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IEEJ OUTLOOK 2022

Energy Supply and Demand Outlook by 2050

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What is IEEJ Outlook?

- Study to quantify the future global energy supply and demand situation until 2050.
- Outlook with forecast-approach, using econometric models etc.
- Scenario analysis on progress and trends in technologies and policies.

[Reference Scenario (REF)]

A scenario in which trends and changes continue while reflecting current energy and environmental policies.

[Advanced Technologies Scenario (ATS)]

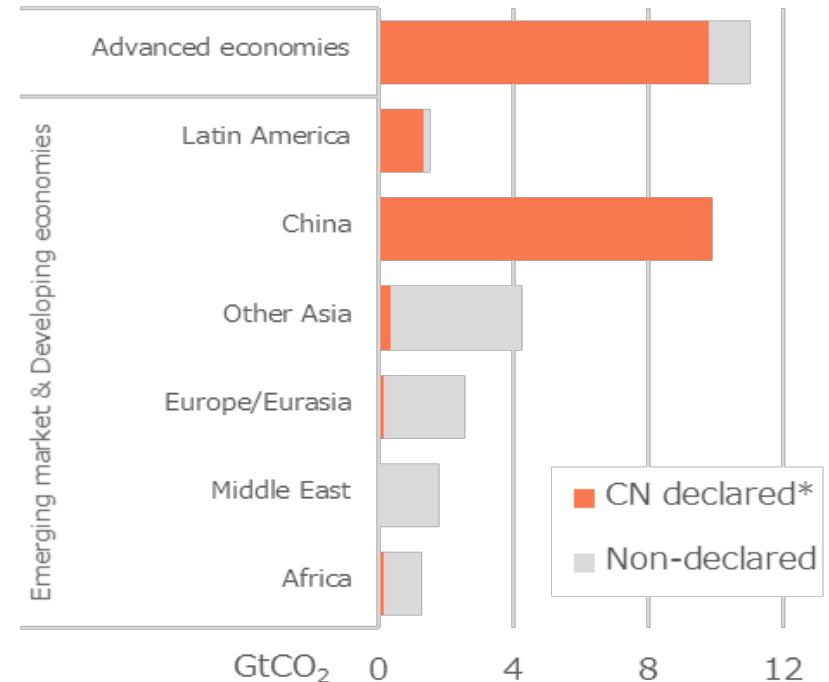
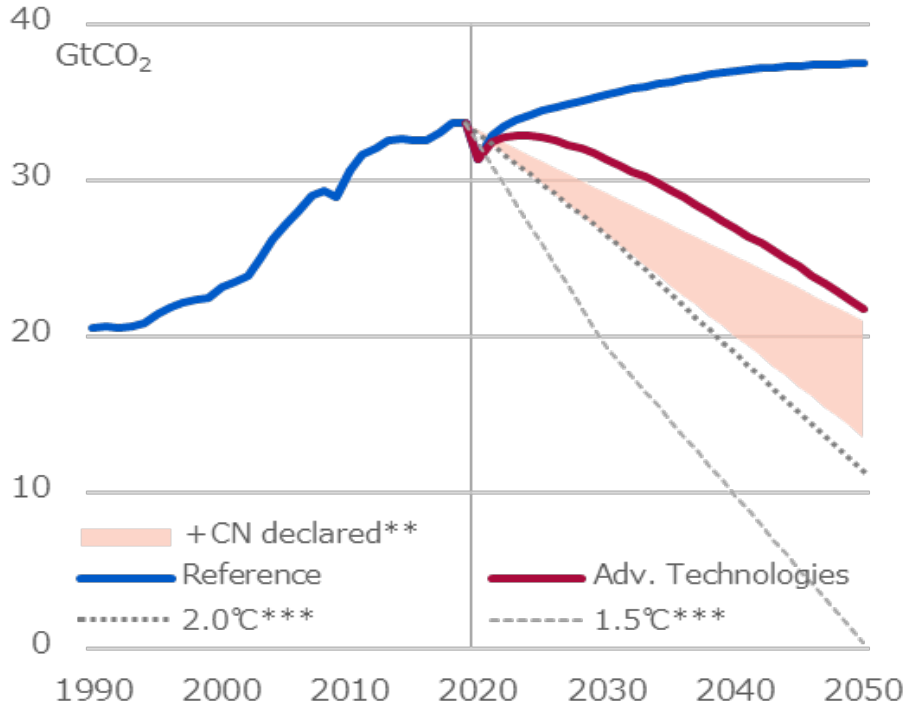
A scenario in which energy and environmental technologies are introduced to the maximum extent in order to secure a stable energy supply and strengthen climate change countermeasures.

