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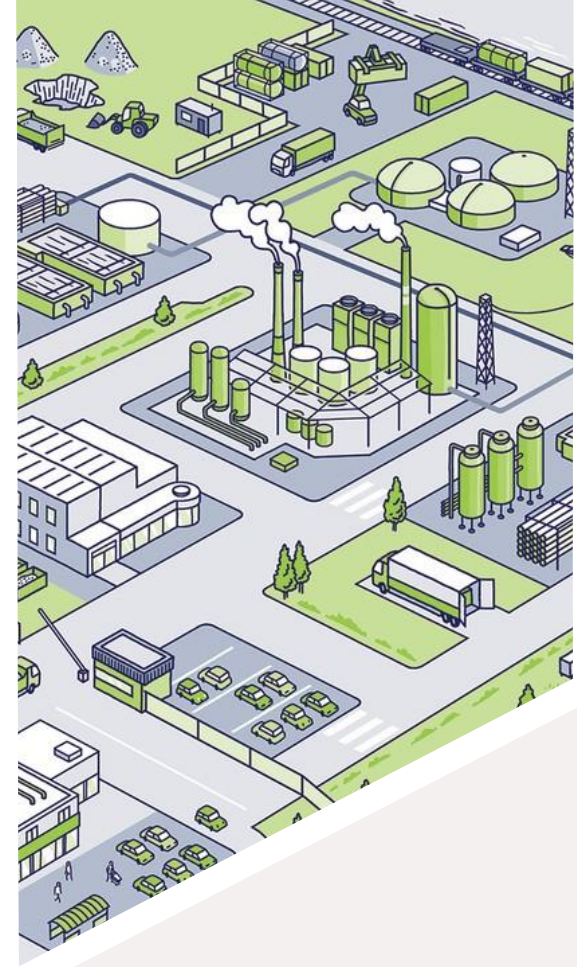
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# Accelerating Industrial Decarbonization through Symbiosis: Insights from the Belgian Case

