# The Net Zero Industry Innovation Centre

Tees Valley: The go-to destination for net zero research & development

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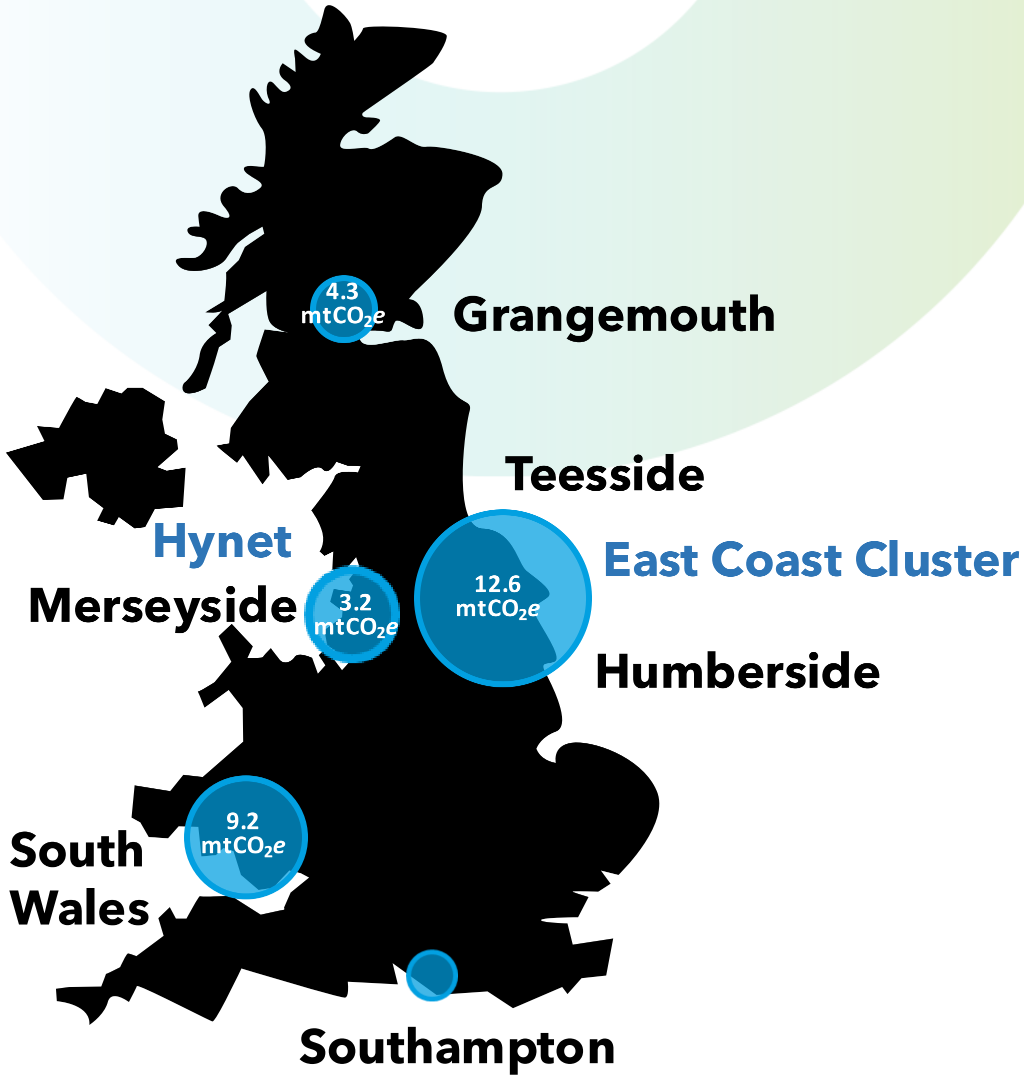
# Why We're All Here...

The Intergovernmental Panel on Climate Change report has delivered a "**final warning**" on the climate crisis, as rising greenhouse gas emissions push the world to the brink of **irrevocable damage** that only **swift** and **drastic action** can avert.

# Industrial Cluster Emissions




**East Coast Cluster**

- Net Zero Teesside Power
- H2Teesside
- Teesside Hydrogen CO2 Capture
- Bioenergy with CCS

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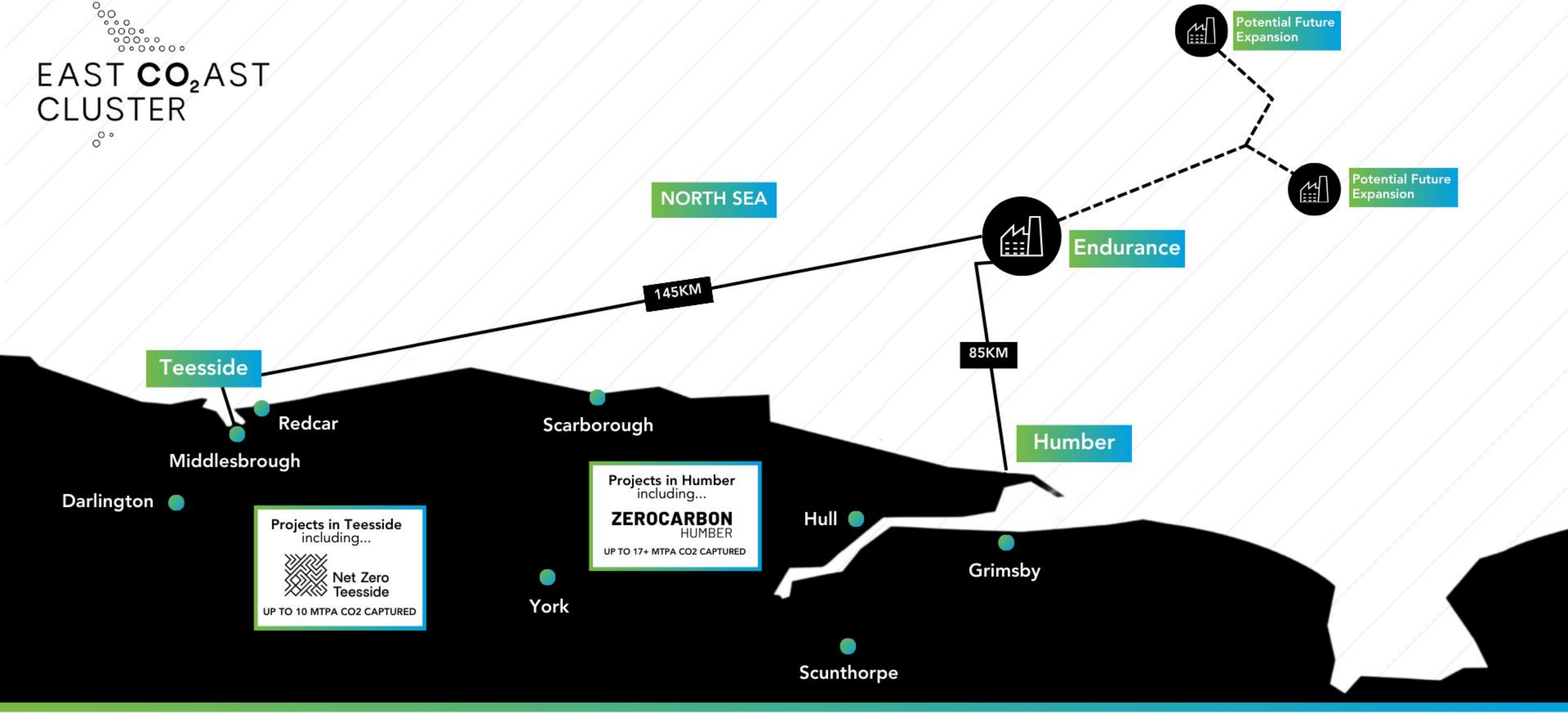
EAST $CO_2$AST CLUSTER

