START 2024 END 2025 COOCK

Map-it CCU

Mapping and evaluation of CCU technologies

CAPTURE

Map-it CCU

Miet Van Dael (VITO)

vito VUB smart delta resources University of Antwerp UNIVERSITEIT GENT CATALISTI WE MEAN BUSINESS flux50 ENERGISING THE FUTURE VLAIO

Start for MAP-it CCU

CCUS as a solution for industrial decarbonization where emissions are unavoidable, efficiency increase limited and/or electrification no option.

umicore

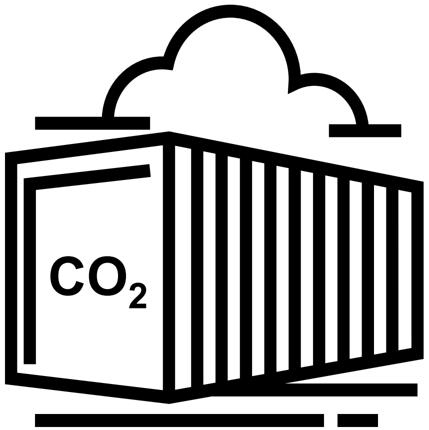
Lhoist

Keppel Seghers

CAPTURE

Idea of
Rapid CCU

Map-it CCU



Mobile testing container

- *Which technologies are currently available?*
- *Which should be demonstrated?*
- *How do we select the most suitable technology?*
- *Which technologies are feasible for specific industrial streams?*

Map-it CCU – First-of-its-kind service

Not available yet in Flanders

Further than former decision support tools in e.g. Moonshot CAPTIN and CO_2PERATE projects

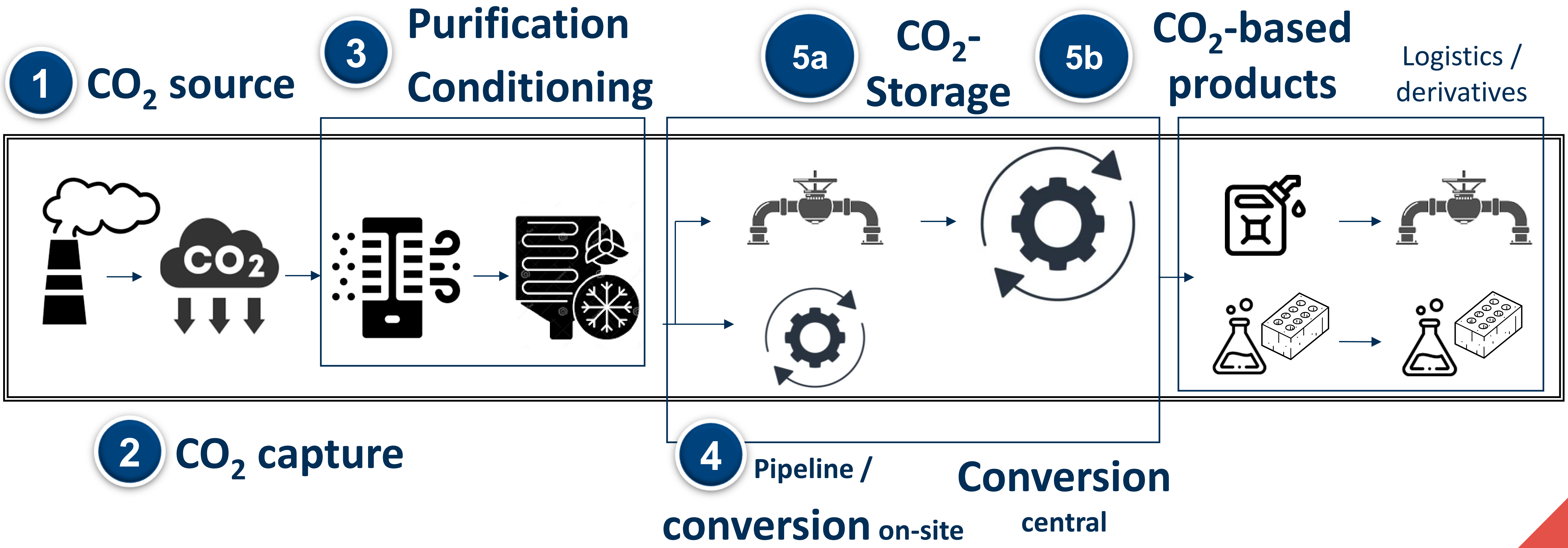
Overview of CCUS possibilities

Companies with lower CO_2 concentrations and volumes (i.e., no CCUS core competence) can learn from the larger emitters

