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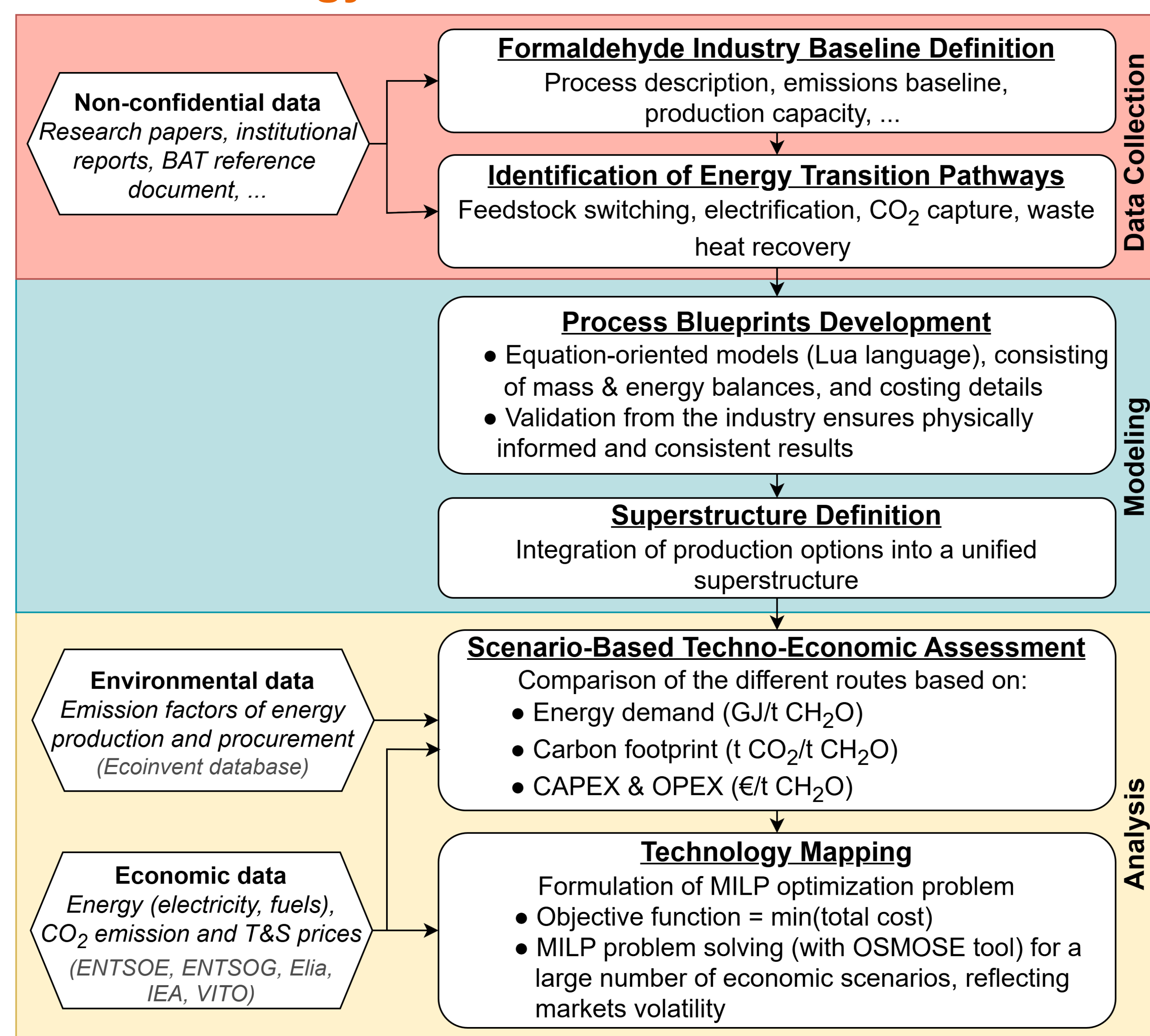
1. Context

The chemical industry is an energy-intensive and highly-emitting sector, representing **6.5% of global greenhouse gases emissions**. Methanol (MeOH) is a key feedstock in the production of various chemicals, with formaldehyde (CH₂O) being its major derivative. However, current MeOH production is almost entirely fossil-based. Hence, decarbonizing MeOH production is essential to reduce the environmental impact of the chemical sector.

