The role of Direct Air Capture (DAC) in e-fuels for aviation

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For Transport & Environment

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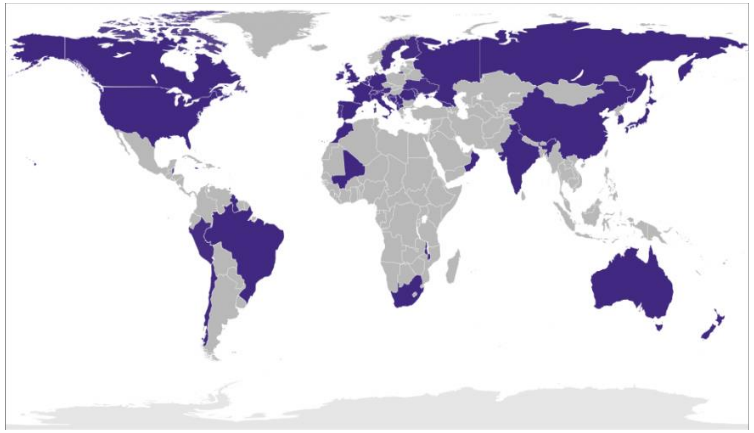
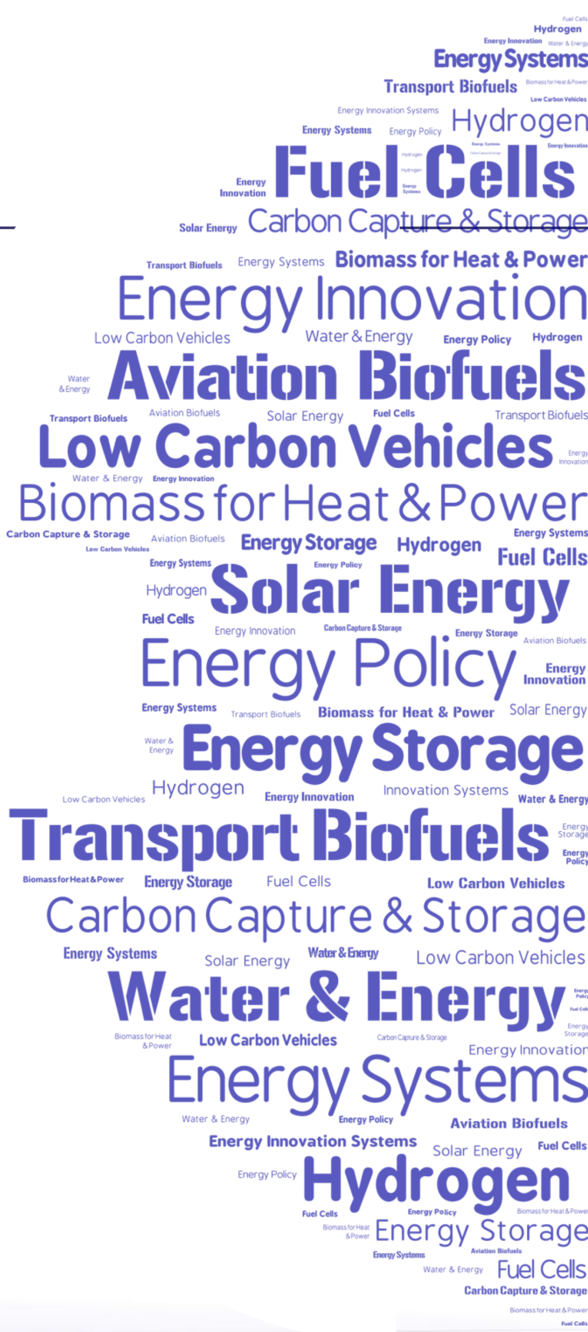
E4tech perspective: Strategy | Energy | Sustainability

- International consulting firm, UK and Swiss offices
- Focus on sustainable energy, transport and systems
- 24 years old, independent until 2021: **now part of ERM**
- Deep expertise in technology, business and strategy, market assessment, modelling, policy support
- Clients from start-ups to global corporations





Key question: whether, when and how DAC could be scaled up to the scale needed to decarbonise European aviation through e-kerosene

