Achieving Net Zero CO2 Emissions by 2050: Energy Demand, Supply, and Emission Scenarios

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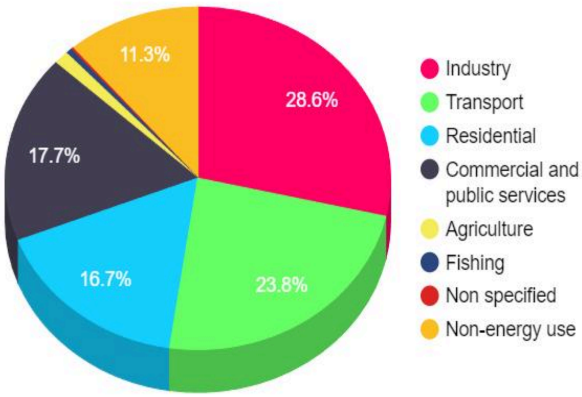
Energy Demand



As per the energy balance table 2020 data, the total final consumption is 1,10,08,801 TJ. The industry sector is contributing to the most demand (28.6%), followed by transport (23.8%). The residential sector (16.7%) and the commercial sector (17.7%) have comparable contributions. Being a developed nation, the data also shows that agriculture sector consumption is lower, i.e., 11.3%.

Figure: Energy consumption by sector
Source: (Energy balance table 2020)

In the end, oil dominated the transportation, agricultural, and fishing industries, accounting for 50.4% of all energy consumption. Thirty percent of the energy consumed was electricity, of which over half came from the residential, commercial, and public services sectors. The electricity industry, which needs to be decarbonized, also uses oil and coal.

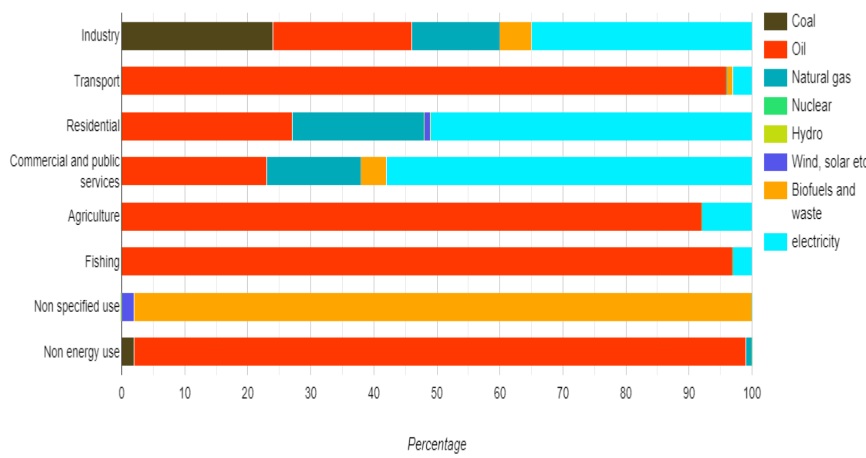


Figure: Energy consumption by sector from different sources
Source: (Energy balance table 2020)

Energy supply

Oil and coal make up 4.27 and 6.20 EJ, respectively. Over 88% reliance on fossil fuels, and less than 9% comes from renewable sources (waste, biofuels, wind, and solar energy).

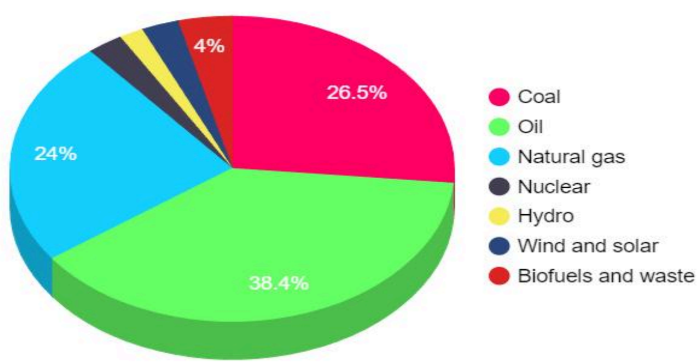
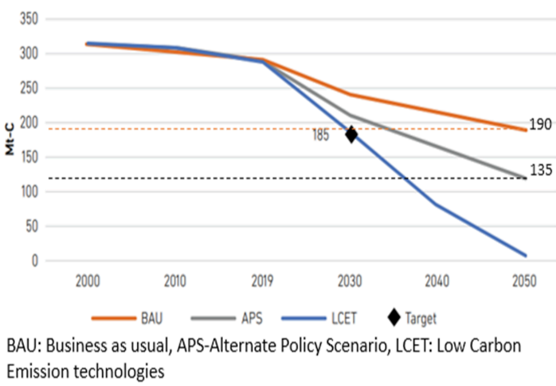


