Assessing Energy Transition Pathways for Industries with Low-Temperature Heat Demand: Insights from the Instant Coffee Industry

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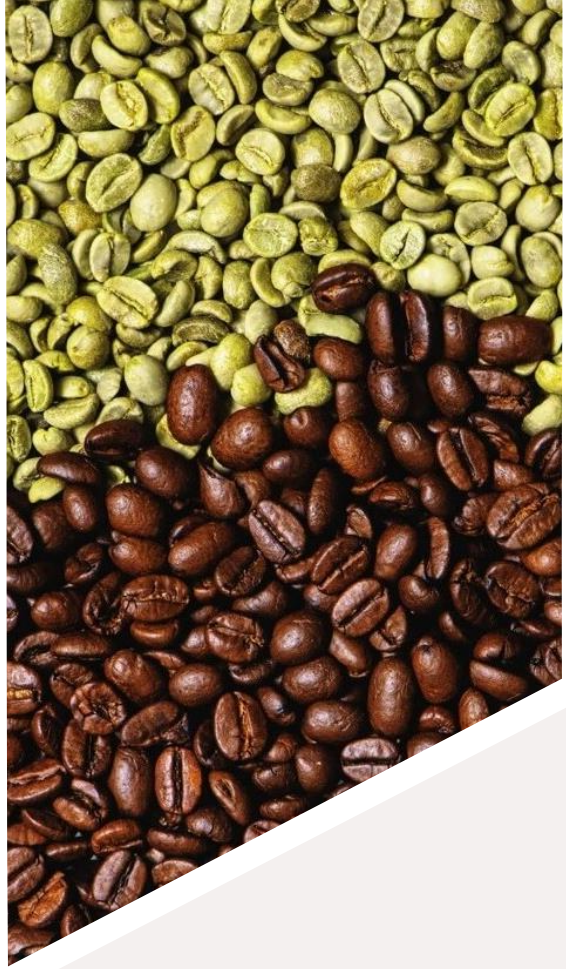
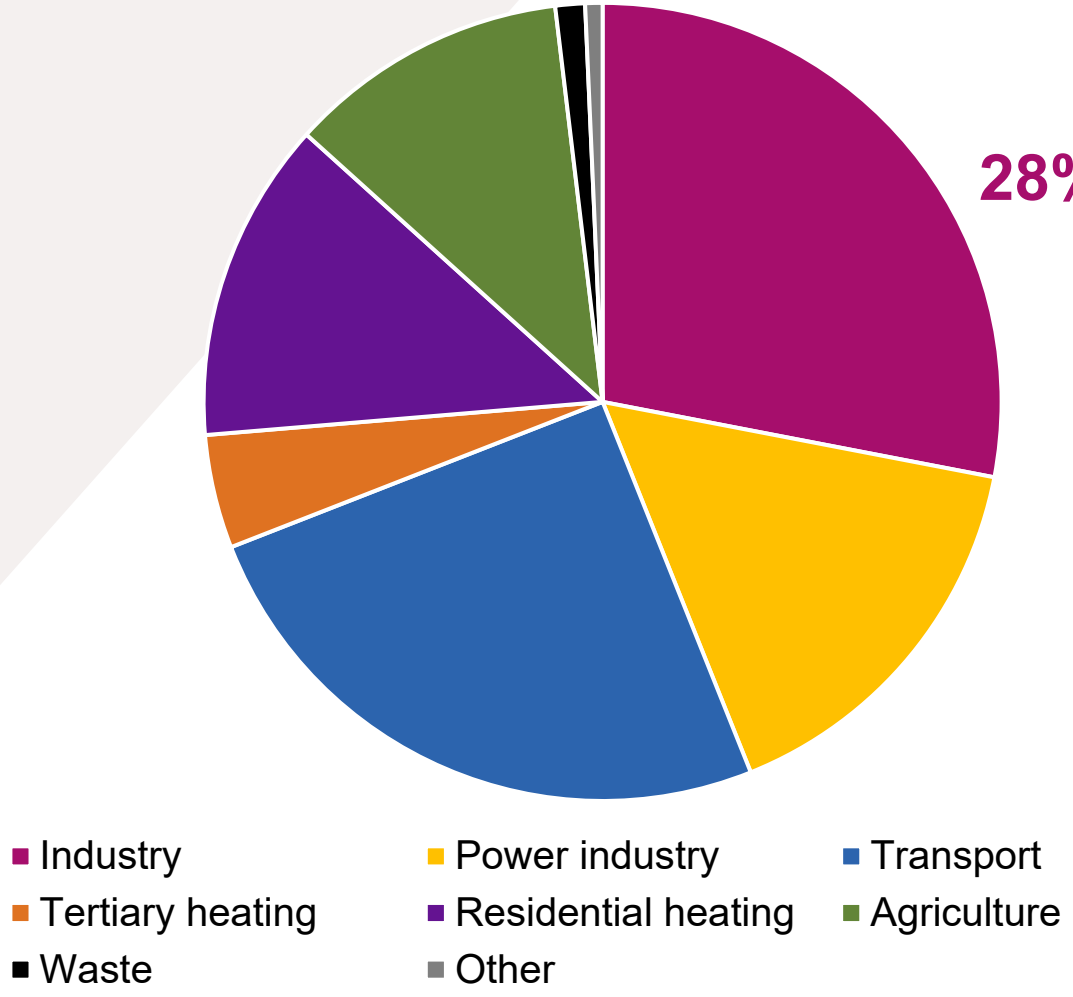
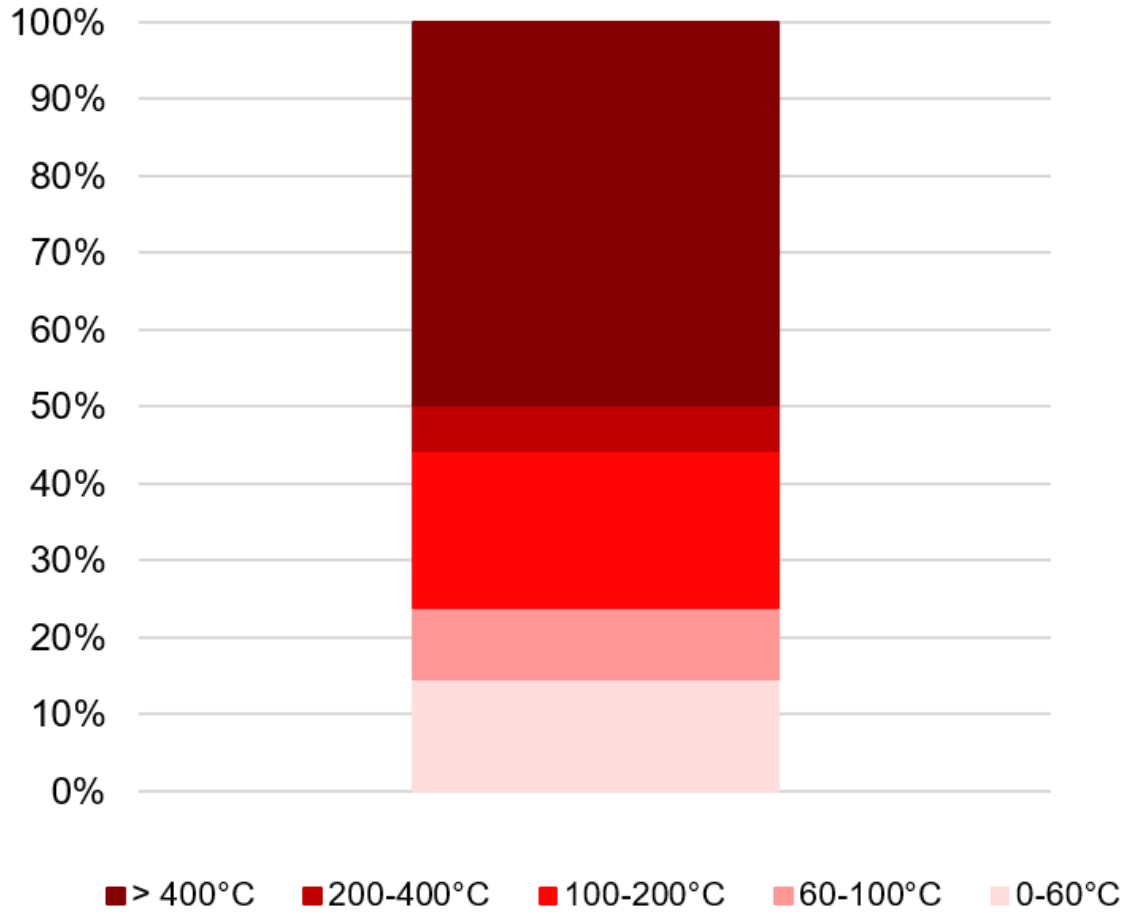