- T&E's 2018 roadmap identified an essential role for **e-kerosene**
- It recommended **direct air capture (DAC)** to supply the CO2 needed
- T&E commissioned this study to assess **whether, when and how DAC could be scaled up** for e-kerosene to decarbonise European aviation.
- Supplying e-kerosene for all flights originating in Europe by 2050 would require **365 Mt/yr of CO_2** to be used

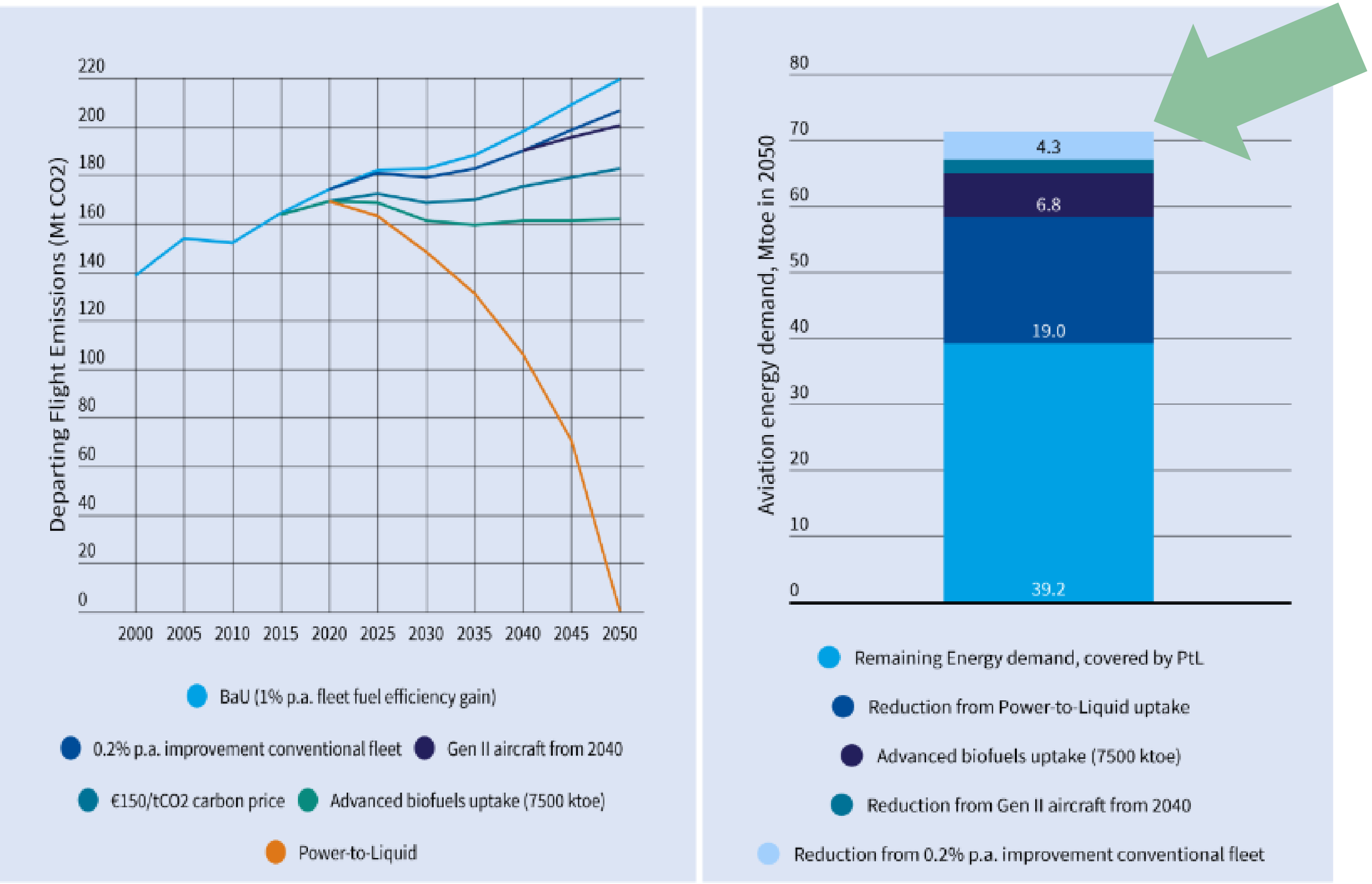
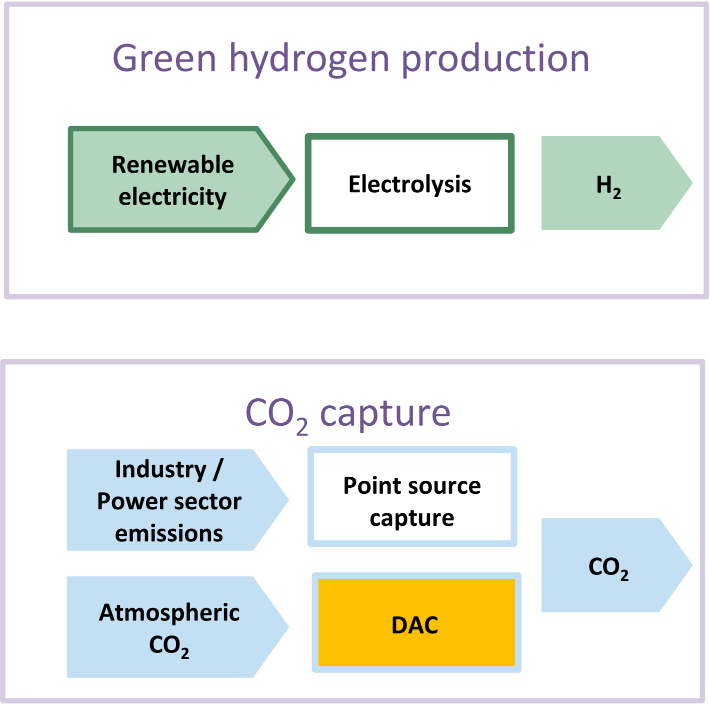
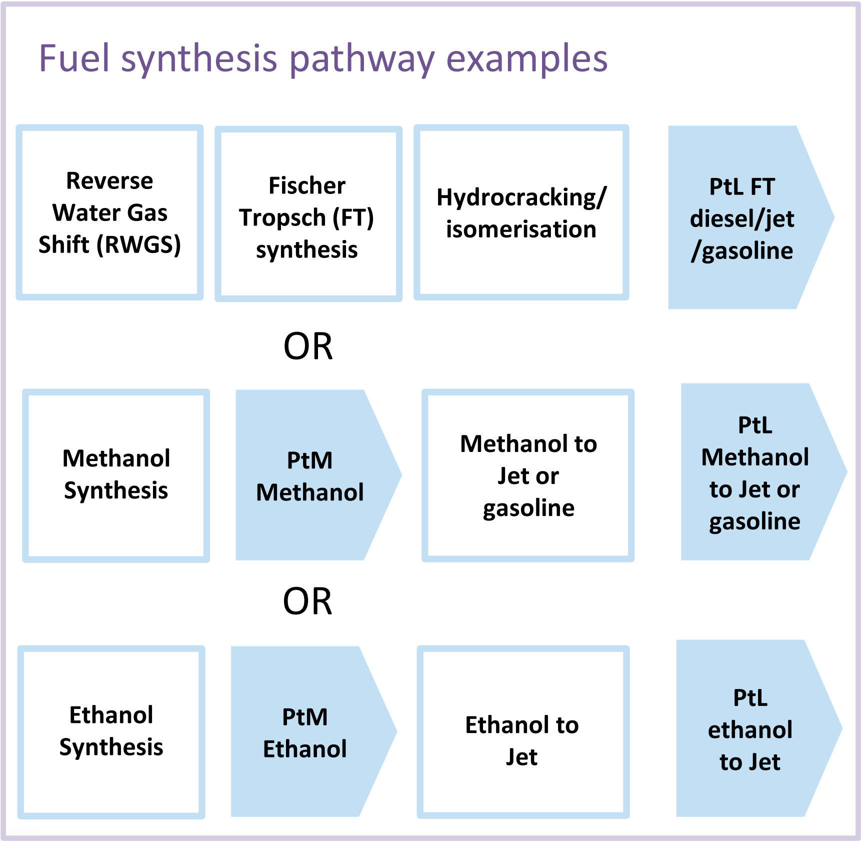


