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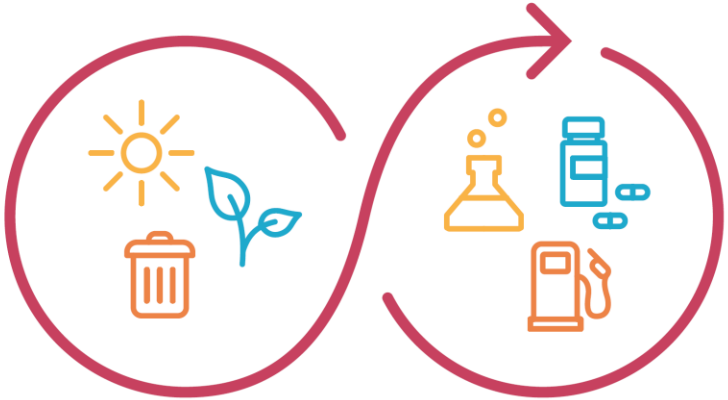
Carbon Capture & Utilization (CCU)



Group 1

Current technologies for CO2 capture [1]

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- Point sources carbon capture:
  - Most efficient technology as CO_2 is highly concentrated
  - Post-Combustion Capture: Largest opportunity in industrial processes combusting fossil fuels
  - Pre-Combustion Capture: CO_2 is separated from syngas in fuel processing plants
  - Oxy-Fuel Combustion: Fuel is burned with pure oxygen, producing only CO_2 and water vapor for easier separation
  - CO_2 is captured through adsorption, absorption, or membrane separation

- Direct air capture (DAC) :
  - Removes CO_2 from ambient air
  - Most plants use liquid or solid sorbent

Current technologies for CO2 capture [1]

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- Indirect air capture (IAC)
  - Enhancing natural carbon capture processes such as photosynthesis and carbon mineralization
- Afforestation and forestry
- Blue carbon and ocean storage
  - Phytoplankton are the main organisms responsible for transferring atmospheric carbon to the ocean
- Algae culturing
  - can capture CO_2 while simultaneously producing large volumes of biomass with high market potential

Options for carbon utilization [1]

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- Enhanced oil recovery (EOR)
  - Goal : recover higher volumes of oil and gas.
  - Most economic option
- Fuel cells
- Biochar
- Valuable chemical production
- Fertilizer
- Building materials
  - Cement, calcite

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What sustainability benefits does CCU offer ?

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Climate impact of CO_2 use depends on five factors [2] :

- Source of CO_2
- Product or service being displaced
- Energy used for CO_2 conversion
- Duration of CO_2 retention in product
- Potential for large-scale deployment

Environmental benefits of CCU [2, 3]

- Enables emissions reduction in hard-to-abate sectors
- Converts CO_2 into useful or durable products (e.g., building materials)
- Replaces fossil-based feedstocks
- Supports energy transition via storable fuels
- Contributes to circular carbon economy

Social and economic contributions of CCU [2, 3]

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Social

- Compatible with existing infrastructure and technologies
- Reduces transition costs in legacy industries
- Encourages job creation and technological innovation

Economic

- Diversifies carbon feedstocks
- Opens new markets for CO_2-based products
- Reduces dependence on imported fossil fuels