Importance of sectors with low-temperature heat demand

Greenhouse gases emissions in Belgium (2023)



Industrial heat demand by temperature range



IEA (2019a), World Energy Outlook 2019.

Why focus on coffee?

- 10 Mt/y consumed worldwide > < about 1/3 in Europe
- Instant coffee production = energy-intensive process

Roasting
(200–250°C)

Brewing
(150–180°C)

Concentration
(55°C)
Freeze-drying
(-50°–10°C)

Objectives & Methodology

Techno-economic comparison of energy transition pathways→ Decision-support tool

Data collection

- Production process
  - Energy demand
  - Emissions
  - …
- Energy transition pathways:
  - Energy efficiency
  - Fuel switching
  - Electrification
  - CCUS

Objectives & Methodology

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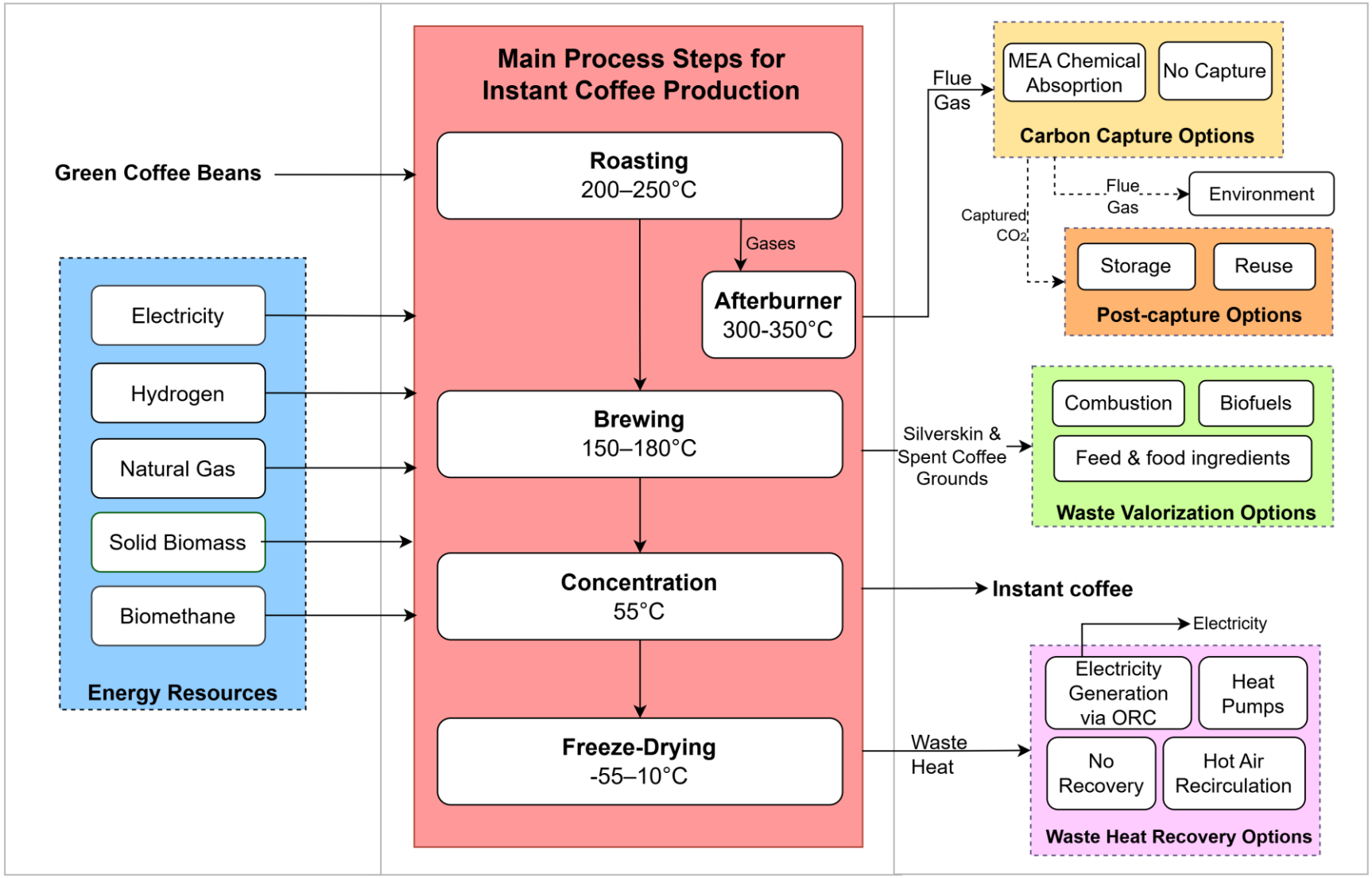
Data collection

- Production process
- Energy transition

Modelling

- Process blueprints
  - Mass & energy balances
  - Costing details
- Superstructure gathering all production routes