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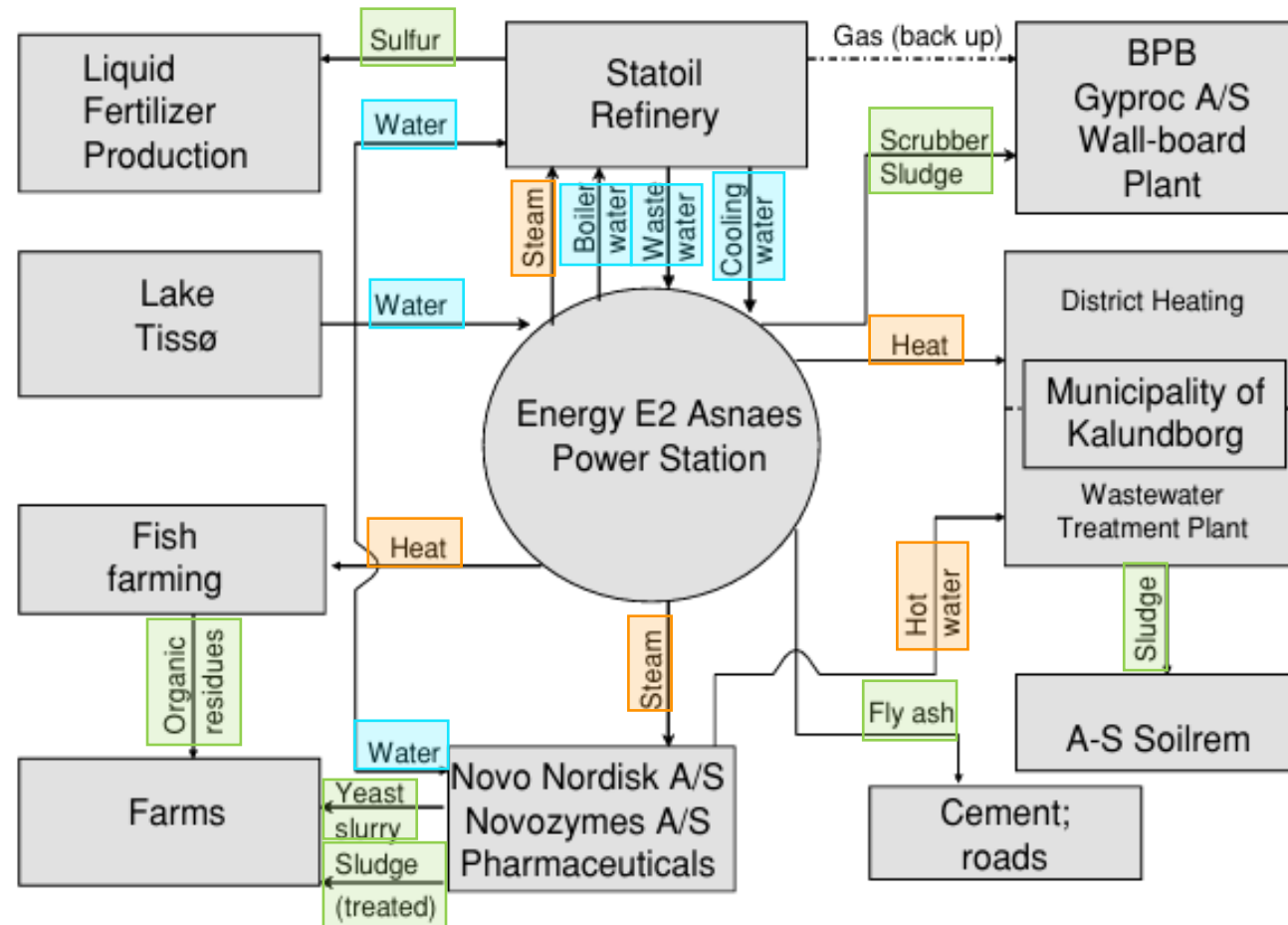
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# What is industrial symbiosis?

## Kalundborg (Denmark)



**Annual economies:** 24 M€, 635 kt<sub>CO2</sub>, 100 GWh<sub>energy</sub>

# Benefits and barriers of industrial symbiosis

## Benefits

- Reduction of **emissions**
- Minimization of virgin materials **extraction**
- Reduction of **waste**
- Higher **revenues** after by-products sales
- Business **expansion**

## Barriers

- Lack of **knowledge** about exchange possibilities
- Increased **reliance** on other actors
- **Regulatory** complexity
- **Pre-treatment** steps potentially required
- **Variability** of waste quality, compared to nominal conditions, ...

- Identify **possible** exchanges
- Compare **local** optimum (industry level) & **global** optimum (cluster level) → robust solution

## Techno-economic comparison of energy transition pathways → Ranking of pathways for future scenarios

### Data collection

- Production process
  - Energy demand
  - Emissions
  - ...
- Decarbonization pathways:
  - Fuel switching
  - Electrification
  - CCUS

### Modelling

- Process blueprints
- Validation through industry
- Superstructure gathering all production routes

### Analysis

- Evaluation → KPIs
  - Thermodynamic
  - Environmental
  - Economic
- Optimization
  - Cost minimization
  - With/without synergies
- Ranking

