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Analysis on Pathways toward Carbon Neutrality in Vietnam using AIM/Enduse

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Background

- In Vietnam, the economy has been growing dramatically and GDP growth rate was above 7% in 2018 and 2019, even under the COVID-19 pandemic, still 2.9% in 2020 and 2.6% in 2021.
- Also CO2 emission is increasing, CO2 emission per capita has doubled in the last 10 years. Vietnam's urgent issue is to reduce emission with maintaining its economic development.
- Vietnam's Prime Minister pledged carbon neutrality by 2050 at COP26 and approved NCCS in July 2022, which includes mainly qualitative description of the decarbonized society.

Purpose

- To calculate emission pathways, electricity demand, necessary counter-measures and additional cost to achieve carbon neutrality in 2050 in Vietnam.
- To highlight the sectors which need early introduction of countermeasures not to make the existing equipment stranded assets.

Methodology

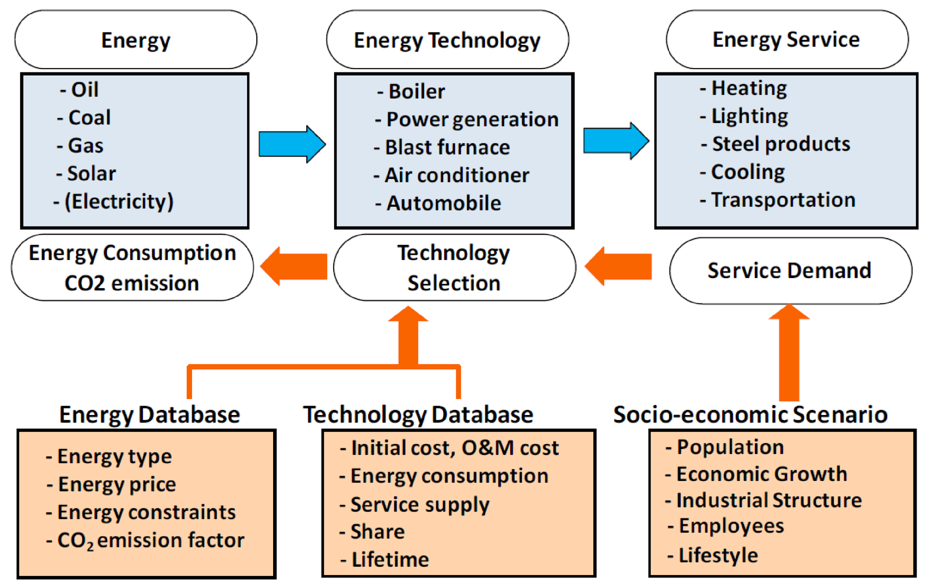
Assumptions of calculation

Base year	2014
Target year	2050
Targeted gas	CO2 emission from energy use and industrial process
Sector	■ Industry (Steel, Cement, Other industry) ■ Residential ■ Commercial ■ Transport (Passenger, Freight) ■ Other Energy Demand ■ Energy supply ■ Industrial process (IPPU)
Scenario	■ **BaU** - Share of technologies on the demand side is fixed after 2020. - The shortage of power supply is met by coal-fired power. ■ **Net Zero-CCS** - Carbon neutrality in 2050 - 80% Renewables in power generation - 250 MtCO2 of CCS ■ **Net Zero-Renewable** - Carbon neutrality in 2050 - 90% Renewables in power generation - 150 MtCO2 of CCS

