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A perspective on accounting for DAC:

- E-Fuel
- Power to Liquid (P2L)
- CO_2 Utilisation (CCU)
- CO_2 Recycle

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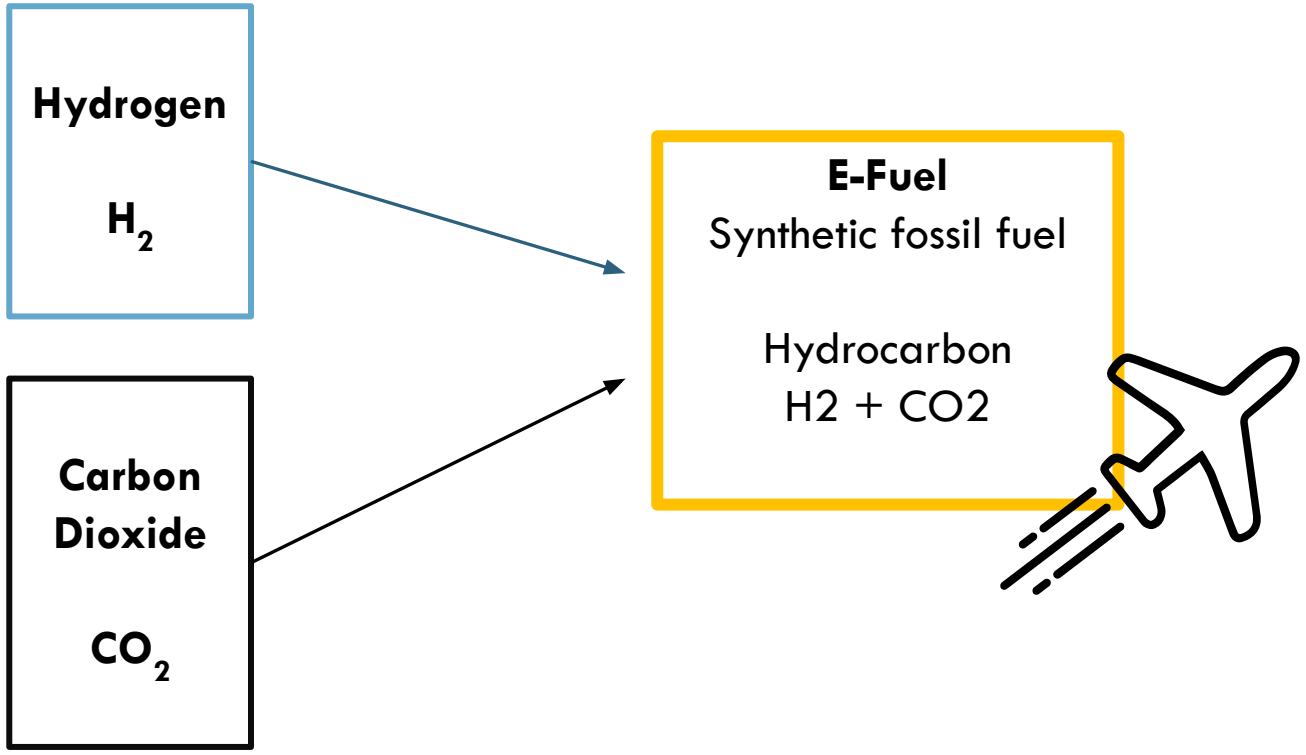
THE RECIPE OF E-FUELS

How is the hydrogen produced?
Where is the energy from?
At what scale can it be produced?

Where is the CO_2 from?
Is the CO_2 fossil ?
Is the CO_2 atmospheric ?



Ueckerdt et al (2021) Potential and risks of hydrogen-based e-fuels in climate change mitigation