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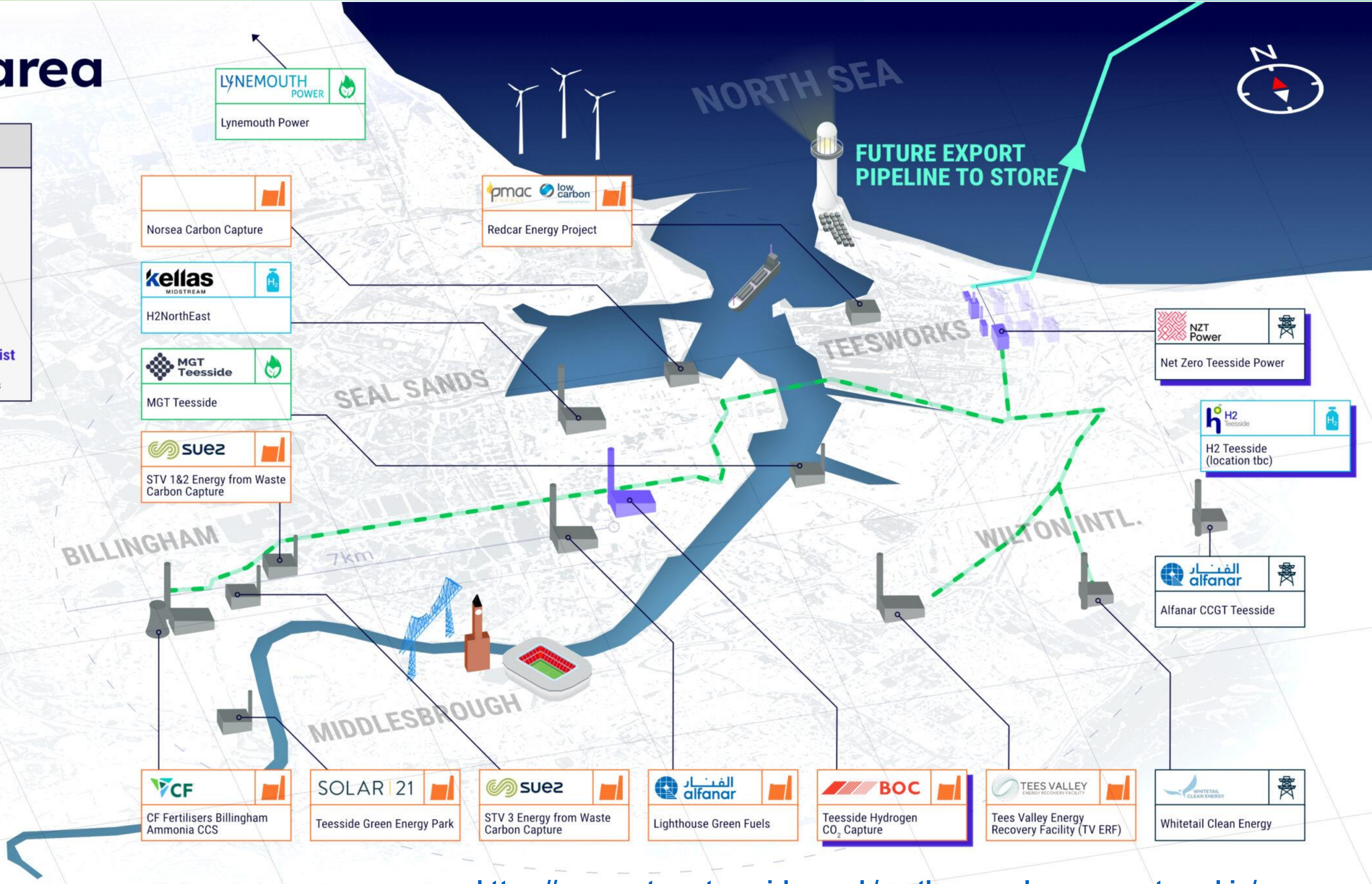
# Teesside area

**KEY**

- GGR BECCS Project
- Industrials
- Hydrogen
- Power
- Future CO2 pipeline
- **Track 1 Project Negotiation List**

All other projects are potential ECC Expansion projects




EAST COAST CLUSTER

• Pipeline routing for illustrative purposes only

https://www.netzeroteesside.co.uk/northern-endurance-partnership/

# Teesside University Research Pillars

**People and Place**

Creating vibrant, cohesive and resilient societies.

**Net Zero**

Forging a smarter, greener industrial economy.

**Health and Wellbeing**

Shaping the future of health, care and wellbeing.

NATIONAL HORIZONS CENTRE

# Net Zero Industry Innovation Centre

NZIIC is a pioneering centre for innovation, research, and collaboration in the field of net zero.

We provide a hub for businesses, researchers, and organisations to accelerate the transition to a sustainable, low-carbon economy.

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# Our Holistic Net Zero Offering

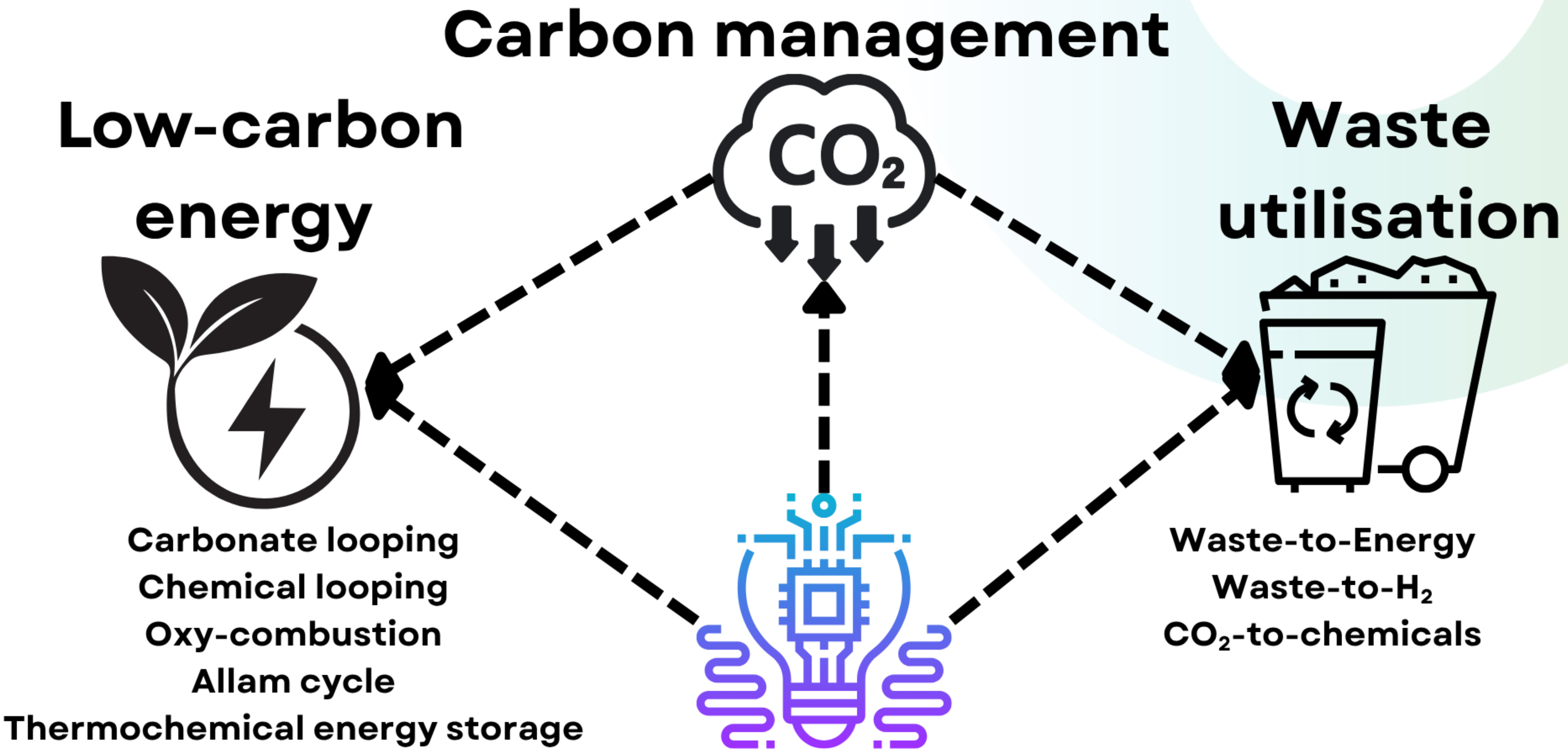
- Carbon Capture & Storage
- Hydrogen Lab
- Smart Energy Systems
- Circular Economy Lab
- Digital Modelling & Simulation Lab
- Business Expertise
- Social Research
- Creative Industries
- Policy & Compliance