# Case study: Mons-Tournai cluster



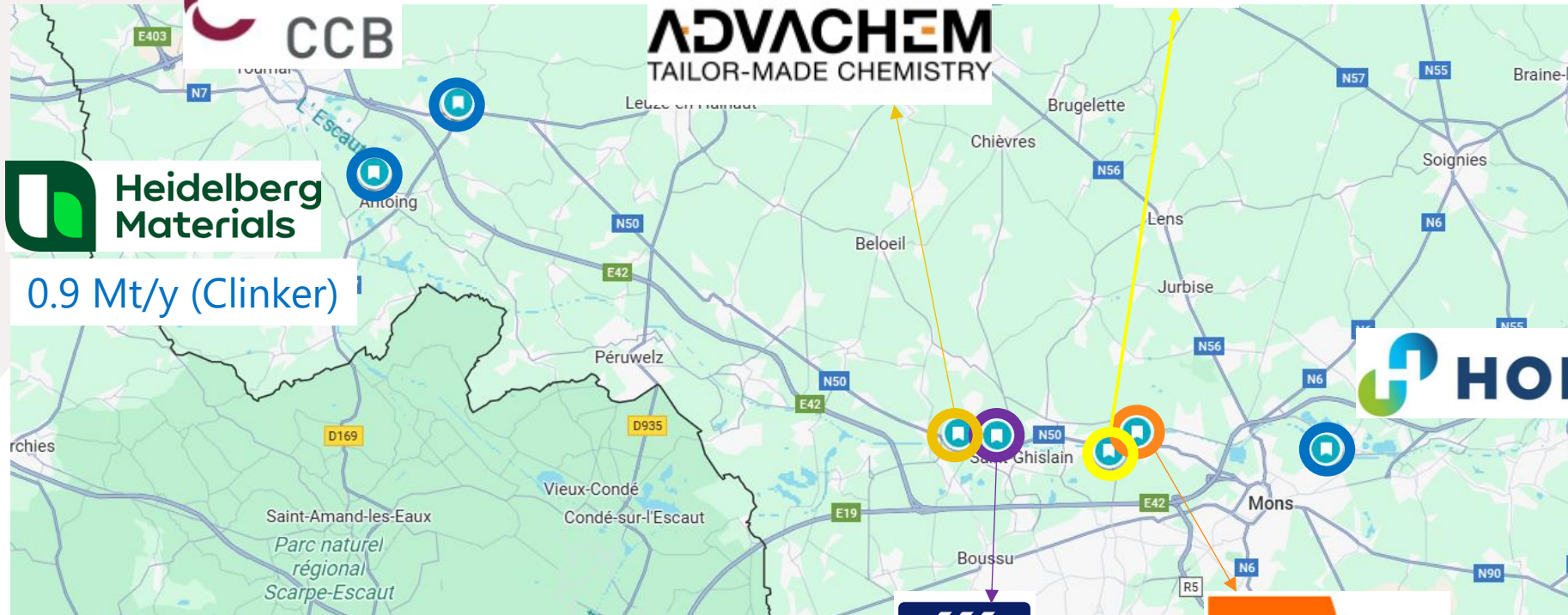
2.3 Mt/y (Cement)