Sector	Countermeasure
Industry	Ironmaking process (High-efficiency), Electric furnace, Cement manufacturing process (High-efficiency), Boiler (High-efficiency), Heat pump, Industrial furnace (High-efficiency), Electric industrial furnace, Motor (High-efficiency), Inverter, CCS, Hydrogen reduced direct iron making, Hydrogen burner, Hydrogen furnace
Residential & Commercial	Insulation, Heat pump, Heat pump air conditioners, Air conditioners (High-efficiency), Gas cooking equipment (High-efficiency), Electric cooking equipment, LED lighting, Household appliances (High-efficiency)
Transport	Hybrid vehicles, Plug-in hybrid vehicles, Electric vehicles, CNG vehicles, Fuel-cell vehicles, Hybrid buses, Electric buses, Electric railways, Hydrogen railways, Motorcycle (High-efficiency, electric), Airplane (High-efficiency), Ship (High-efficiency), Bio-mixed fuels (Gasoline, Diesel, Jet fuel, Heavy oil)
Energy supply	Coal and Gas fired (High-efficiency, CCS), Hydropower, Wind, Solar, Biomass(High-efficiency, CCS), Electrolysis, Reduction of transmission loss

Sector	Service demand			
	Unit	2014	2030	2050
Steel (production)	Mton	6	48	64
Cement (production)	Mton	61	140	100
Other Industry	Index (2014 =100)	100	336	661
Residential		100	195	333
Commercial		100	295	935
Transport (passenger)		100	280	585
Transport (freight)		100	239	550
Others (Agriculture and Forestry)		100	199	322

Model structure of AIM/Enduse



Minimize *Total Cost (TC) at year t*
TC= Initial investment cost ($)
+ Operating and maintenance cost ($/year)
+ Energy cost ($/year)
+ Payment for energy tax ($/year)
+ Payment for emission tax ($/year)

• Service demand

$$D(j) \leq \sum_{l} A(j,l) \cdot X(l)$$

$D(j)$: Service demand quantity of service type j
$A(j,l)$: Output of service j per unit operation of device l
$X(l)$: Operating quantity of device l

• Stock dynamics

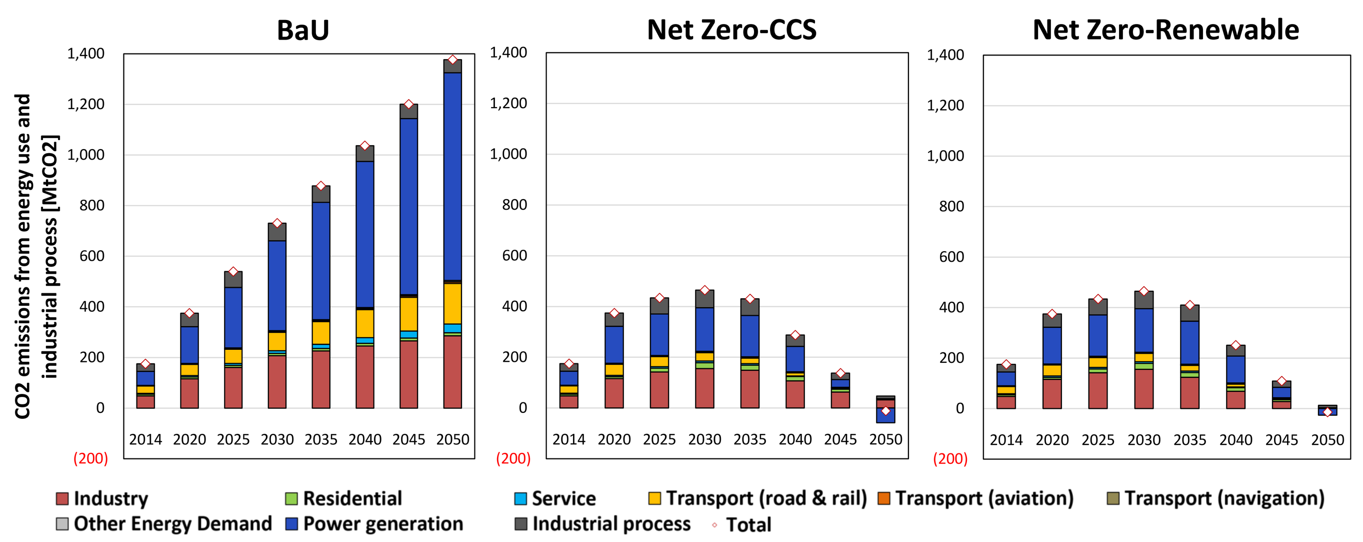
$$S(l) = \bar{S}(l) \cdot \left(1 - \frac{1}{T(l)}\right) + r(l) - w(l)$$