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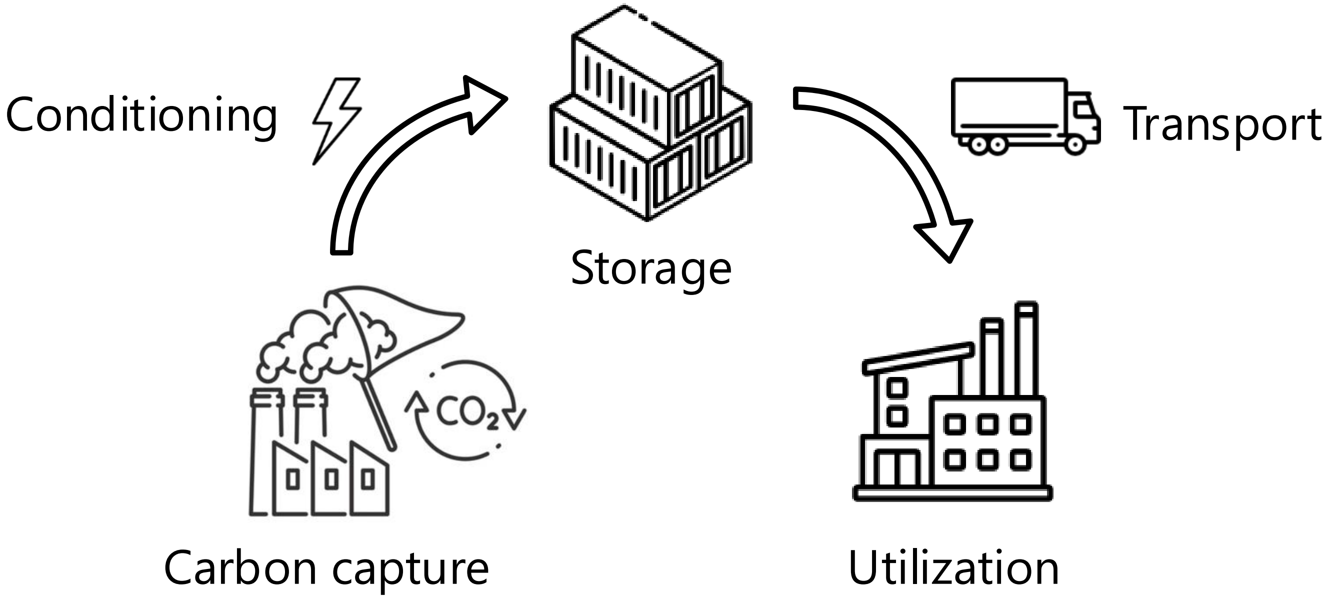
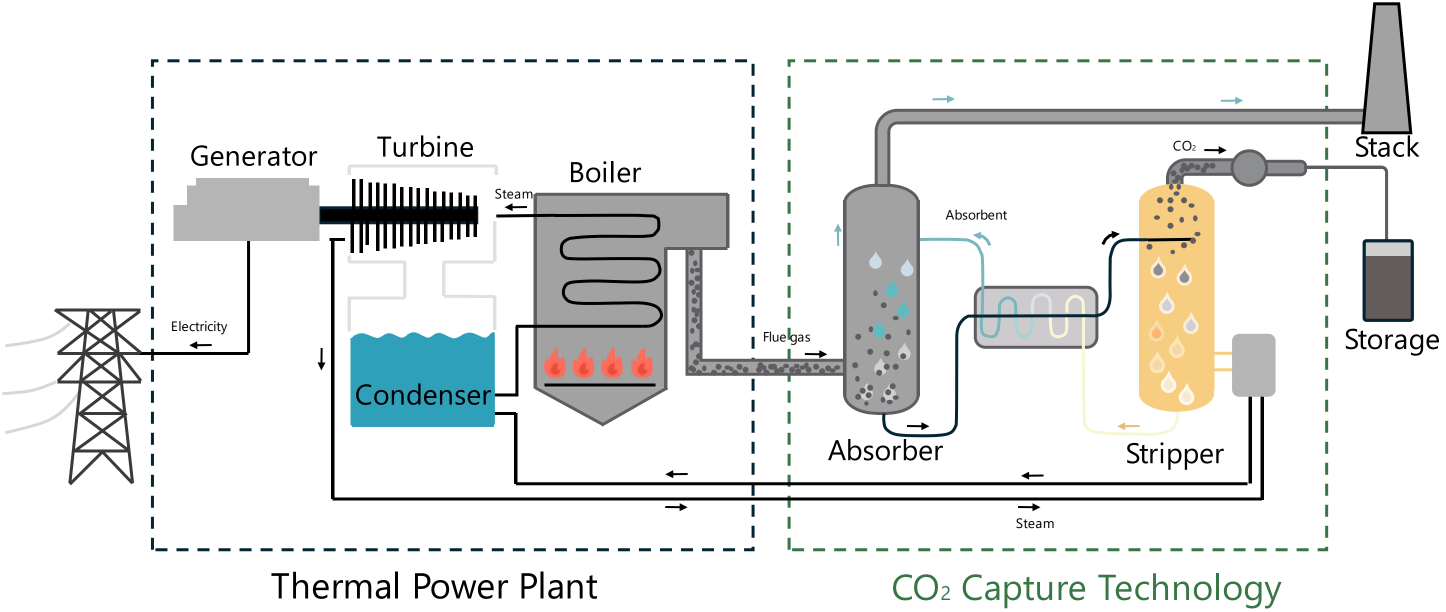
CCU Chain


