OVERVIEW: DIRECT AIR CAPTURE

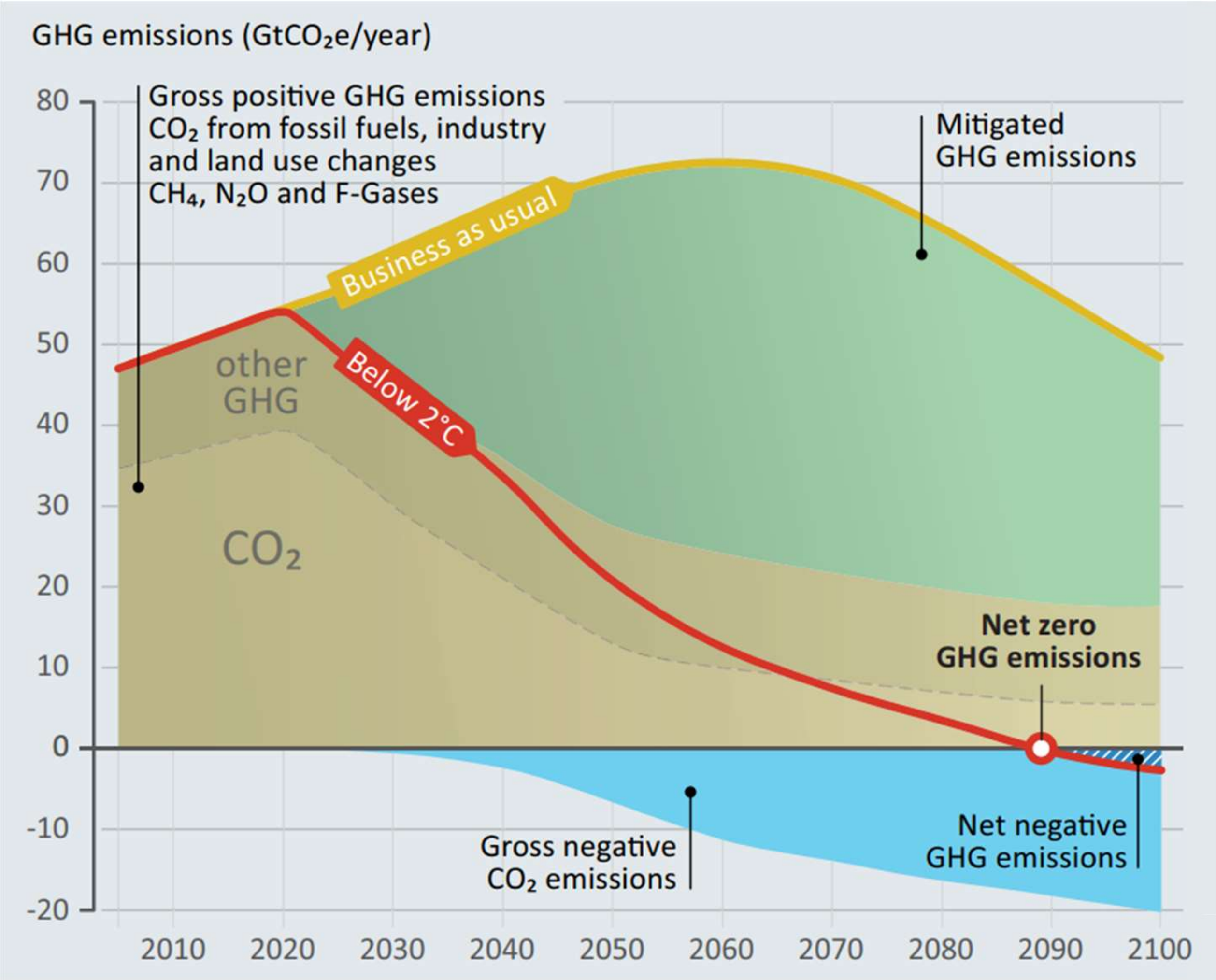
Enric Prats-Salvado – aireg | **Taskforce 08.09.2023**

Who am I?

- BSc Chemical Engineering – Universitat Rovira i Virgili (URV), Spain
- Erasmus – Lappeenranta University of Technology (LUT), Finland
- Engineering Internship (Gas Industry) – BASF, Spain
- MSc Chemical Engineering – Universitat Rovira i Virgili (URV), Spain
- Process Engineer (Paper Industry) – Essity, Spain
- Researcher – Institute of Future Fuels (DLR), Germany

What is direct air capture of CO_2?