$S(l)$: Stock of device l
$\bar{S}(l)$: Stock of device l in the previous year
$T(l)$: Life time of device l
$r(l)$: Recruited quantity of device l
$w(l)$: Retired quantity of device l

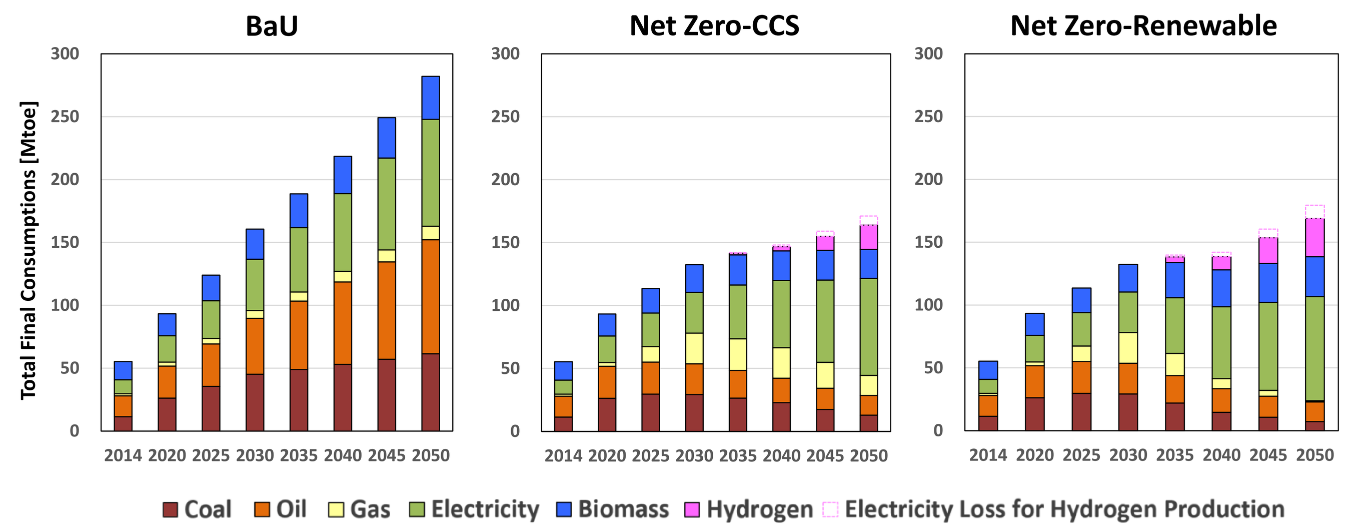
- Using AIM/Enduse, we estimate CO2 emissions from energy use and industrial process, energy demand and share of countermeasures in Vietnam up to 2050.
  - ➢ AIM/Enduse model selects technologies to meet the service demand with minimizing the total cost.
  - ➢ "Net Zero-CCS" and "Net Zero-Renewable" scenarios are set to achieve carbon neutrality in 2050.
    In Net Zero-CCS scenario, the amount of CCS is large, 250 MtCO2 in 2050. In Net Zero-Renewable scenario, the ratio of renewables is high, 90% of power supply in 2050.
  - ➢ Future service demand is estimated based on various sources, including GDP growth rate, calculation result from AIM/ExSS and assumptions from Vietnamese government.
  - ➢ Calculation results of this analysis are not necessarily consistent with the emission pathway and peak year of the latest NCCS.