[Circular Carbon Economy/4R Scenario (CCE)]

A scenario based on the concept of a circular carbon economy with the "4Rs" (Reduce, Reuse, Recycle, Remove). The scenario reflects not only the Advanced Technologies Scenario assumptions, but also examines the maximum introduction of decarbonization technology using fossil fuels.

Emitters of two-thirds of the emissions declare CN, but...

❖ Energy-related CO₂ emissions (global) ❖ Breakdown of CO₂ Emissions (2019)



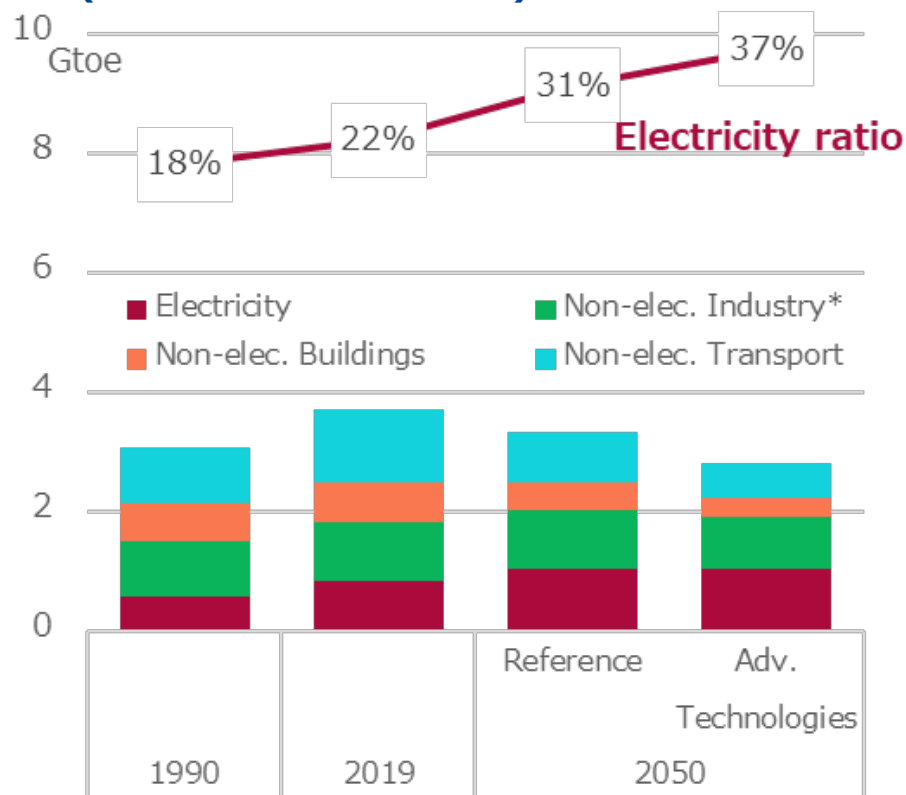
* United States, Brazil, South Korea, Poland, China and Climate Ambitions Alliance (121 countries). ** When the CN-stated countries achieve zero emissions in 2050 based on the emissions in the Reference / Advanced Technologies scenarios (For China, that announced 2060 CN, the emissions as of 2050 by linear interpolation between today and 2060). *** Average paths referred to the IPCC "Global Warming of 1.5°C".

There is a worldwide movement to pursue carbon neutral (CN).

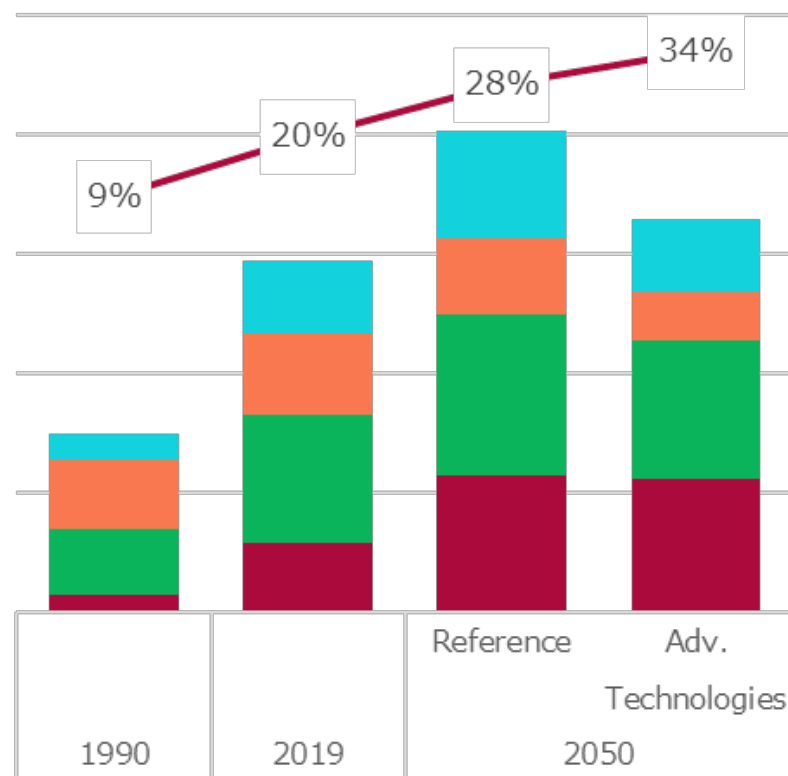
Currently, countries and regions emitting about two-thirds of the world's CO₂ emissions have announced CN. Even if those countries succeed, global emissions in 2050 will be only half of current levels.

