Korea's 2050 Carbon Neutrality Technology Pathways

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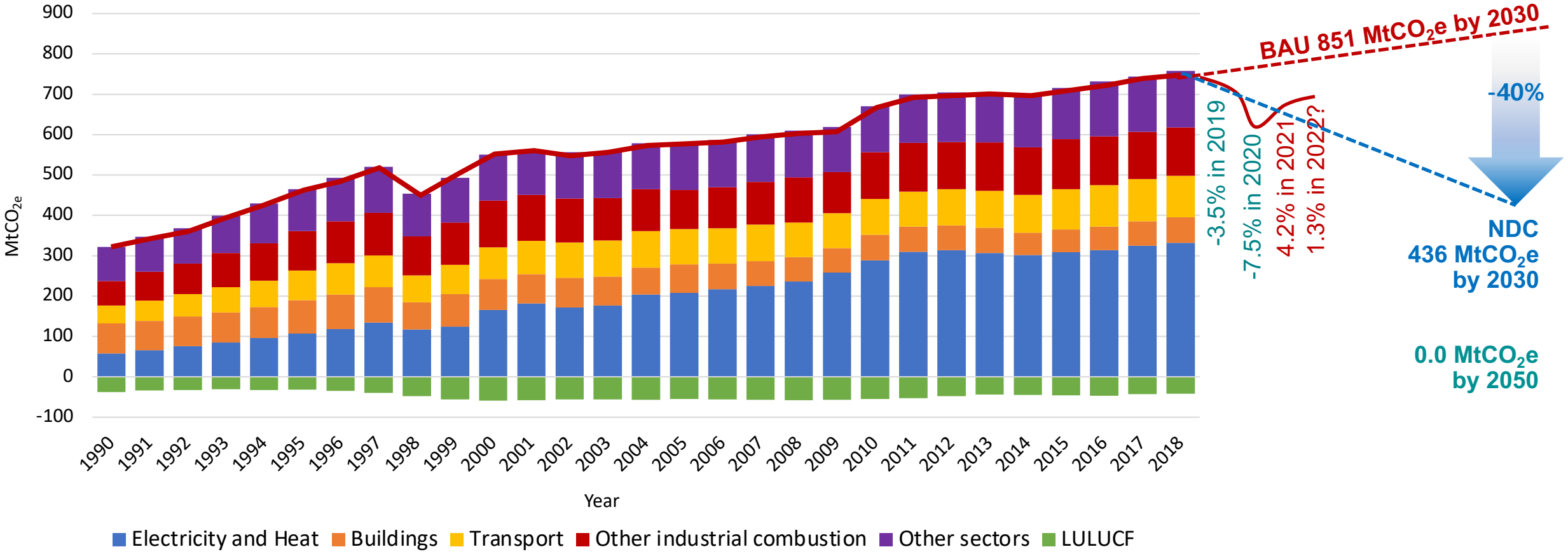
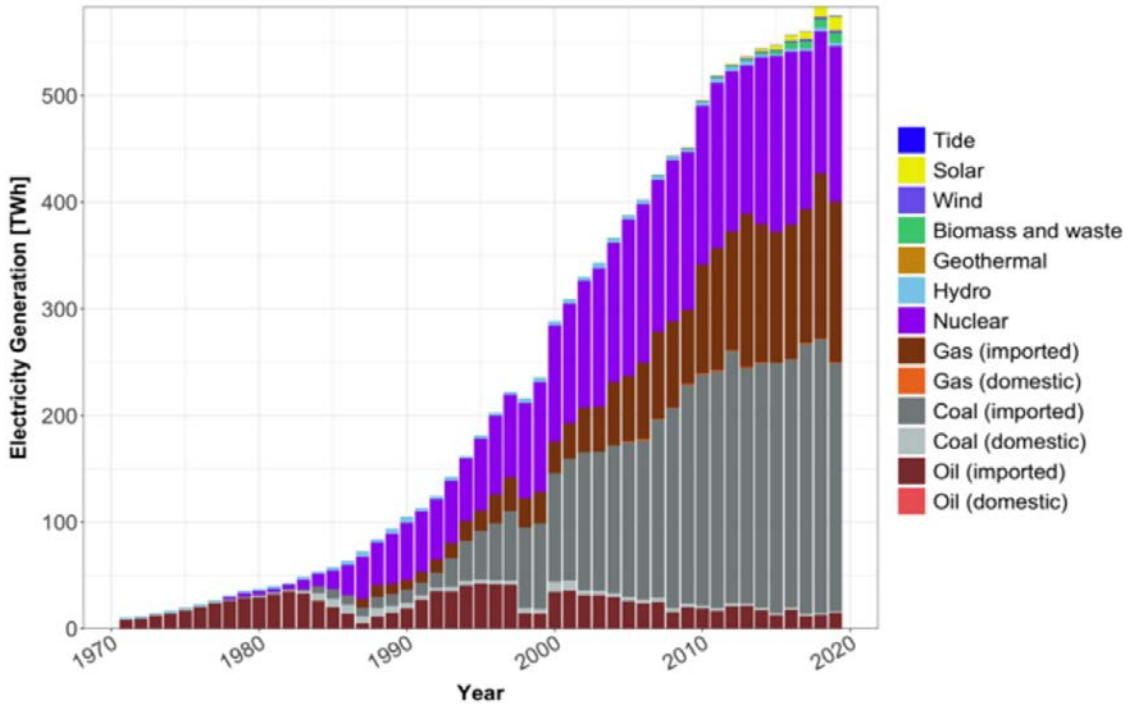
GHG emissions in Korea and mitigation targets

- 2050 carbon neutrality declared in October 2020 (joining 138 countries)
- Revised up 2030 NDC target to -40% (from 2018 level) in October 2021
- Carbon neutrality and green growth framework act came into force in March 2022

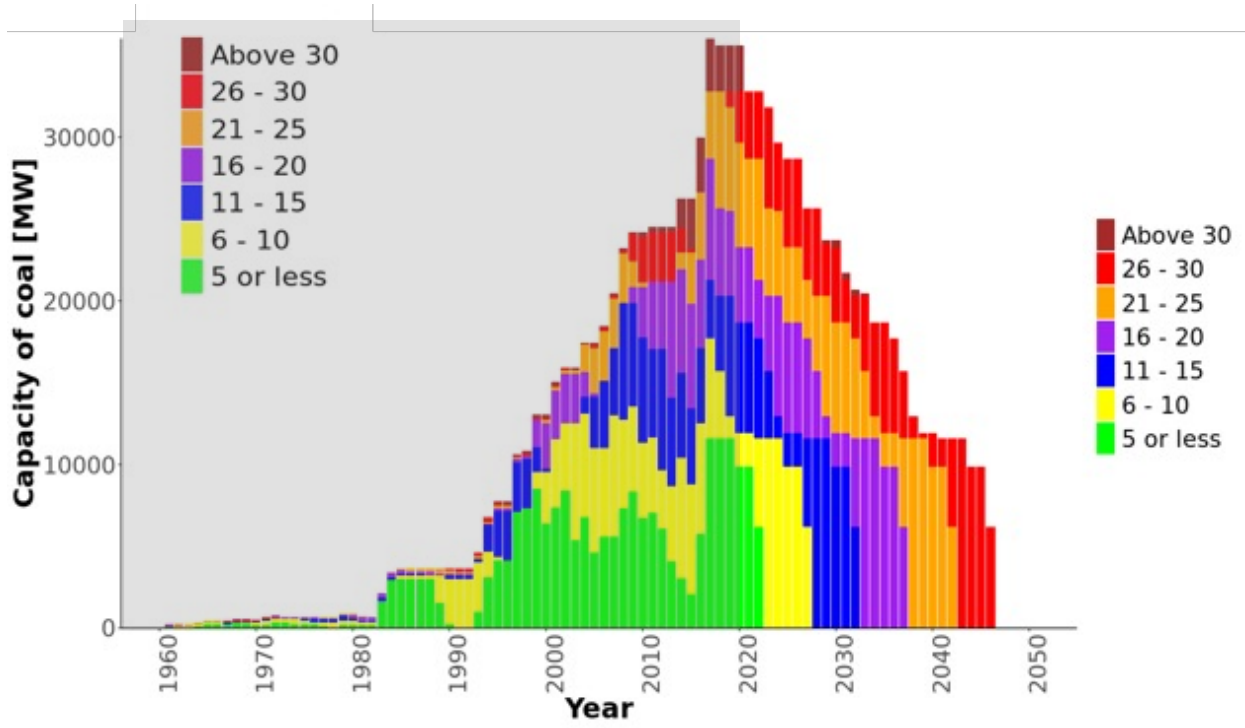


Korea’s carbon lock-in seems significant.