Value chain approach, not stand-alone technology

Look at commercial, state-of-the-art technologies as well as innovations

Value chain approach



Focus Group

30 members

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cyclic adsorption
processes
Carbon capture

MAP-IT CCU
Integrated Framework for Technology Assessment

infosheets ⟷ Decision Support Framework ⟷ CO_2 Capture Cost Calculator

Technology Information Backbone

Smart Technology Shortlisting

Interactive Cost Estimation Tool

Link to knowledge platform: About Map-it CCU | EMIS

Infosheets

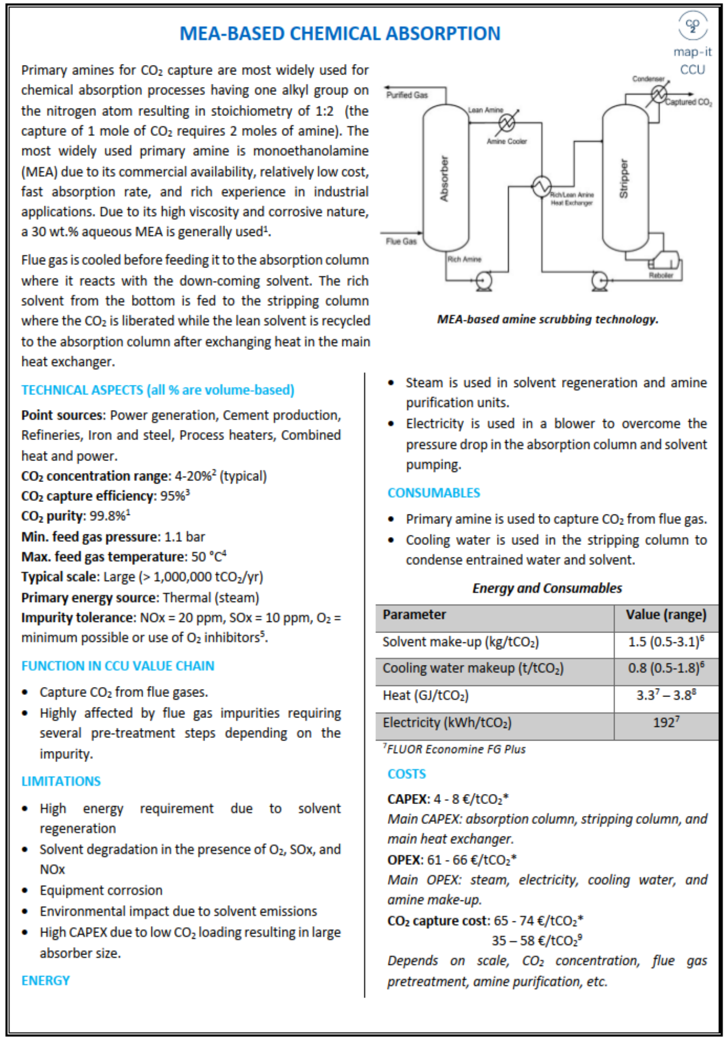
infosheets

01 Purpose	02 Content	03 Methodology	04 Data sources
Assess and compare various technologies for decision making and data-driven technology selection.	Transparent, systematic and structured overview of technical, economic, environmental, and engineering dimensions.	Literature review combined with stakeholder engagement to ensure real-world relevance and informed feedback.	VITO project experience, expert input, FEED studies, technology supplier data, publicly available reports, and open literature.

What Do the Infosheets Contain? (1)

infosheets

Technology description	Description and flow diagram providing a complete view of the technology's working principles
Technical parameters	Key process parameters (CO_2 concentration, scale, efficiency, CO_2 purity, pressure, temperature)
CCU Value Chain Role	Step in the CCU chain the technology addresses (e.g. capture, purification) and associated effects.
Limitations	Technical, operational, or environmental drawbacks
Energy and consumables	Types and amounts of energy, material, and chemical input required
Cost indicators	CAPEX, OPEX, capture and avoidance costs per tonne of CO_2
Environmental footprint	Emissions, space requirements, and other impacts



MEA-BASED CHEMICAL ABSORPTION

map-it CCU

Primary amines for CO_2 capture are most widely used for chemical absorption processes having one alkyl group on the nitrogen atom resulting in stoichiometry of 1:2 (the capture of 1 mole of CO_2 requires 2 moles of amine). The most widely used primary amine is monoethanolamine (MEA) due to its commercial availability, relatively low cost, fast absorption rate, and rich experience in industrial applications. Due to its high viscosity and corrosive nature, a 30 wt.% aqueous MEA is generally used[1].

