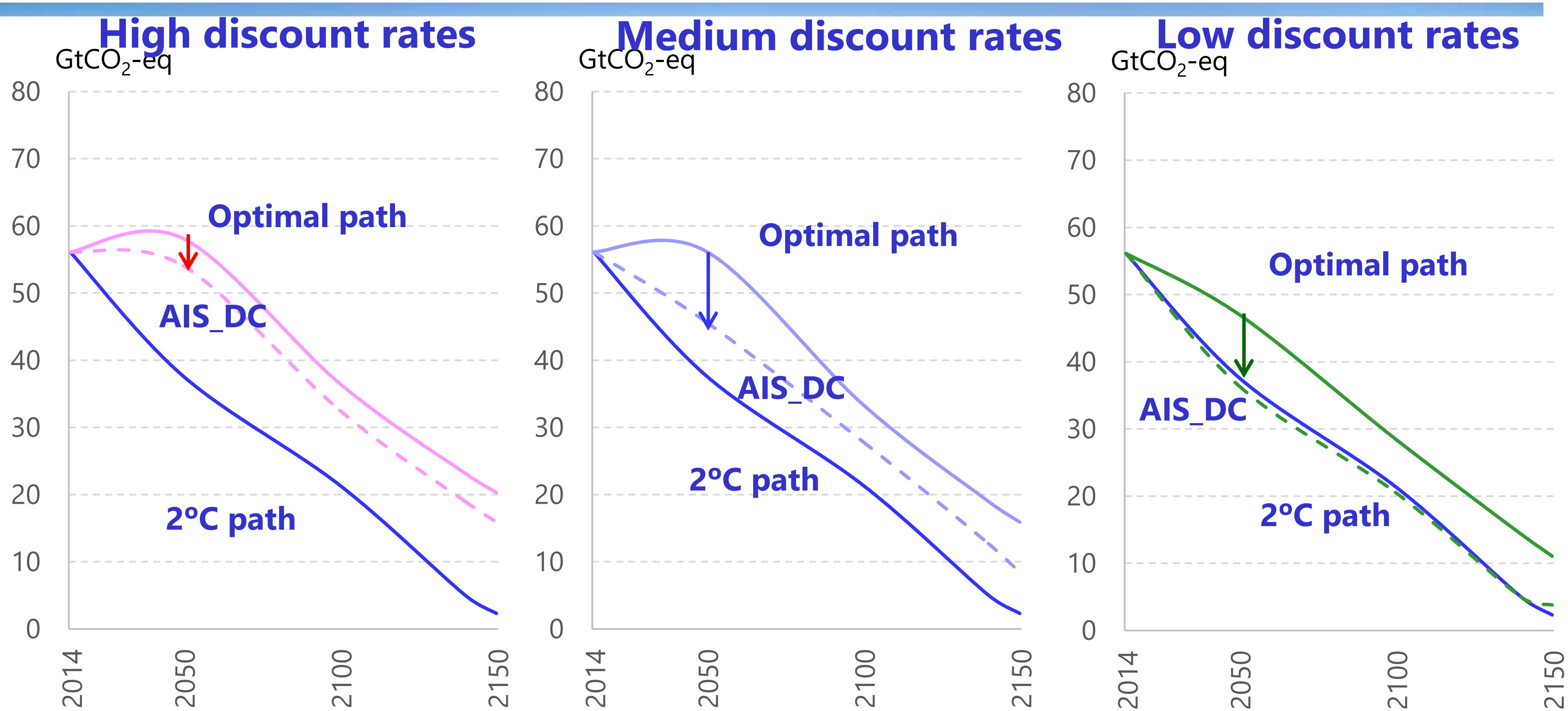
Changes in the total cost by different major tipping elements



- Considering Greenland ice sheet, permafrost, or Antarctic ice sheet without MICI boosts the total cost only slightly (a. versus b., c., and e.)
- With explicit consideration of Antarctic ice sheet with MICI, or coral reefs, the total cost rises considerably (d. and f.) Although the economic damages related to the loss of coral reefs may be huge, it hardly affects the optimal path, because most part of coral reefs will be lost even with a temperature rise of 1.5°C.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Effect of tipping element with different discount rates



- Assuming lower discount rates, the optimal path moves downwards, and becomes closer to the 2°C path.
- In addition, if the Antarctic Ice Sheet collapses rapidly with MICI (AIS_DC), the optimal path moves downwards further; we can observe larger change in the optimal path for the cases with lower discount rates.