Development of electricity mix in Korea



Age structure of coal plants & expected phase-out



Source: Hyun et al. (2021), available at https://arxiv.org/abs/2111.02872

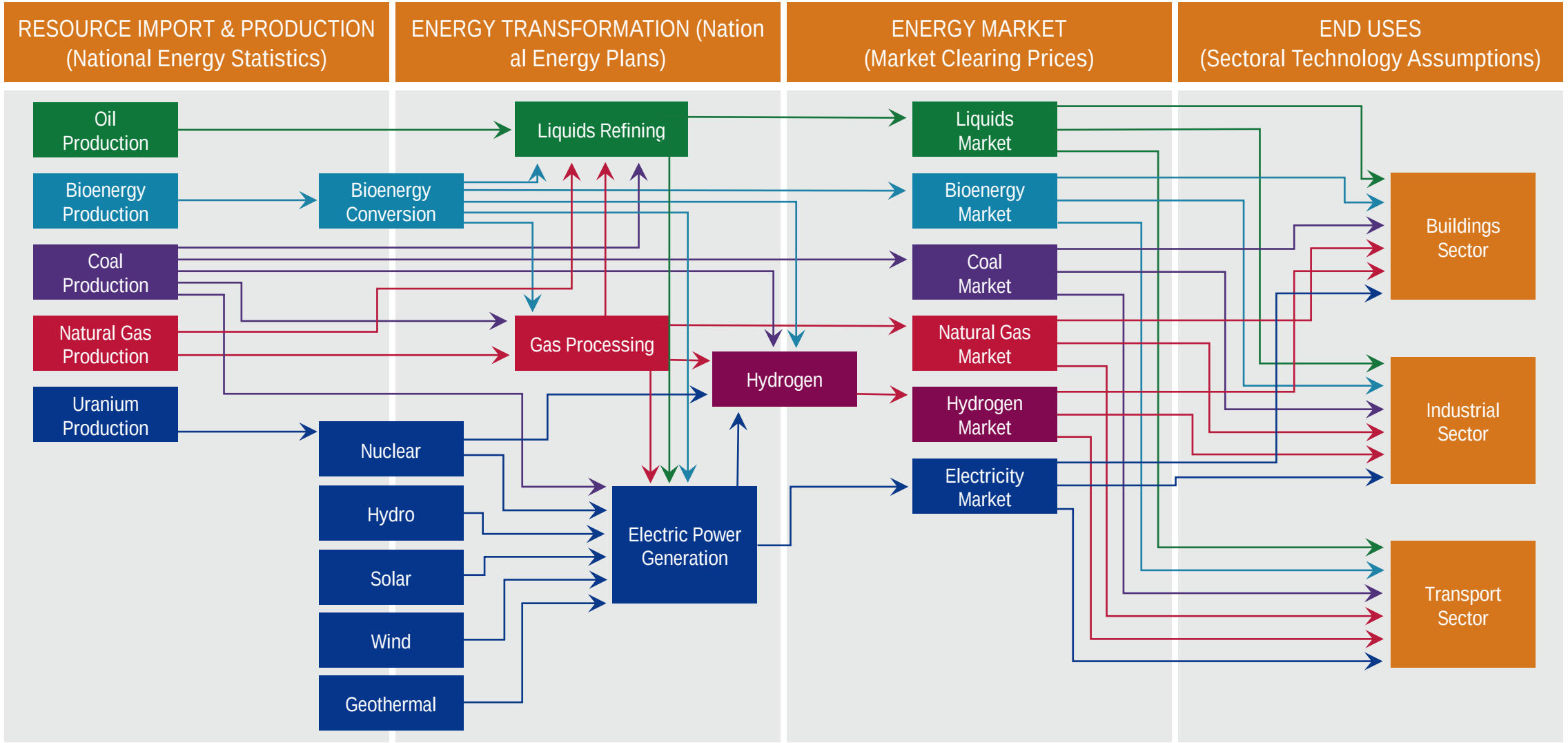
Research questions

- What does the 2050 carbon neutrality target mean for Korea's energy system?
- What is the role of the power sector for the 2050 carbon neutrality target vis-à-vis the other sectors?
- How does the availability of critical mitigation technologies play out?
- What is the feasibility of alternative carbon neutrality scenarios?
- What are the trade-offs between constraints associated with deploying critical mitigation technologies?

➢ We **develop scenarios** spanning key uncertainties associated with the target based on an integrated assessment model, GCAM-KAIST 1.0, and **assess policy feasibility** by contextualizing them with the history.

Source: Kim, McJeon, Jung, Lee, Bergero, Eom, 2022, "Integrated Assessment Modeling of Korea's 2050 Carbon Neutrality Technology Pathways," *Energy and Climate Change* https://www.sciencedirect.com/science/article/pii/S2666278722000058