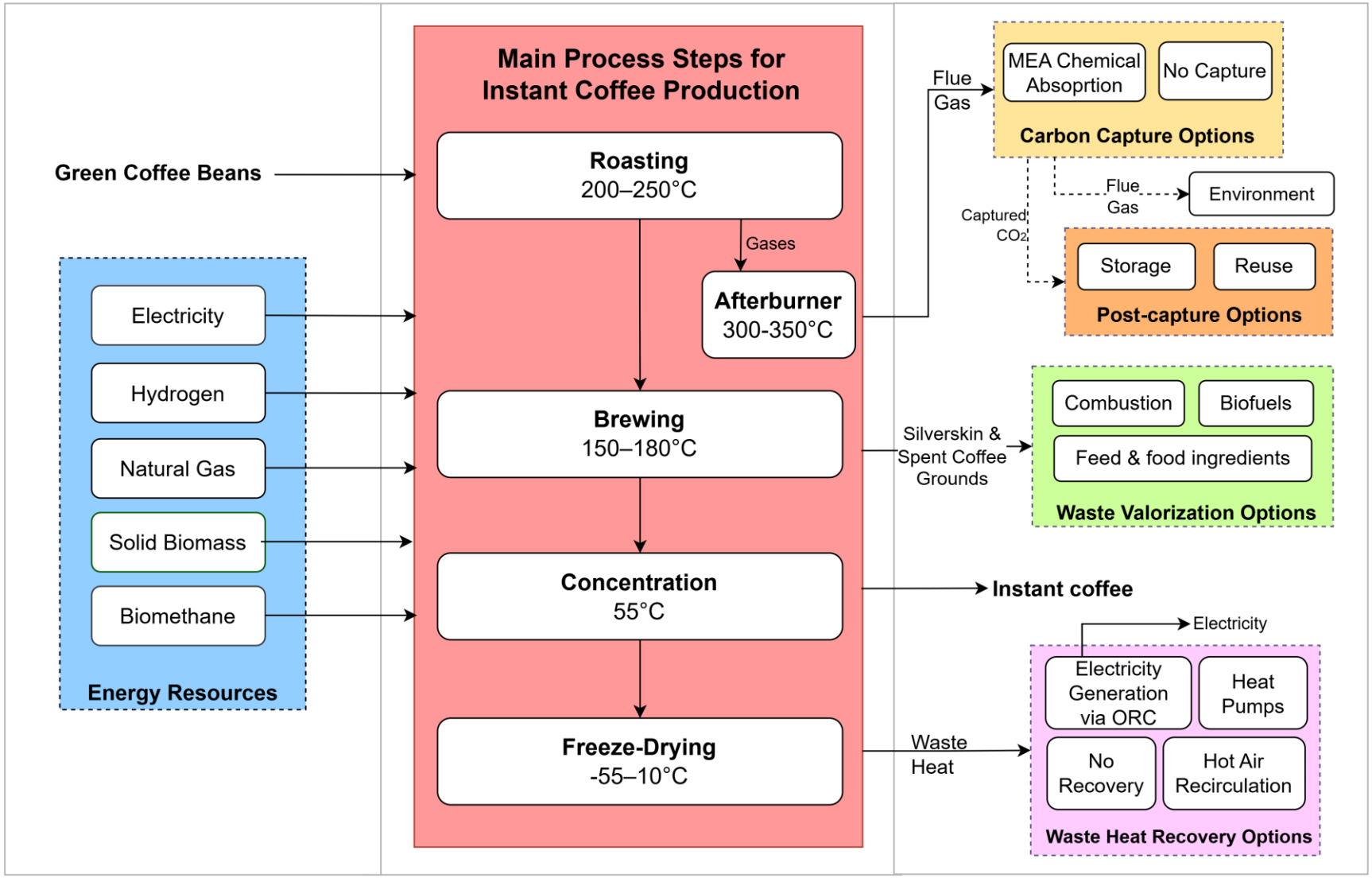
Objectives & Methodology

Techno-economic comparison of energy transition pathways→ Decision-support tool

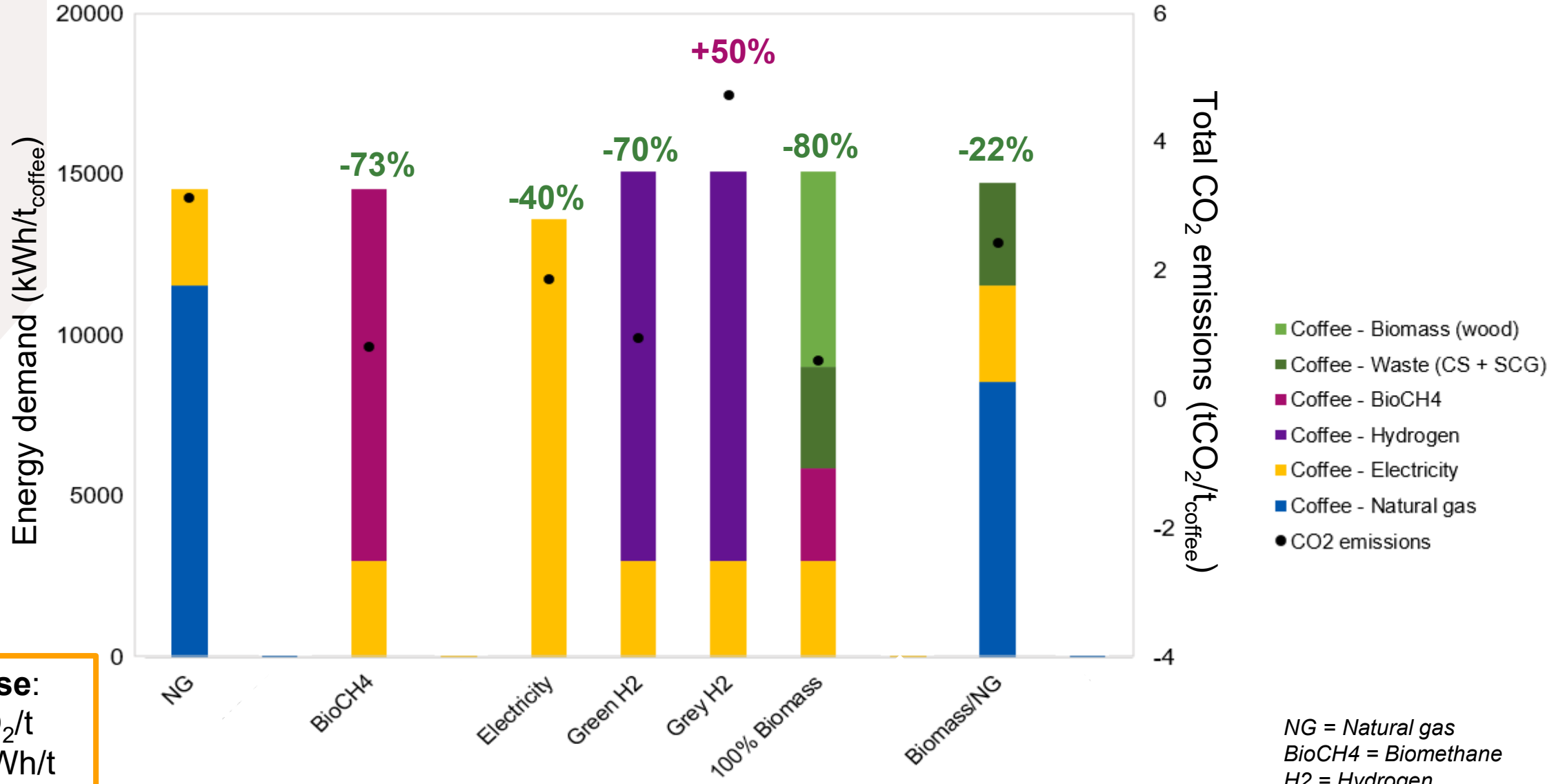
Data collection
- Production process
- Energy transition

Modeling
- Process blueprints
- Superstructure

Analysis
- Evaluation → KPIs
  - Thermodynamic
  - Environmental
  - Economic
- Optimization
  - Cost minimization
  - OSMOSE framework (MILP) by EPFL
- Ranking