2. Objective

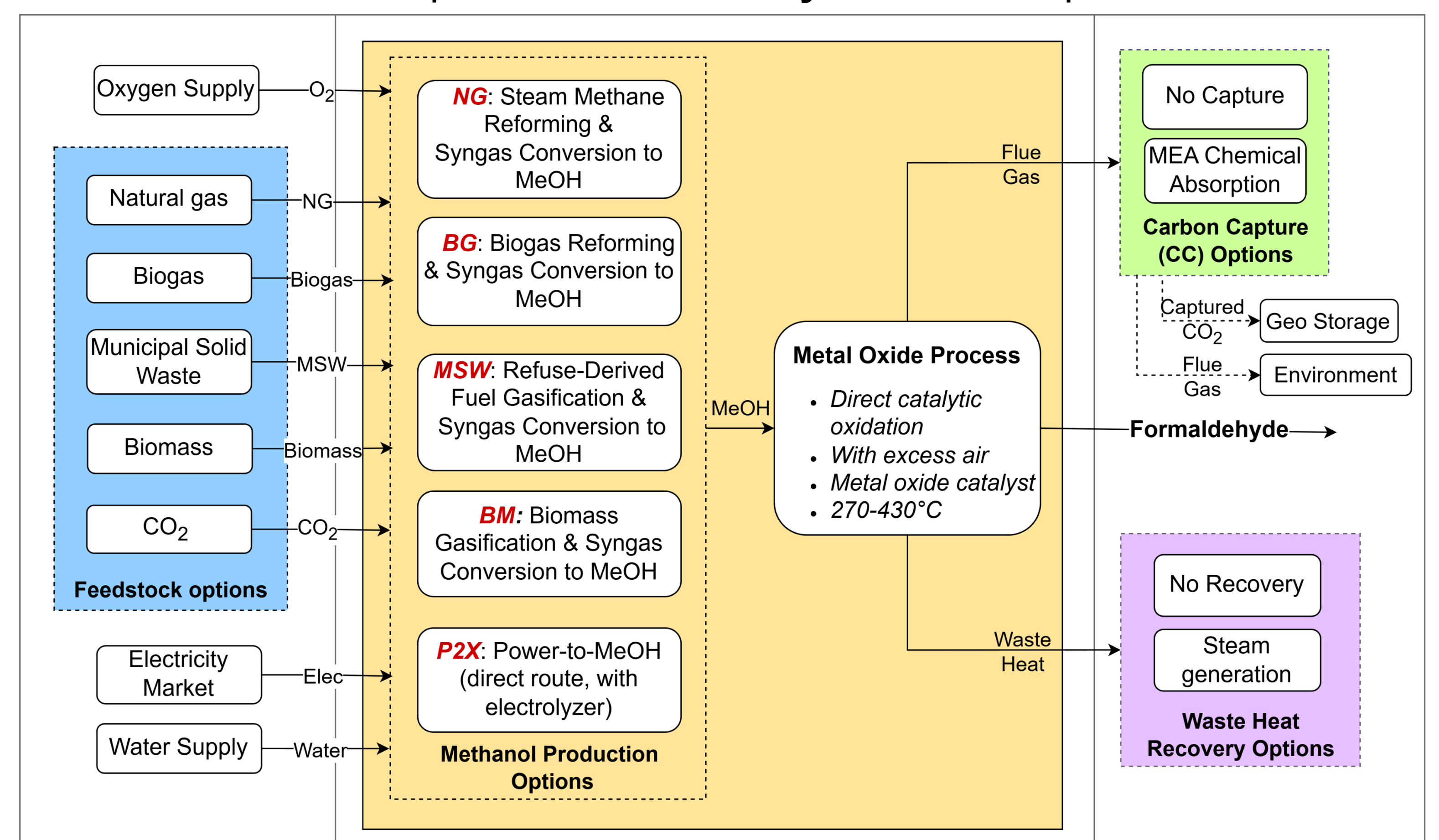
This study aims to develop a **decision-support framework**, modeling and comparing various pathways reducing CO₂ emissions during the production of methanol and, subsequently, formaldehyde. These pathways include **feedstock switching**—towards biogas, solid biomass, or municipal solid waste—process **electrification**, and **CO₂ capture**. The techno-economic assessment conducted supports policy and investment decision-making through superstructure optimization.