Power demand is certain to grow

❖ Final Energy Consumption (Advanced Economies)



❖ Final Energy Consumption (Emerging and Developing Economies)



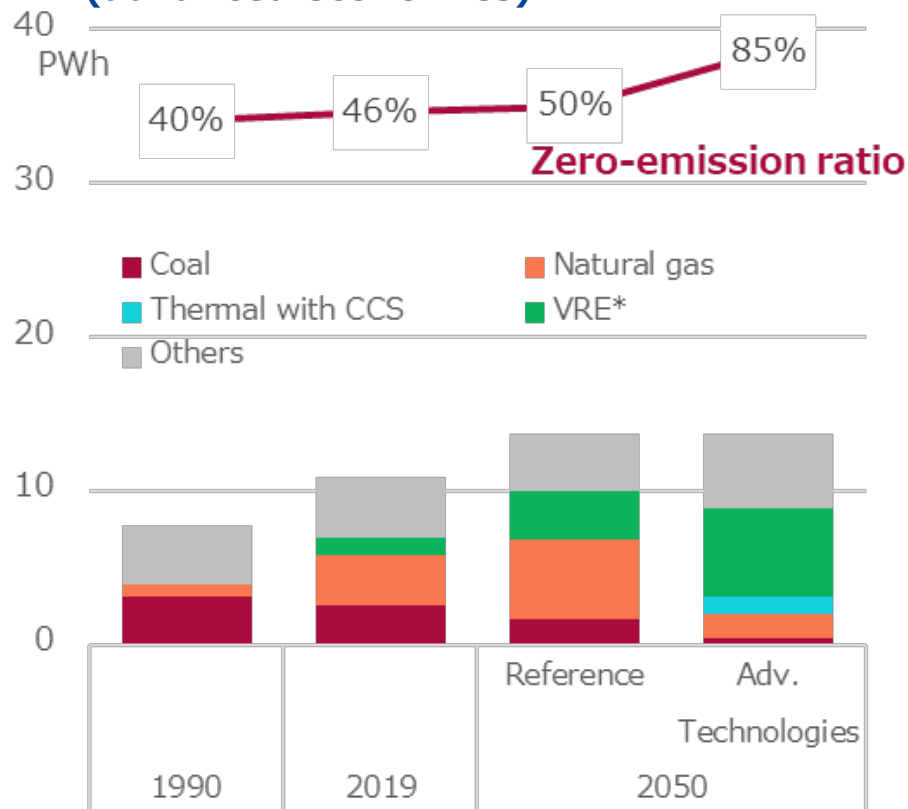
* Industry includes agriculture, forestry and fisheries and non-energy sector.

Energy demand in both developed and developing countries will be electrified more. Although the electrification of heat demand in the industrial sector is limited, the electricity ratio will rise further in the ATS.

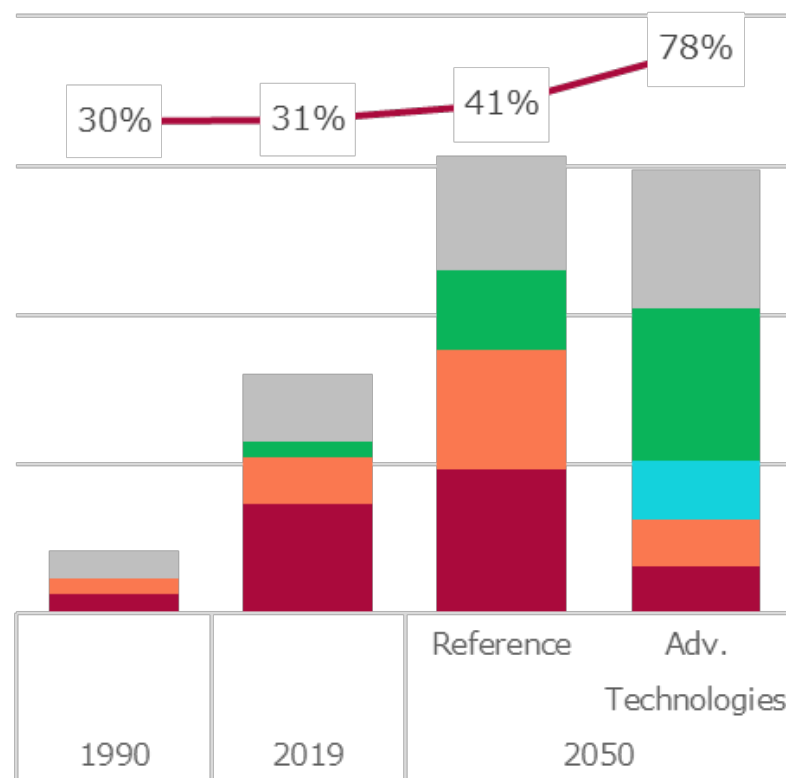
Electricity demand is not much different between both scenarios. The stability, reliability and security of electricity supply are issues that must be addressed.