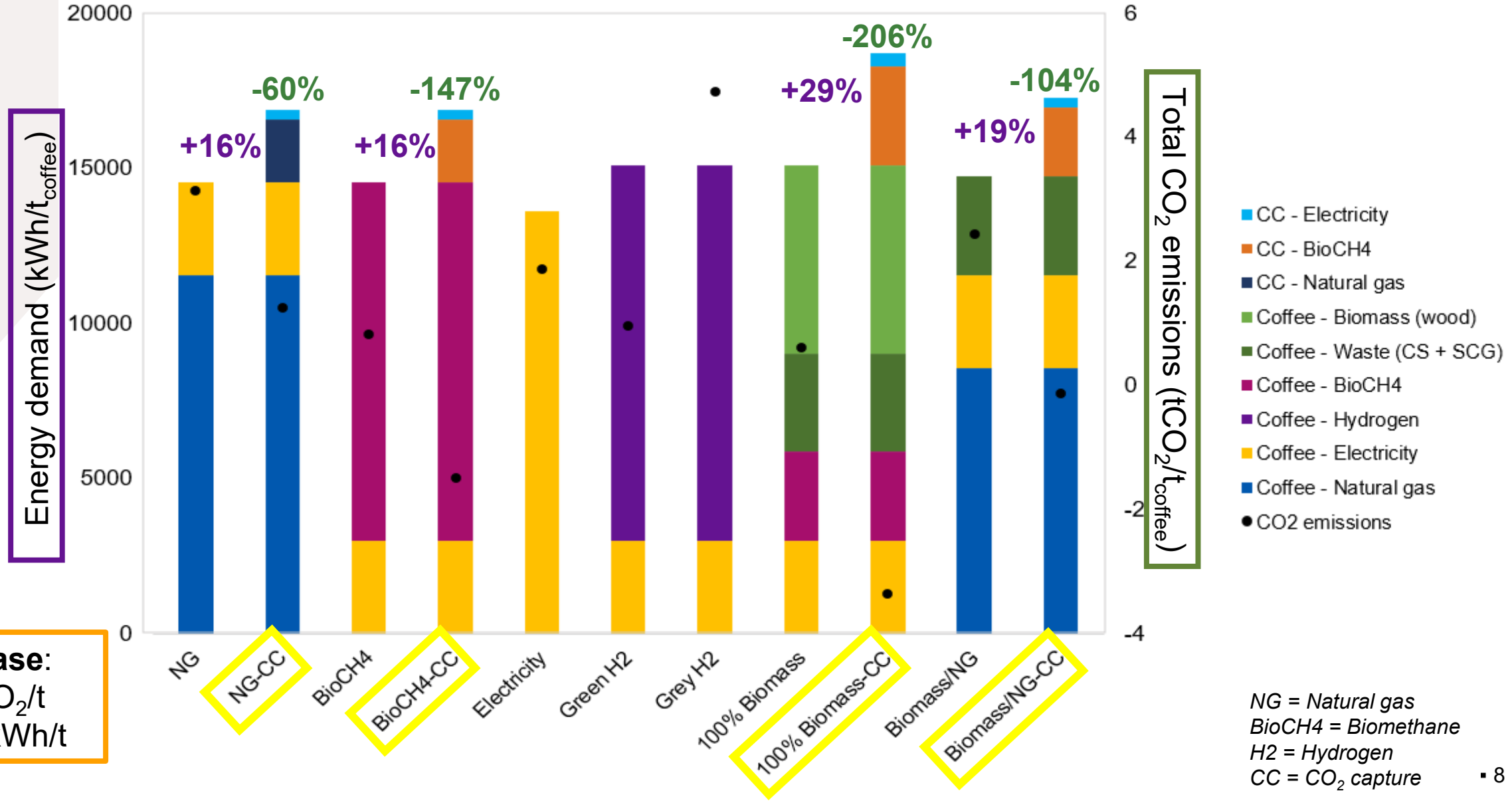
Results: Energy demand & CO_2 emissions



Base case:
3.15 tCO_2/t
14550 kWh/t

NG = Natural gas
BioCH4 = Biomethane
H2 = Hydrogen

Results: Energy demand & CO_2 emissions



Base case:
3.15 tCO_2/t
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NG = Natural gas
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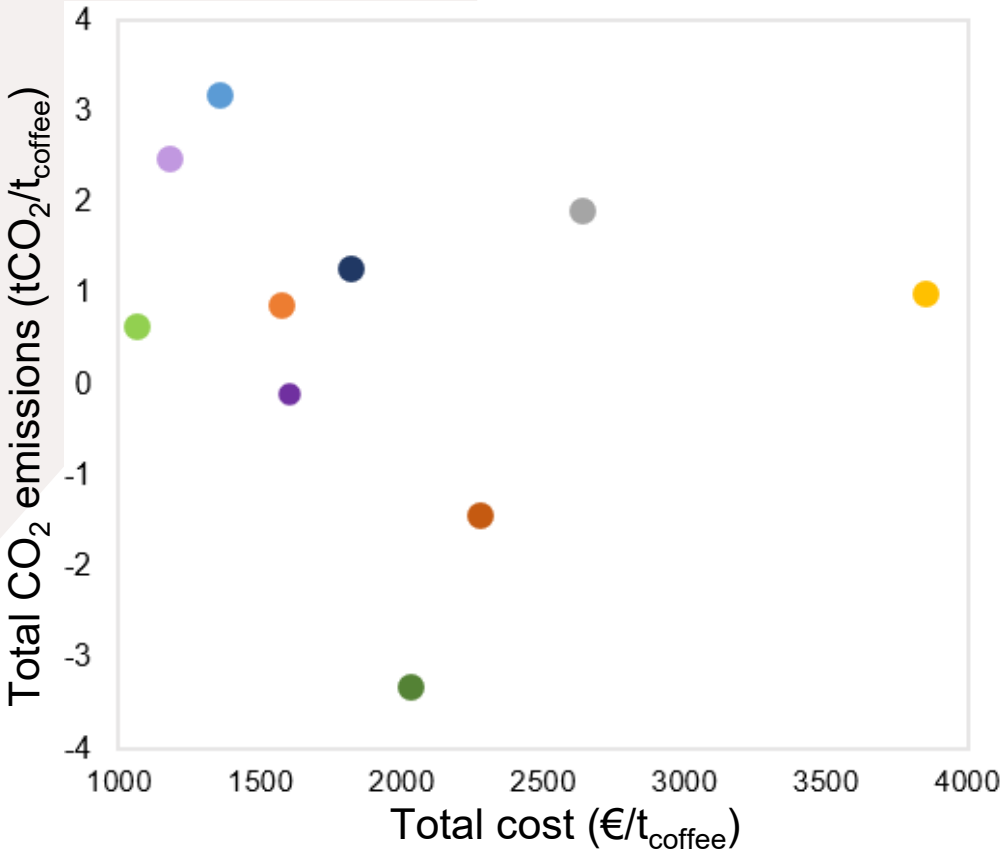
H2 = Hydrogen
CC = CO_2 capture