3. Methodology



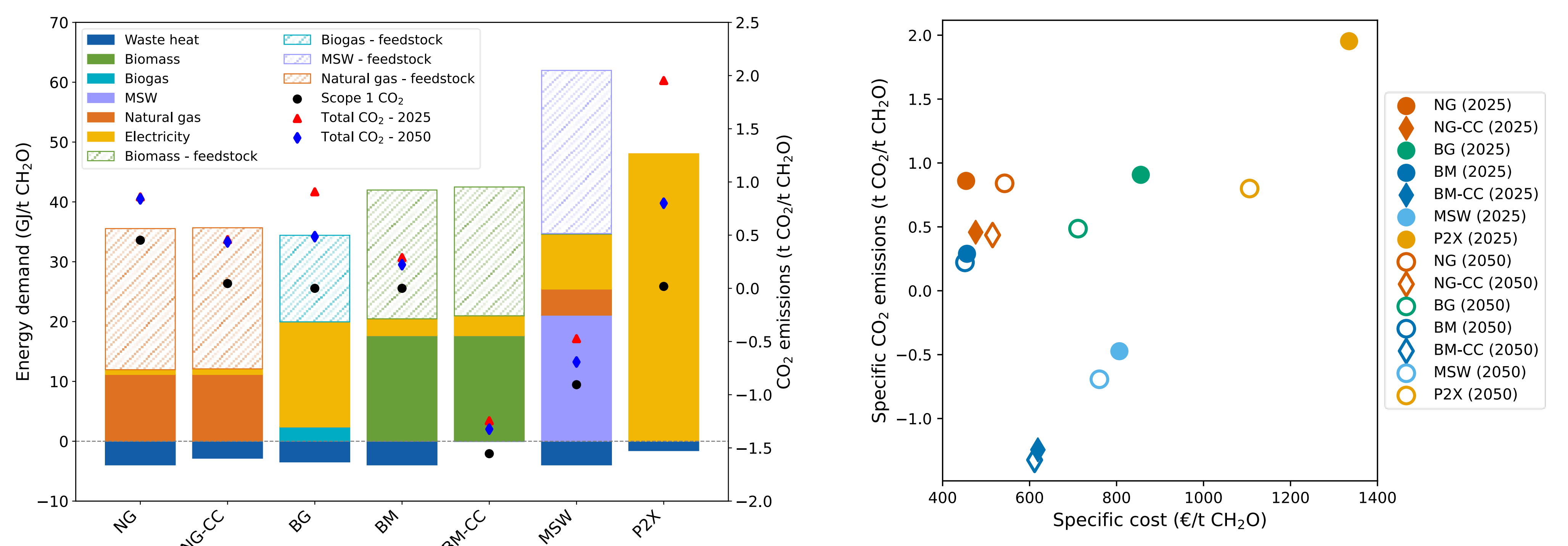
Case studies:

- **Production capacity:** 100,000 t CH₂O/y
- **Base case:** feedstock = MeOH produced via steam methane reforming
- **Alternatives:** feedstock switching (biogas, biomass, waste), electrification (Power-to-MeOH), and CO₂ capture (CC)
- All alternatives compete **simultaneously** within the superstructure