0.1 Mt/y (Formaldehyde)



613 GWh<sub>heat</sub>/y

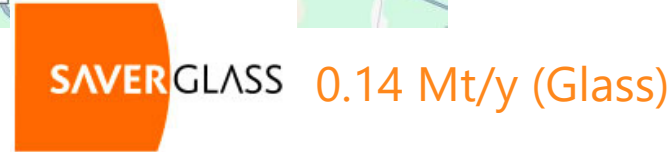


0.9 Mt/y (Clinker)



1.7 Mt/y (Cement)

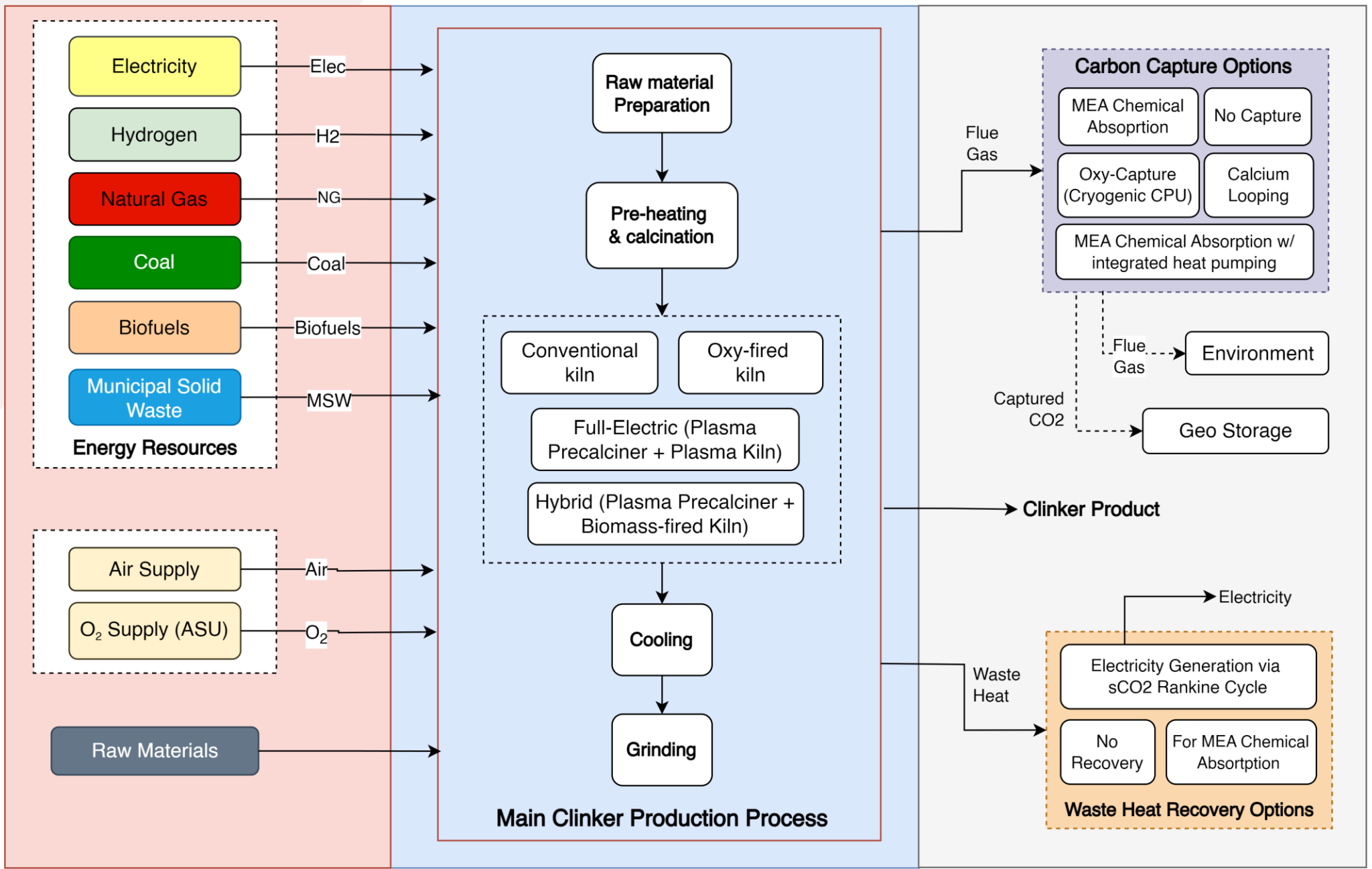
0.4 Mt/y (Ammonia)  
0.8 Mt/y (Nitric acid)