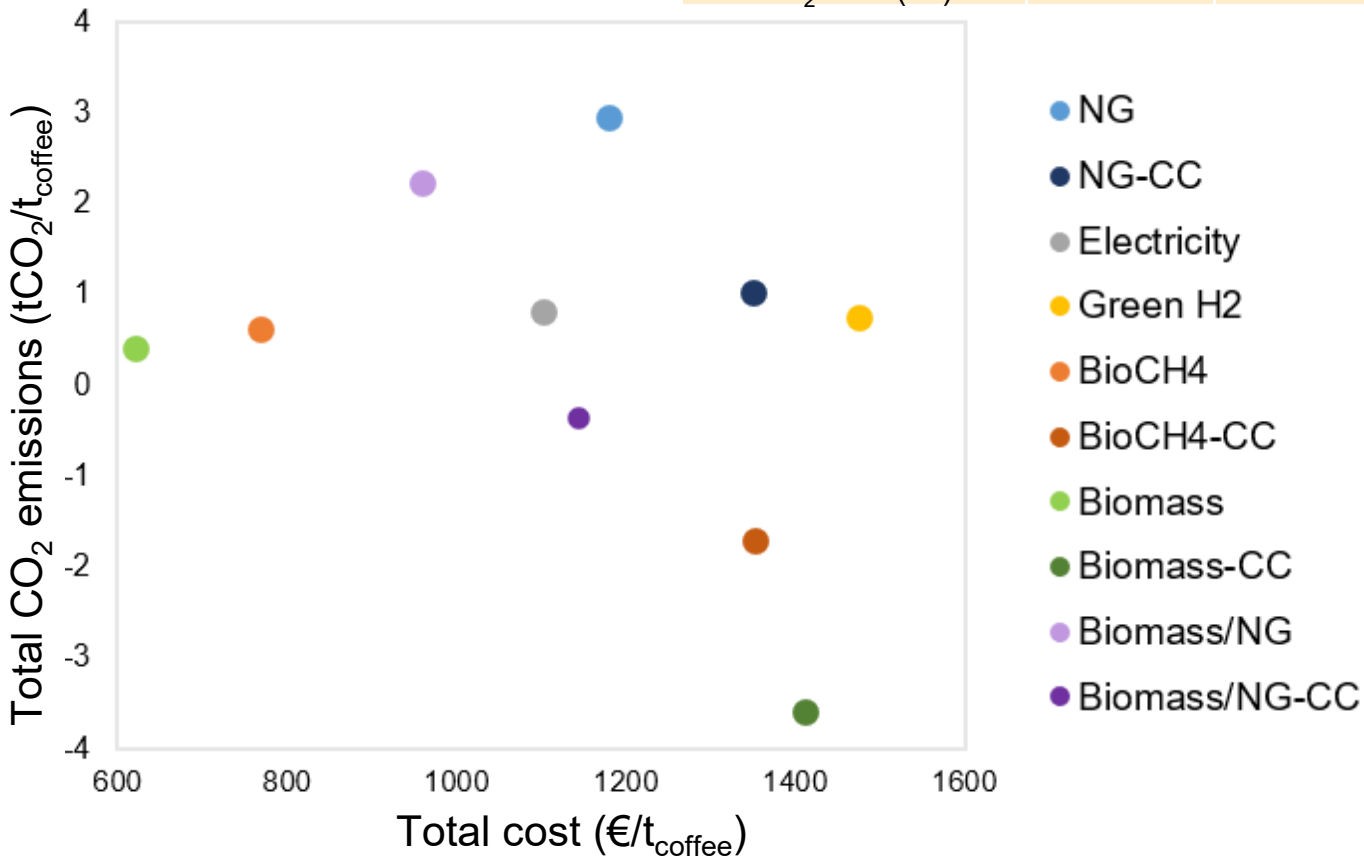
Results: Scenario-based pathways ranking

Commodities	2025	2050
Electricity (€/MWh)	193	80
Natural gas (€/MWh)	50	40
Biomass (€/MWh)	28.5	30
Biomethane (€/MWh)	85	44
Hydrogen (€/MWh)	269	100
CO_2 ETS (€/t)	80	200
CO_2 T&S (€/t)	50	50



2025

(High energy prices & low ETS price)