Result

Estimates of CO2 emissions from energy use and industrial process



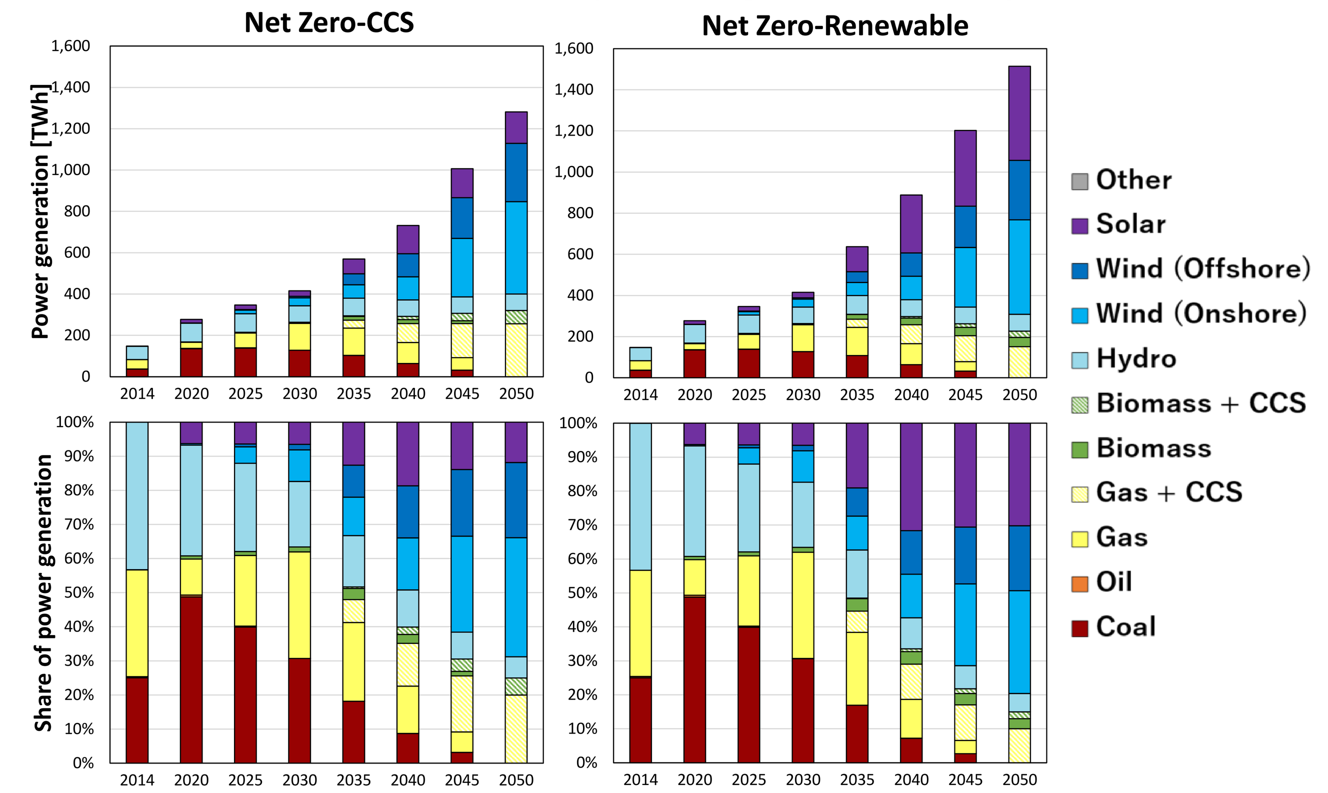
Estimates of total final consumptions of energy



- In both countermeasure scenarios, CO2 emissions from energy use and industrial process peak at about 500 MtCO2 in 2030, and reach carbon neutrality in 2050.
- Even if carbon neutrality is achieved in 2050, emissions from some sectors remain because of the use of fossil fuels. CCS offsets these residual emissions.
- Total final consumptions decrease by about 40% compared to BaU scenario because of energy savings by high-efficient technologies and the shifts from fossil fuels to electricity.