Source: “IEEJ Outlook 2021” (IEEJ, October 2020)

Ongoing new "Global energy transition"

- **19th century: Coal became dominant under Industrialization**
- **20th century: "the century of oil"**
  - ✓ Background factors: economic competitiveness, supply potential, convenience, technology advancement, etc.
- **1970s: Oil crisis and oil substitution policy**
  - ✓ Enhancement of energy security policy in OECD resulted in energy diversification (away from oil)
- **21st century: What's next after "the century of oil"?**
  - ✓ Need to address carbon neutrality and energy security problems
  - ✓ Technology development/deployment in renewable, ZEV, Hydrogen, etc.
  - ✓ Possibility to develop new unconventional energy sources/technologies

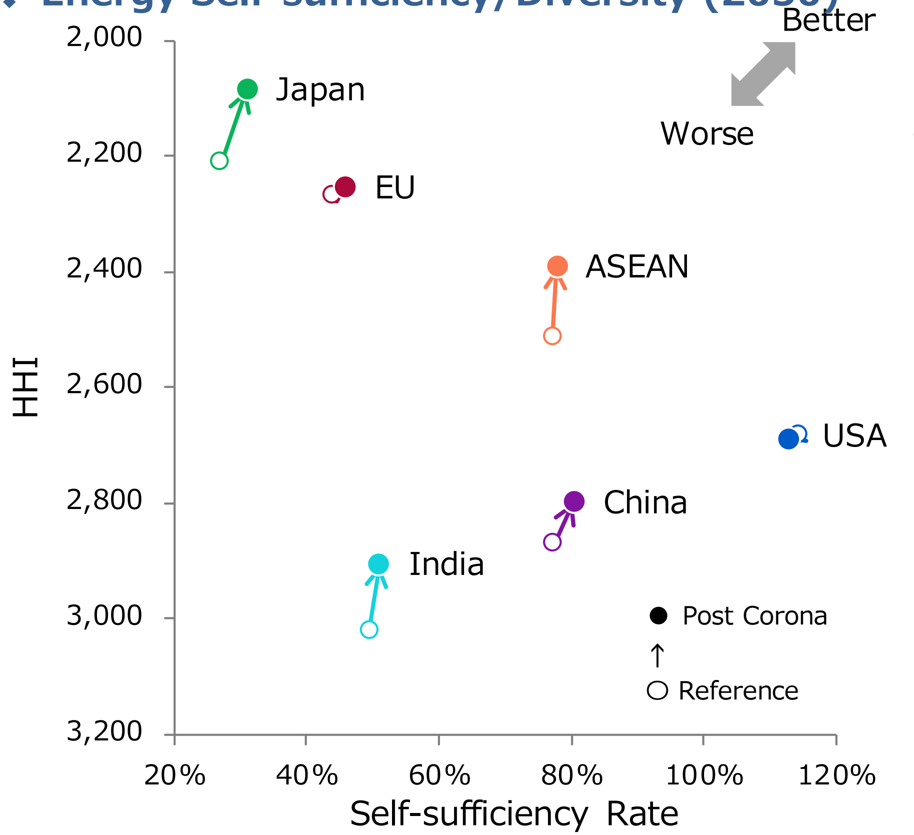
- **Impact of post-corona world transformation on the global energy transition**
- **Technology supremacy may decide the winner in the global energy transition**

Thank you very much for your kind attention.

Post-Corona

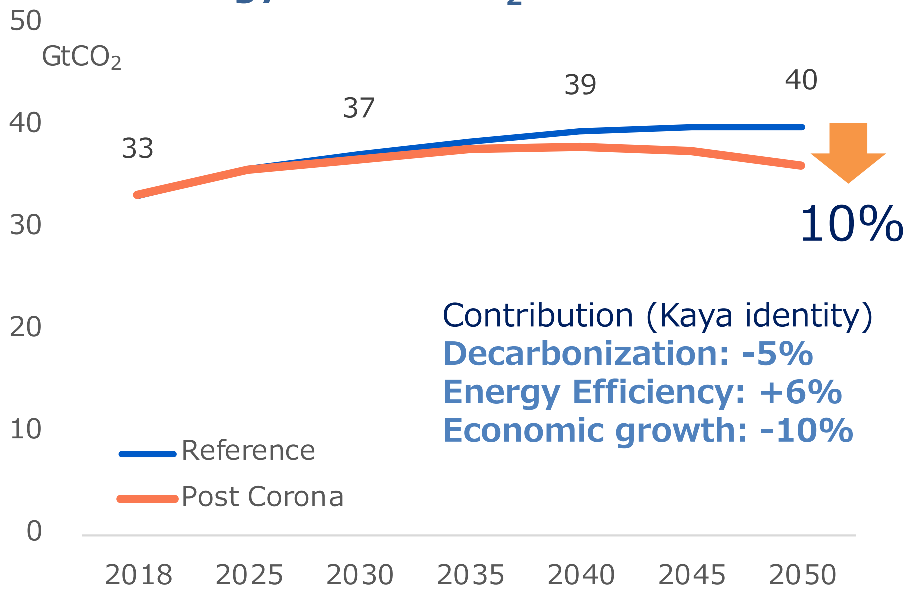
Self-sufficiency / diversity improves and CO_2 peaks earlier