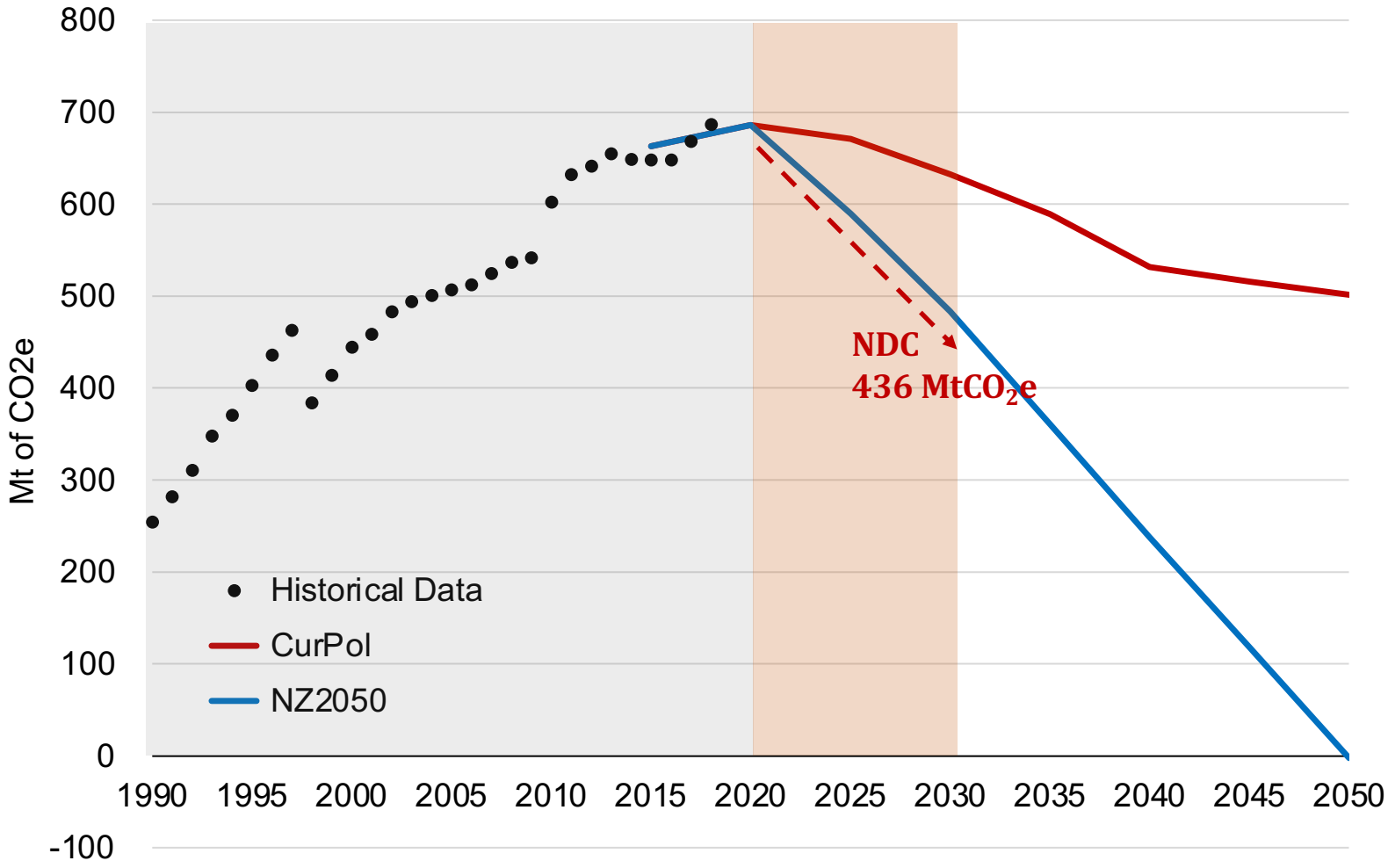
Overview of GCAM-KAIST 1.0



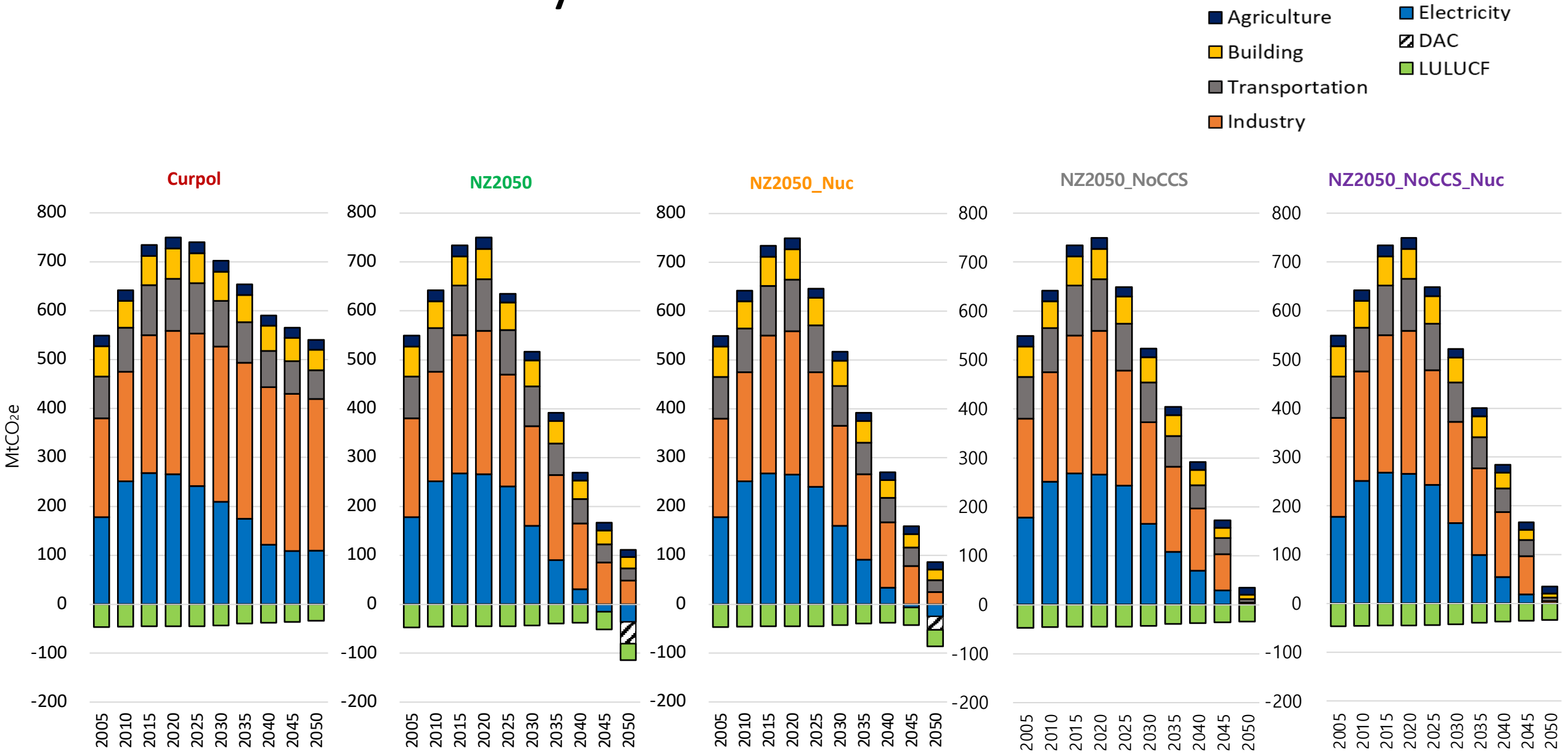
Scenario design

- **CurPol**
  - Current policy scenario that reflects current and planned energy and climate policy measures, including the 9th plan for electricity supply & demand and other sectoral instruments (coal and nuclear phase-out assumed)
- **NZ2050**
  - Scenario that achieves net-zero GHG emissions by 2050 with linearly shrinking yearly carbon emissions (coal and nuclear phase-out assumed)
- **NZ2050_Nuc**
  - Scenario that achieves net-zero GHG emissions by 2050 while permitting nuclear power to be introduced based on economics (coal phase-out assumed)
- **NZ2050_NoCCS**
  - Scenario that achieves net-zero GHG emissions by 2050 without permitting CCS to be introduced (coal and nuclear phase-out assumed)
- **NZ2050_Nuc_NoCCS**
  - Scenario that achieves net-zero GHG emissions by 2050 while permitting nuclear power, but not CCS, to be introduced (coal phase-out assumed)