EMISSIONS MAY GO UP / AS WELL AS DOWN

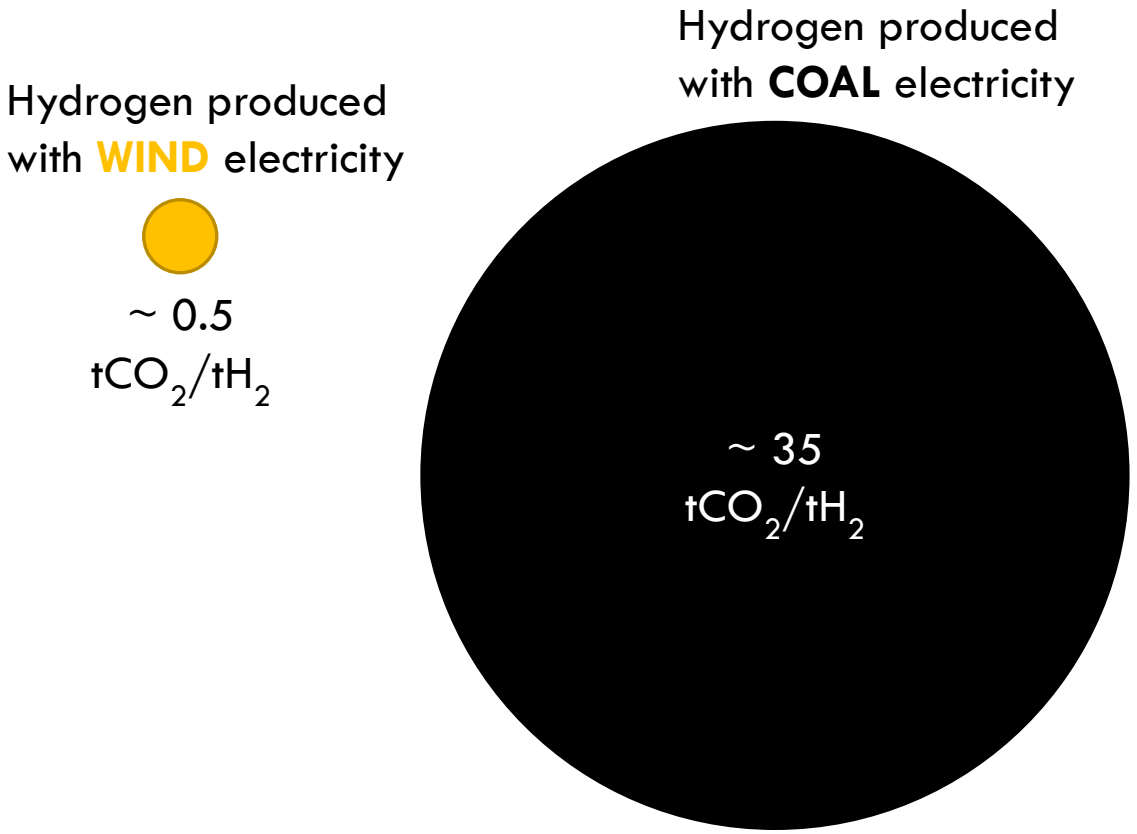
Hydrogen is produced from Electricity

- The hydrogen is as clean as the electricity used to produce it
- Dirty electricity = dirty hydrogen and even dirtier E-Fuel

E-Fuel can increase emissions over conventional fossil fuels

- Low efficiency and energy loss

E-Fuel production nearly-exclusively requires Renewable Electricity to reduce emission



RENEWABLE ELECTRICITY FOR E-FUELS

E-Fuel require large amounts of renewable electricity (Hydrogen)

- Low CO_2 reduction per unit of Renewable electricity used
- E-Fuels when deployed will <u>not be powered</u> by Excess / Curtailed / Marginal electricity

New/Additional electricity demand from E-fuel production

- Over and above the current concept of "greening the grid"
- New E-fuel production should be matched by new/ additional renewable generation

Example:

Denmark

Replacing all aviation fuel sold in Denmark with equivalent E-Fuel

- ~25 TWh (unit of electricity)
- 70% of total electricity
- ~ 3 Million tonne CO_2 saved (best case)

Replacing all cars with Electric Vehicle (equivalent km)

- ~ 8 TWh
- ~ 6.5 Million tonnes of CO_2 saved

Using electricity in EVs ~6 times more efficient on a climate measure

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CO_2 SOURCE / CO_2 DESTINATION