0.14 Mt/y (Glass)

Superstructure of Cement Industry

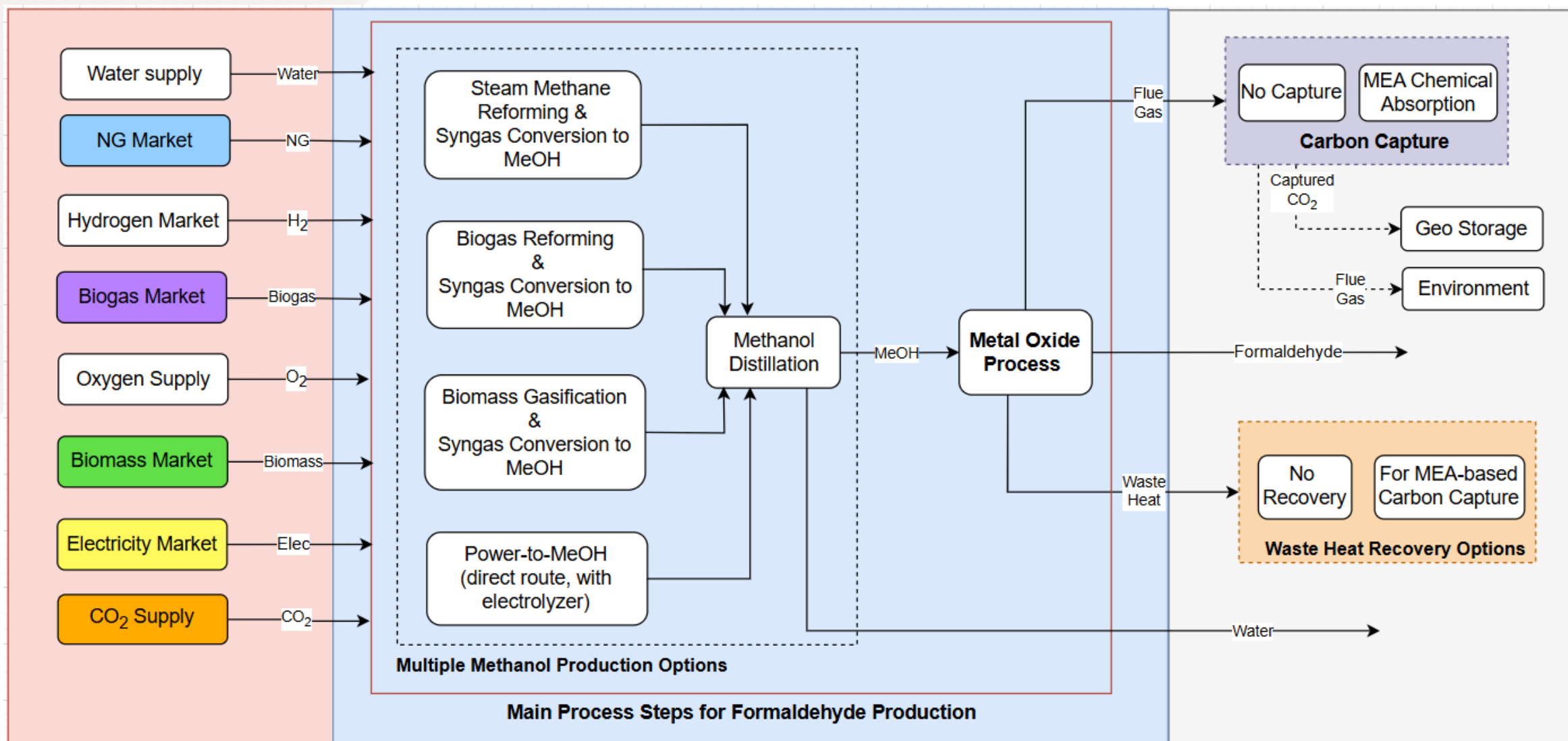
32 configurations





## 8 configurations

# Superstructure of Formaldehyde Industry



## Sector-specific results: clinker & formaldehyde

- ▶ Clinker: Municipal Solid Waste (MSW) Oxycombustion + CC

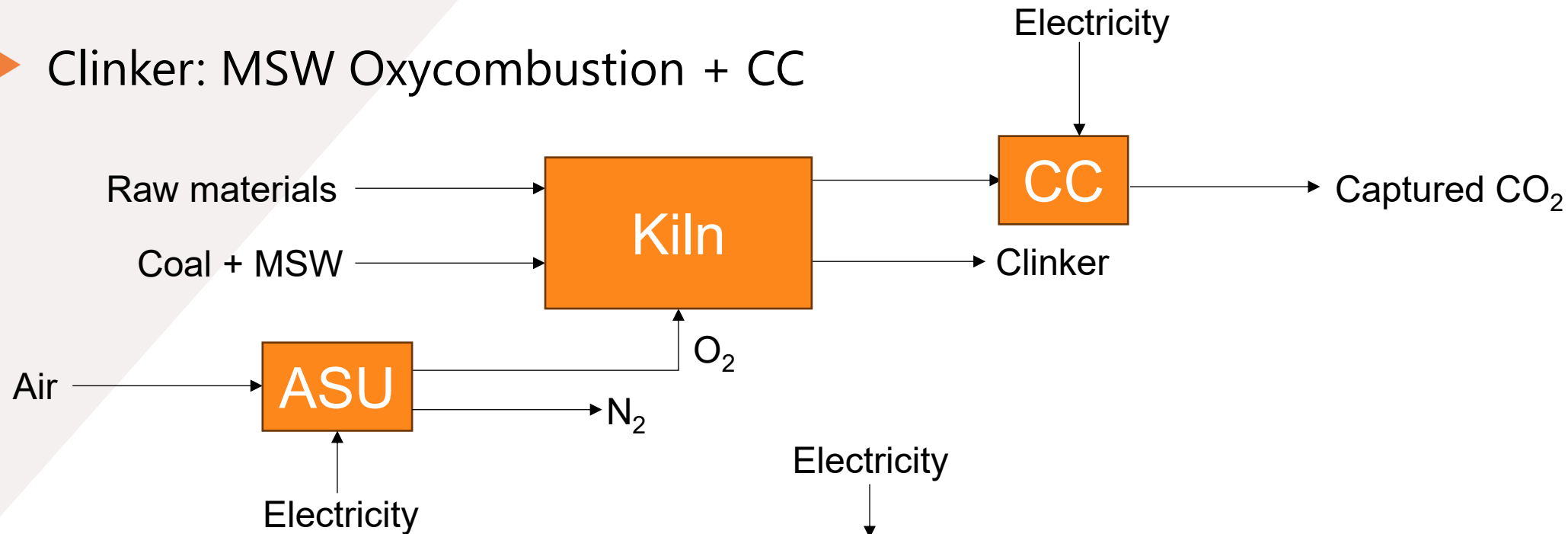
Is it possible to **decrease** the **cost** of Power-to-X processes by implementing industrial **symbiosis**?

- ▶ Formaldehyde:
  - Base case (NG): €570/t
  - **NG-CC: €544/t**
  - Biomass: €620/t
  - Biogas: €693/t
  - **Power-to-X: €1230/t**

Commodities	Cost
Natural gas (€/MWh)	40
Coal (€/MWh)	11.5
MSW (€/MWh)	3
Biomass (€/MWh)	18
Electricity (€/MWh)	58
Biogas (€/MWh)	30
Biomethane (€/MWh)	44
CO <sub>2</sub> ETS (€/t)	200
CO <sub>2</sub> T&S (€/t)	50