# Industries we work with

- Aviation
- Chemicals
- Forestry
- Waste
- Maritime
- Power
- Sports
- Construction
- Data
- Food

# Carbon Capture and Utilisation Research Overview

Prof. Dawid Hanak
Net Zero Industry Innovation Centre




# COMPUTER-AIDED CHEMICAL ENGINEERING

**Process design & synthesis | Surrogate Models | TEA | LCA | Stochastic assessment**

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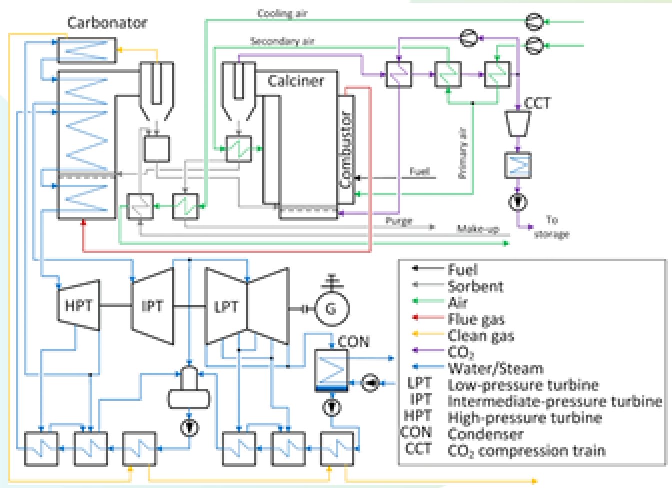
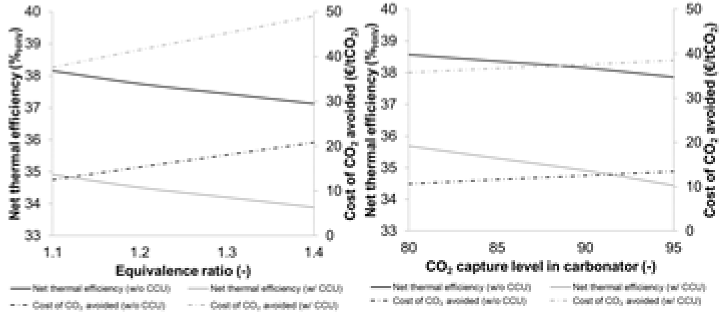
# Process design and feasibility

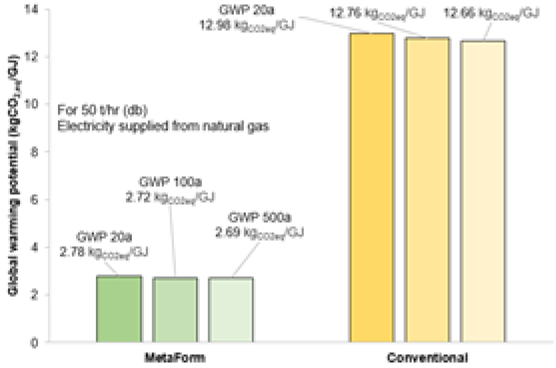
**Development of breakthrough net-zero process concepts and assessment of their techno-economic viability and life-cycle environmental impact**

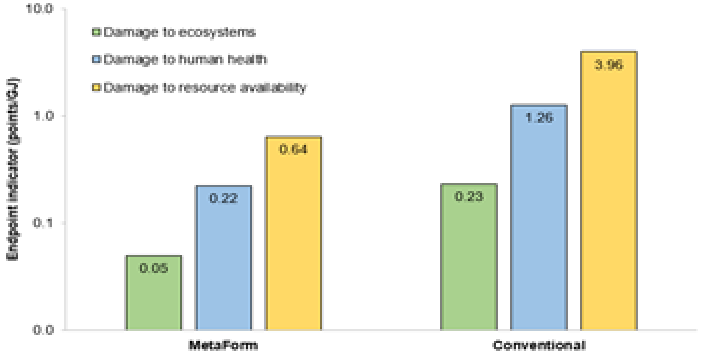
**Process design and engineering assessment of sustainable processes:**

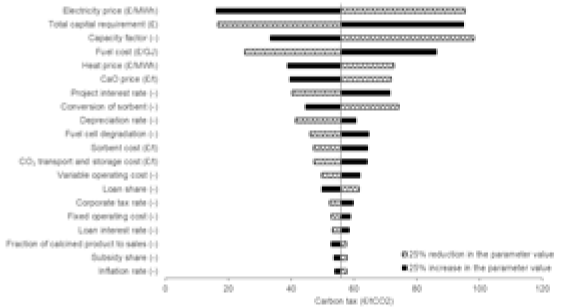
- High-temperature solid looping cycles (carbonate/chemical looping) for carbon capture, direct air capture and hydrogen production
- Process-intensified $CO_2$ use for bulk chemical production
- Hydrogen production via thermochemical and electrochemical routes
- Power-to-X processes



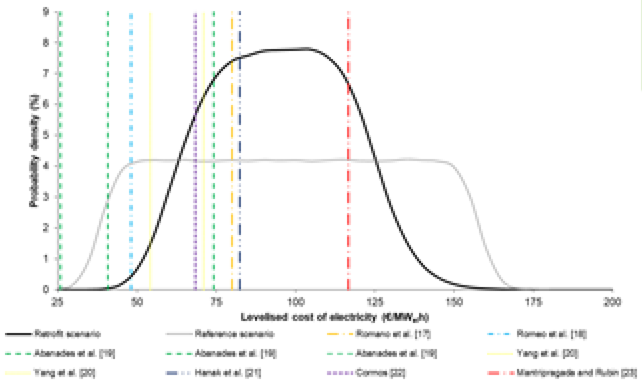



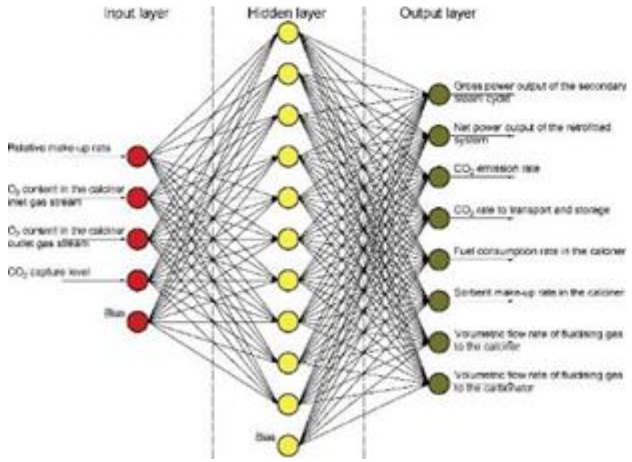
# Digital twins for risk assessment and business modelling