Conditioning
Storage
Transport
Carbon capture
CO_2
Utilization

Carbon capture for a power plant



- Post-combustion capture with chemical absorption [4]
- Flue gas = pretreated (dust removal, denitrification and desulphurization) [4]

Adapted from: Toshiba. *Efforts for CO2 emission reduction-CO2capture technology : Systems & Solutions*. https://www.global.toshiba/ww/products-solutions/thermal/products-technical-services/zero-emissions.html/1000 (accessed 2025-04-01).

Sustainability trade-offs

- High energy demand [5]

  → Energy required for solvent regeneration (0.25-0.3 MWh/tCO2)

  If used after a coal power plant

  → Reduction of energy generation efficiency of about 10%

  Perspective: discover new solvents with better performances (lower energy requirements, higher capacity)

Sustainability trade-offs

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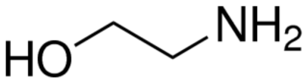
- Environmental impact

  → Use of corrosive, toxic, volatile solvents [5]

Monoethanolamine (MEA) [4]  

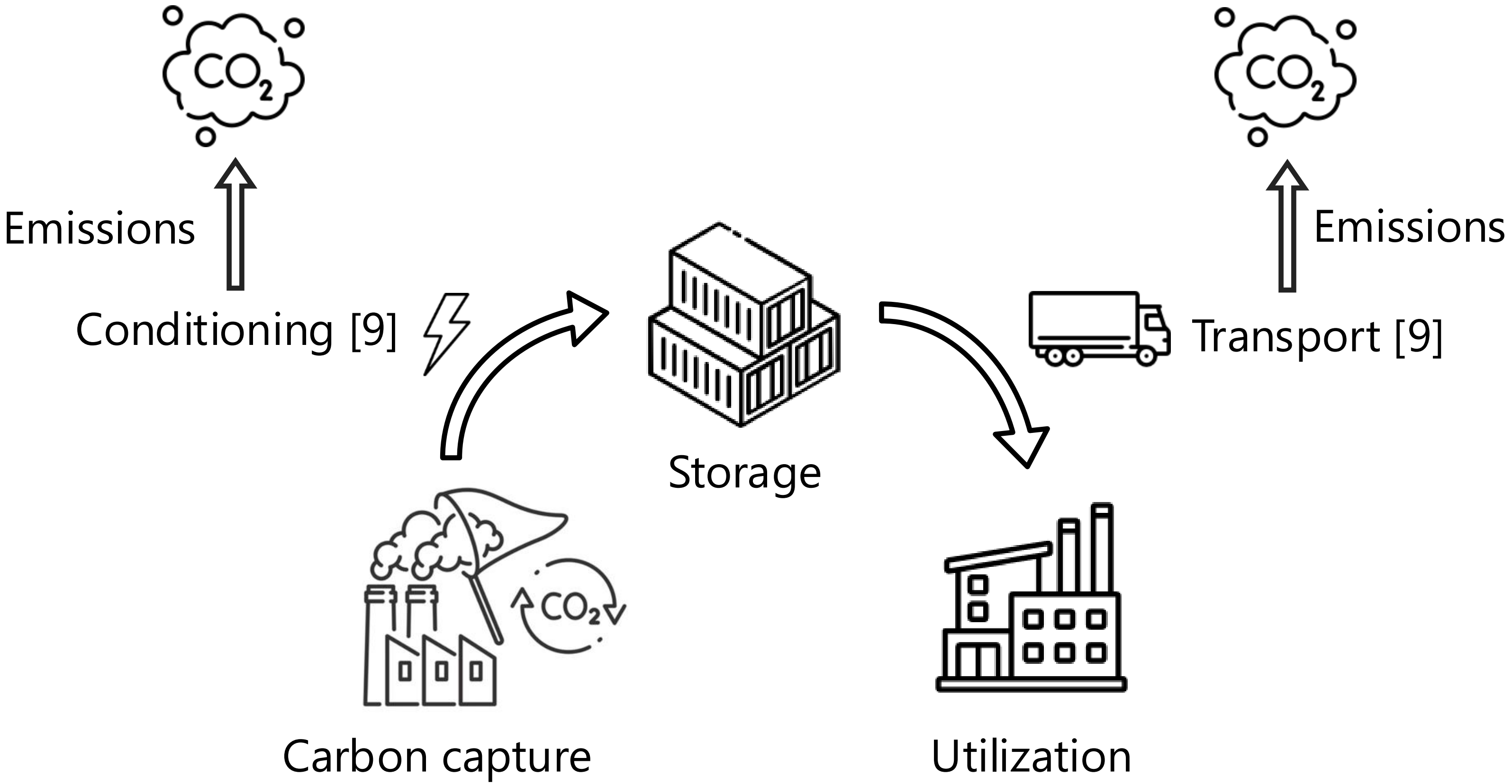
Degradation of MEA may lead to the emission of some hazardous compounds [6]:

- Nitrosamine 
- Ammonia 

→ Increase in freshwater toxicity & human toxicity [6]

→ <u>**BUT**</u> data gap [6, 7, 8]: Requires additional bioassays to assess the risks

Post-capture challenges



Key barriers of CCU

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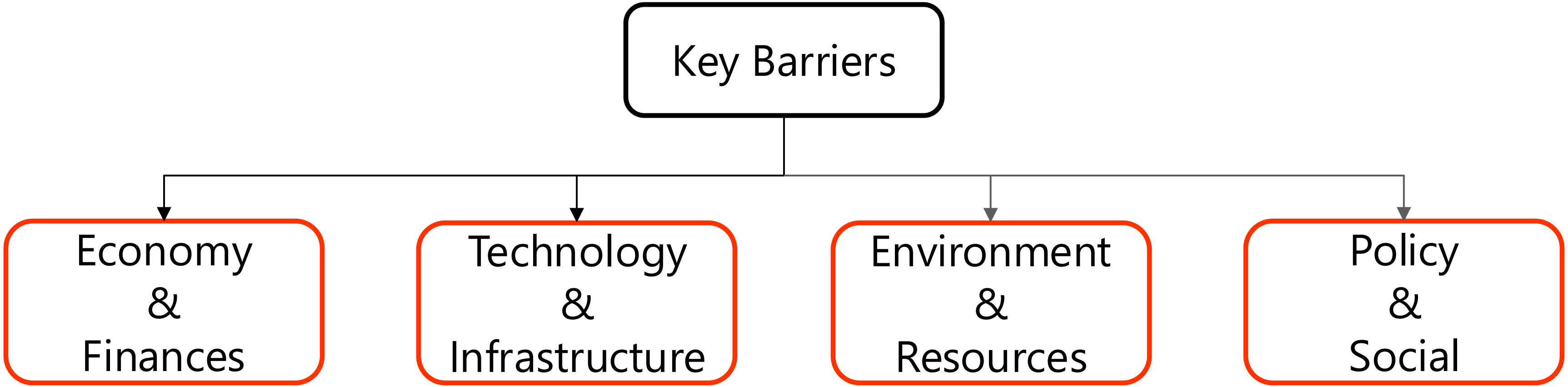