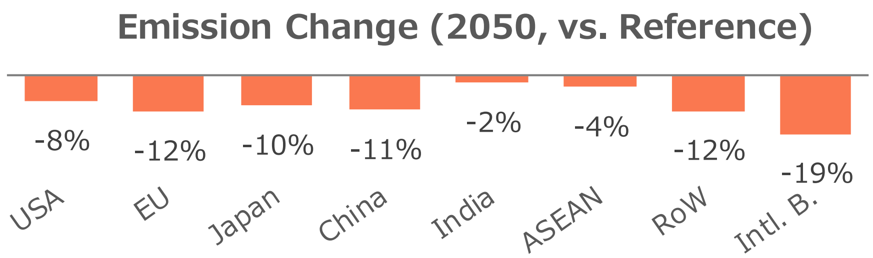
Energy Self-sufficiency/Diversity (2050)



HHI (Herfindahl-Hirschman Index): An indicator of concentration. The higher the number, the higher the concentration, and the lower the number, the more diversified.

Energy-related CO_2 Emissions



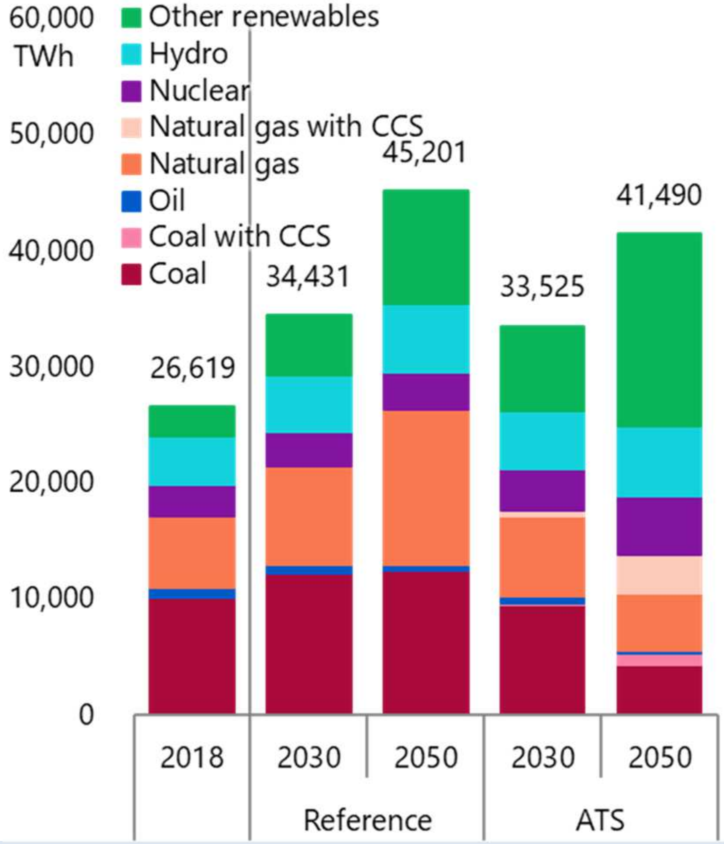


In the RS, the energy self-sufficiency rate of ASEAN and India dropped significantly and CO_2 emissions peak in the late 2040s.