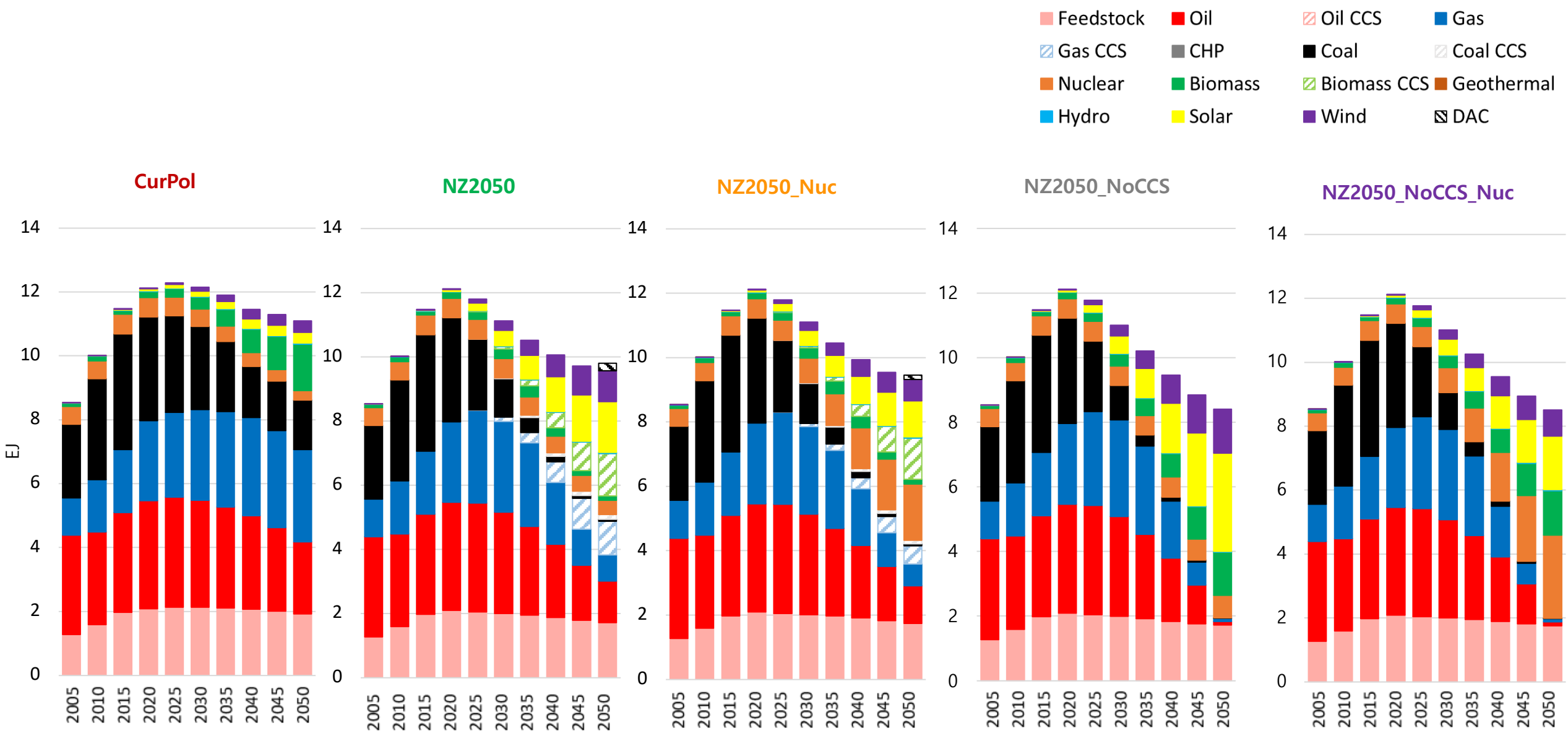
GHG emissions through 2050



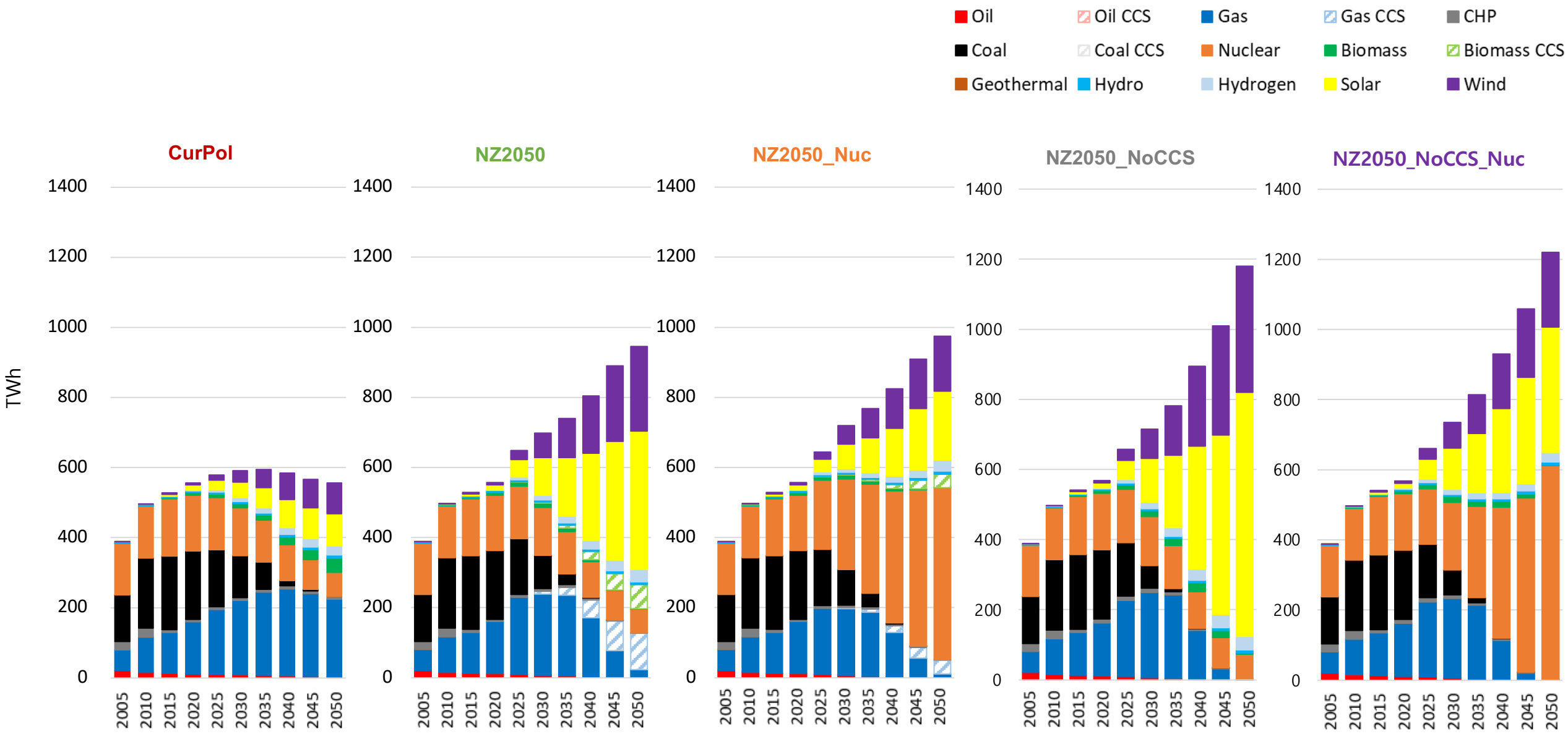
GHG emissions by sector



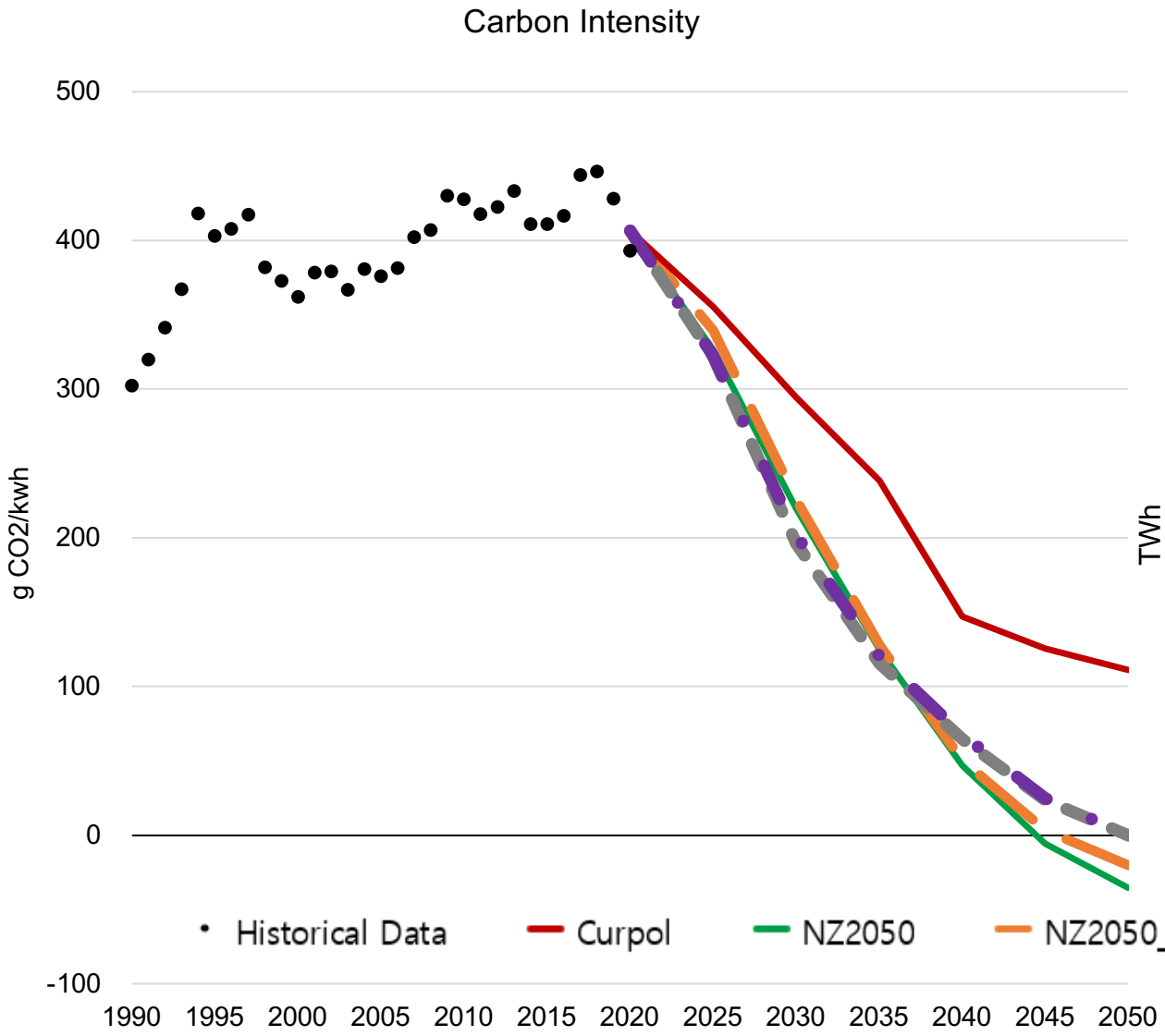
Primary energy consumption by fuel