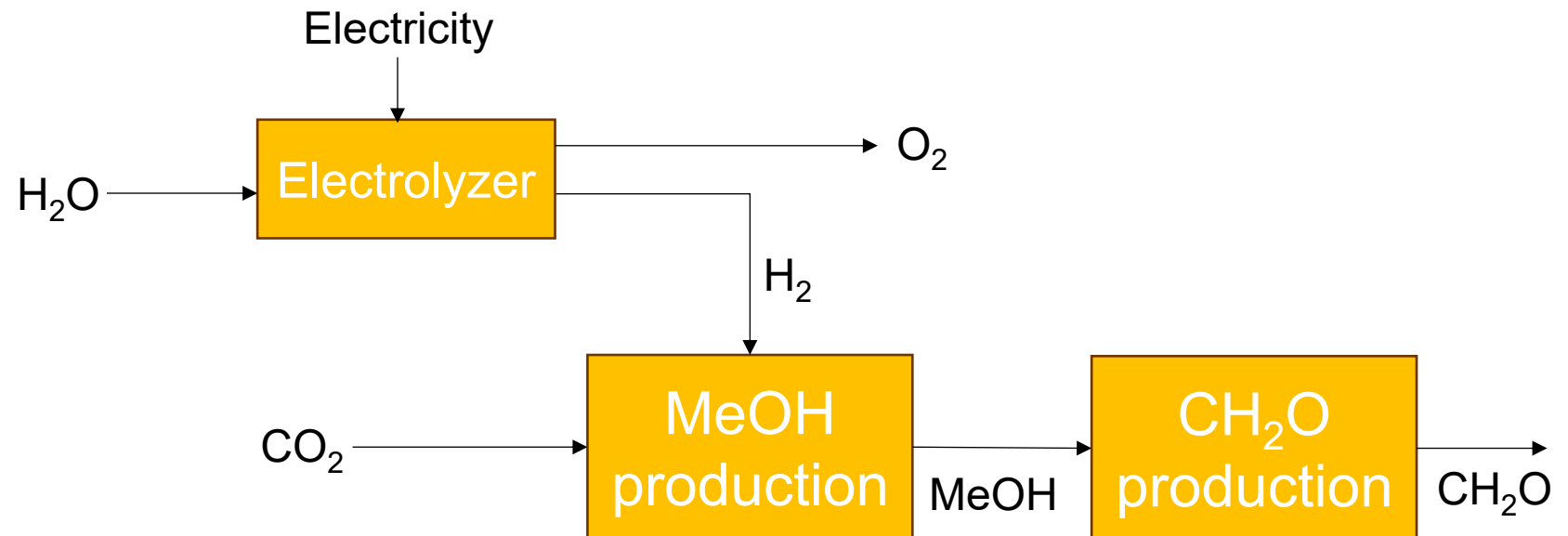
# Sector-specific results: clinker & formaldehyde