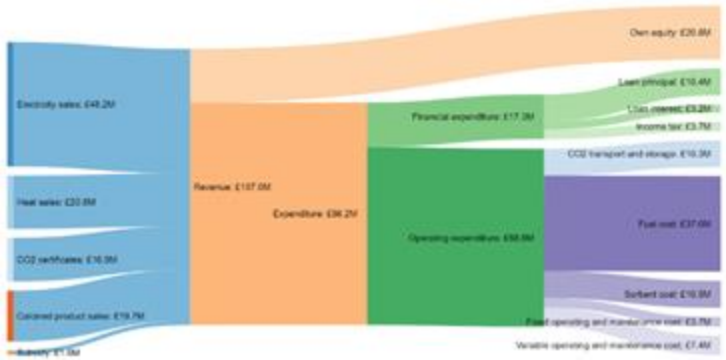
**Stochastic modelling and uncertainty modelling to quantify risk in investment decision making process and business model development**

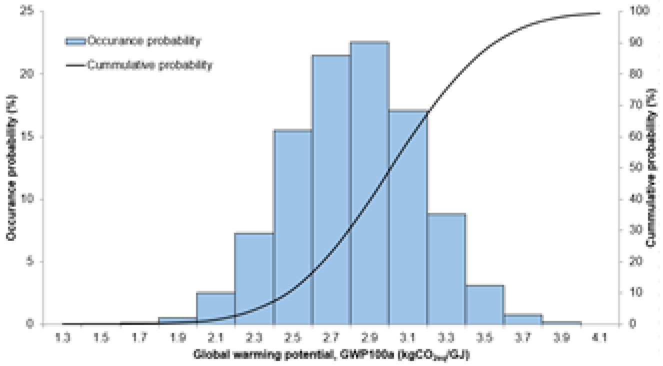



**Current active research in:**

- Reduced-order models and surrogate modelling (machine learning) for stochastic analysis
- Standardisation of economic assessment for net-zero technologies
- Quantification of uncertainties in economic and environmental models
- Development of sustainable business models based on $CO_2$ use





# Carbon capture and utilisation

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# Cleveland WtE plant Case Study

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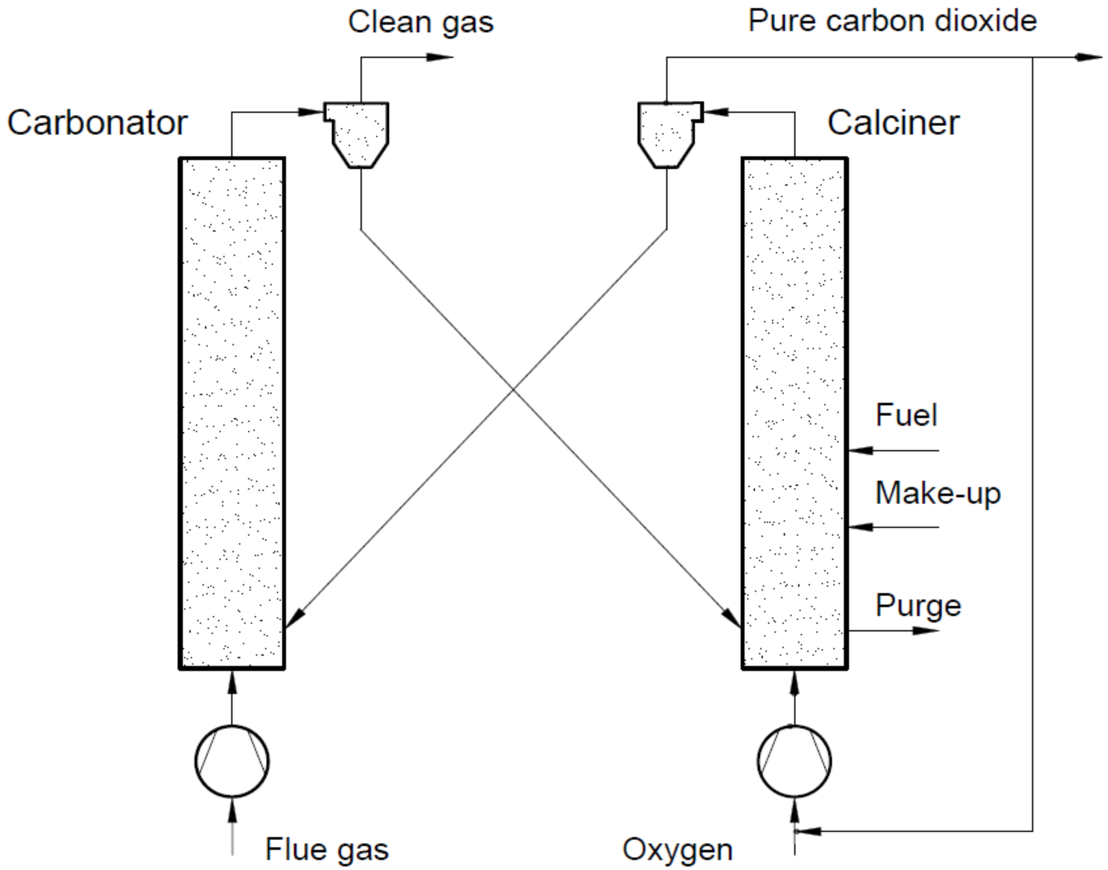
# Carbonate looping




## Reaction

$$CO_2 + CaO \rightarrow CaCO_3$$

**Operating conditions**

Carbonator: 650°C, 1.05 bar

Calciner: >900°C, 1.05 bar

Average sorbent conversion: 18%

# WtE case study overview

| Parameter | Host WtE | WtE+CaL | *Δ* (%) |
|---|---|---|---|
| Electrical output ($MW_e$) | 10.4 | 14.3 | +37.5% ↑ |
| Electrical efficiency ($\%_{HHV}$) | 22.6 | 14.5 | -8.1% points ↓ |
| Waste processing rate (t/h) | 18.2 | 33.6 | +84.6% ↑ |
| Net $CO_2$ emissions (g/kWh) | 659.8 | -1284 | -295% ↑ |
| CAPEX (£m) | 164 | 271 | +65.2% ↓ |
| OPEX (£m/a) | 5.2 | 8.8 | +69.2% ↓ |
| Electricity price (incl. gate fee £/MWh) | 154 | 165 | +7.1% ↓ |
| Electricity price (excl. gate fee £/MWh) | 329 | 399 | +21.3% ↓ |

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# Quorn™ mycoprotein Case Study