Why do we need direct air capture?



Carbon Capture & Storage (CCS):

- Reverse emissions

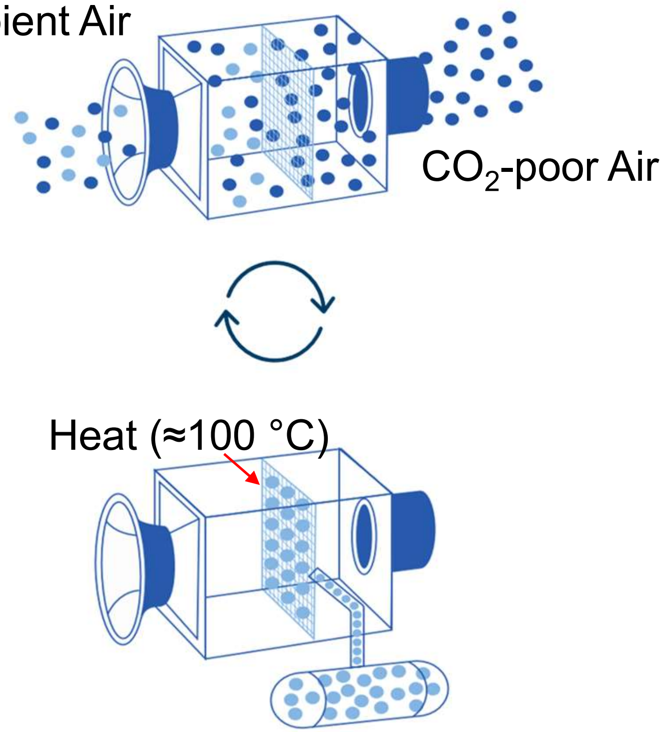
Carbon Capture & Utilization (CCU):

- Main solution for hard-to-abate sectors
- Accelerate transition in other sectors

Source: UNEP Emissions Gap Report 2017

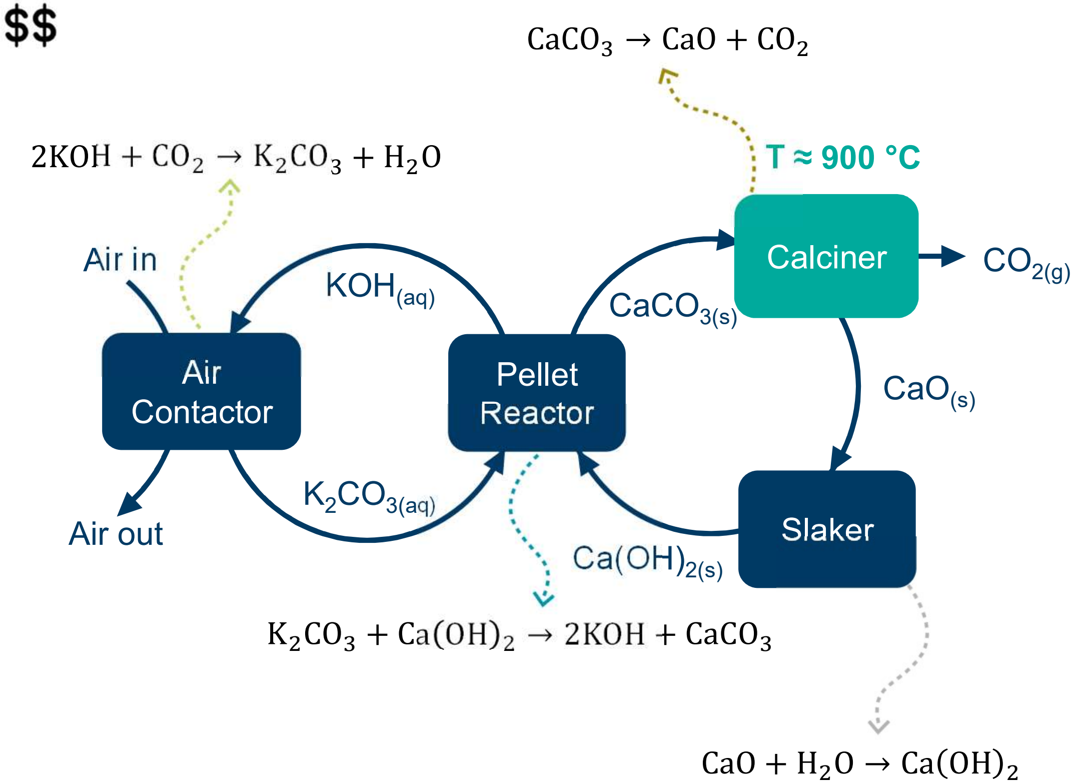
How does direct air capture work?