Flue gas is cooled before feeding it to the absorption column where it reacts with the down-coming solvent. The rich solvent from the bottom is fed to the stripping column where the CO_2 is liberated while the lean solvent is recycled to the absorption column after exchanging heat in the main heat exchanger.

MEA-based amine scrubbing technology.

TECHNICAL ASPECTS (all % are volume-based)

Point sources: Power generation, Cement production, Refineries, Iron and steel, Process heaters, Combined heat and power.
CO_2 concentration range: 4-20%[2] (typical)
CO_2 capture efficiency: 95%[3]
CO_2 purity: 99.8%[1]
Min. feed gas pressure: 1.1 bar
Max. feed gas temperature: 50 °C[4]
Typical scale: Large (> 1,000,000 tCO_2/yr)
Primary energy source: Thermal (steam)
Impurity tolerance: NOx = 20 ppm, SOx = 10 ppm, O_2 = minimum possible or use of O_2 inhibitors[5].

FUNCTION IN CCU VALUE CHAIN

- Capture CO_2 from flue gases.
- Highly affected by flue gas impurities requiring several pre-treatment steps depending on the impurity.

LIMITATIONS

- High energy requirement due to solvent regeneration
- Solvent degradation in the presence of O_2, SOx, and NOx
- Equipment corrosion
- Environmental impact due to solvent emissions
- High CAPEX due to low CO_2 loading resulting in large absorber size.

ENERGY

- Steam is used in solvent regeneration and amine purification units.
- Electricity is used in a blower to overcome the pressure drop in the absorption column and solvent pumping.

CONSUMABLES

- Primary amine is used to capture CO_2 from flue gas.
- Cooling water is used in the stripping column to condense entrained water and solvent.

Energy and Consumables

Parameter	Value (range)
Solvent make-up (kg/tCO_2)	1.5 (0.5-3.1)[6]
Cooling water makeup (t/tCO_2)	0.8 (0.5-1.8)[6]
Heat (GJ/tCO_2)	3.3[7] – 3.8[8]
Electricity (kWh/tCO_2)	192[7]