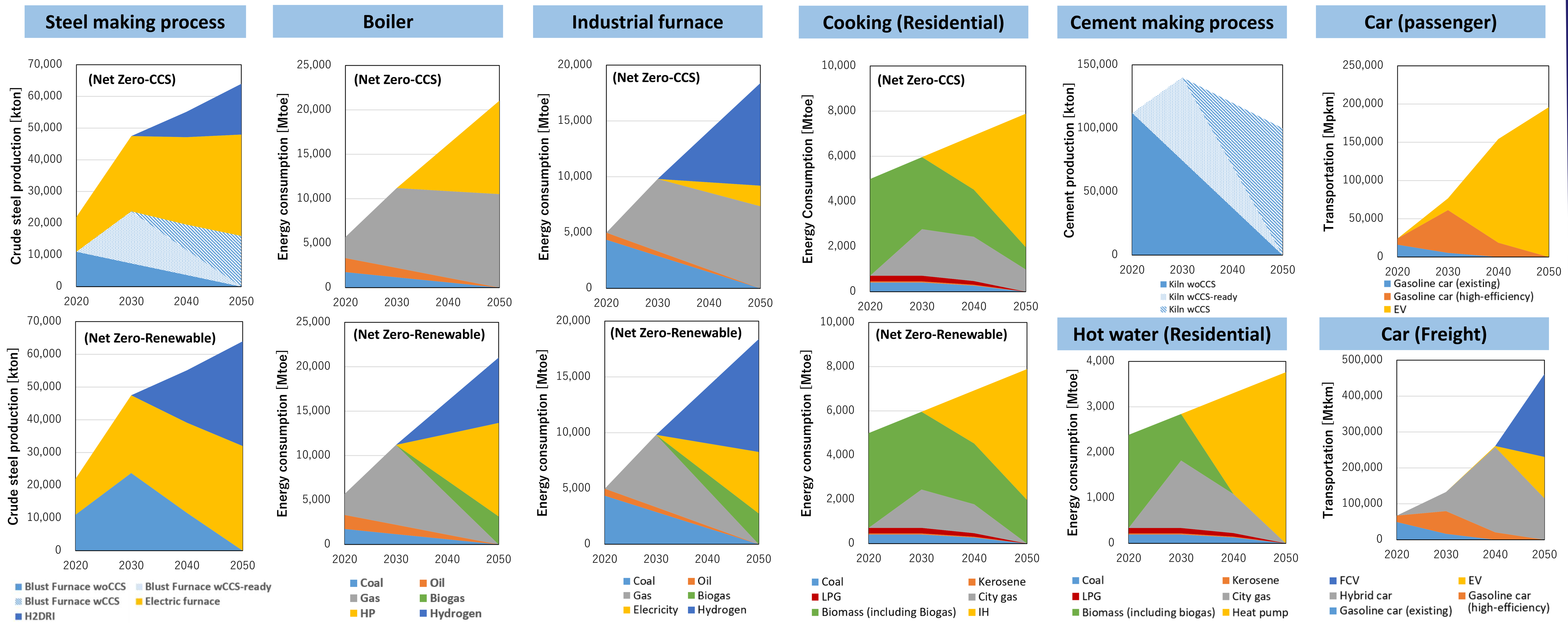
- Power generation increases up to 1,281 TWh in Net Zero-CCS scenario and 1,514 TWh in Net Zero-Renewable scenario because of acceleration of electrification and use of hydrogen (Imports or exports are not considered, and fully self-sufficient in hydrogen).
- Large-scale renewables are required and coal power plant cannot be built after 2025 to achieve carbon neutrality.