Solid Direct Air Capture (S-DAC)



S-DAC	L-DAC
$$$	$$

Liquid Direct Air Capture (L-DAC)



Source: Deutz and Bardow 2021

How does direct air capture work?

Solid Direct Air Capture (S-DAC)

Climeworks (2021, 4 kt CO_2/y, Iceland)

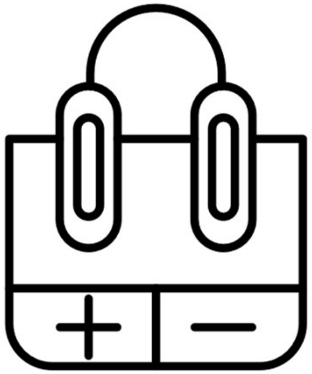
Liquid Direct Air Capture (L-DAC)

Carbon Engineering (2024, 0.5 Mt CO_2/y, US)

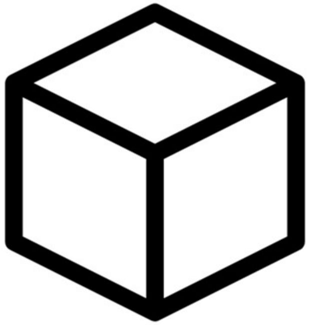
Sources: climeworks.com; iea.org

Other DAC approaches

DLR



Electricity-based approaches



Metal-organic frameworks (MOFs)

Passive capture approaches

CARBON BLADE

VERDOX

PrometheanParticles™
Nanomaterials reimagined

CARBON INFINITY

INFINITREE

Heirloom

Sources: Casaban 2022, Küng 2023

The Good: DAC is the golden standard carbon source

Direct air capture (DAC)

Biogenic sources

Point source capture (PSC)

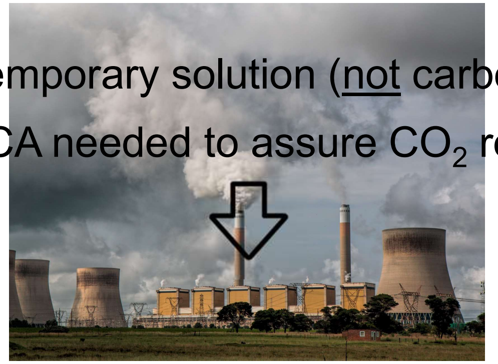
The Good: DAC is the golden standard carbon source

Direct air capture (DAC)

- Has biophysical limits
- Competes with other SDGs

Biogenic sources

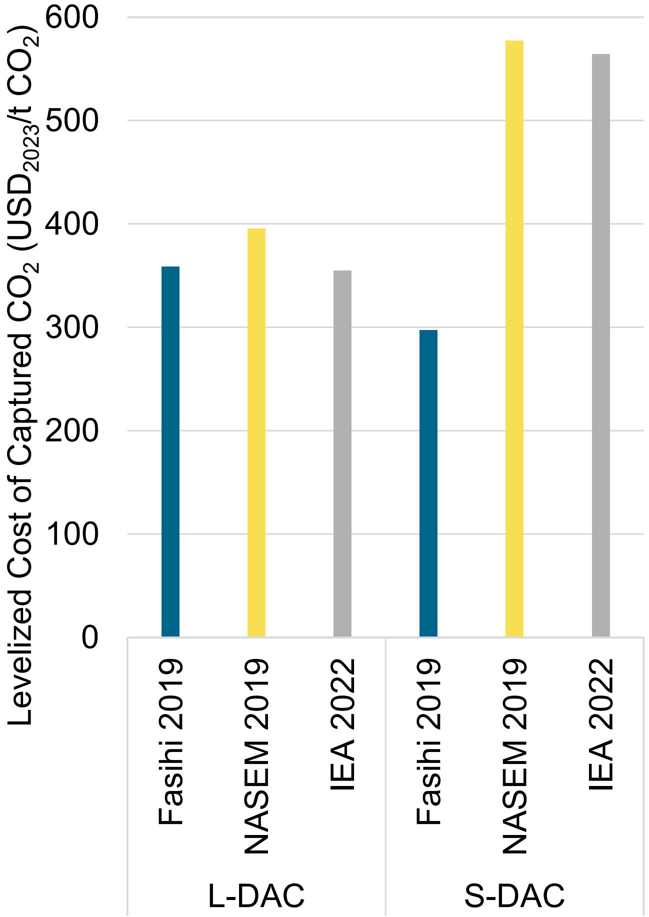
- Temporary solution (not carbon-neutral)
- LCA needed to assure CO_2 reductions