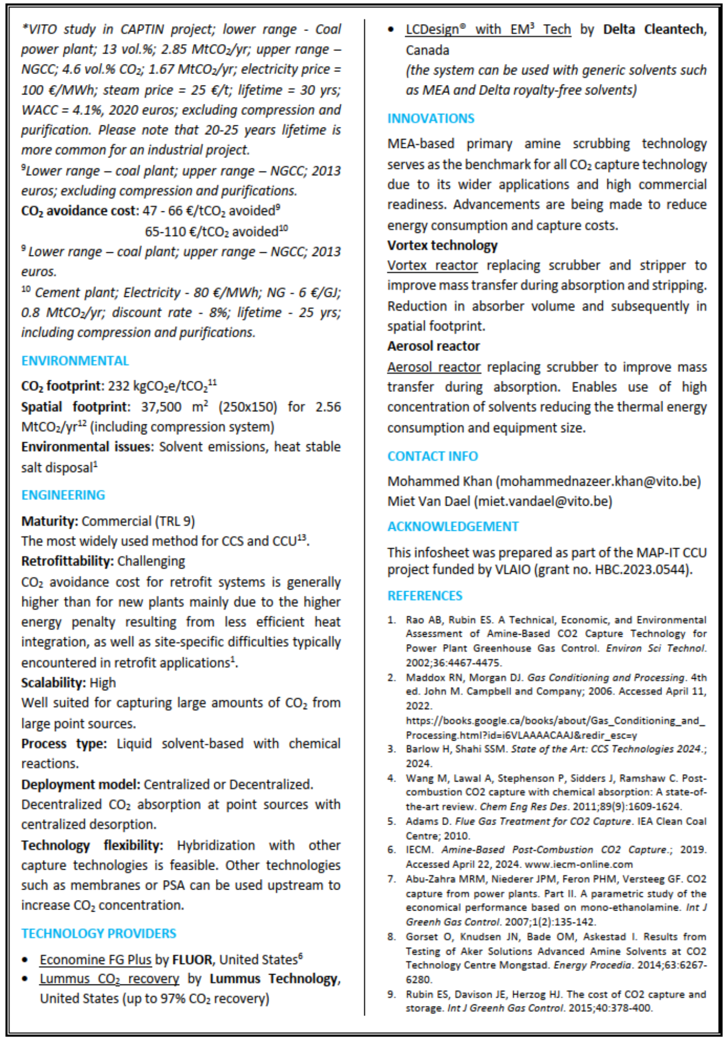
[7] *FLUOR Economine FG Plus*

COSTS

CAPEX: 4 - 8 €/tCO_2*
Main CAPEX: absorption column, stripping column, and main heat exchanger.
OPEX: 61 - 66 €/tCO_2*
Main OPEX: steam, electricity, cooling water, and amine make-up.
CO_2 capture cost: 65 - 74 €/tCO_2*
35 – 58 €/tCO_2[9]
Depends on scale, CO_2 concentration, flue gas pretreatment, amine purification, etc.

What Do the Infosheets Contain? (2)

Engineering & Deployment	TRL, retrofit potential, scalability, deployment models
Technology Providers	Companies offering commercial or pilot-scale solutions
Innovations	Emerging improvements and hybrid solutions
Contact Info	VITO experts or project leads for follow-up
References & Acknowledgements	Source studies and funding context



**VITO study in CAPTIN project; lower range - Coal power plant; 13 vol.%; 2.85 $MtCO_2$/yr; upper range – NGCC; 4.6 vol.% CO_2; 1.67 $MtCO_2$/yr; electricity price = 100 €/MWh; steam price = 25 €/t; lifetime = 30 yrs; WACC = 4.1%, 2020 euros; excluding compression and purification. Please note that 20-25 years lifetime is more common for an industrial project.*

[9]Lower range – coal plant; upper range – NGCC; 2013 euros; excluding compression and purifications.

CO_2 avoidance cost: 47 - 66 €/tCO_2 avoided[9]
65-110 €/tCO_2 avoided[10]

[9] Lower range – coal plant; upper range – NGCC; 2013 euros.

[10] Cement plant; Electricity - 80 €/MWh; NG - 6 €/GJ; 0.8 $MtCO_2$/yr; discount rate - 8%; lifetime - 25 yrs; including compression and purifications.

ENVIRONMENTAL

CO_2 footprint: 232 $kgCO_2e/tCO_2$[11]
Spatial footprint: 37,500 m^2 (250x150) for 2.56 $MtCO_2$/yr[12] (including compression system)
Environmental issues: Solvent emissions, heat stable salt disposal[1]

ENGINEERING

Maturity: Commercial (TRL 9)
The most widely used method for CCS and CCU[13].
Retrofittability: Challenging
CO_2 avoidance cost for retrofit systems is generally higher than for new plants mainly due to the higher energy penalty resulting from less efficient heat integration, as well as site-specific difficulties typically encountered in retrofit applications[1].
Scalability: High
Well suited for capturing large amounts of CO_2 from large point sources.
Process type: Liquid solvent-based with chemical reactions.
Deployment model: Centralized or Decentralized.
Decentralized CO_2 absorption at point sources with centralized desorption.
Technology flexibility: Hybridization with other capture technologies is feasible. Other technologies such as membranes or PSA can be used upstream to increase CO_2 concentration.

TECHNOLOGY PROVIDERS

- Economine FG Plus by **FLUOR**, United States[6]
- Lummus CO_2 recovery by **Lummus Technology**, United States (up to 97% CO_2 recovery)
- LCDesign® with EM³ Tech by **Delta Cleantech**, Canada
(the system can be used with generic solvents such as MEA and Delta royalty-free solvents)

INNOVATIONS

MEA-based primary amine scrubbing technology serves as the benchmark for all CO_2 capture technology due to its wider applications and high commercial readiness. Advancements are being made to reduce energy consumption and capture costs.
Vortex technology
Vortex reactor replacing scrubber and stripper to improve mass transfer during absorption and stripping. Reduction in absorber volume and subsequently in spatial footprint.
Aerosol reactor
Aerosol reactor replacing scrubber to improve mass transfer during absorption. Enables use of high concentration of solvents reducing the thermal energy consumption and equipment size.

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ACKNOWLEDGEMENT

This infosheet was prepared as part of the MAP-IT CCU project funded by VLAIO (grant no. HBC.2023.0544).