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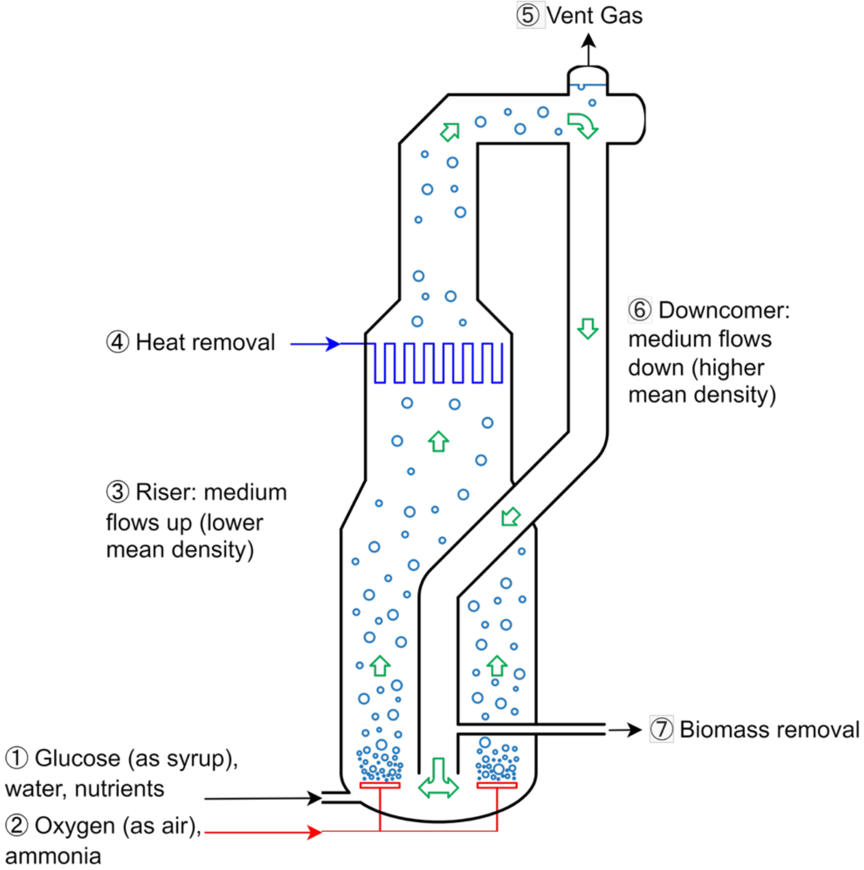
# Quorn mycoprotein process

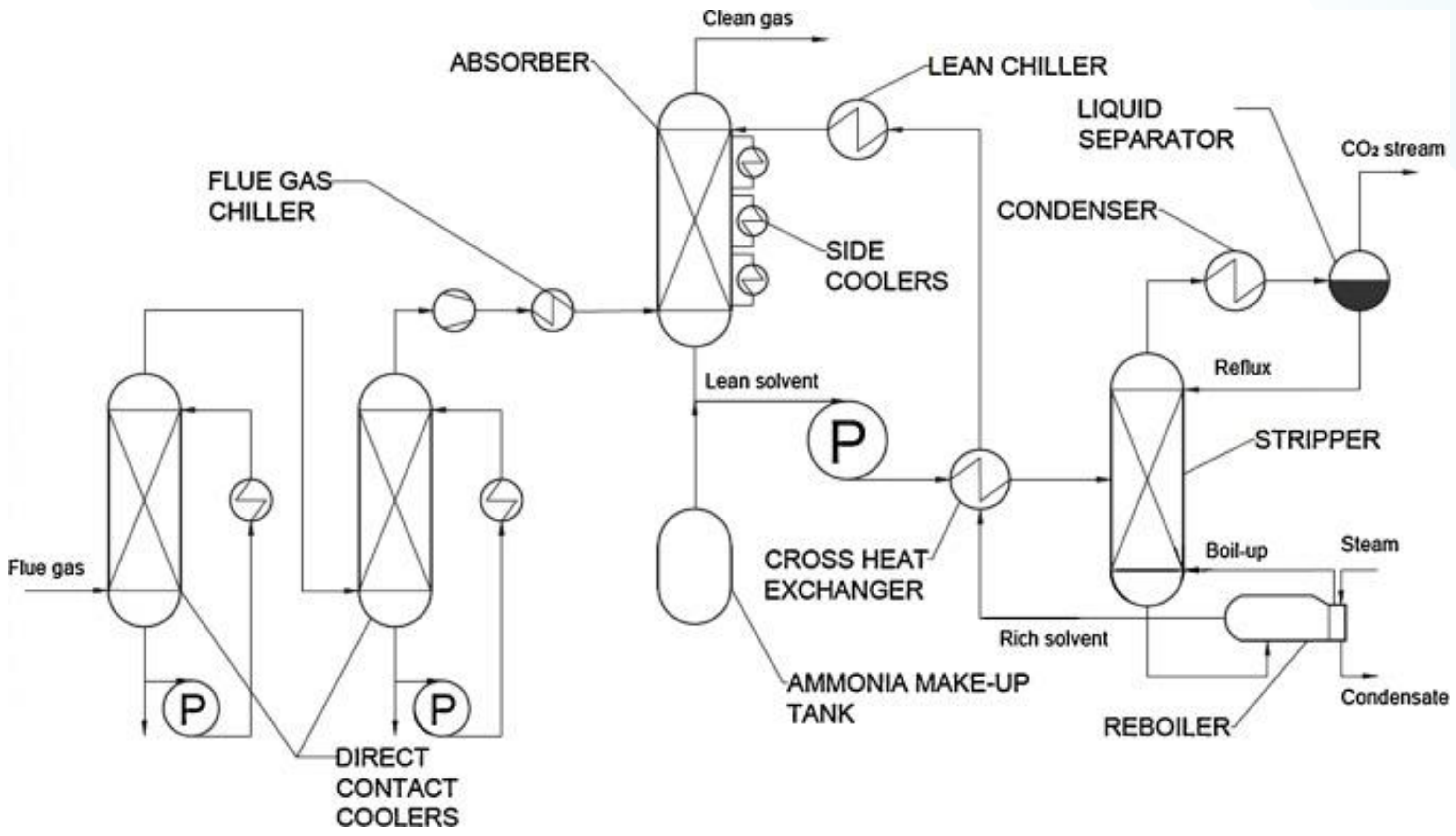



Controlled Mold, Quorn: A story about Single Cell Protein
https://controlledmold.com/quorn-a-story-about-single-cell-protein/

Key operating characteristics: (open source – to be validated)

- $CO_2$ in vent gas: 429-580 kg/h
- $CO_2$ concentration: 3-4%$_{vol}$
- "Clean" vent gas – no $SO_x$/$NO_x$