Decarbonization of the power sector is progressing

❖ Power Generation Mix (advanced economies)



❖ Power Generation Mix (Emerging and Developing Economies)



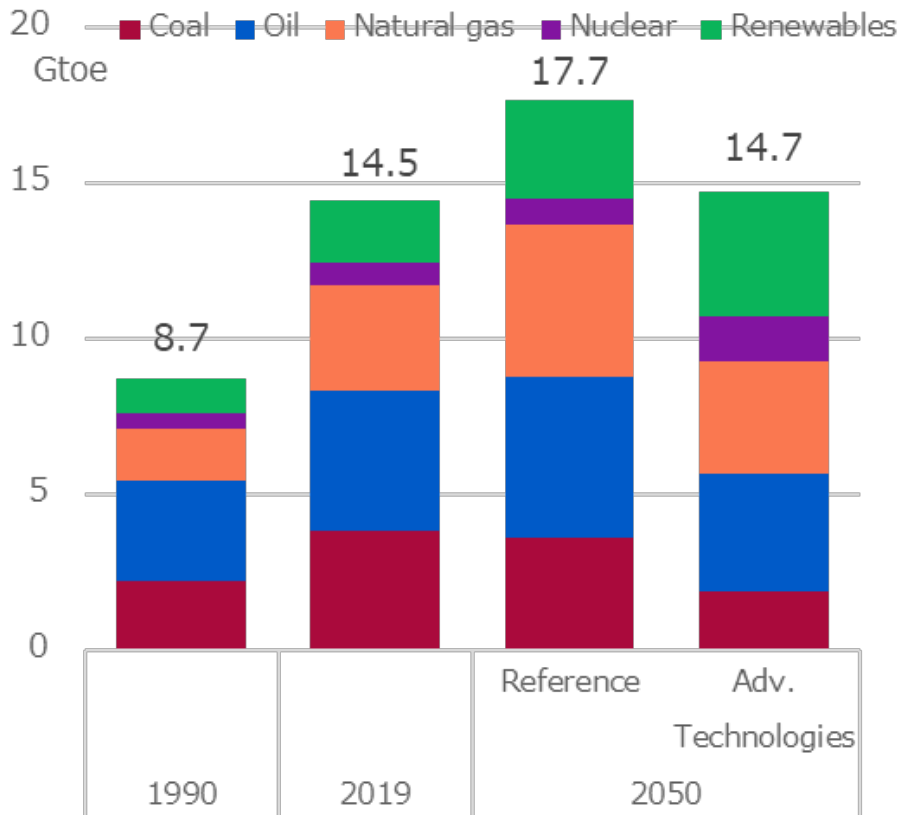
* VRE (Variable Renewable Energy): photovoltaic power, wind power, etc.

In the REF, more than half of the increase in electricity demand is supplied by VRE. However, in emerging and developing economies, thermal power generation remains necessary to meet a strong electricity demand.