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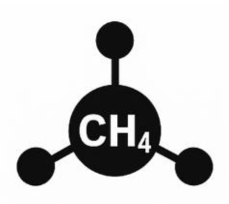
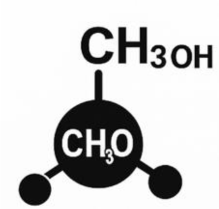
Infosheets CO_2 Utilization

infosheets

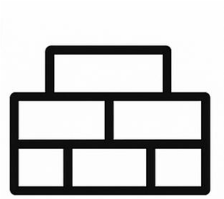
Provide **insights in the status of different CO_2 conversion options**: technology, maturity, markets, economics, legislative aspects, trends & recent investments.



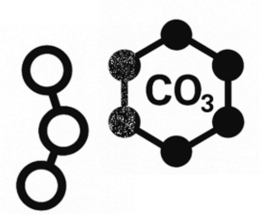
Methane



Methanol



Mineralisation



Polymers and chemicals

Aviation fuels

Decision Support Framework

Decision Support Framework

Key Criteria

CO_2 Concentration in Feed Gas

Different technologies perform optimally at specific CO_2 concentration ranges.

<10% (or) **10-30%** (or) **>30%**

Scale of CO_2 capture

Economies of scale influence technology choice and cost-efficiency.

<100 kt (or) **100–1.000 kt** (or) **>1.000 kt**

Preferred Energy Source

Determines the compatibility with heat or electricity-based systems.

Heat (or) **Electricity**

Pressure of the Feed Gas + Compressor

Affects the energy demand for compression and the type of capture system.

LP + Comp (or) **LP + No Comp**
HP + Comp (or) **HP + No Comp**

Temperature of the Feed Gas + Cooler

Defines cooling needs and viable technology.

LT + Cooler (or) **LT + No Cooler**
HT + Cooler (or) **HT + No Cooler**

Availability of Waste Heat

Can lower energy costs using process integration.

Yes (or) **No**

Pretreatment availability

Impurities like NOx, SOx, PM, and H_2O can degrade solvents, poison catalysts, or foul membranes.

Low pressure (LP) <=1.2 bar; High pressure (HP) >1.2 bar
Low temperature (LT) <=40 °C; High temperature (HT) >40 °C

Decision Support Framework

Why These Criteria?

DEFINE TECHNICAL FEASIBILITY

Criteria such as CO_2 concentration, pressure, and temperature are non-negotiable physical realities of the feed gas.

If a technology cannot technically operate under these gas conditions, cost or footprint becomes irrelevant.

ENABLE EARLY COMPATIBILITY FILTERING

These parameters allow quick elimination of incompatible technologies.

Serves as a "technical filter" before applying economic or environmental filters.

CAPTURE TECHNOLOGIES ARE ENERGY-INTENSIVE

Preferred energy source and waste heat availability directly influence energy integration and operational efficiency.

This impacts not only performance but also life-cycle emissions, a crucial factor in net-zero scenarios.

IMPURITIES INFLUENCE LIFETIME AND OPEX

Presence of NO_x, SO_x, PM, H_2O can degrade solvents, poison sorbents, foul membranes

These issues lead to higher maintenance, solvent/sorbent replacement costs, and downtime.

Decision Support Framework

Decision Support Framework

What is the CO2 concentration in your feed gas? *
- ( ) Low (<10%)
- (•) Medium (10-30%)
- ( ) High (>30%)

What is the scale of CO2 capture? *
- (•) Small (<100 kt)
- ( ) Medium (100-1000 kt)
- (•) Large (>1000 kt)

What is your preferred energy source? *
- ( ) Electricity
- (•) Heat

What is the pressure of the feed gas and would like to invest/add a feed gas compressor? *
- ( ) Low (<=1.2 bar) with compressor
- (•) Low (<=1.2 bar) without compressor
- ( ) High (>1.2 bar) with compressor
- ( ) High (>1.2 bar) without compressor

What is the temperature of the feed gas and would like to invest/add a feed gas cooler? *
- ( ) Low (<=40 °C) with cooler
- ( ) Low (<=40 °C) without cooler
- (•) High (>40 °C) with cooler
- ( ) High (>40 °C) without cooler

Is waste heat available? *
- ( ) Yes
- (•) No

Is pre-treatment already available?
- [x] NOx
- [ ] SOx
- [x] PM
- [ ] H2O
- [ ] O2