Figure: Primary energy supply in 2020

Source: (Energy balance table 2020)

CO2 Emissions



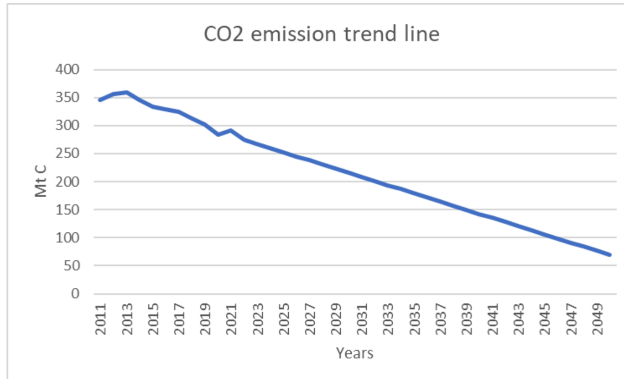


Figure: Different policy scenario as per ERIA
Source: ("Energy outlook 2021" 2021)

Figure: Extrapolated CO2 emissions in 2050
Source: ("Per capita CO2 emissions", n.d.)

In 2019, 301.86 Mt-C of CO2 were emitted. The extrapolated data until 2050 from 2011 shows that current trends will still lead to 69.5 Mt-C, which is far from zero. The ERIA report estimates that in 2050, 190 Mt-C of CO2 emissions would result from the current policy scenario, which is the business-as-usual scenario. But the LCET scenario—which assumes an 85% reduction in fossil fuels and a 60% increase in renewables—is presumptive. There will be no net CO2 emissions. We will only examine scenarios that pertain to the LCET focus.

Net Zero Scenario

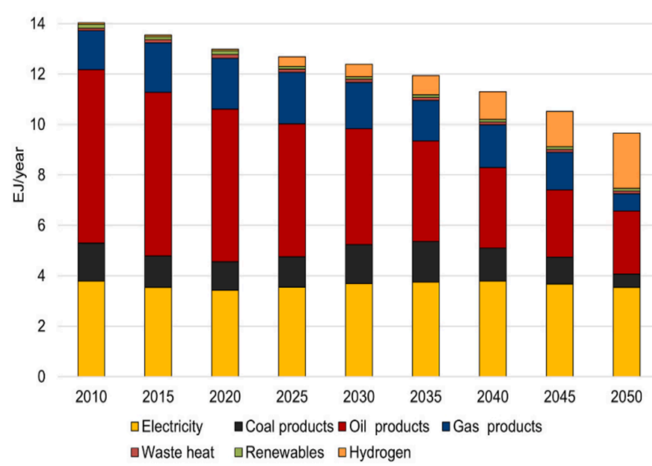
The model used is consistent with Japan's LCET scenario; the data on CO2 emissions matches our estimates for emissions in 2050.

Demand-side assumptions:

Crude oil, coal, and liquefied natural gas (LNG) will see increases in cost, insurance, and freight (CIF) of 67%, 27%, and 34%, respectively, between 2010 and 2050. In 2050, the cost of hydrogen (CIF) will be 330 JPY/kg H2 (3.0 USD/kg H2). By 2050, the population will have dropped to 97 million. There will be 47.2 million households, which will offset the gains in building energy efficiency. The energy demand for transportation is significantly reduced as a result of advancements in internal combustion engine efficiency and the expansion of battery-electric vehicles in the road transportation sector.

Demand projections:

Fuel switched from gasoline to electricity in transportation due to the decarbonization of electricity, which accounted for 3.8 EJ of energy consumption in 2050. Between 2010 and 2050, the percentage of electricity and hydrogen will rise from 27% (3.8 EJ) to 59% (5.7 EJ). Since the nation has fewer CCS



facilities and more biomass available for dispatchable power plants (2 EJ in 2050), hydrogen will become increasingly important.

A decrease in population and an increase in electricity due to the electrification of the transportation sector are the reasons for the electricity plateau. ("Japan's pathways to net zero", n.d.)

Transition of Primary energy consumption in LCET case scenario

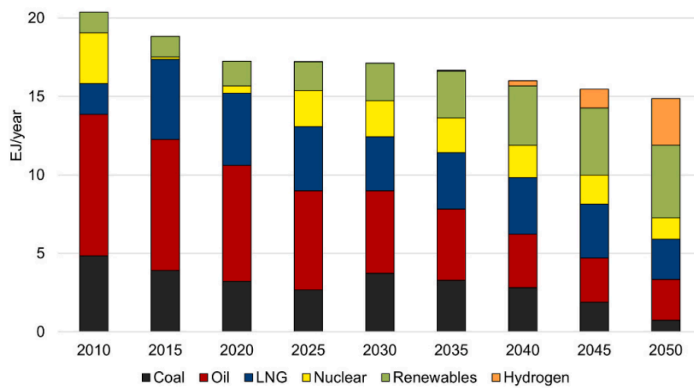
Source: ("Japan's pathways to net zero", n.d.)