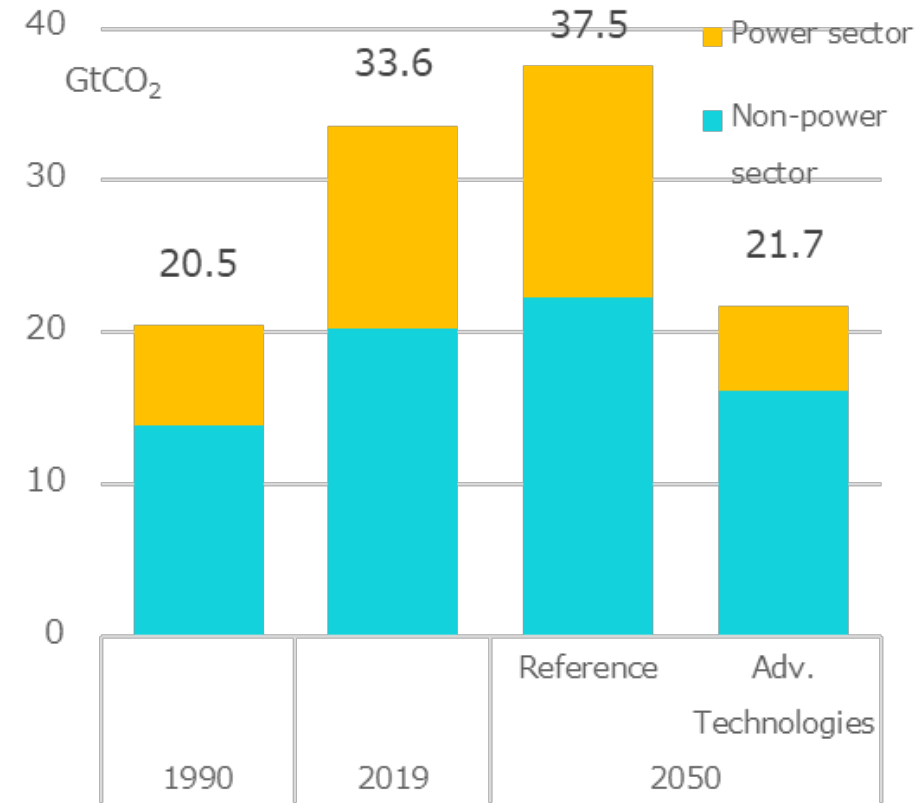
In the ATS, the decarbonization of the power generation sector will be greatly advanced by a large introduction of VRE and thermal power with CCS.

Decarbonization of non-power generation sector is difficult

❖ Primary energy demand



❖ Energy-related CO₂ emissions



The primary energy demand in the ATS in 2050 is almost the same as today. Demand for fossil fuels declines, but still accounts for 60% of the total.

On the other hand, CO₂ emissions are two-thirds of current levels. The emissions reduction from the power generation sector is significant, however, the reductions in the non-power generation sector are not progressing much.

Circular Carbon Economy/4R Scenario

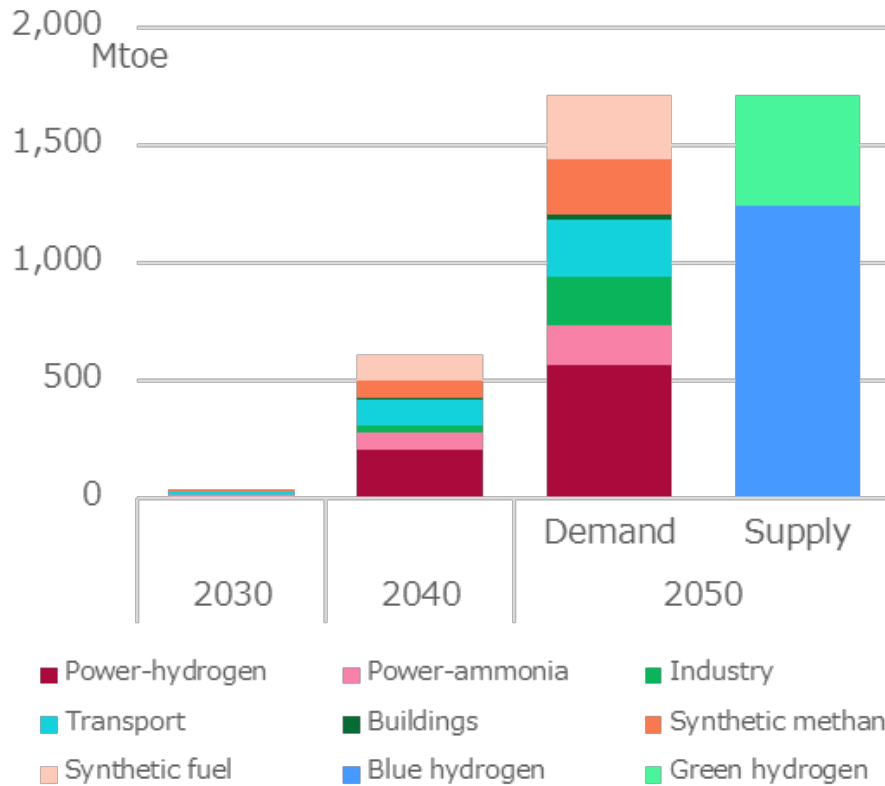
❖ Assumptions in CCE (in addition to the ATS)