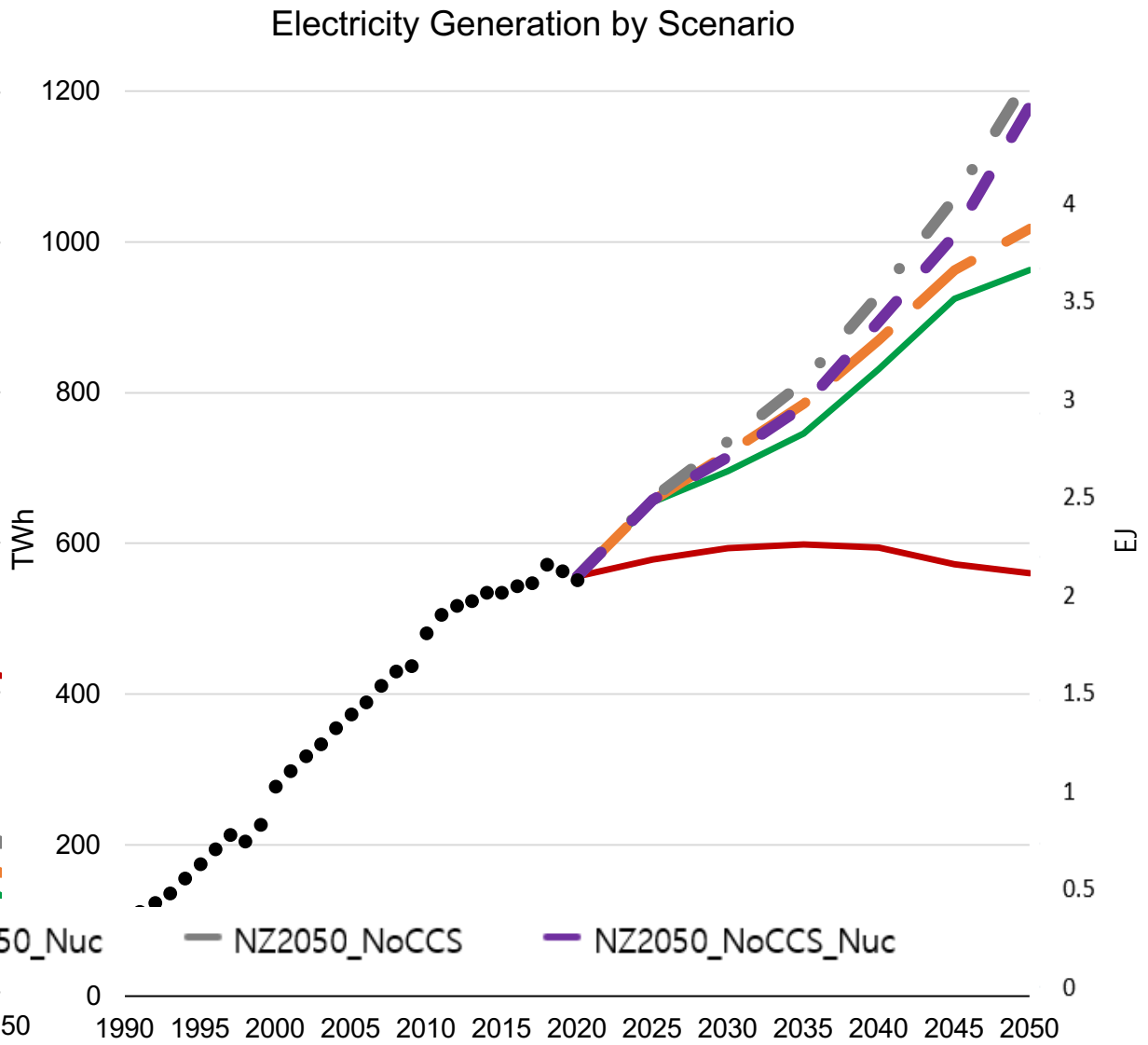


Electricity generation by technology

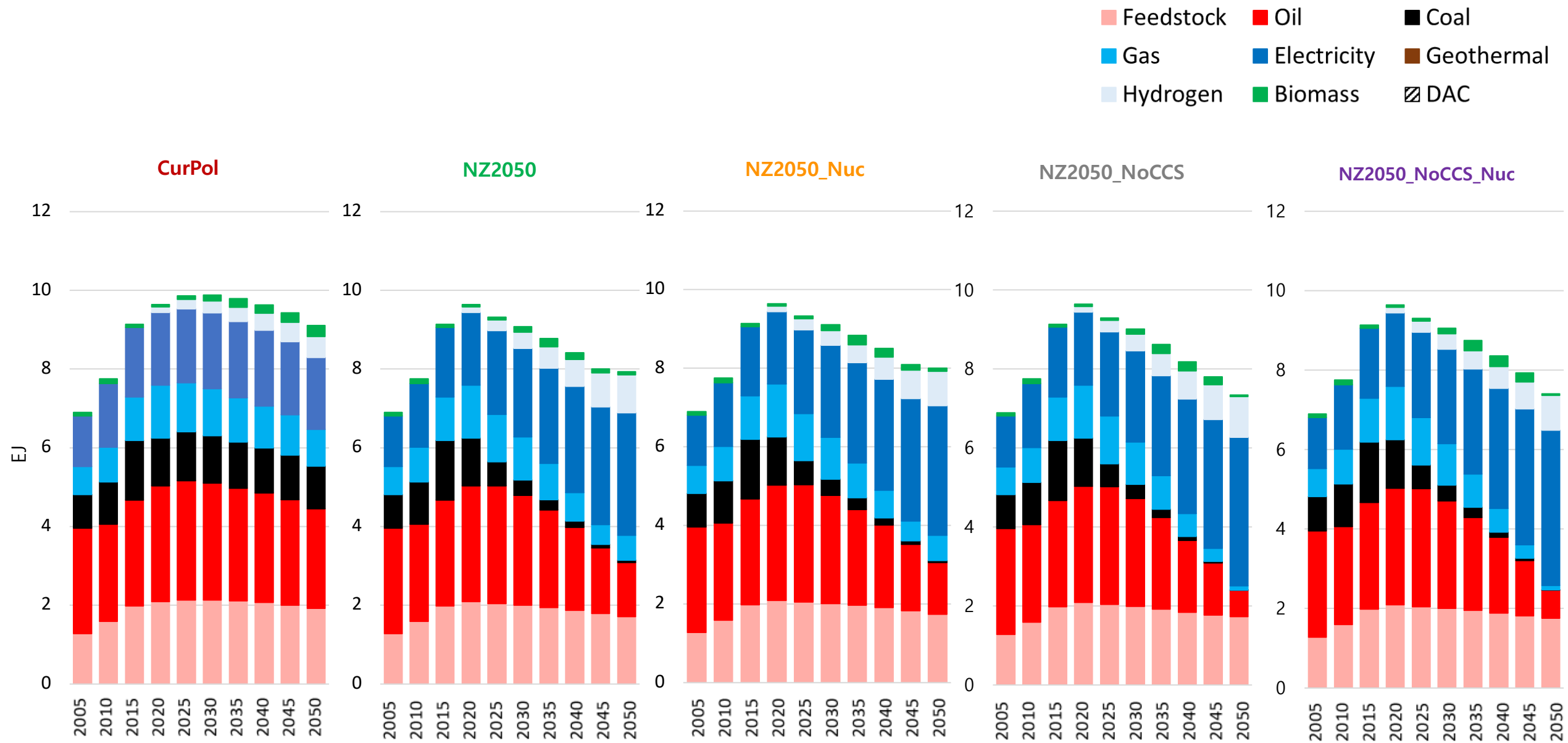


Carbon intensity of electricity generation (left) and total electricity generation (right)