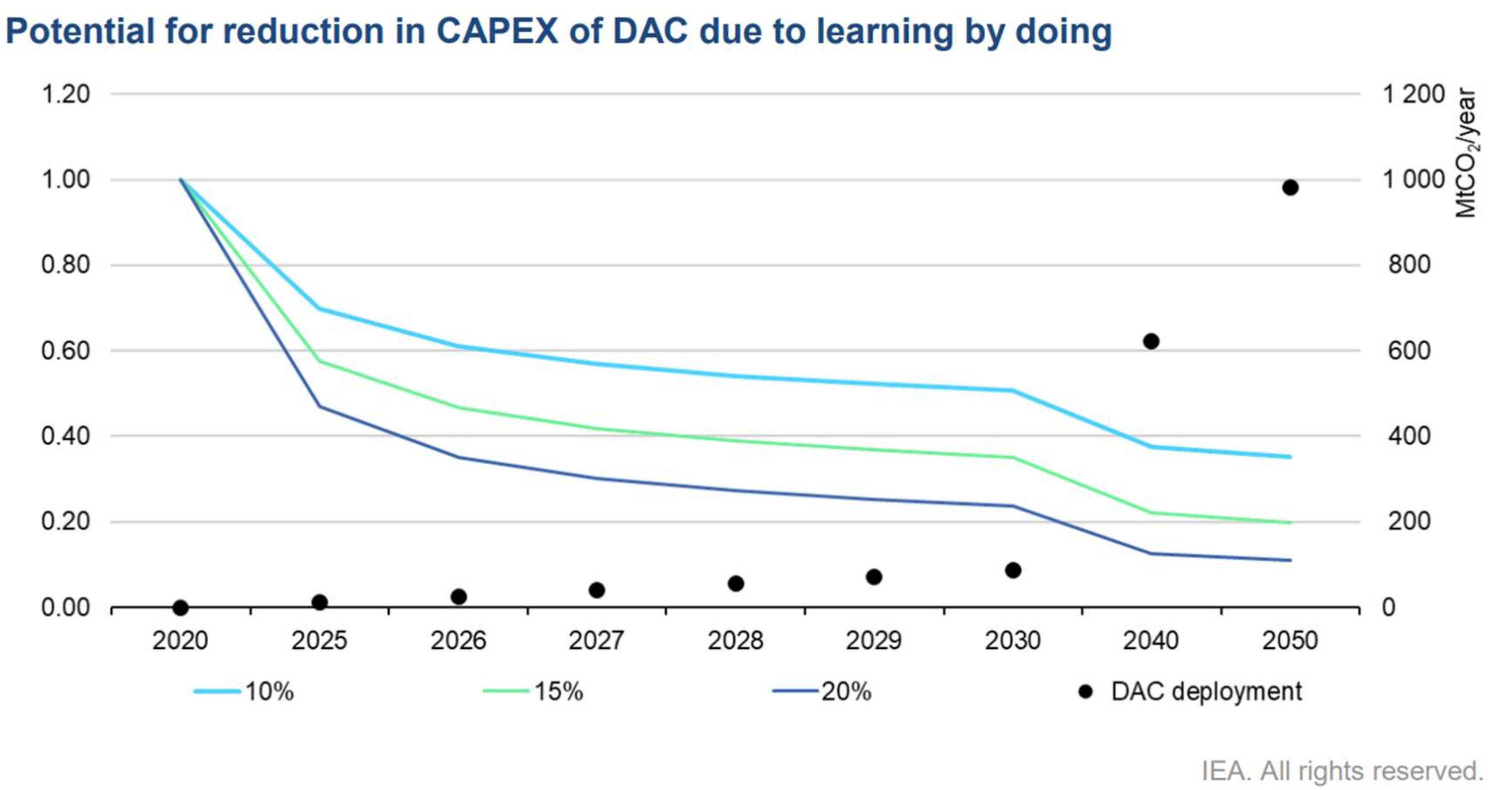
Point source capture (PSC)