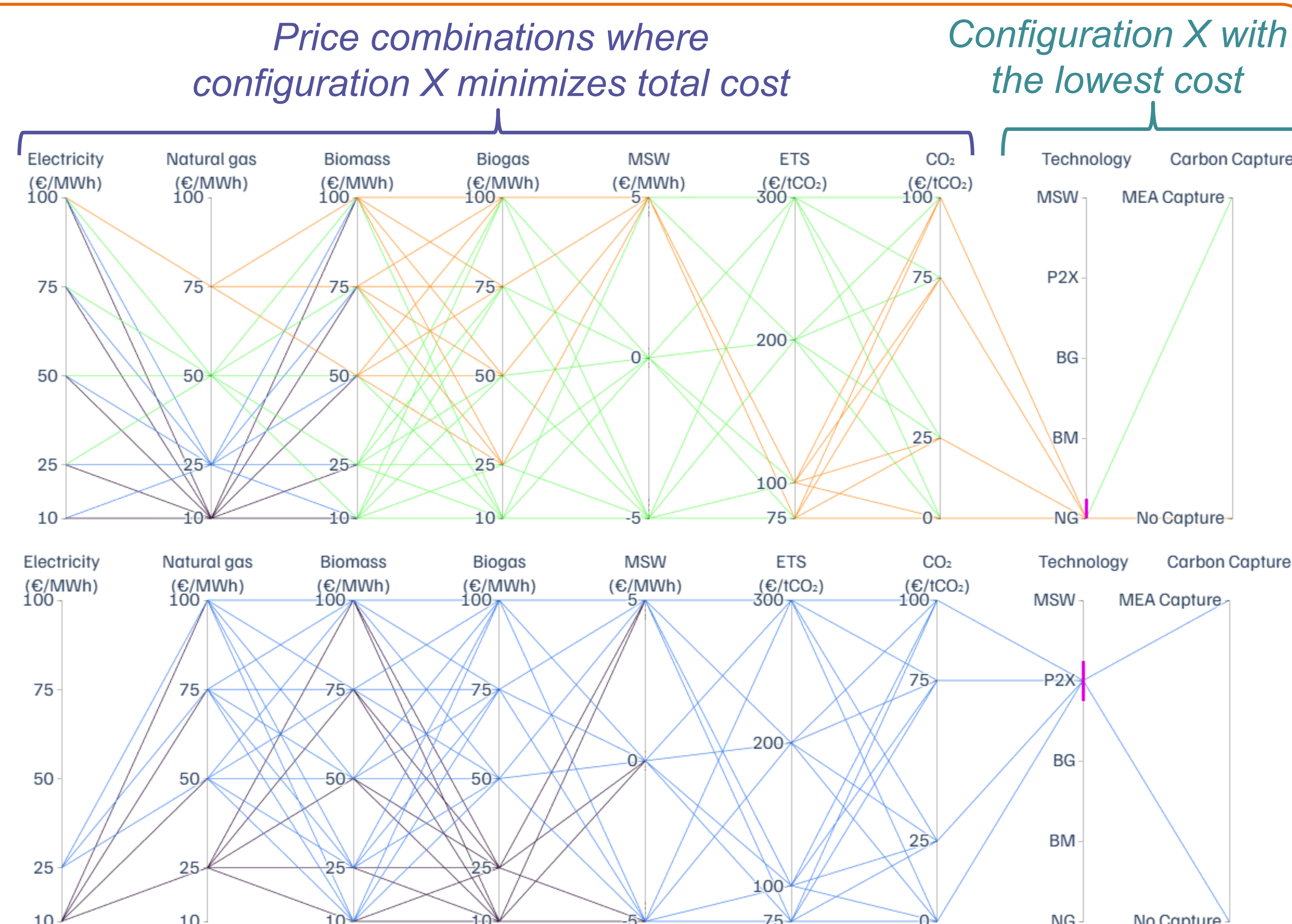
4. Techno-economic analysis

- **NG**-based production is the most or second-most cost-competitive route
- **NG-CC** achieves ~50% CO₂ emissions reduction at the lowest cost
- Currently, **MSW** and **BG** are not economically competitive
- **P2X** is the least attractive option
- **BM & BM-CC** are the most promising decarbonization routes, with BM-CC achieving net-negative CO₂ emissions



5. Technology mapping

- **NG/NG-CC**: optimal for 49% of scenarios (flexible & robust)
- **P2X**: optimal for 14% of scenarios (stringent conditions: extremely low electricity prices)
- **BM/BM-CC** : optimal for 5% of scenarios (stringent conditions for optimality $\rightarrow \leq \text{€}25/\text{MWh}_{\text{BM}}$ & $\geq \text{€}75/\text{MWh}_{\text{NG}}$)
- **MSW & BG** : both optimal for 16% of scenarios (expensive NG is required)



6. Conclusion and outlook

- Challenge for the chemical sector:
NG and **NG-CC** are the most **flexible** and **robust** production pathways
- **BG** and **MSW** arise as **promising candidates** for non-fossil chemicals
→ need efficiency improvements, supportive policies, and funding to **enable cost-competitiveness**
- **Outlook:**
 - Bioenergy availability constraints
 - Integration of P2X in the production mix
 - Regret analysis