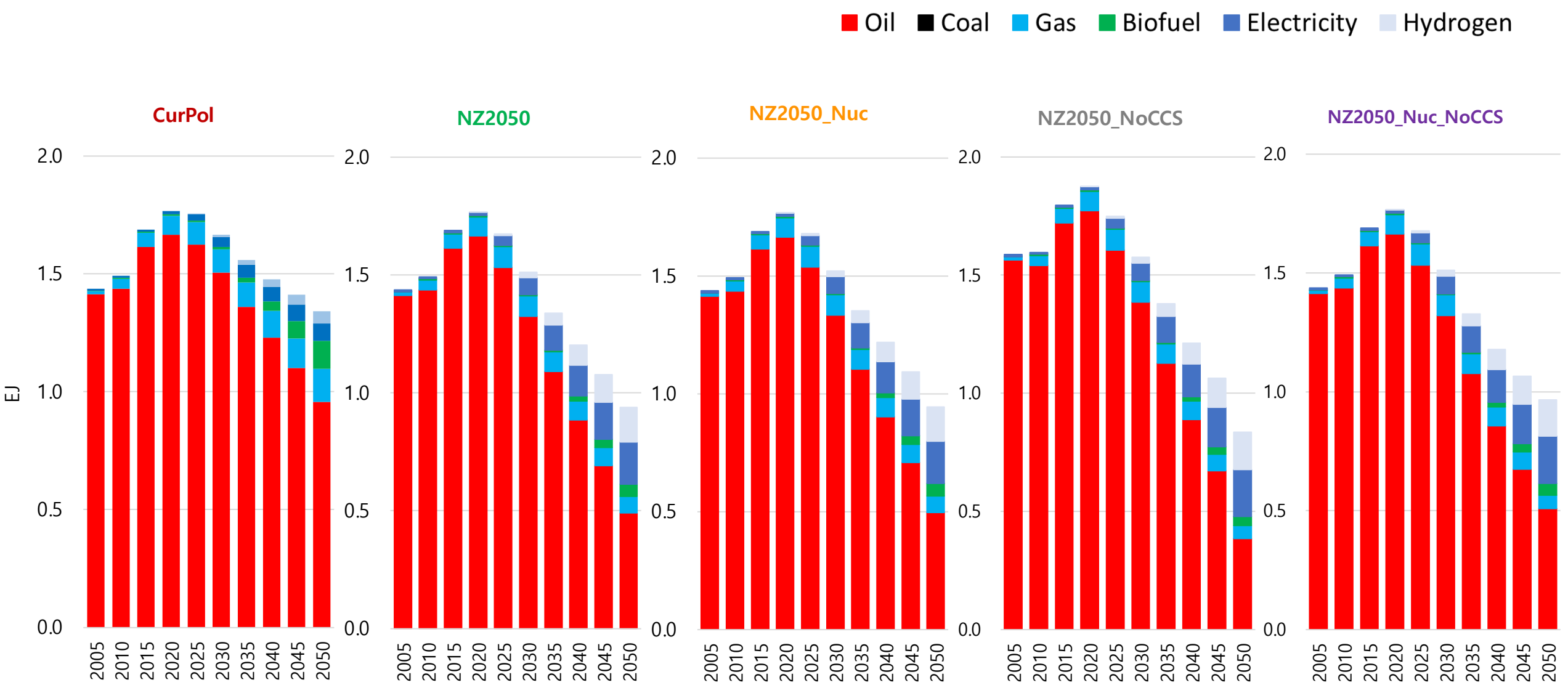


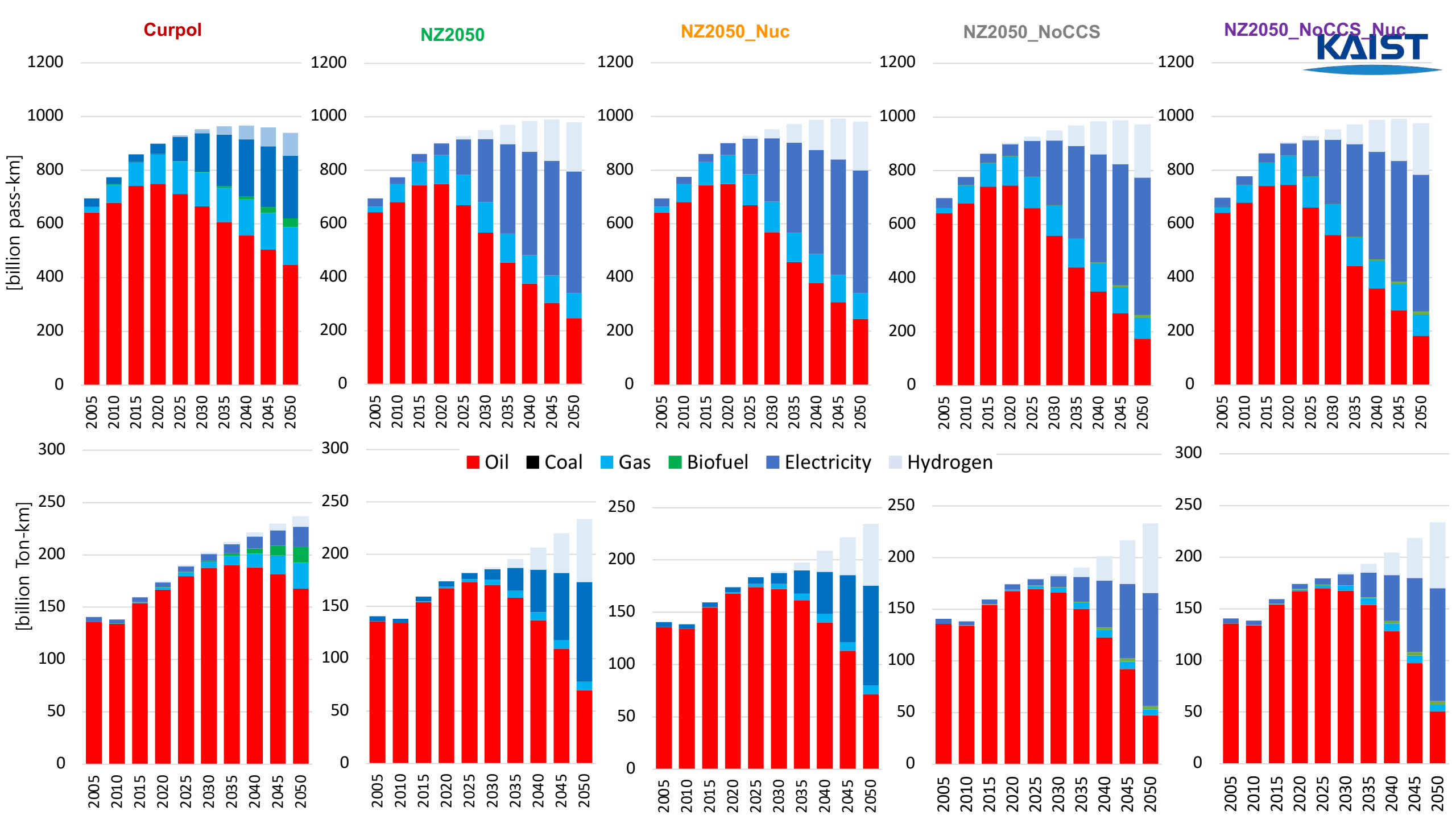


Final energy consumption by fuel

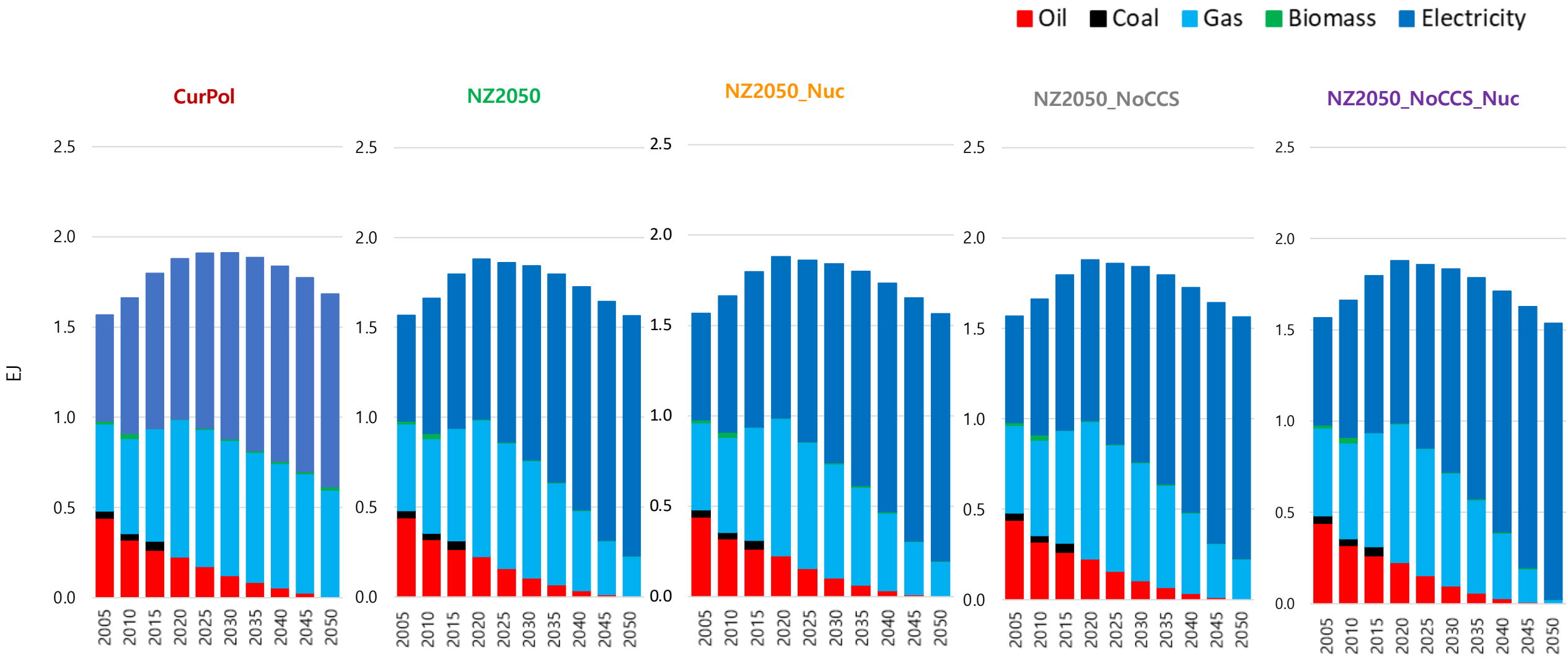


Transportation energy consumption by fuel

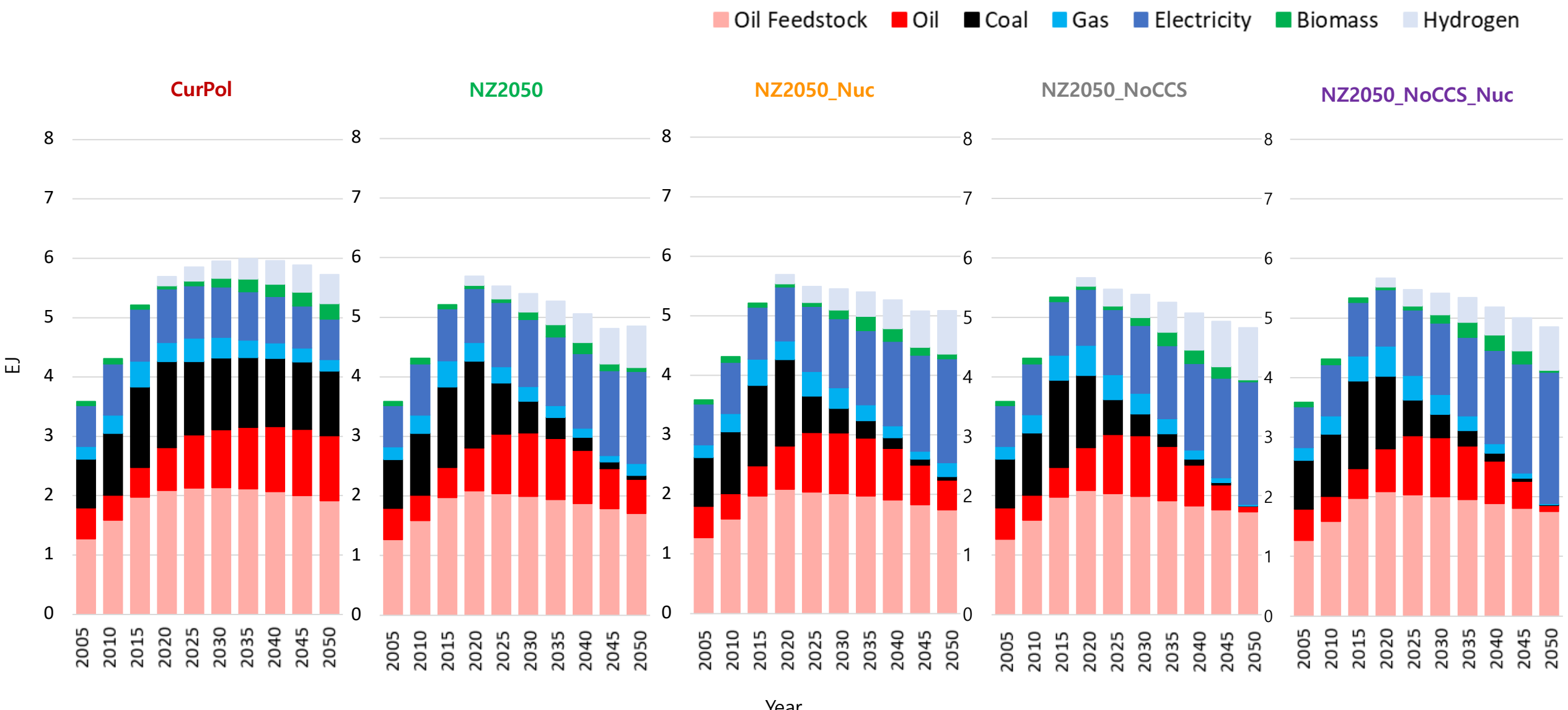



Curpol
NZ2050
NZ2050_Nuc
NZ2050_NoCCS
NZ2050_NoCCS_Nuc
KAIST
[billion pass-km]
[billion Ton-km]
Oil
Coal
Gas
Biofuel
Electricity
Hydrogen
0
200
400
600
800
1000
1200
50
100
150
200
250
300
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

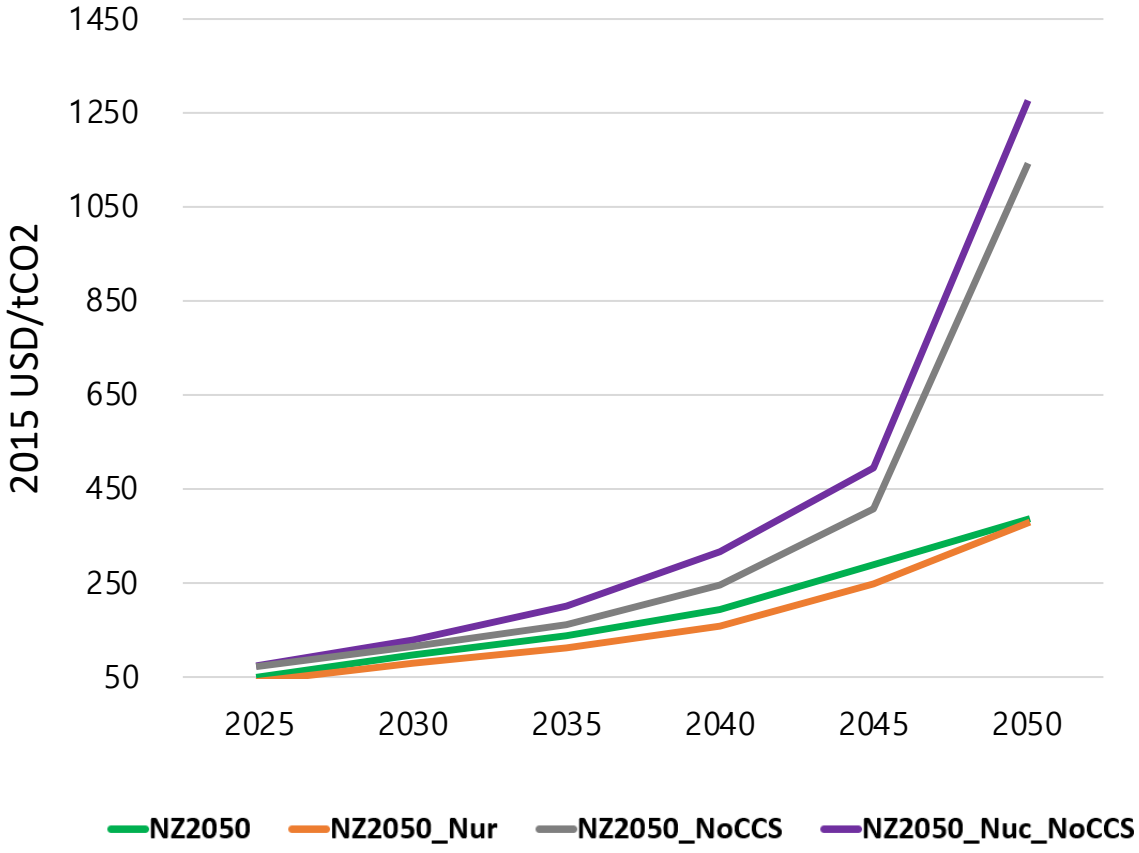
Buildings final energy consumption by fuel