Figure 4: (Left) Reduction in European departing flight CO_2 emissions. (Right) PtL consumption of European departing flights in 2050 after demand reduction measures have been applied.

How is e-kerosene made?

- E-fuels (also called power to liquids, renewable fuels of non-biological origin - RFNBOs, synthetic fuels) are fuels produced from electricity and CO_2
- Many routes to many fuel types are possible
- Some of the steps required are commercially available; others are at pilot or demonstration stage





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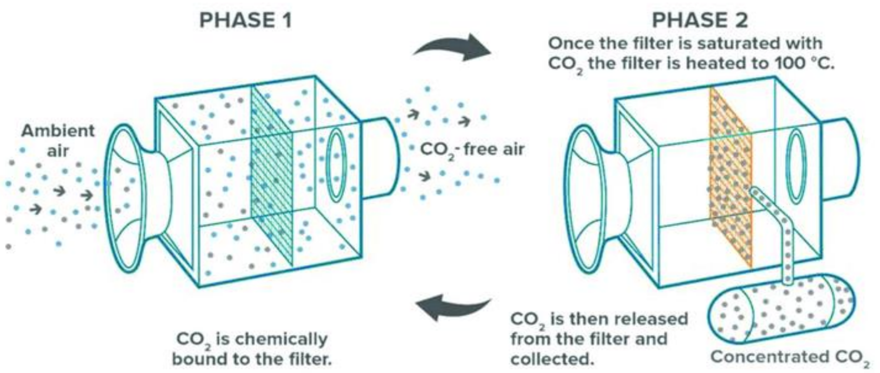
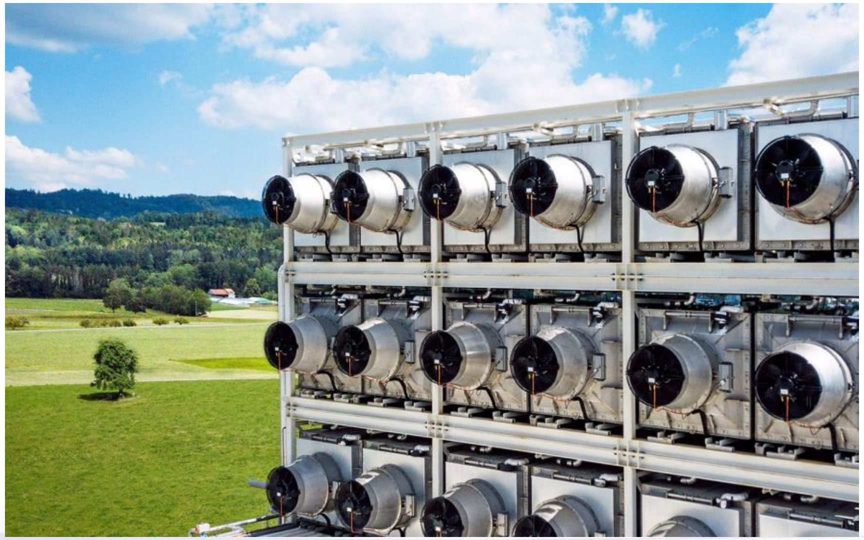
What is direct air capture?

- DAC captures CO_2 from the air by bringing it into contact with a solid sorbent or aqueous solution.
- Two main approaches:
  - **High temperature liquid sorbent**, where CO_2 reacts with a liquid solvent to form a carbonate. Heat (900 °C) is applied to release the CO_2 and regenerate the solvent.
  - **Low temperature solid sorbent**, where CO_2 bonds to a solid sorbent material. The CO_2 is released, and the sorbent regenerated by heating (80-100 °C) or by adding water.