4R	Technology	Assumptions
Reduce	Hydrogen for power generation	Adopt hydrogen/ammonia power generation for 50-75% of coal- and gas-fired power plants without CCS facility as of 2050.
	Hydrogen for transportation	Replace 10-15% of liquid fuels demand in the road sector in advanced economies and 20-30% in the international bunkers with hydrogen as of 2050.
	Hydrogen in industry sector	Replace 10-30% of natural gas demand in the industry sector with hydrogen as of 2050 in advanced economies with abundant hydrogen supply.
	Direct reduction in steel making by hydrogen	Adopt direct reduction technology utilizing blue hydrogen to 25% of crude steel production in advanced economies, China, India and Brazil as of 2050.
	Hydrogen in building sector	Replace 10% of natural gas demand in the building sector with hydrogen as of 2050 in advanced economies.
	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 as of 2050.
Recycle	Concrete curing capturing CO ₂	Adopt concrete curing capturing CO ₂ technology to 25-50% of the world concrete production as of 2050.
	Synthetic methane	Replace 20-40% of natural gas demand in the industry and building sectors with synthetic methane as of 2050.
	Synthetic fuels	Replace 10-20% of liquid fuels demand in the transport sectors with synthetic fuels as of 2050.
Remove	Carbon capture and storage	Adopt CCS for blue hydrogen production.

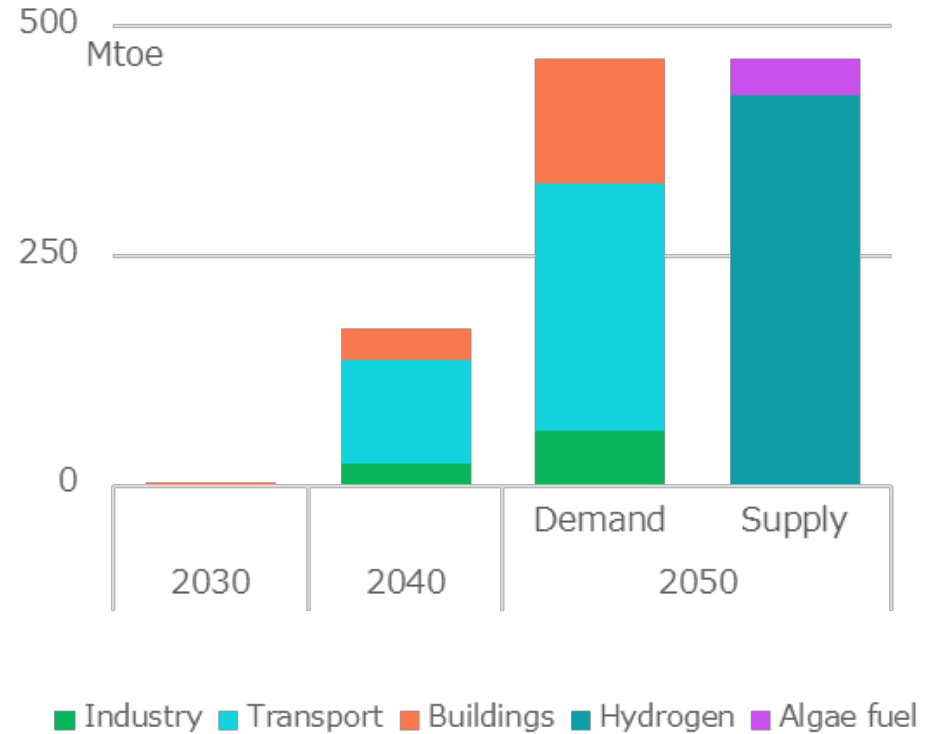
From the perspective of decarbonizing fossil fuel utilization, this scenario considers the maximum introduction of 4R (Reduce, Reuse, Recycle, Remove) technologies in addition to the ATS assumptions.