## ▶ Clinker: MSW Oxycombustion + CC



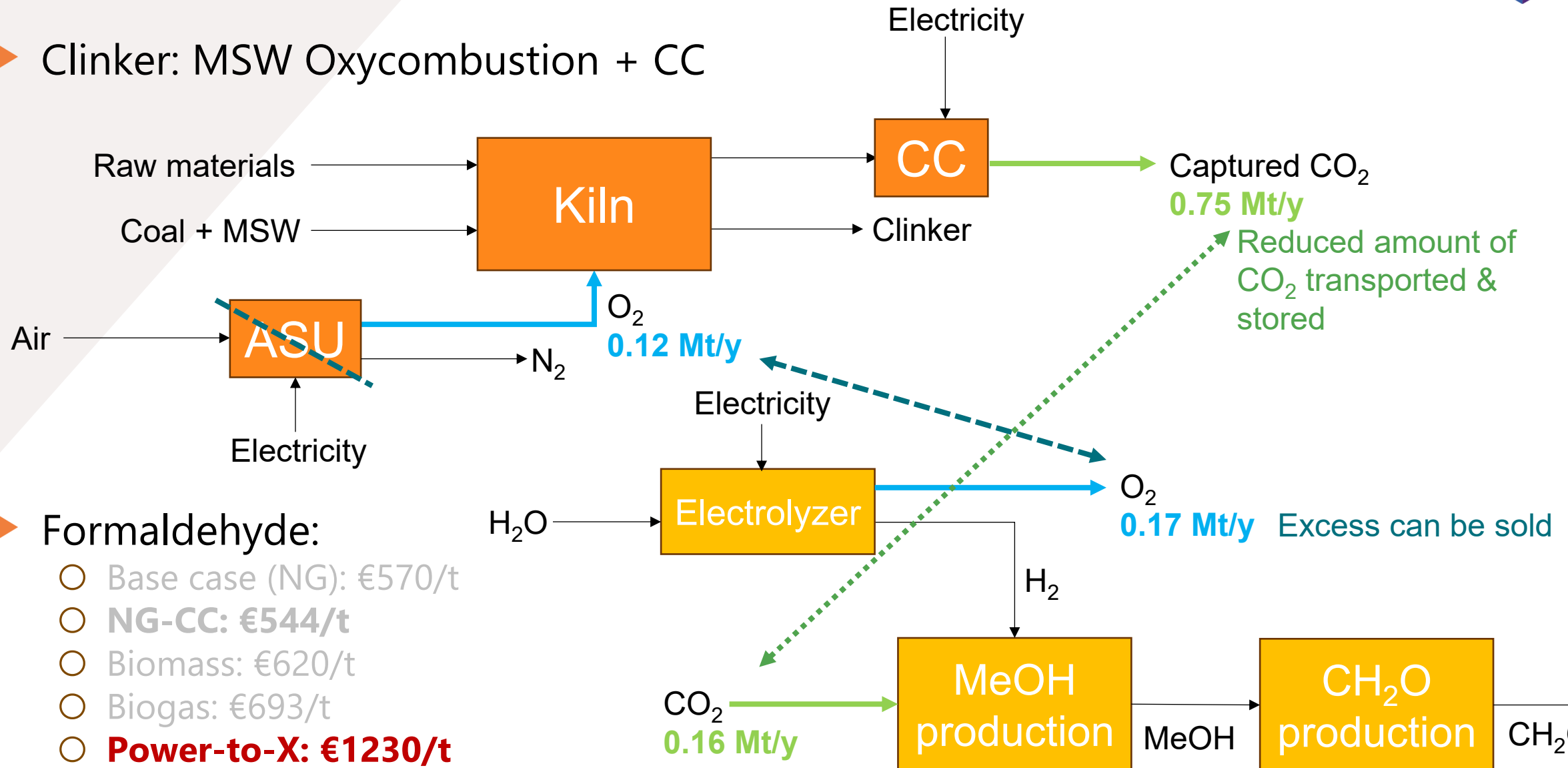
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# Cluster-specific results

-4.2 ktCO<sub>2</sub>/y (2025)

▶ Total energy demand: -28 GWh<sub>e</sub>/y

	No symbiosis	With symbiosis	
MSW (GWh/y)	423	423	-
Coal (GWh/y)	423	423	-
Electricity (GWh/y)	1482	1454	-1.9%

▶ Specific and total cost: 0.9 Mt<sub>clinker</sub>/y & 0.1 Mt<sub>formaldehyde</sub>/y → -45.6 M€/y

	No symbiosis	With symbiosis	
Clinker (€/t <sub>clinker</sub> )	123	116	-6%
Formaldehyde (€/t <sub>CH2O</sub> )	1230	835	-32%
<b>TOTAL (M€/y)</b>	<b>233.4</b>	<b>187.8</b>	<b>-20%</b>

## Take-away messages & future steps

- ▶ Environmental & economic **benefits** with industrial symbiosis
- ▶ Two main **barriers**:
  - Lack of **knowledge** about exchange possibilities
  - Increased **reliance** on other actors
- ▶ Next steps:
  - Explore full potential → **optimization** at **cluster-level**
  - Identification of **robust** (> < optimal) solutions
  - Include **distance** aspects
  - Identification of **required infrastructure**
    - ▶ Higher electric grid capacity?
    - ▶ CO<sub>2</sub>/Molecules (H<sub>2</sub>, NH<sub>3</sub>, biomethane) pipeline?
    - ▶ ...

 Full picture of energy transition in Belgian industry:  
energy, emissions, infrastructure



# Thank you for your attention!

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