Taking Carbon from the ground and adding it to the atmosphere is Climate Change

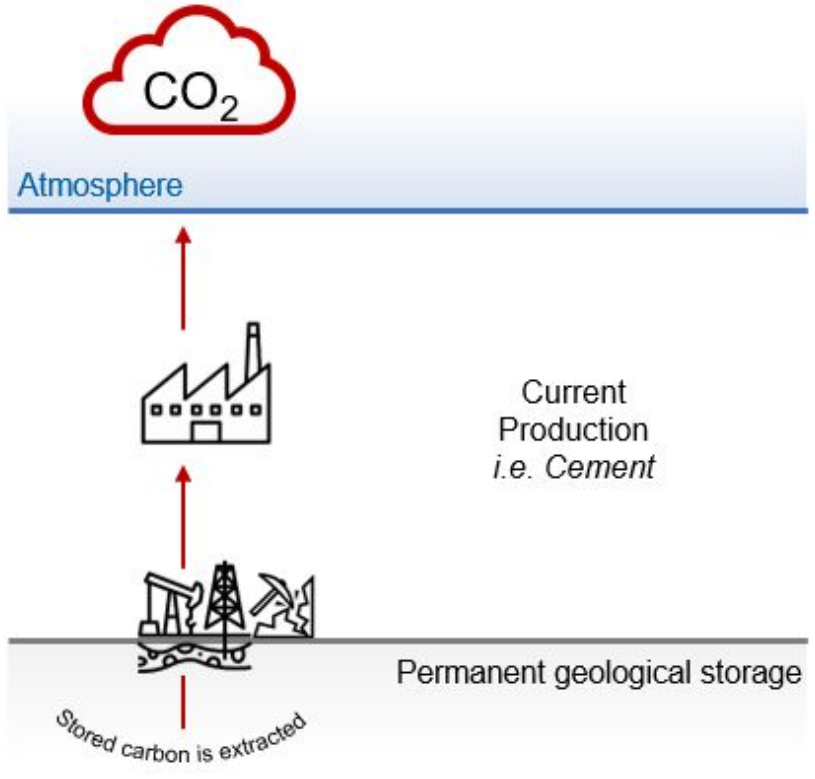
CO_2 concentration in the atmosphere

- Now – **417** ppm
- In 1990 it was **353** ppm

Using CO_2 to make E-fuels raises questions

- Where has the CO_2 come from?
- Where will it end up?
- Whose responsibility is it?

Its about climate change – this point is critical



NET-ZERO BASELINE

The Net Zero Target: Balance between the amount of greenhouse gas produced and the amount removed from the atmosphere

Carbon Dioxide Removal (carbon negative)

Scoping criteria

1. ***Carbon dioxide is physically removed from the atmosphere***
2. ***The removed carbon dioxide is stored out of the atmosphere in a manner intended to be permanent***

Two bits of binary information need for initial scoping assessment of CO2 flow to atmosphere for CO_2 use, CO_2 recycle, CO_2 storage etc.

Is the CO_2 from the atmosphere? Yes (1) or No (0)

Is the CO_2 permanently stored? Yes (1) or No (0)

This is really simple stuff in the end.
Where does the CO_2 come from (binary) where does it go (binary).

Ramirez et al (2020) LCA4CCU Guidelines for Life Cycle Assessment of Carbon Capture and Utilisation LCA4CCU-March-2020-Release-v1-0.pdf (ifeu.de)

Deutz & Bardow (2021). *How (Carbon) Negative Is Direct Air Capture? Life Cycle Assessment of an Industrial Temperature-Vacuum Swing Adsorption Process* https://chemrxiv.org/engage/chemrxiv/article-details/60c754339abda21fd7f8e13e

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ATMOSPHERE & STORAGE

CARBON REMOVAL (-)

Capturing atmospheric carbon and permanently storing it so that it does not enter the atmosphere results in a removal of CO2 from atmosphere. The concentrations of CO2 in the atmosphere is reduced.