- High initial costs
- Uncertain ROI
- Market competition

- Immature technology
- New infrastructures
- Integration, adaptation

- Environmental impact
- Resource scarcity

- Inconsistent regulations
- Slow policy
- Public perception

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Opportunities of CCU

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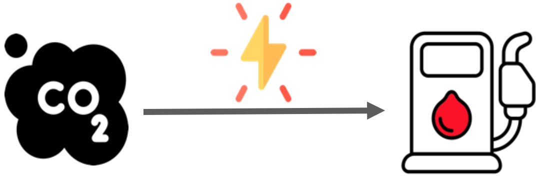
1- Technological innovation:

- **Integration with Green Energy:**

  - Coupling CCU with Renewable Energy: Excess renewable energy could be used for CO_2 conversion

  - Power-to-Fuel (P2F) Technologies: Converting CO_2 into fuels like methane, methanol, or ammonia using hydrogen from water electrolysis powered by renewables.



Methane, methanol or ammonia,

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Opportunities of CCU

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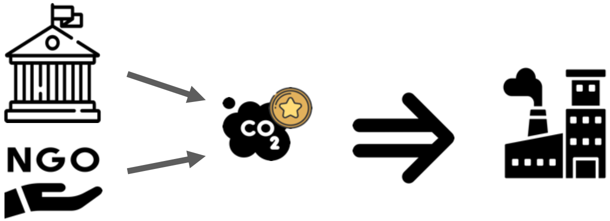
2- Policy Support & Investment:

Carbon Pricing & Market Incentives:

- Carbon Credits Systems:



To favour industries to reduce CO_2 emissions

- Tax Incentives & Subsidies: Financial mechanisms (e.g., tax breaks, grants) to lower the economic barriers to CCU investments.

- Government-Funded CCU Initiatives: Increase funding for CCU startups for cost-effective and scalable solutions to reduce CO_2 emissions.

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Opportunities of CCU

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■ 2- Public-Private Collaboration

- **Cross-Sector Partnerships:**

  - Public-Private Partnerships (PPPs)**:** Joint investments between governments, research institutions, and industry to scale up CCU technologies.

  - International Agreements & Climate Policies: Initiatives like the Paris Agreement and Kyoto Protocol driving countries to explore CCU as part of their climate mitigation strategies.

    ⇒ The goal of Switzerland is to have a zero net emission of CO_2 by 2050

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(2) What are the key benefits of CCU ? *CO2 Value Europe*, https://www.co2value.eu/wp-content/uploads/2020/02/A-condensed-guide-to-CCU.pdf

(3) What is CCU ? *Econic Technologies*, https://www.econic-technologies.com/what-is-carbon-capture-and-utilization-ccu/

(4) Osman, A. I.; Hefny, M.; Abdel Maksoud, M. I. A.; Elgarahy, A. M.; Rooney, D. W. Recent Advances in Carbon Capture Storage and Utilisation Technologies: A Review. *Environ Chem Lett* **2021**, *19* (2), 797–849. https://doi.org/10.1007/s10311-020-01133-3.

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(9) Burger, J.; Nöhl, J.; Seiler, J.; Gabrielli, P.; Oeuvray, P.; Becattini, V.; Reyes-Lúa, A.; Riboldi, L.; Sansavini, G.; Bardow, A. Environmental Impacts of Carbon Capture, Transport, and Storage Supply Chains: Status and the Way Forward. *International Journal of Greenhouse Gas Control* **2024**, *132*, 104039. https://doi.org/10.1016/j.ijggc.2023.104039.

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