Supply-side assumptions:

By 2050, nuclear power will have a maximum generation capacity of 19 GW (compared to 47.5 GW in 2011). 337.6 GW is the maximum amount of renewable power that can be produced by 2050.

Primary energy supply projections:

Systems that use low-carbon energy sources, like hydrogen and nuclear power, account for 3.4 EJ (60%). 650 TWh of renewable energy will be produced. The capacities of wind and solar will increase by 11.2 and 4.5 times, respectively. 178.4 Mt-C of CO2 emissions reduction by using fossil energy at 10.47 EJ (62% fewer fossil fuels). Coal will not phase out completely in any scenario, even though Japan declared net zero by 2050. ("Japan's pathways to net zero", n.d.)



Transition to primary energy supply in LCET scenario

Source: ("Japan's pathways to net zero", n.d.)

Carbon capture side assumptions:

Properties of the DAC process.

Property [Unit]	Value
Investment cost [JPY/t-CO_2 (USD/t-CO_2)]	20,600 (188)
Labor cost [JPY/t-CO_2 (USD/t-CO_2)]	100 (0.9)
Fuel cost [JPY/t-CO_2 (USD/t-CO_2)]	13,300 (121)
Utility cost [JPY/t-CO_2 (USD/t-CO_2)]	1400 (13)
Fuel consumption [MJ/t-CO_2]	5966
$CaCO_3$ consumption [kg/t-CO_2]	20.5
Water consumption [kg/t-CO_2]	3199

Properties of CO_2 capture process from biomass power plants.

Property [Unit]	Value
Additional investment cost [JPY/MW (USD/MW)]	108 (0.98)
Additional fixed O&M cost [JPY/MW/yr. (USD/MW/yr.)]	4 (0.04)
Additional variable O&M cost [JPY/MWh (USD/MWh)]	554 (4.95)
Efficiency loss [%pt.]	15.9

Source: ("Basic Hydrogen Strategy" 2023)

81.88 Mt-C of maximum annual CO2 storage capacity. By 2030, bioenergy utilizing direct air capture and carbon capture and storage will be accessible. Post-combustion CO2 capture technologies based on monoethanolamine. ("Japan's pathways to net zero", n.d.)

NET ZERO TRANSITION

58.68 Mt-C of CO2 (carbon capture) will have been eliminated by 2050 thanks to DACCS and BECCS procedures. reduction of CO2 emissions by 178.4 Mt-C due to the use of low-carbon energy sources and a decrease of 10.47 EJ in the supply side of fossil fuel consumption. The remaining 35.85 Mt-C reduction will be due to energy efficiency and population decline.

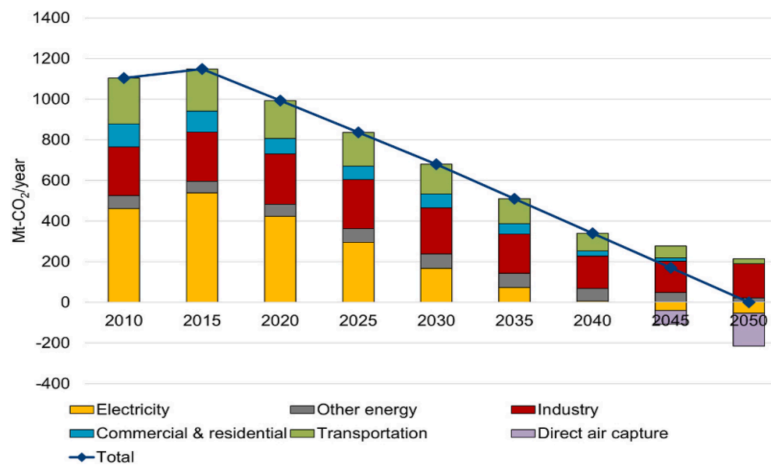


Figure: Transition of CO2 emission in base-case scenario
Source: (“Japan's pathways to net zero”, n.d.)

Additional Policy Measures

- The "three E's"—environment, energy security, economic efficiency, and safety—are the cornerstones of Japanese policy. More focus on energy security and economic efficiency should be implied.
- Policies that support the growth of dispatchable capacity and modify the capacity to account for variations in renewable energy output.
- Policies pertaining to the importation of hydrogen as a stable substitute for fossil fuels (“Japan 2021 - Energy Policy Review”, n.d.)

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