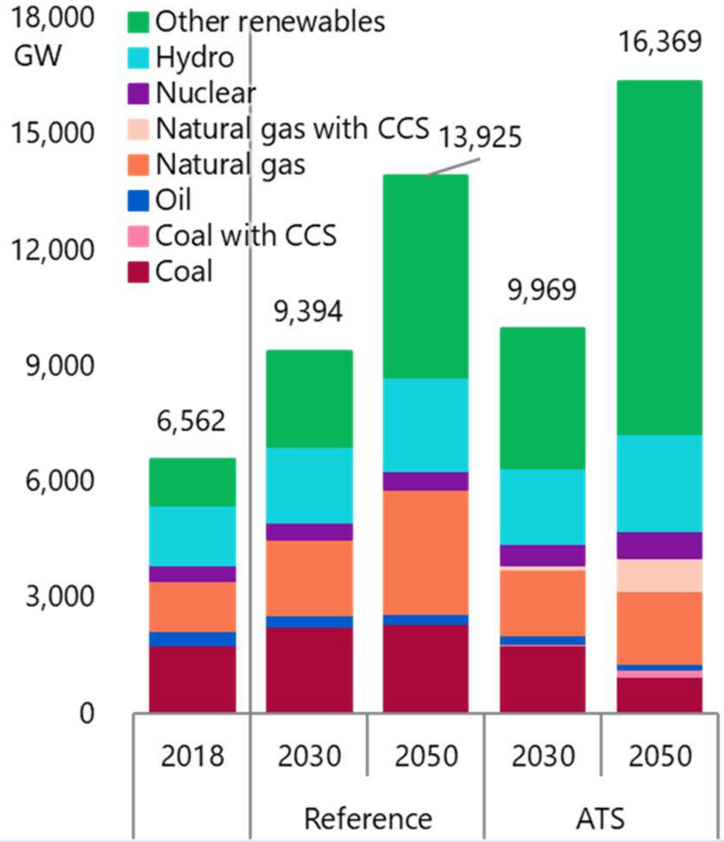
In the PCS, the self-sufficiency / diversity improve in importing countries. The peak of CO_2 emissions is accelerated by 10 years due to economic slowdown and decarbonization.

Electricity generation

Electricity generation



Generation capacity



The total electricity generation will decline in ATS. Electricity demand of the transportation sector will grow in ATS, but the decline of the demand of the industrial, residential, and commercial sectors more than offset the growth.

The share of other renewable (solar, wind, etc.) will grow to the largest electricity generation source while the share of coal will decline.

4R technologies to manage carbon

Major 4R technologies

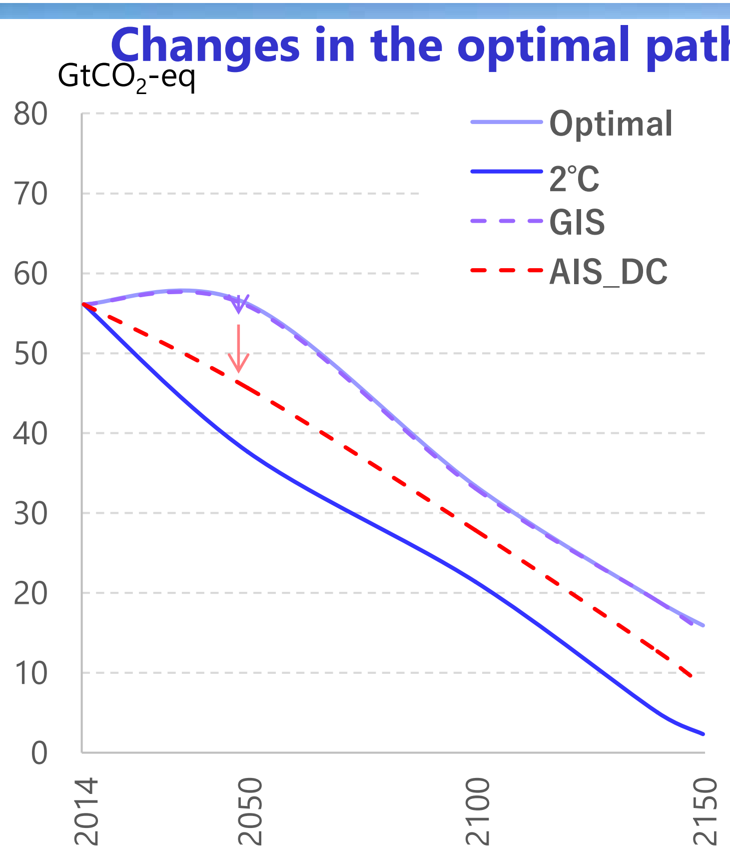
Reduce	Reuse	Recycle	Remove
Reducing the amount of carbon entering the system	Reusing carbon without chemical conversion	Recycling carbon with chemical conversion	Removing carbon from the system
• Energy and materials efficiency • Renewable energy, including hybrid use with fossil fuel • Nuclear energy, including hybrid use with fossil fuel • Advanced ultra-super-critical technologies for coal power plants • Hydrogen (blue/green) fuel cells for long-distance heavy-duty vehicles • Ammonia produced from zero-carbon hydrogen (blue/green) for power generation and ships • Direct reduction in steel making by using CO_2 free hydrogen (blue/green)	• Carbon capture and utilization (CCU) • Use CO_2 at carbon utilization facilities, such as at greenhouses for enhancing crops • Bio-jet fuels with reed beds • Algal synthesis	• CCU • Artificial photosynthesis • Bioenergy recycle in the pulp and paper industry • Bioenergy with carbon capture and storage • Carbamide (urea production using CO_2 as feedstock) • Coal ash concrete curing with absorbing CO_2 • Electrochemical reduction of CO_2 • Fine chemicals with innovative manufacturing processes and carbon recycling • Fischer-Tropsch exothermic of carbon dioxide with hydrogen syngas • Hydrogenation to formic acid • Oil sludge pyrolysis • Sabatier synthesis (CO_2 methanation: exothermic of carbon dioxide with blue/green hydrogen) • Thermal pyrolysis	• CCS • Direct air capture (DAC) • Carbon dioxide removal • Fossil fuels-based blue hydrogen