Sources: Hanna 2021, IEA 2022

The Bad: DAC is expensive



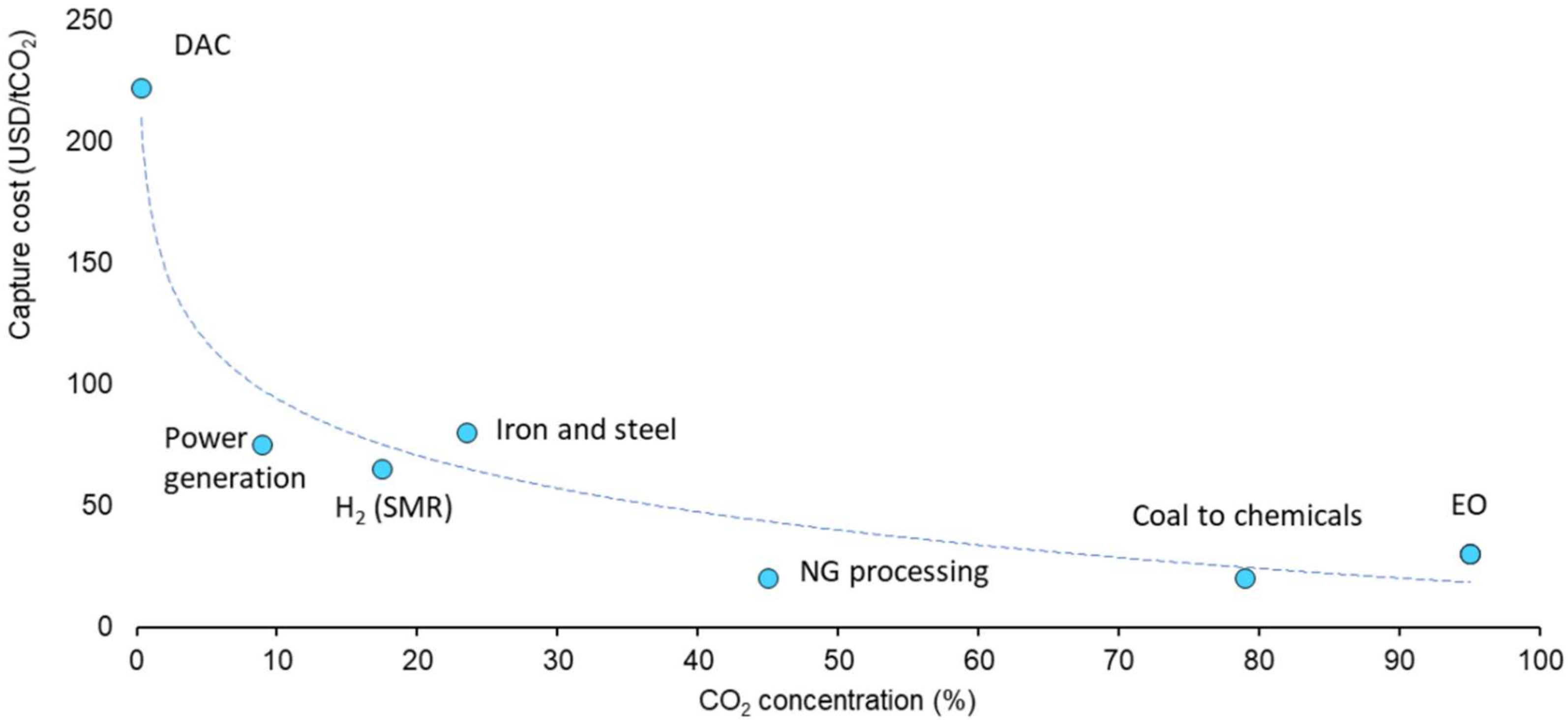
For ranges, the average is shown.
Costs have been adjusted with inflation to 2023.