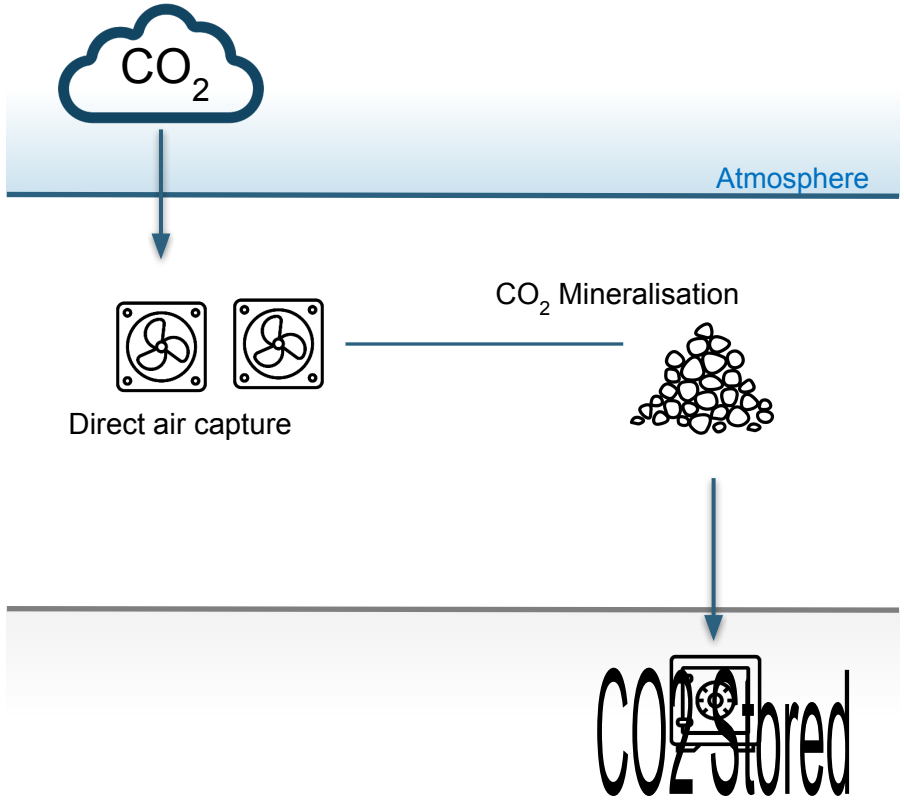
Atmospheric Carbon

+

Non Emissions to Atmosphere

=

Carbon Dioxide Removal



Direct Air Capture of CO2 to permanent storage

*Highly idealised carbon flow, excluding energy emissions, capture rate, leakage etc.

ATMOSPHERIC CO_2 / DAC

CLIMATE NEUTRAL (=)

Air fuels / E-Fuel from Sun and Air

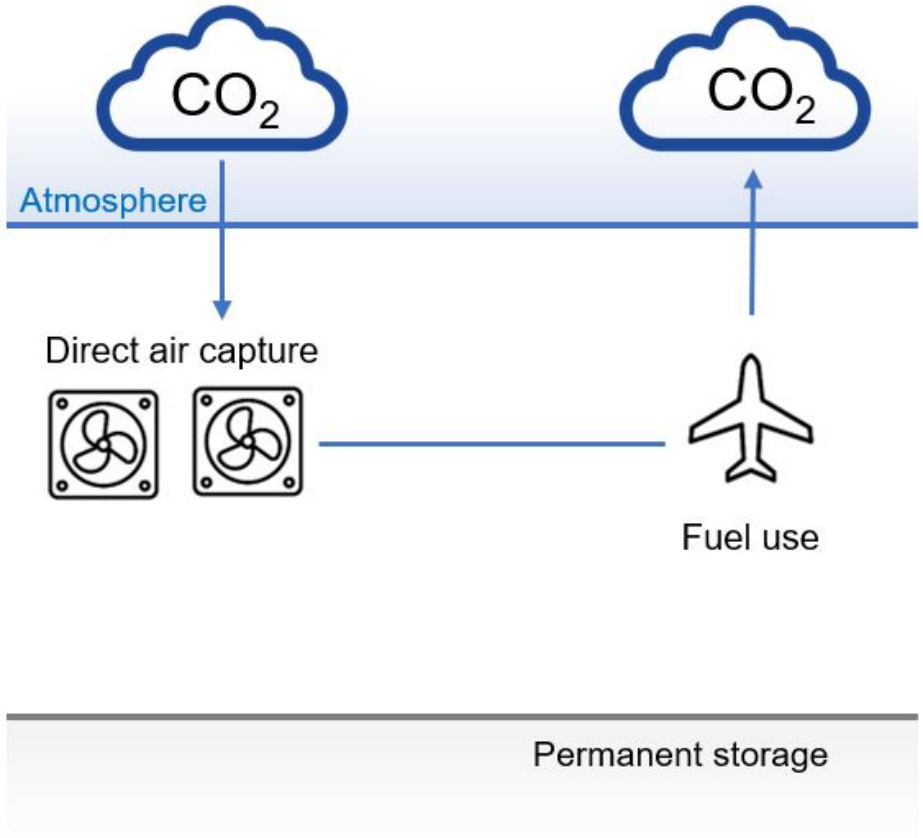
DAC + E-Fuel can be carbon neutral

- CO_2 in the atmosphere is unchanged

Capturing CO_2 from the atmosphere is difficult

- Concentration of CO2 in atmosphere comparatively low
- Direct Air Capture (DAC) is energy intensive

Atmospheric Carbon + Emissions to Atmosphere = Climate Neutral



*Highly idealised carbon flow, excluding energy emissions, capture rate, leakage etc.

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FOSSIL CO_2 AND LOW-CARBON E-FUELS ?