Utilize clean hydrogen/ammonia

❖ Supply and demand of hydrogen/ammonia



❖ Supply and demand of synthetic methane/fuel

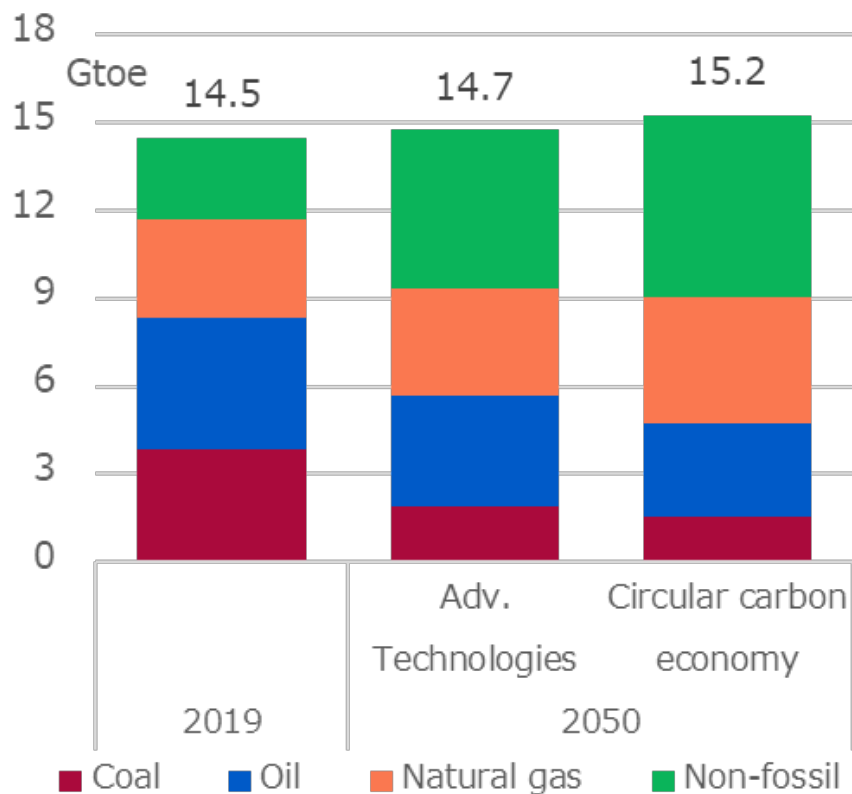


Hydrogen/ammonia, not emit CO₂ during combustion, are utilized in the industry sector and for power generation. Hydrogen production could be blue, using fossil fuels and CCS, or green, using renewable energy.

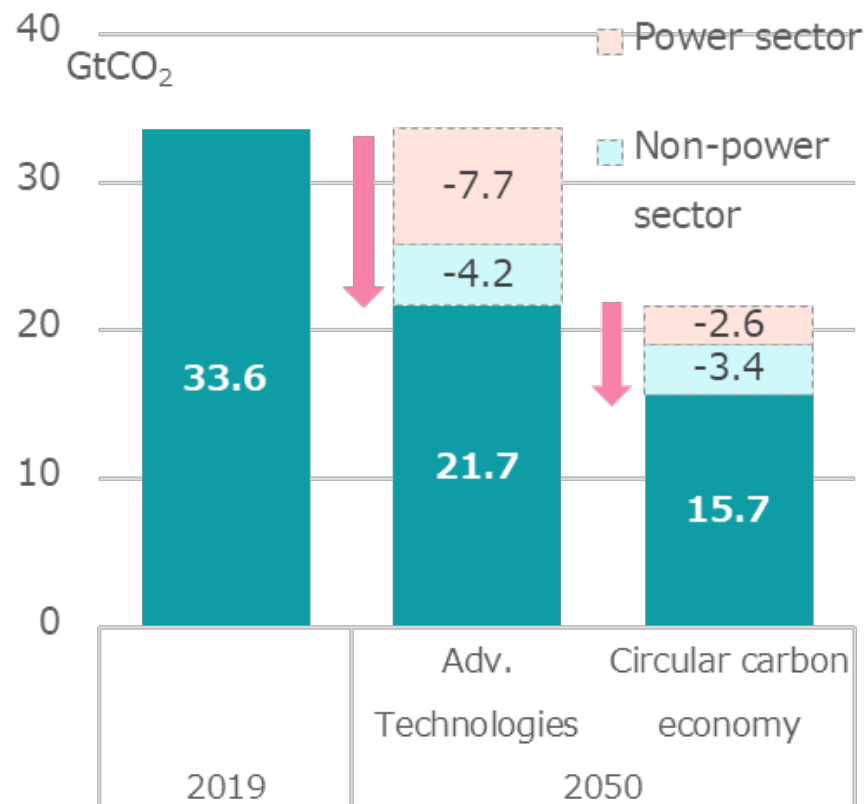
Synthetic methane and fuels produced from clean hydrogen can be used in sectors where electrification is difficult, by utilizing existing infrastructure in the non-power generation sector.