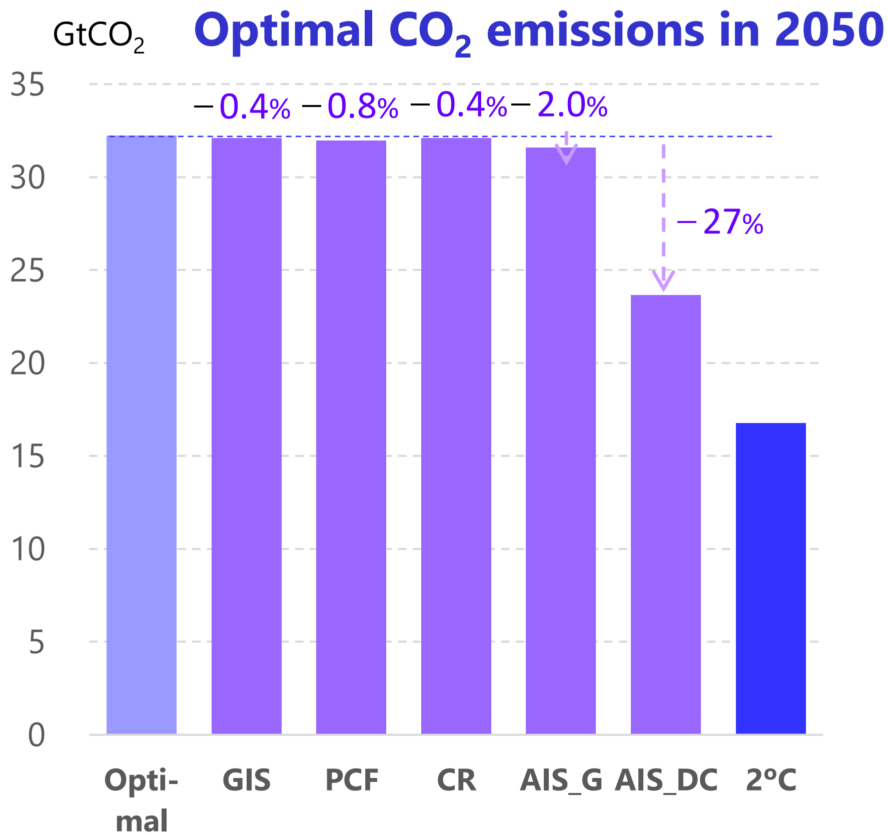
Source : Mansouri, N. Y. *et al.*(2020) "A Carbon Management System of Innovation: Towards a Circular Carbon Economy"

The "4R" in CCE covers all available technology options to reduce CO_2 in a systematic manner.

The concept of 4R highlights the importance of Reuse and Recycle technologies that regard carbon as a resource.