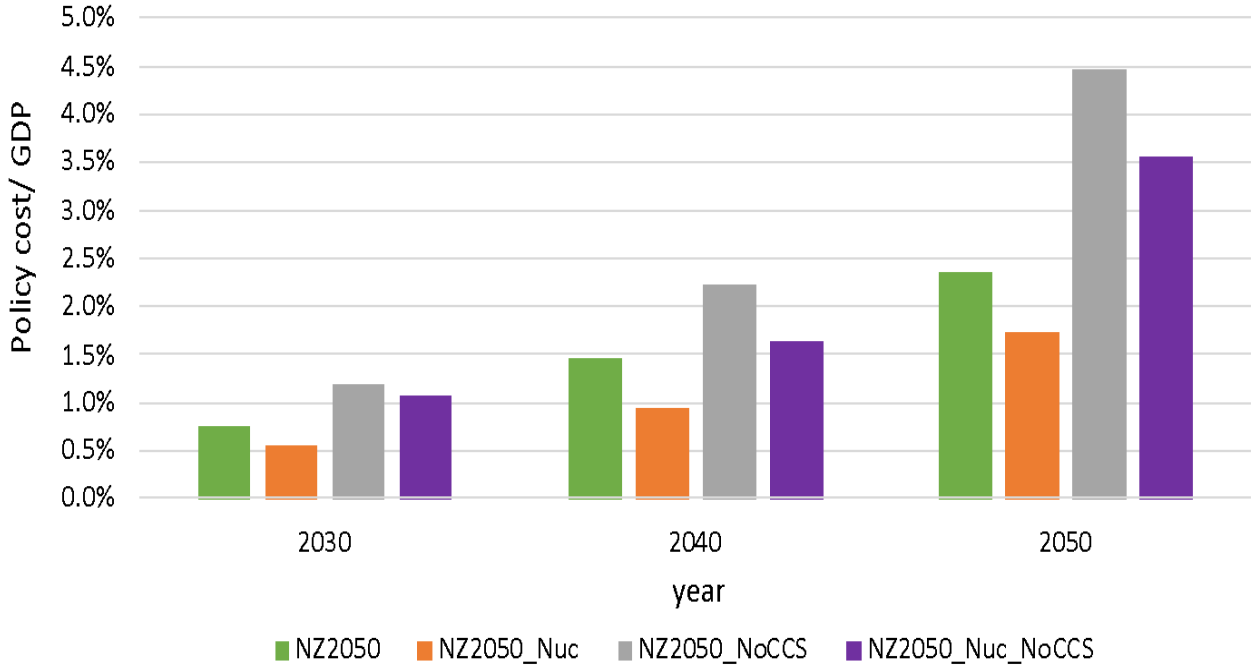


Industry final energy consumption by fuel



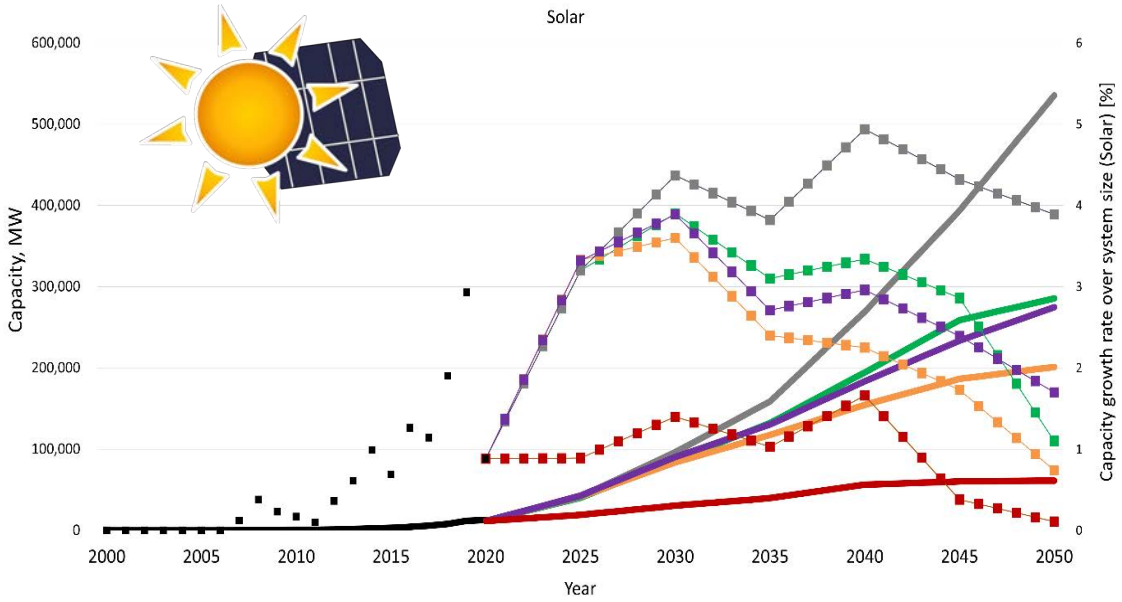
Carbon price and policy costs (total abatement cost)

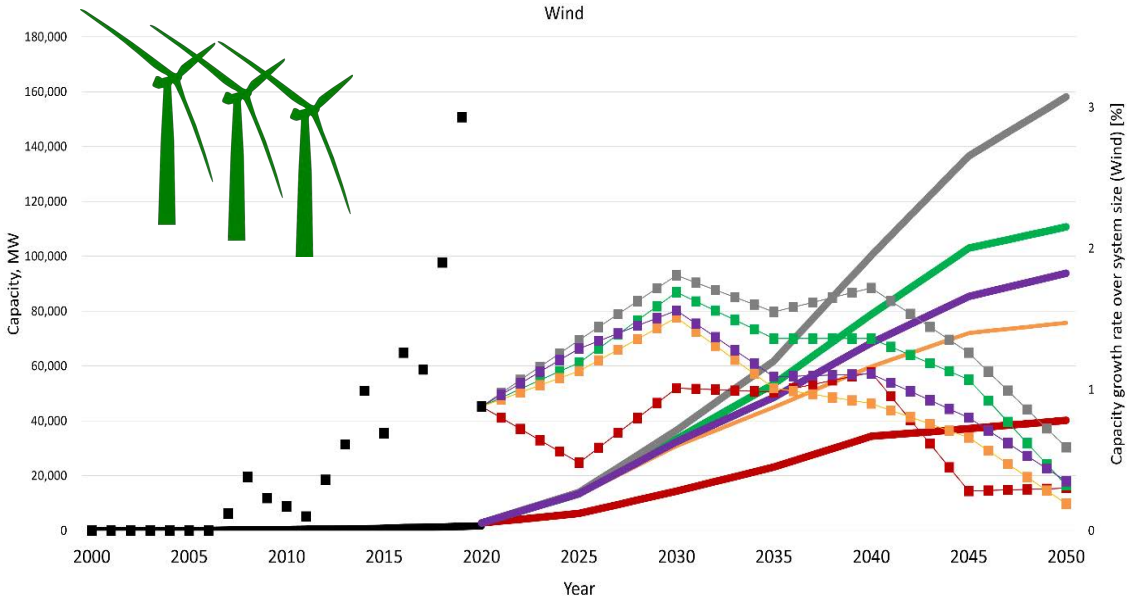


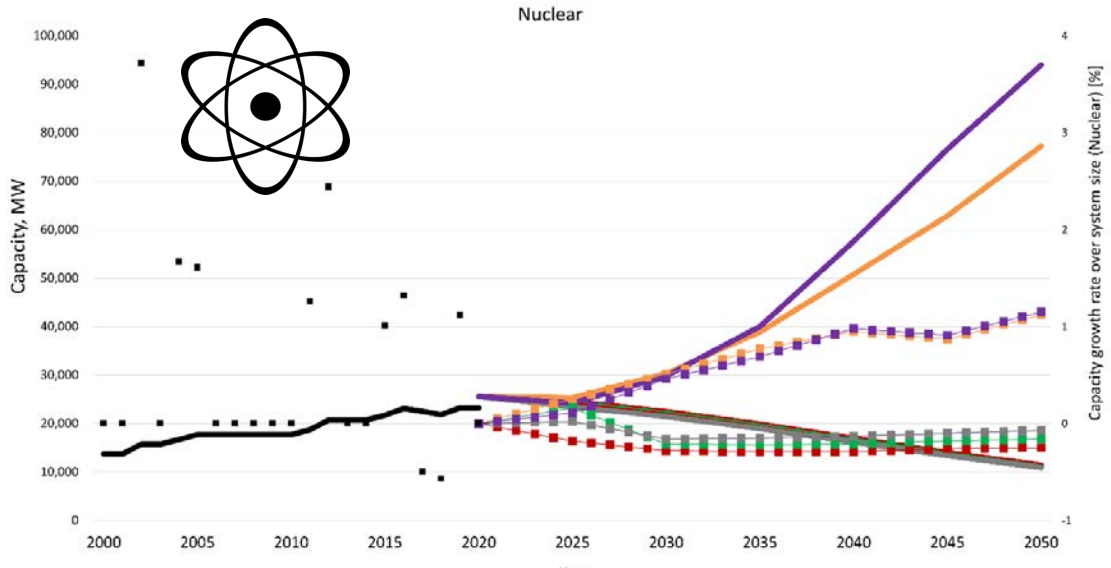


*Policy cost in our study is measured by the area under the marginal abatement cost curve as determined by endogenous choices among competing technologies and its impacts on the demand for energy services.

