What is DAC?

- Direct Air Capture is a technology that captures carbon dioxide (CO2) directly from the atmosphere.

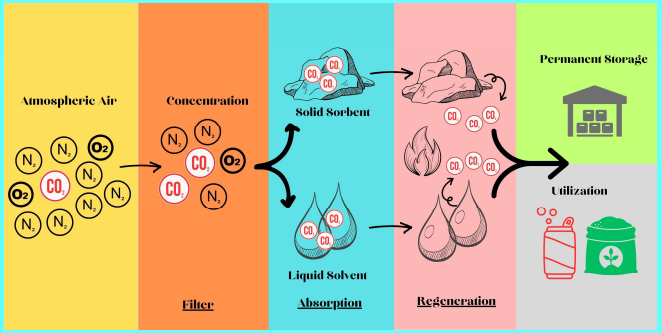

Fig 1. Illustration of the Direct Air Capture process.

- Due to the low concentration of CO2 in the atmosphere fans and filter systems are used to concentrate CO2
- Air passes through a capture medium that selectively binds to CO2 molecules.
  - ➔ Solid Sorbent
  - ➔ Membrane-based Solvent
- Captured CO2 is released through heating or pressuring for storage or utilization

Orca Case Study

- First large-scale DAC and permanent storage plant.
- Absorbs 4,000 tCO2/year with an area of 8,600 ft^2.

Air Contractor	Vacuum/Pump	Heating
Energy: 1.12 GJ/tCO2	Energy: 1.18 GJ/tCO2	Energy: 4.8 GJ/tCO2
Cost: $4.30/tCO2	Cost: $0.30/tCO2	Cost: $43.00/tCO2
Capital: $988.00 /tCO2	Capital: $8.40/tCO2	Capital: $4.60/tCO2

Other Operating Cost
~20 $/tCO2

Total Average Cost
~7.1 GJ/tCO2
~$1000/tCO2

Orca Reported Cost
~$600/tCO2

Fig 2. Illustration of the average energy and monetary cost of DAC. [2]

To meet the target 20 GtCO2/year
- ➔ 2.4 million Orca plants are required.
- ➔ Energy consumption ~1.4x10^{20}J
- ➔ Cost ~$20x10^{12}

Table 1. Examples of current DAC capacity

Company	Country	Capacity (tCO2/year)
Global Thermostat	United States	1,000
Carbon Engineering	Canada	365
Climeworks	Switzerland	600
Climeworks	Germany	50
Climeworks	Iceland	4000

Paris Agreement

The Paris Agreement is an international treaty on climate change to prevent the worst impacts of global warming. [4]

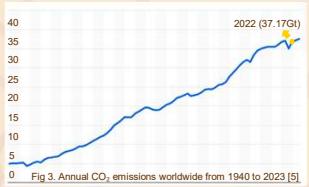

Fig 3. Annual CO_2 emissions worldwide from 1940 to 2023 [5]

2°C

- It aims to limit the global temperature increase in this century to 2˚C from pre-industrial average.
- In 2022, we were 1.2 ˚C above pre-industrial average and released 37.15 Gt CO2.

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Review and Challenges of Direct Air Capture (DAC) to Achieve Paris Agreement Objectives

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Future Work

The feasibility of DAC depends highly on
➔ storage and reuse strategy
energy and economical cost➔
Some works to improve the technology includes [3]:
➔Geological storage in deep porous rocks
CO2 reuse for fuel production➔
➔Electric heating methods for regeneration
Increase efficiency by reducing regeneration temperature➔
➔Increase rate of absorption of solvents

What Needs to Happen?

- With the slow transition to renewable energy and lack of greenhouse gas emission reductions, there is a concern that we will not meet the targets of the Paris Agreement. [1]

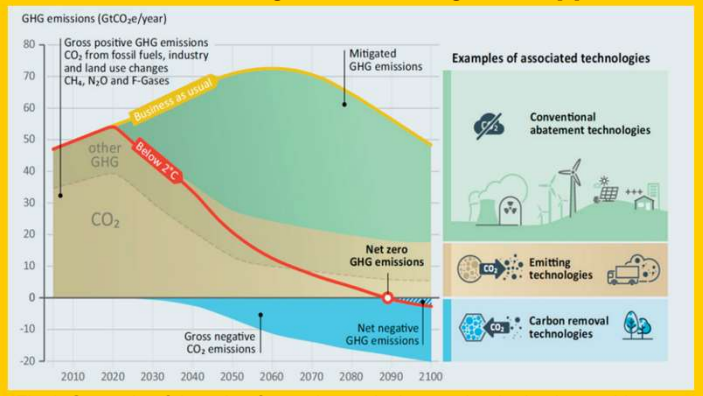

Fig 4. Scenario of the role of negative emissions technologies in reaching net zero emissions. Taken from the National Academies of Sciences, Engineering, and Medicine [1].

- Removal of 20 GtCO2/year is necessary by 2100 [1].
- The current global DAC capacity is 0.04258 GtCO2/year.
- Assuming a linear growth in global DAC capacity, it would take 36,000 years to reach required capacity.
- Significant scale-up of DAC capacity is required, but it faces challenges due to technological immaturity.

Conclusion

- At the current state of DAC technologies, scaling up DAC technology to the required GtCO2/year is currently unfeasible due to the high economic and energy costs.
- The most important factor in addressing climate change is still reducing emissions and transitioning to sustainable energy
- Many in the literature view DAC as a technology to be deployed to reduce atmospheric CO2 after fossil fuel emission are reduced to near zero.
- However, negative emission technology must continue to develop technologically and improve efficiency as it is a part of the mitigation portfolio to ease the pace of transitions.
- Current leaders in the field such as Climeworks, have shown that the technology is viable and are quickly trying to scale up their operations.

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