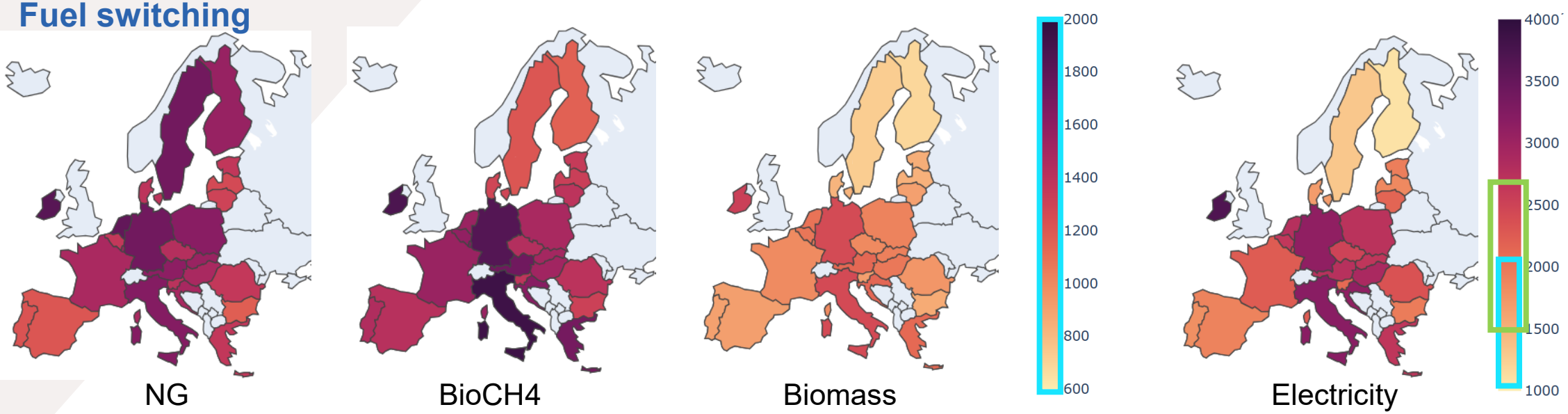


2050

(Lower energy prices & high ETS price)

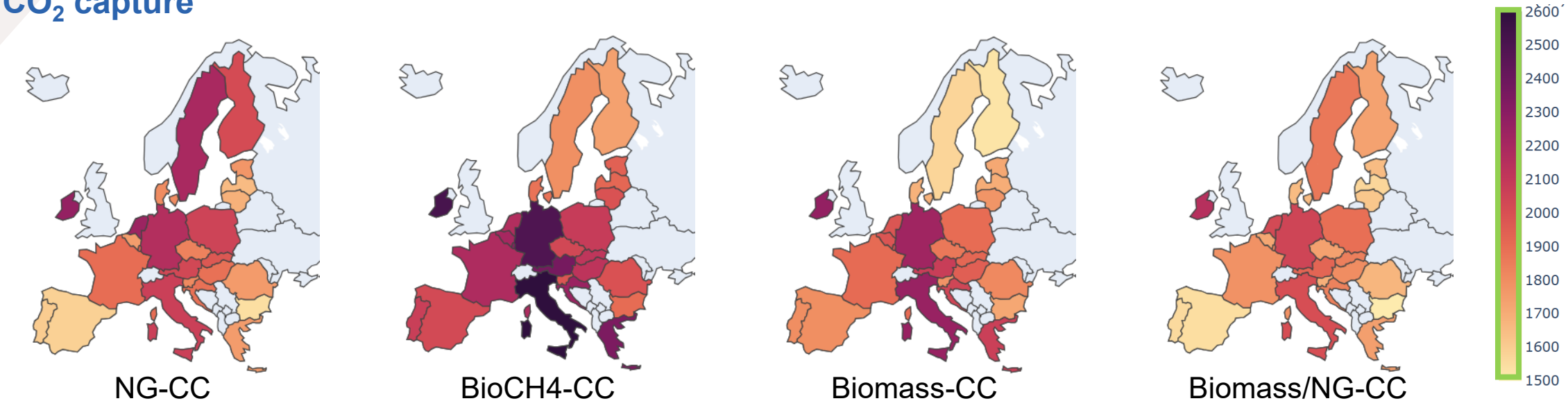
Results: specific production cost (€/t) across Europe

Fuel switching



NG BioCH4 Biomass Electricity

CO_2 capture



NG-CC BioCH4-CC Biomass-CC Biomass/NG-CC

Conclusion

- CO_2 emission reduction
  - First, valorize biomass **waste** (silverskin + spent coffee grounds)
  - Huge potential for **biomass/biomethane** combustion **!!! Availability** issues
  - Access to **cheap, low-carbon electricity** is a key driver for process electrification
  - **Hydrogen** = too expensive
- To support industrial energy transition:
  - Increase **biomethane** production **capacity**
  - **Decarbonize electricity** production across Europe
  - **Reduce** energy **consumption** for coffee production **!!!**
- Next steps
  - Potential for **heat recovery**:
    - Hot gases recirculation
    - Heat pumps
    - Electricity generation via ORC
  - Other **waste valorization** options to be considered: biofuels (biochar, biodiesel, biogas); feed & food ingredients production

Acknowledgements

Thank you for your attention!

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