Capacities and deployment rates through 2050 for solar PV, wind, and nuclear power

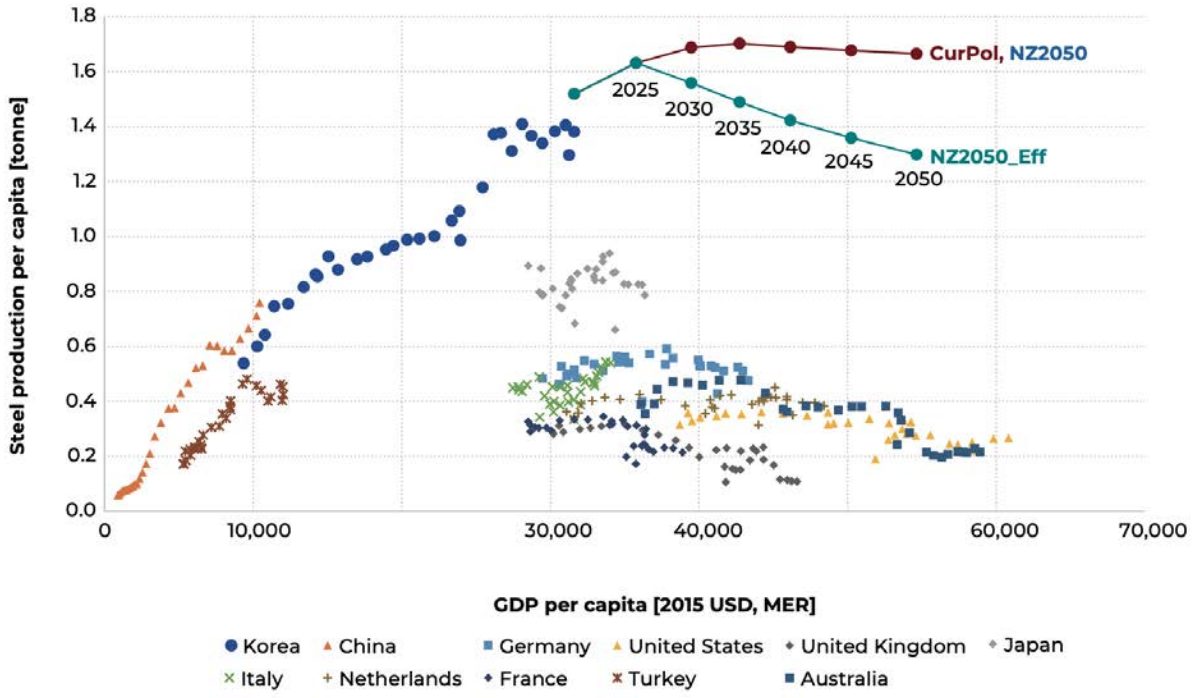


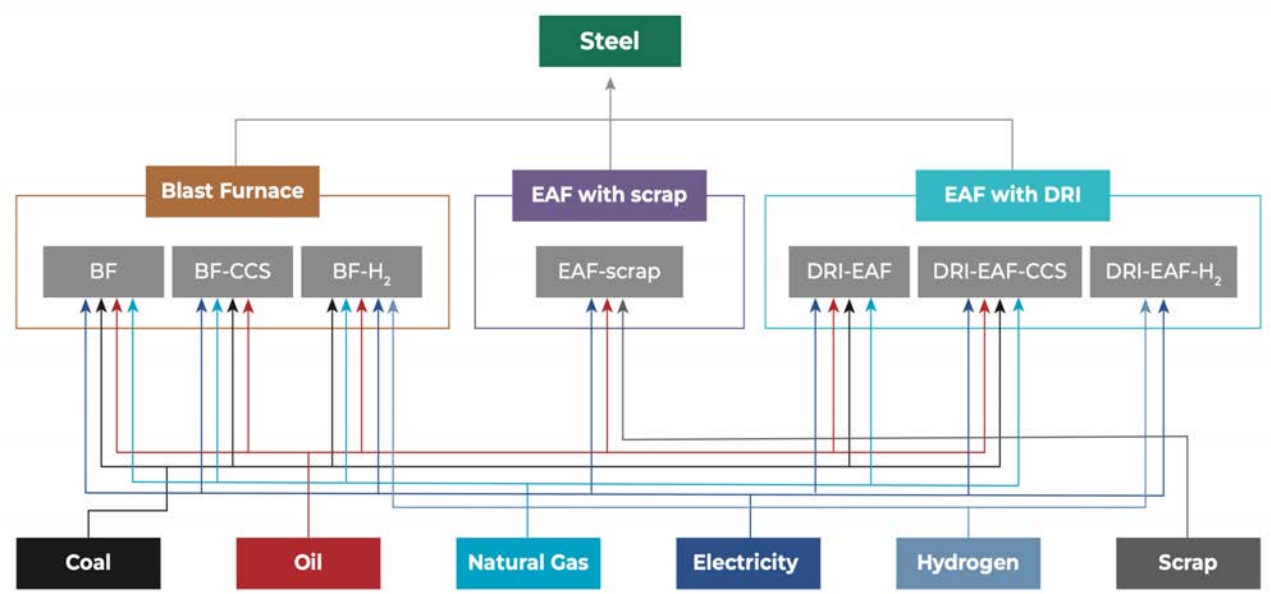




- Capacity Historical Data
- Capacity_NZ2050
- Capacity_NZ2050_NoCCS
- Historical Data_Expansion_rate
- NZ2050_Expansion_rate
- NZ2050_NoCCS_Expansion_rate
- Capacity_Curpol
- Capacity_NZ2050_Nuc
- Capacity_NZ2050_NoCCS_Nuc
- Curpol_Expansion_rate
- NZ2050_Nuc_Expansion_rate
- NZ2050_NoCCS_Nuc_Expansion_rate

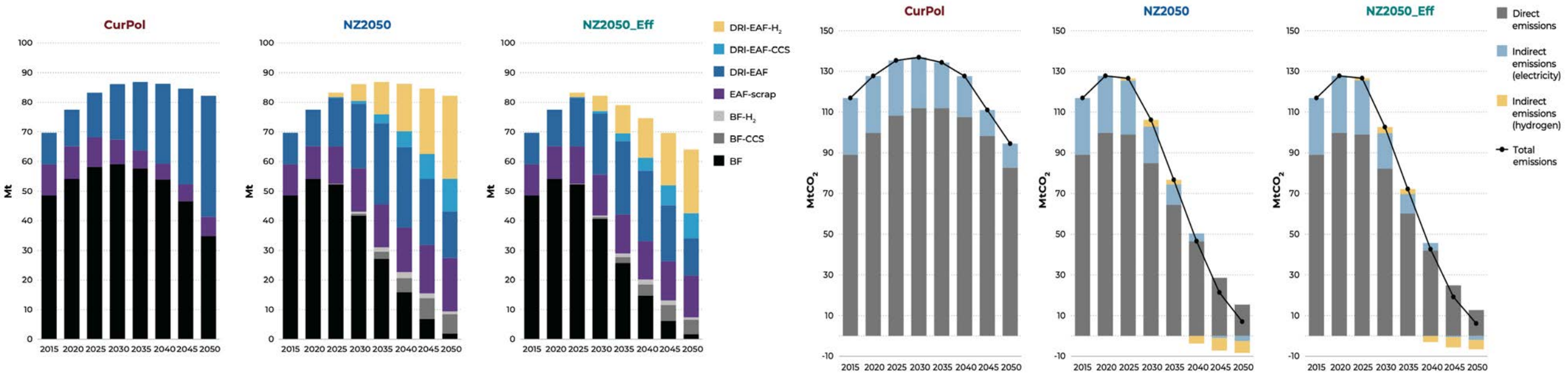
Steel production in Korea and alternative technologies





Source: Eom et al., 2022, "Steel Sector Pathways for Korea's 2050 Carbon Neutrality," KAIST and SFOC, http://www.forourclimate.org/sub/data/view.html?idx=72&curpage=1

Steel sector pathways for 2050 carbon neutrality: steel production (left) and CO_2 emissions (right)



Source: Eom et al., 2022, “Steel Sector Pathways for Korea’s 2050 Carbon Neutrality,” KAIST and SFOC, http://www.forourclimate.org/sub/data/view.html?idx=72&curpage=1

Summary

- The carbon-neutrality target requires rapid decarbonization of the energy system over the next three decades and incur **substantial policy costs**, regardless of scenarios.
- Korea's current policies **falls short** of what its **2030 NDC target** would require.
- **The power sector** play a pivotal role in Korea's carbon-neutrality transition. The power sector's **rapid decarbonization** is combined with the **rapid electrification** of the end-use sectors. And, coal power phases out by the 2030s.
- In the longer term, **negative emissions technologies (NETs)** come online in a considerable proportion to offset hard-to-abate emissions from the economy.
- Economics-based expansion of **nuclear power** would reduce the need for a rapid build-up of renewables and CCS, alleviating the stress on terrestrial and geological systems.
- Yet, **exclusive reliance on renewables** without any contributions from nuclear power would require **unprecedentedly rapid ramp-up of solar power and CCS**. This means significantly higher policy costs.

Summary

- The promising decarbonization strategy for Korea's steel sector would be to scale up **hydrogen DRI** and **DRI w/CCS** up to about half the production and phase out **unabated blast furnaces** by 2050.
- The carbon neutrality target would **not** require the complete removal of CO_2 emissions from the steel sector by 2050. However, its associated **indirect emissions from the power and hydrogen sectors** would bring the steel sector's total emissions closer to zero by 2050.

Acknowledgement

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Questions & Comments

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