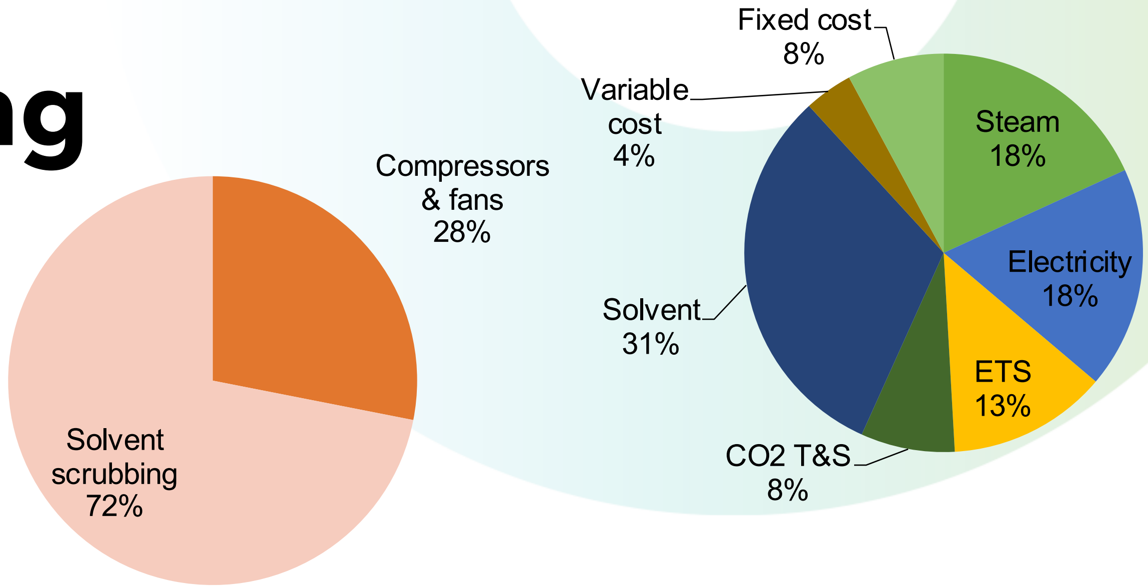
# Amine solvent scrubbing



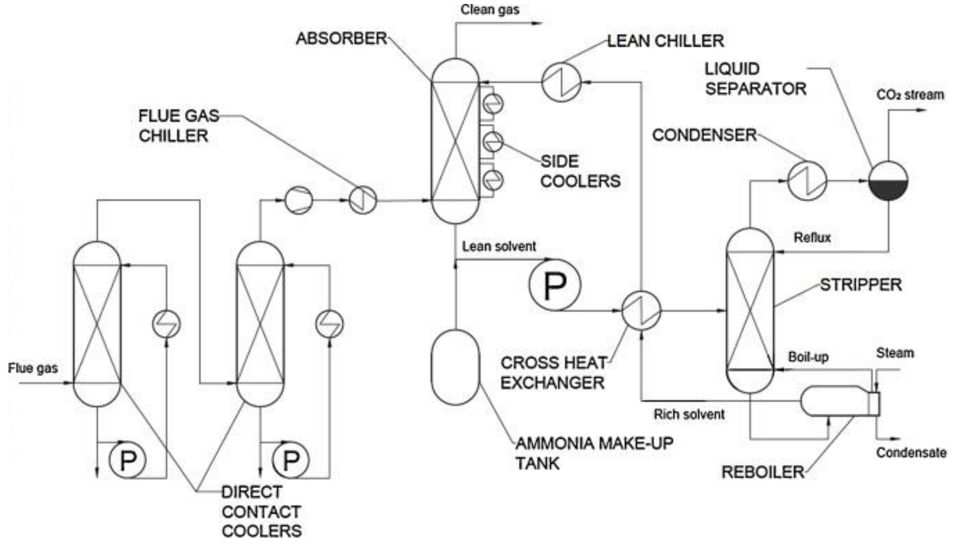

Hanak et al. (2015), International Journal of Greenhouse Gas Control, 34, 52-52

- Commercial technology
- Needs steam @ >130°C for solvent regeneration (2.28 kg/kg$CO_2$)
- Solvent scrubbing would add to current steam & electricity demand

# Amine solvent scrubbing




- Steam requirement: +170%
- Power requirement: +8.6%
- $CO_2$ emissions: -90%
- Lifecycle Cost: £330/t$CO_2$

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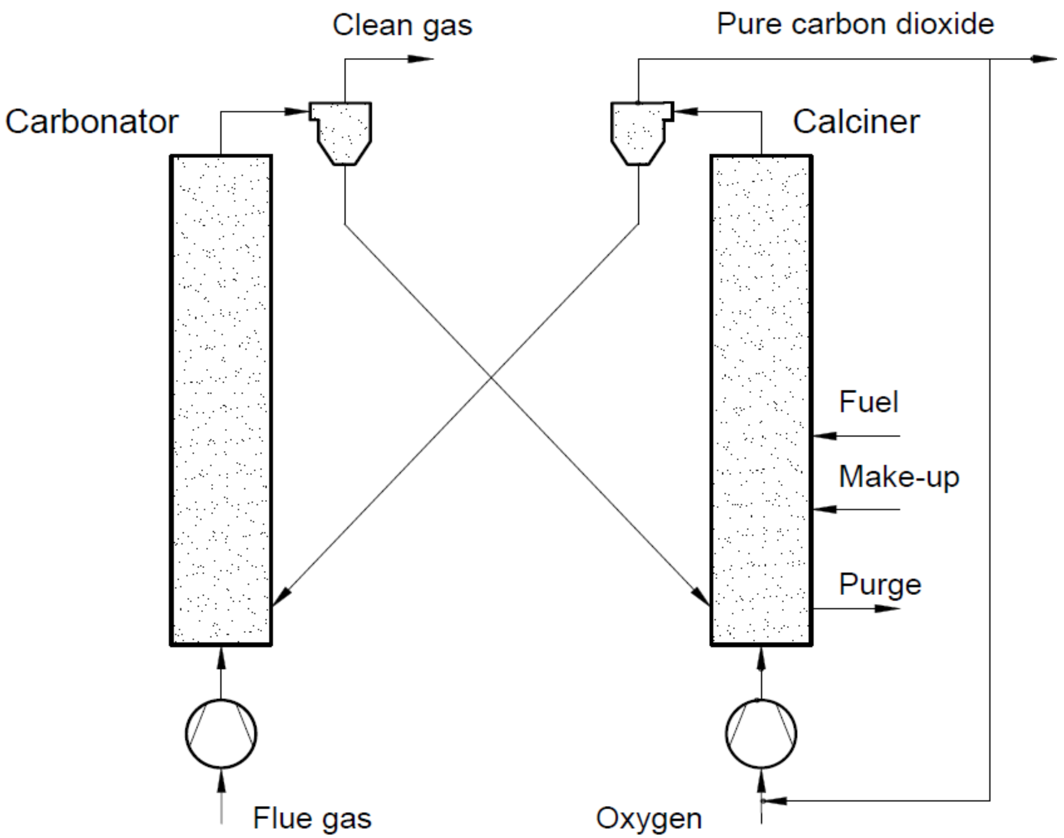
# Carbonate looping