Changes in the optimal path by different tipping elements

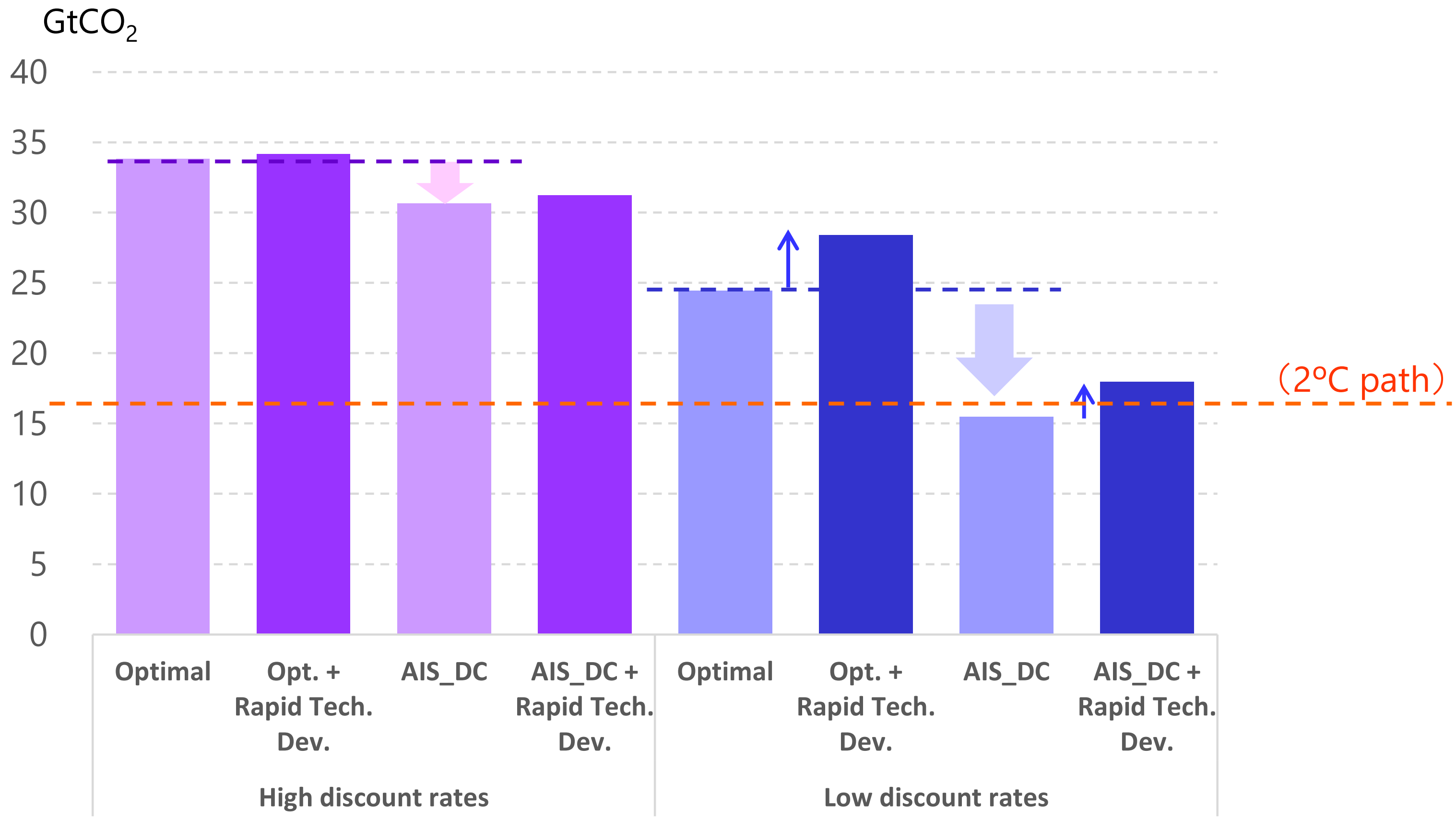




GIS：Greenland Ice Sheet, PCF: Permafrost Carbon Feedback, CR: Coral Reefs, AIS_G: Antarctic Ice Sheet without MICI, AIS_DC: Antarctic Ice Sheet with MICI.

- The optimal path does not change greatly with consideration of GIS, PCF, CR, and AIS without MICI (AIS_G).
- On the other hand, if we assume the rapid collapse of AIS by MICI (AIS_DC), the optimal path changes largely to the red dotted path, and the optimal global CO_2 emission in 2050 declines by 27%, although still larger than that in the 2°C path.

Effect of technology Advancement: CO_2 emission in 2050



- With high discount rate assumptions, rapid technology advancement does not affect the optimal emissions in 2050 greatly, as high discount rates put more focus on the costs and damages in the near future.
- On the other hand, with low discount rate assumptions, rapid technology advancement increases the optimal emission in 2050, which implies that the low discount rates represent views that emphasizes the importance of long-term technology advancement.

Source: "IEEJ Outlook 2021" (IEEJ, October 2020)

Session

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