CLIMATE CHANGE (+)

Point Source CO_2 Capture

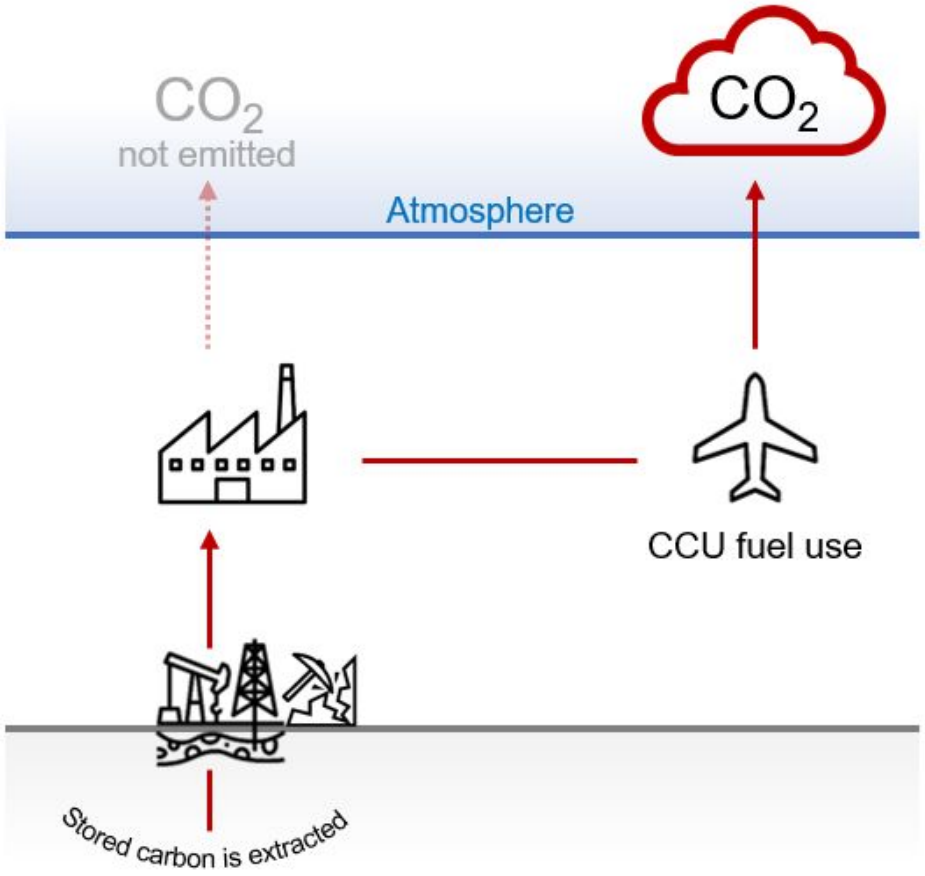
- Cement, Fertilisers, Coal …. many choices

The CO_2 provider would like to take the credit

- CCU (CO_2 utilisation) / CO_2 Valorisation
- "*We can decarbonise our industrial sector by using our CO_2 to manufacture fuel*"

How do we allocate of the CO_2 reduction?

- Double Counting / Creative accounting
- CO_2 is ultimately dumped in the atmosphere
- <u>One party can be low carbon – the other must be full carbon</u>



Carbon Fossil (Geological) + Emissions to Atmosphere = Global Warming

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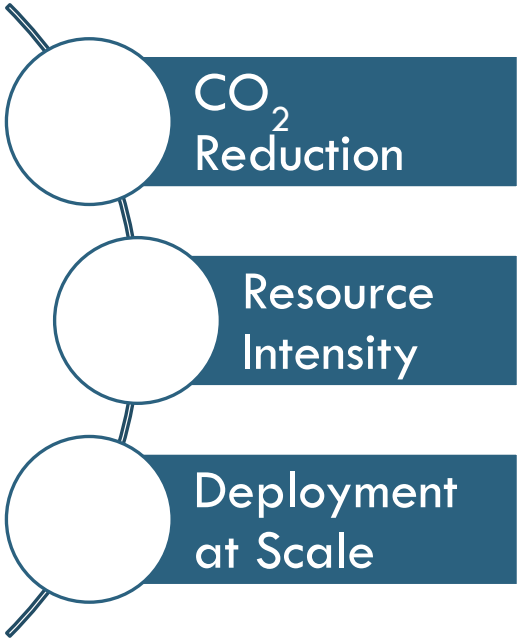
KEY TAKEAWAYS FOR E-FUELS



Hydrogen: Needs to be Renewable

CO_2 Used: Needs to be Atmospheric for Net-Zero

Low CO_2 reduction per unit of renewable electricity used

Only to be used where other solutions are absent

Very large new electricity requirements for aviation alone

Renewables must be additional

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