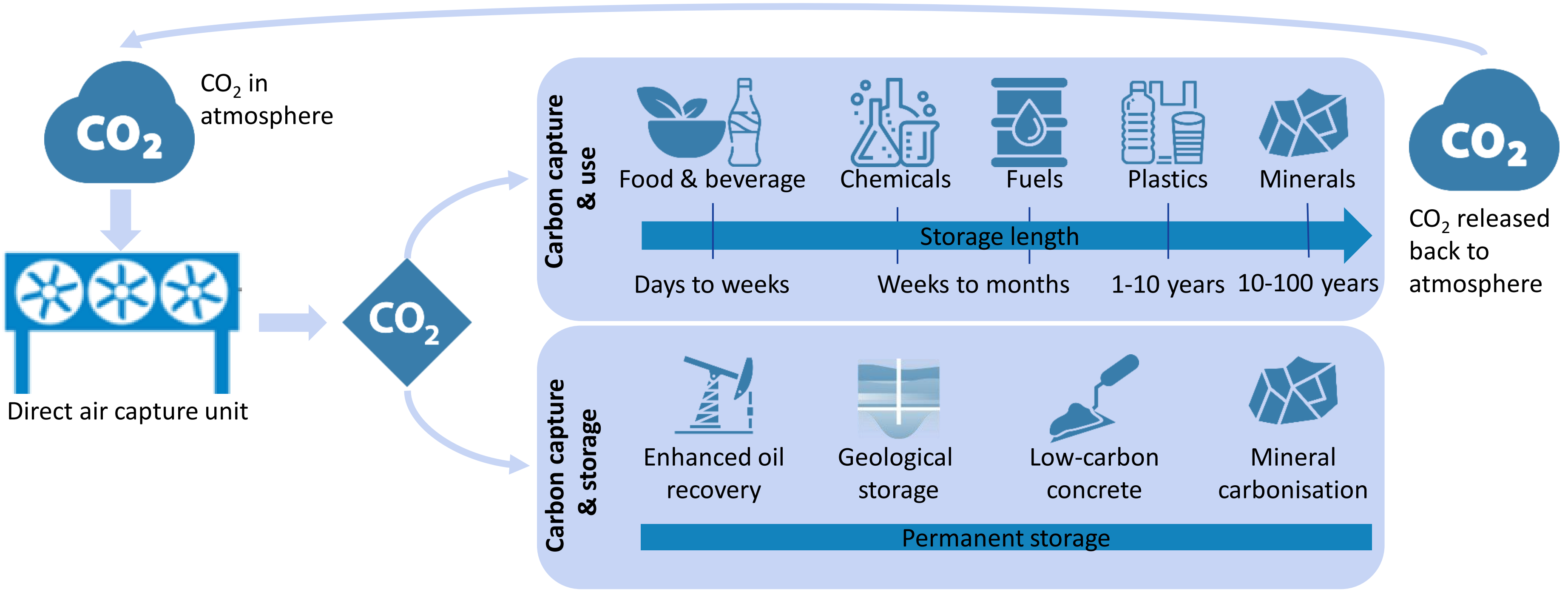
Schematic of Climeworks' DAC system



Climeworks' DAC system



CO_2 from DAC can have many uses, resulting in temporary or permanent CO_2 storage



Adapted from IEA, Mander and Miller 2018, and Royal Society and Royal Academy of Engineers

- CO_2 captured from DAC can be used directly, as a feedstock, or be stored permanently (forming a negative emissions technology)

Where is DAC technology today, and what are the next steps for scale up?

Selected players

Company	Plants	Largest plant	Tech Type	Energy source	Future plans
Carbon Engineering	1	365 t/year	HT aqueous solution	Natural gas (CO_2 is captured) and renewable electricity	Developing plant in US to remove 1 $MtCO_2$/year FEED on UK commercial- scale plant and pre FEED on 0.5-1 $MtCO_2$/year plant
Global Thermostat	2+	4000 t/year	LT solid sorbent	Waste heat (electricity requirements not stated)	Partner with ExxonMobil to scale up and remove 1 $GtCO_2$/yr and expand to 40 $GtCO_2$/yr
Climeworks	14	900 t/year	LT solid sorbent	Renewable electricity or waste heat	Project Orca to capture 4000 tCO_2/year in Iceland. 3 plants in planning or production