Reduce CO₂ emissions without reducing fossil fuels

❖ Primary energy demand



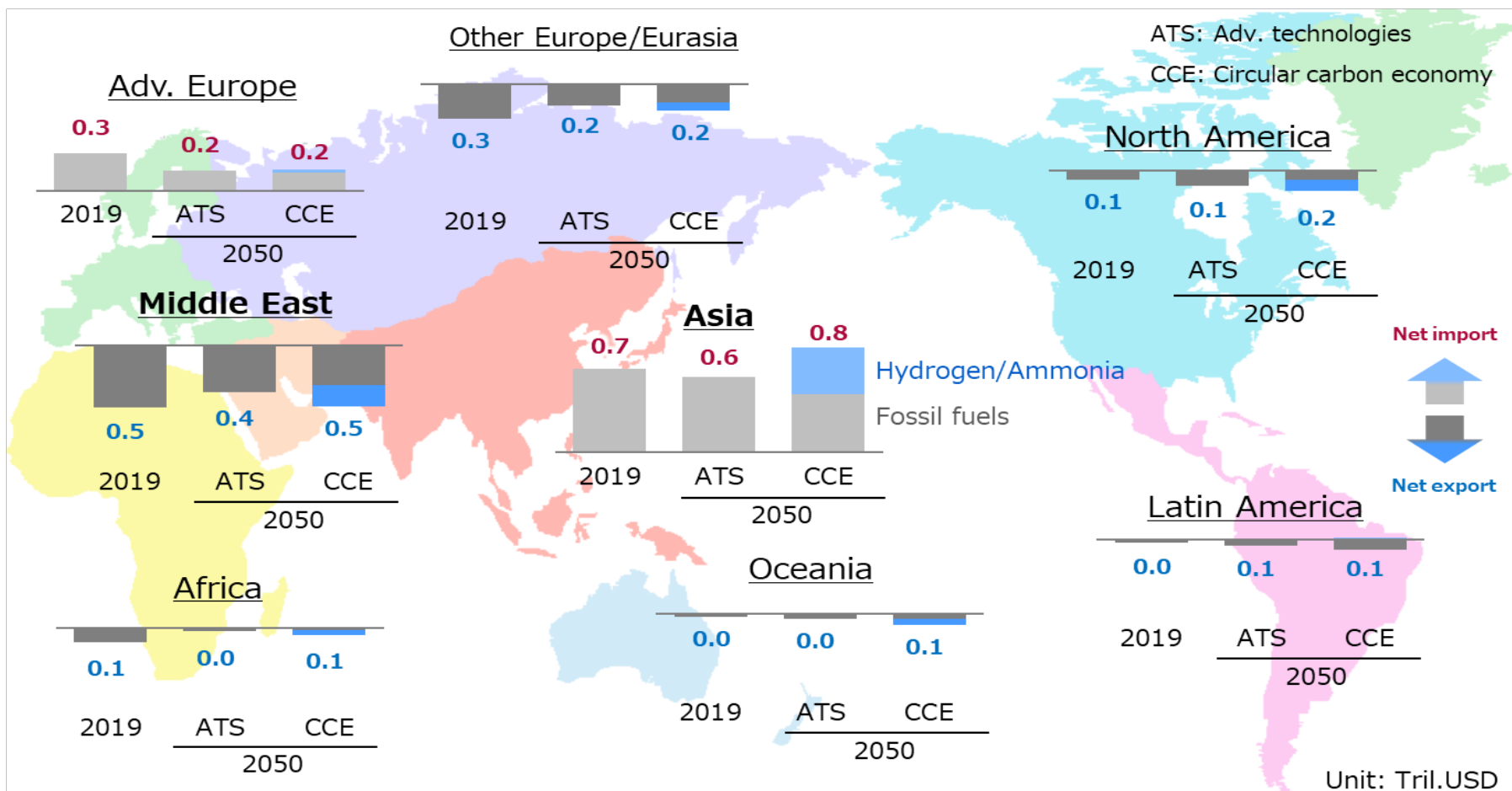
❖ Energy-related CO₂ emissions



Fossil fuel consumption in the CCE scenario is almost the same as that in the ATS. Demand for natural gas for hydrogen production will increase slightly.

On the other hand, the CO₂ emissions decline significantly. The center of gravity for emission reductions is shifting to the non-power generation sector.

Asia-Middle East relations remain unchanged



In the CCE, there is a shift from fossil fuel trade to hydrogen/ammonia trade.

In the Middle East, hydrogen exports compensate for the decline in oil and gas exports. On the other hand, imports of hydrogen will increase significantly in Asia. Even in a world aiming for decarbonization, the importance of trade relations between Asia and the Middle East remains unchanged.

Summary

【 Reference and **Advanced Technologies Scenarios**】

- CO₂ emissions are expected to grow in countries that have not expressed carbon neutrality (CN), such as India, ASEAN, the Middle East, Africa, and others.
- CO₂ reduction in the power generation sector is likely to proceed, but emission reductions in the non-power generation sectors will not progress much. Decarbonization in the non-power generation sector is key to achieve CN.

【**Circular Carbon Economy Scenario**】

- In order to decarbonize the non-power generation sector, clean hydrogen/ammonia and synthetic methane/fuels using these materials will be required.
- There is a shift from fossil fuel trade to hydrogen/ammonia trade, but the importance of trade relations between Asia and the Middle East remains unchanged.