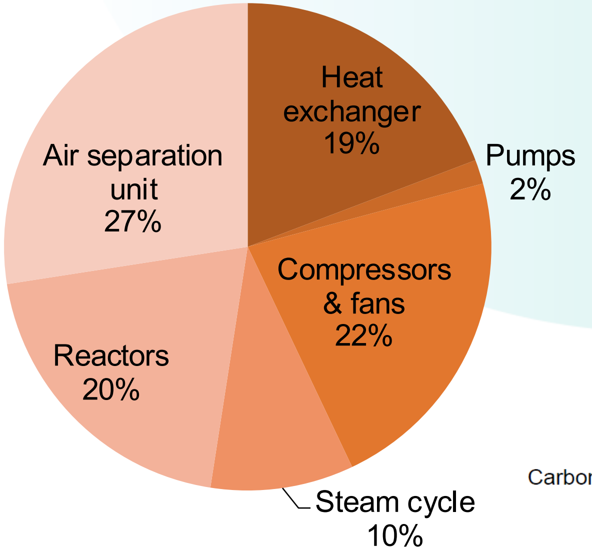


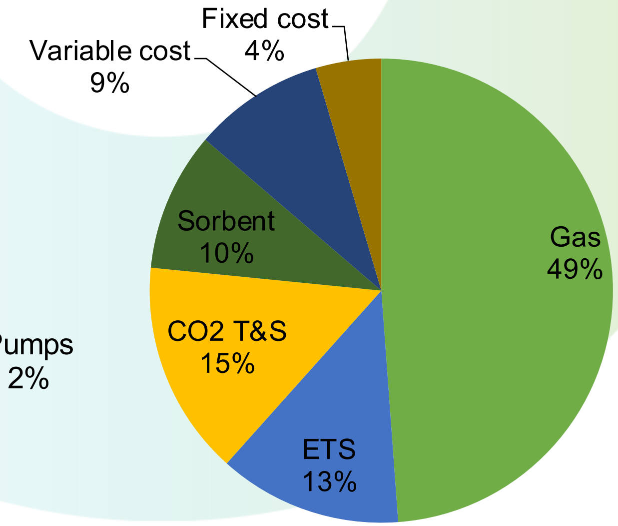

Hanak et al. (2015), Energy and Environmental Science, 8(8), 2199-2249

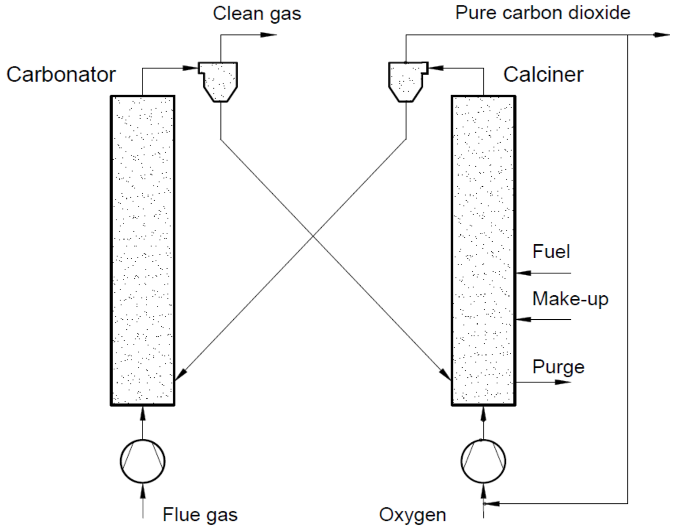
- Needs energy for sorbent regeneration (gas @ 0.1 kg/kg$CO_2$ or electricity @ 1.56 MWh/t$CO_2$)
- Carbonate looping can reduce energy requirement (heat or power)

# Carbonate looping (power)

- Gas requirement: 0.1 $t/tCO_2$
- Power requirement: -26.4%
- $CO_2$ emissions: -90%
- Lifecycle Cost: £112.7/$tCO_2$

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# Airhive Case Study

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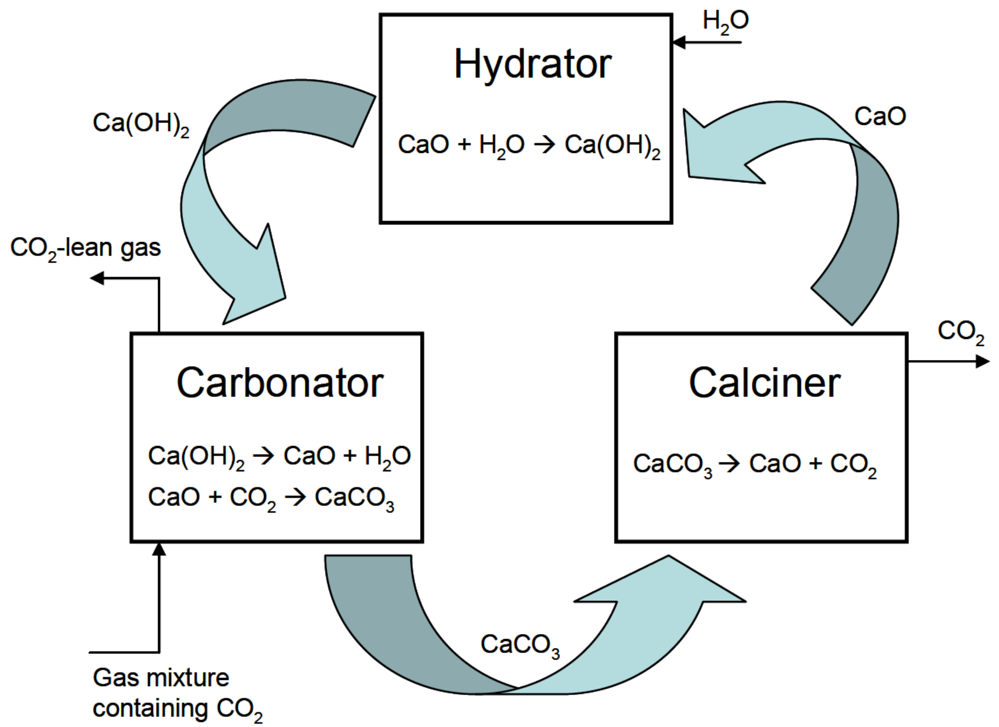
# Carbonate looping for DAC




Source: OHIO UNI

## Reaction

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$

### Operating conditions

Carbonator: 25°C, 1.05 bar

Hydrator: 200 °C, 2 bar

Calciner: >800°C, 1.05 bar

Average sorbent conversion: 30%

# Carbonate looping for DAC

**At 1000 t$CO_2$ per annum:**

- Investment cost: £1.93m
- Operating cost: £0.194m/a
- $CO_2$ removal cost: £452/t

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# Innovation in carbon capture and use

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# Integrated carbon capture and use

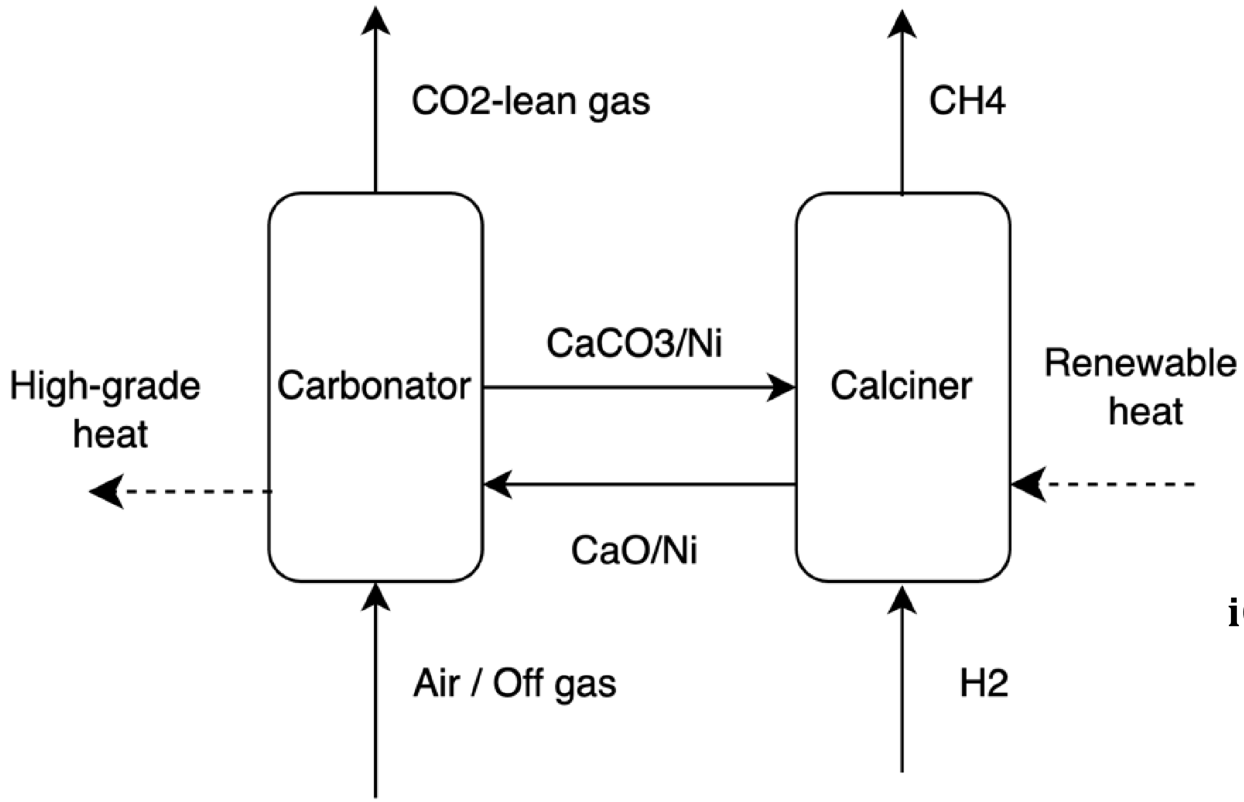
## HORIZON-CL5-2026-04-Two-Stage-D3-02: Next generation of renewable energy technologies (TRL4/5)

**Main challenge:** Sequential CO2 capture and utilisation is economically unattractive, resulting in the cost of renewable hydrocarbons of 2-3x of fossil fuel counterparts.