Next steps

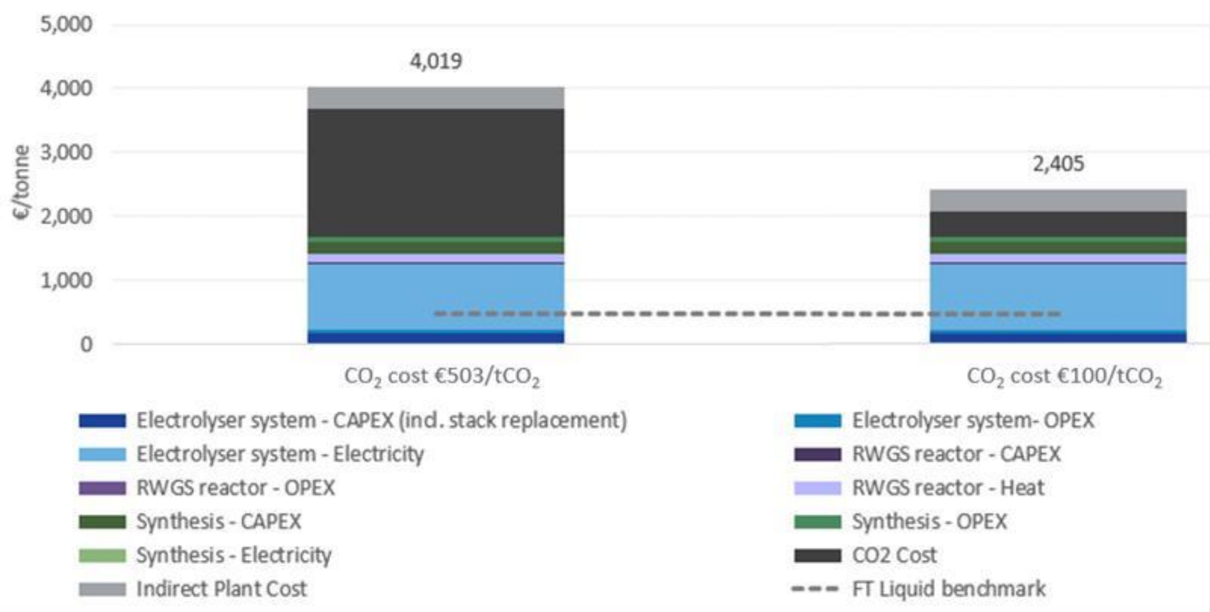
- scale up
- reduced costs and energy use
- demonstrated operation with proven reliability
- exploring early markets for the CO_2 captured

DAC is projected to have the potential for significant cost reduction

- Costs reported today are **€100-500/tCO_2**
- Main contributors to the cost are
  - capital costs
  - energy used
  - any steps needed to enable the end-use of the CO_2, such as compression and transport.
- All companies have future projections of much lower costs, with a typical range of **€40-170/tCO_2** Only some of these are backed up by published data!

Example: E-kerosene synthesis by FT

- E-fuel production costs vary widely depending on assumptions: this is one example
- Reducing DAC cost from €503/tCO_2 to €100/tCO_2 reduces fuel costs from €4020/t to €2400/t



- For comparison, average jet fuel price ~€550/t. Point source CO_2 capture €70-150/t for 2020-35, €30-50/t beyond 2035

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What determines how fast DAC could scale up?

	Near term	Long term
High temperature liquid sorbent	• Large scale (1 $MtCO_2$/yr) • Based on components already in commercial use • Could be built through licensing so roll out relatively fast • More constraints on siting	• Economic viability – policy dependent in most cases
Low temperature solid sorbent	• Modular systems • Will be manufactured in centralised facilities • Simpler installation at multiple sites of varying scales.	

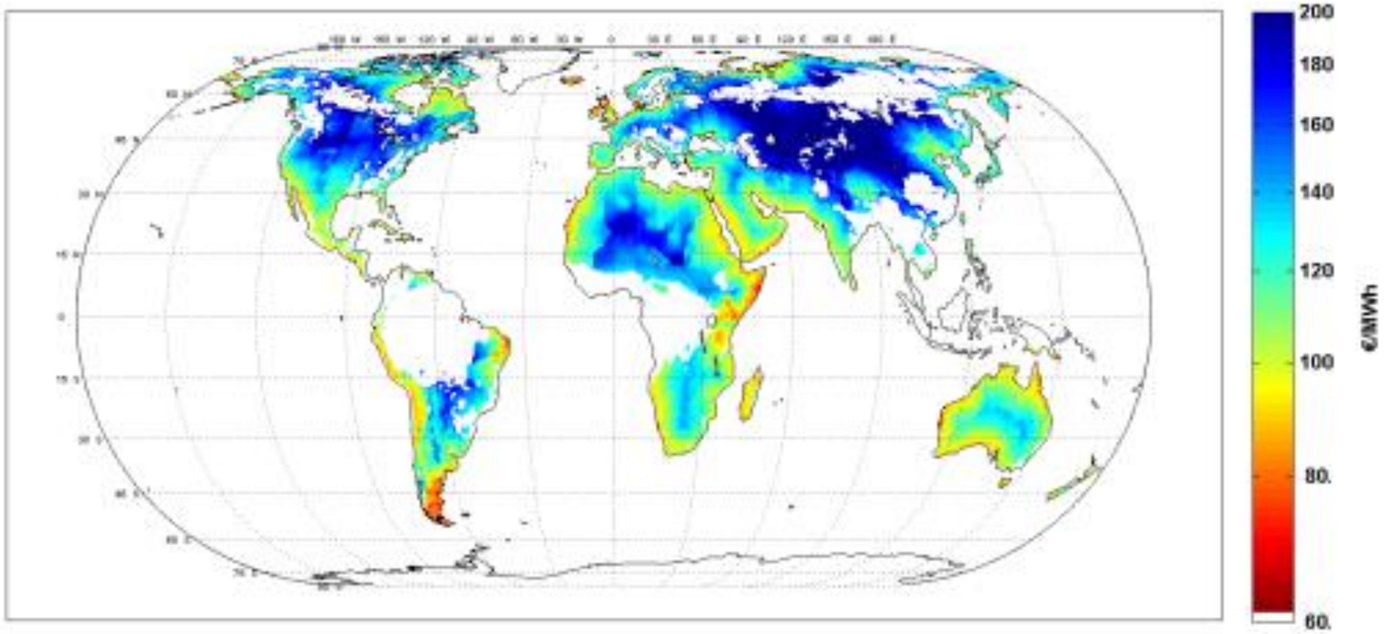
Use for e-kerosene in Europe: depends on relative support for other fuels and CO_2 uses