RESULTS >

Technologies

Show innovations (<TRL 7) ☐

Technology	Critical impurities
Pressure swing adsorption 1✗ Physical adsorption Mature Post	H2O
Vacuum-temperature swing adsorption 1✗ Physical adsorption Mature Post	SOx, H2O
Cryogenic carbon capture 2✗ Physical separation Mature Post	H2O
Membranes 2✗ Physical separation Mature Post	H2O, SOx, NOx, O2
Temperature swing adsorption 2✗ Physical adsorption Mature Post	H2O
Amines/blends chemical absorption 3✗ Chemical absorption Mature Post	H2O, SOx, NOx

Pressure swing adsorption

View technology sheet

Question	Your answer(s)	Match?
What is the CO2 concentration in your feed gas?	Medium (10-30%)	✓
What is the scale of CO2 capture?	Small (<100 kt)	✓
What is your preferred energy source?	Electricity	✓
What is the pressure of the feed gas and would like to invest/add a feed gas compressor?	Low (<=1.2 bar) without compressor	✗ i
What is the temperature of the feed gas and would like to invest/add a feed gas cooler?	High (>40 °C) with cooler	✓
Is waste heat available?	No	✓
Is pre-treatment already available?	P,M	✓

CO_2 Capture Cost calculator

Capture Cost Calculator

Key Inputs infosheet

- Reference data (CAPEX, scale, year, lifetime, financial parameters, scaling exponent)
- Utility consumption (heat, electricity, water, solvent, sorbent)

Outputs

- Total CAPEX
- Annualized CAPEX
- OPEX (variable + fixed)
- CO_2 capture cost (€/tCO_2)

Calculator to estimate the cost of CO_2 capture through customizable parameters for scale, energy use, financial assumptions, and utility inputs.

User Inputs

- Actual scale
- Year
- Heat and electricity prices
- Material and chemicals prices

Dynamic Scaling

Projects costs based on current plant size vs. reference using a scaling exponent and adjusts for inflation (CEPCI) and financial viability (WACC).

MOOC

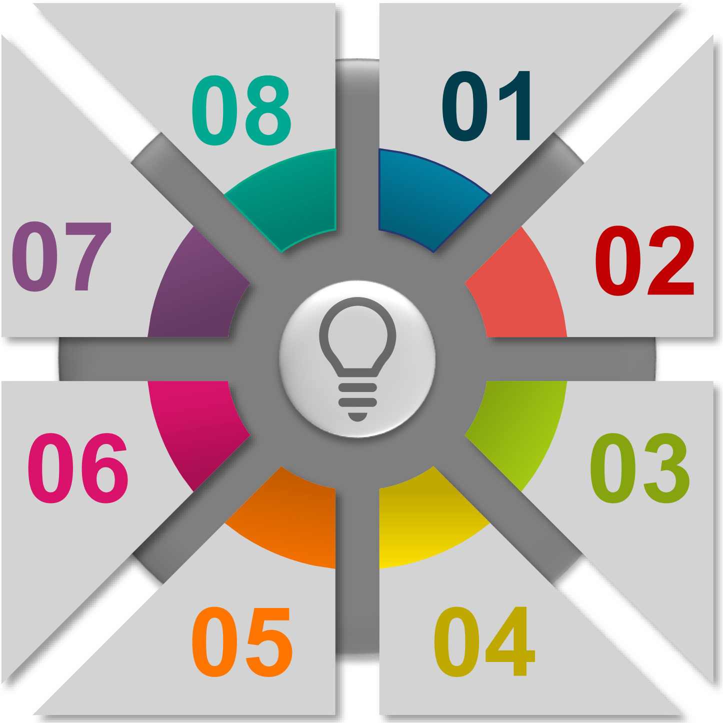
Video lessons, text lessons, and exercises prepared by 33 experts, 13 video studio operators and 4 capture staff allows to learn more at your own pace.

HETEROGENEOUS CATALYSIS

BIOCATALYSIS

PHOTOCATALYSIS

CCUS IN NET-ZERO TRANSITION



MAP-IT CCU TECHNOLOGY TOOL

CAPTURE AND SEPARATION OF CO_2

PLASMA TECHNOLOGY

ELECTROCATALYSIS

Link to CAPTURE Academy

Key Takeaways

- MAP-IT CCU simplifies complex technology decisions.
- It allows to tailor recommendations to site-specific needs.
- It’s transparent, data-driven, and easy to use.
- It’s ready to support both SMEs and large emitters.

START 2024 END 2025 COOCK

Map-it CCU

Mapping and evaluation of CCU technologies

CAPTURE

We would like to hear from you!

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