**Main objective:**
To develop TRL4/5 pilot for an integrated capture–conversion system for renewable fuels production from biogenic/waste CO2 (biogas upgrading, WtE, breweries).

**The idea:**
The innovation is in integrated calcination and $CO_2$ utilisation with a) methanation reaction to produce synthetic natural gas b) reversed water-gas shift reaction to produce syngas, c) integration with methanol, FT fuels production

# Integrated carbon capture and use



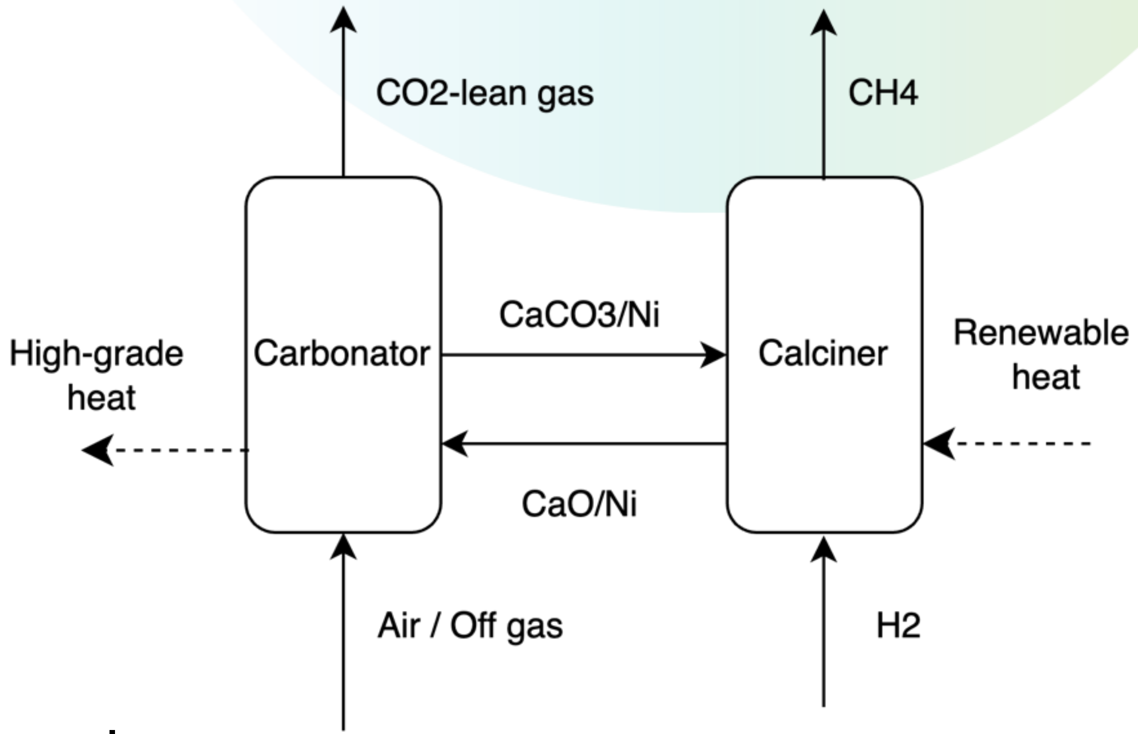

**Carbonation**: $CO2 + MO \rightarrow MCO3 \quad \Delta H^0 < 0 \ \frac{kJ}{mol}$

**Methanation**: $CO2 + 4H2 \rightarrow CH4 + 2H2O \quad \Delta H^0 = -164 \frac{kJ}{mol}$

**iCCU − METH**: $4H2 + MCO3 \rightarrow MO + CH4 + 2H2O \quad \Delta H^0 < 0 \ \frac{kJ}{mol}$

# Integrated carbon capture and use

- TRL3-4
- 50% reduction in energy intensity
- 20% reduction in CAPEX
- Opportunities for integration with existing infrastructure




Needs: Materials-Reactor-Process development

# Integrated carbon capture and energy storage

**HORIZON-CL5-2027-05-D2-08: Demonstration for Long-duration Battery Energy Storage Systems (BATT4EU Partnership) TRL6/7 &**
**HORIZON-CL5-2027-07-D3-28: Integrated Approaches for Retrofitting Infrastructures with Innovative Energy Storage Technologies (TRL6/8)**

**Main challenge:** CCUS can provide energy balancing services to the electricity and district heating networks, yet this functionality has not been explored beyond modelling studies.

**Main objective:**
To develop a TRL6 pilot for an integrated $CO_2$ capture-energy storage system demonstrated for selected industrial clusters.

**The idea:**
The innovation is in solar/wind energy driving the calcination process CaCO3⇄CaO+CO2 (charging). The reverse reaction (discharge) delivers 300–700°C heat and optional power (steam/sCO2), while capturing CO2 from industrial flue gases.

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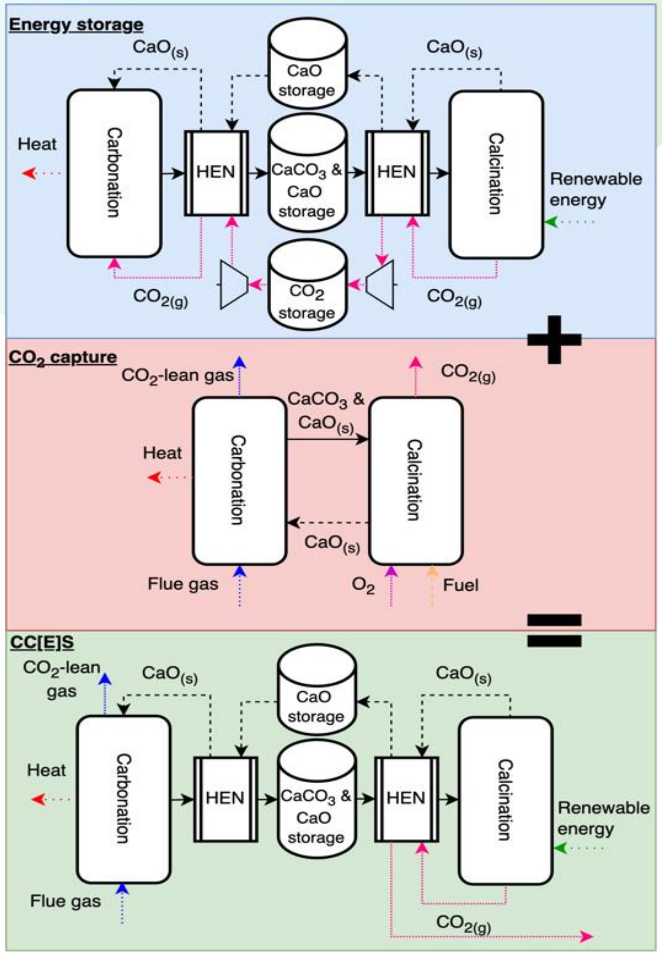
# Integrated carbon capture and energy storage

- TRL3-4
- 25% reduction in the cost of $CO_2$ avoided
- Energy storage at CAPEX of <5 £/kWh
  - Hydrogen storage CAPEX -> 15-40 £/kWh
  - Electric thermal energy storage -> 50-60 £/kWh
  - Battery storage CAPEX -> 300-1500 £/kWh



# Thank you for your time!

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