LCA and resource needs: limited evidence, and so further work needed specific to each developer

Where can DAC be sited?

- Reliable, abundant, continuous, low cost **renewable electricity**
- No particular **land** type
- HT liquid sorbent: access to natural gas and/or high temperature waste heat and access to water
- LT solid sorbent: lower temperature waste heat, water requirements vary.
- Electricity and heat used must be low carbon or have CO_2 capture.
- **Storage** locations (if for CCS)
- **Fuel export** infrastructure

Cost of synthetic liquid fuels in 2030



Source: Overview of PTX Options Studied in NCE and their global potential based on PV-Wind Power plants, Fasihi. 2017. http://www.neocarbonenergy.fi/wp-content/uploads/2016/02/13_Fasihi.pdf

- **Most suitable locations** for e-fuel plants
  - Long term: trade off between the factors above.
  - Short term: practical considerations - proximity to the technology developer, funding, political stability, infrastructure and proximity to market

DAC is important for e-fuels production in a net zero energy system, but point sources are also important for e-fuels in the near term

- CO_2 can be captured from **point sources** - fossil and biomass power plants, cement production, chemical industry - with lower costs and energy use than DAC.

- But in a **net zero world**:
  - The few point sources remaining may not be co-located with low cost renewable electricity
  - Any point source CO_2 needs to be matched by CO_2 sequestration elsewhere in the system.

- However in the **near term**:
  - Requiring DAC for e-fuels would place a very high cost and technology risk burden on the emerging e-fuels sector
  - Use of point source CO_2 should be allowed with rigorous project level GHG assessment
  - Commercialisation of DAC requires additional supply side policy support, future mandates for DAC use within fuels policy, or as part of wider GHG removal policy.

Enabling the use of DAC in e-kerosene production for European aviation will require policy support

Aviation fuels policy

- Additional support for e-fuels, including those using DAC, in SAF policies
- Sub-targets and/or supply side support.

Wider fuels policy

- EU rules on GHG calculation and use of renewable electricity in e-fuels
- EU rules on CO_2 used in e-fuel production
- Additional support for DAC use through supply side policy and/or future mandates for DAC

Greenhouse gas removal policy

- Policy mechanisms for GHG e.g. participation in carbon trading policies, separate policy targets and mechanisms.

Support for DAC RD&D

- Continued support for RD&D through European and Member State funding programmes
- Investment support for demonstration plants
- Include a requirement for a full LCA

Key question: whether, when and how DAC could be scaled up to the scale needed to decarbonise European aviation through e-kerosene

Whether

- DAC has no fundamental limits on scale up potential that would stop it being able to used to supply CO_2 for e-kerosene for EU aviation

When

- Large scale projects being developed today - ~1 Mt/yr expected by 2023/4
- Fast roll out required depends on existence of viable markets for CO_2 capture

How

- Market based support: for greenhouse gas removal and for e-fuels from DAC
- Supply side support: RD&D, project investment