Estimates of trends in power generation up to 2050



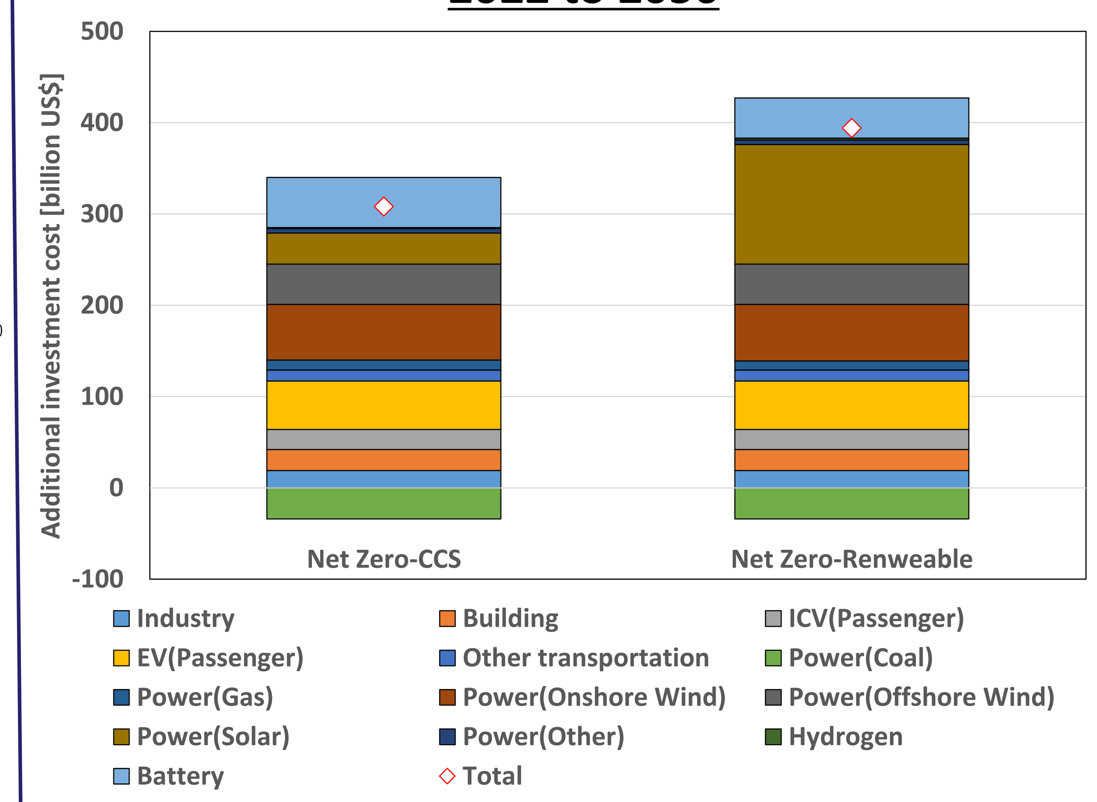
- Electrification should be promoted in all sectors.
- Use of hydrogen is needed in the industry sector after 2030 and in the freight transport sector after 2040.
- Early introduction of countermeasures is important not to make the existing equipment stranded assets.

Transition of main technologies up to 2050



- Additional investment cost is US $308 billion in Net Zero-CCS scenario and US $394 billion in Net Zero-Renewable scenario. EV, renewables and battery cover the major part of additional cost.

Estimates of additional investment cost from 2022 to 2050



* Assumptions : Discount rate is 10%. 1% of wind power generation will be stocked by battery after 2035.

Conclusion

- We show the pathways to achieve carbon neutrality in 2050 in the two scenarios, Net Zero-CCS scenario and Net zero-Renewable scenario. Both scenarios show that more than 150 MtCO2 of CCS and 80% of renewables are needed in 2050 and the emission peak year is 2030.
- Electricity demand in 2050 will be 8 to 10 times larger than in 2014 because of acceleration of electrification and use of green hydrogen.
- Additional investment cost from 2022 to 2050 to achieve net zero is around US $300 to US $400 billion. EV, renewables and battery cover the major part of additional cost.
- To avoid making stranded assets as far as possible, calculation results suggest that, 1. in the industry sector, industrial facilities that can use hydrogen or CCS in future should be introduced as soon as possible, 2. in the transport sector, new gasoline cars should not be sold after 2030, and 3. in the power sector, coal-fired power plant should not be built after 2025.
- Regarding innovative technologies, not only domestic R&D but also technological partnership with developed countries will be important.

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