Sources: NASEM 2019, Fasihi 2019, IEA 2022

The Bad: DAC is expensive

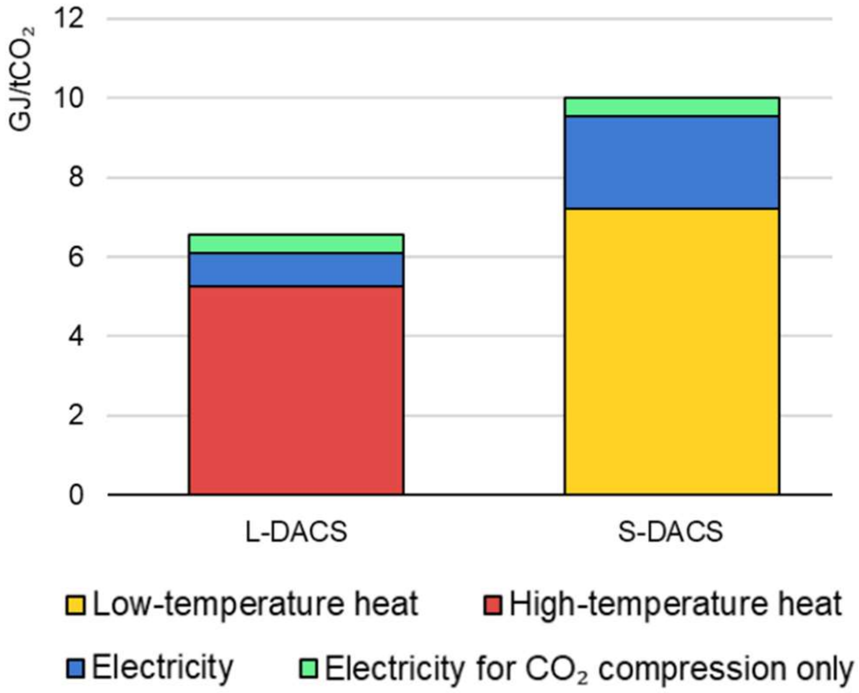
CO_2 capture cost at varying CO_2 concentrations, 2020



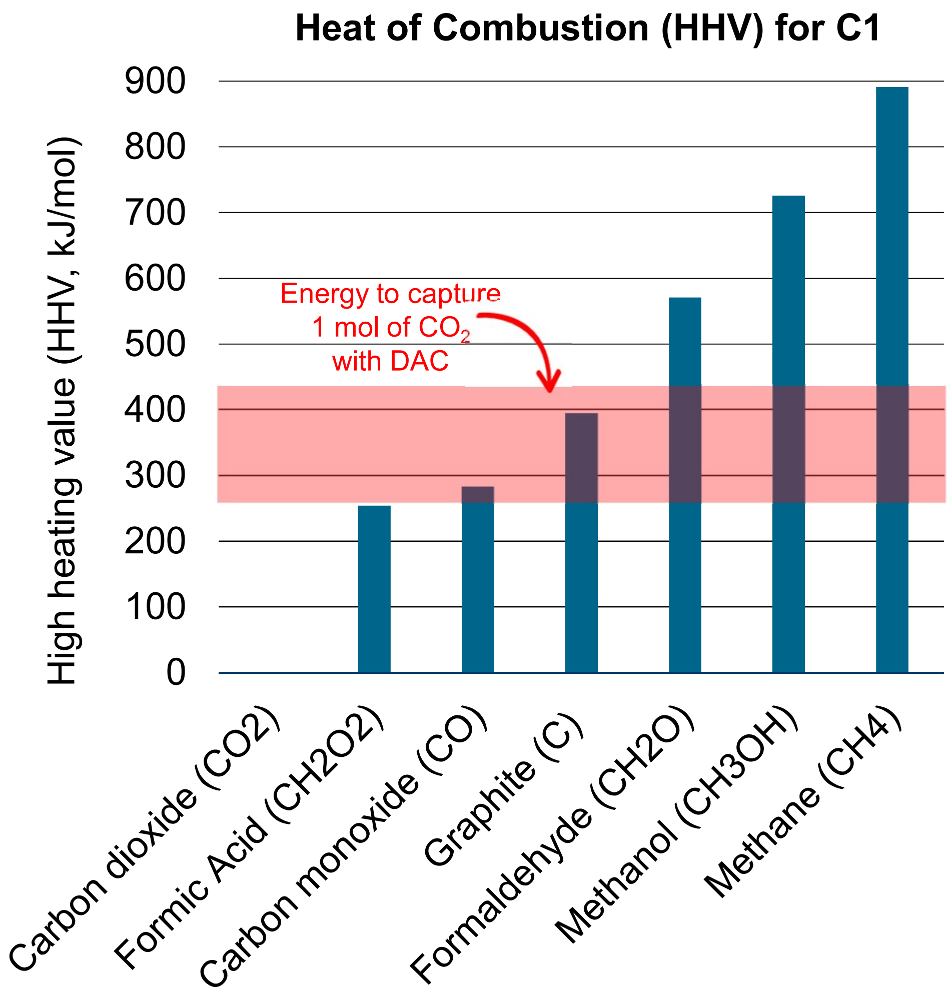
Notes: Average values by application. H_2 = hydrogen; SMR = steam methane reforming; NG = natural gas; EO = ethylene oxide. The empirical trend line shows the correlation between capture cost and CO_2 concentration.

Source: IEA 2022

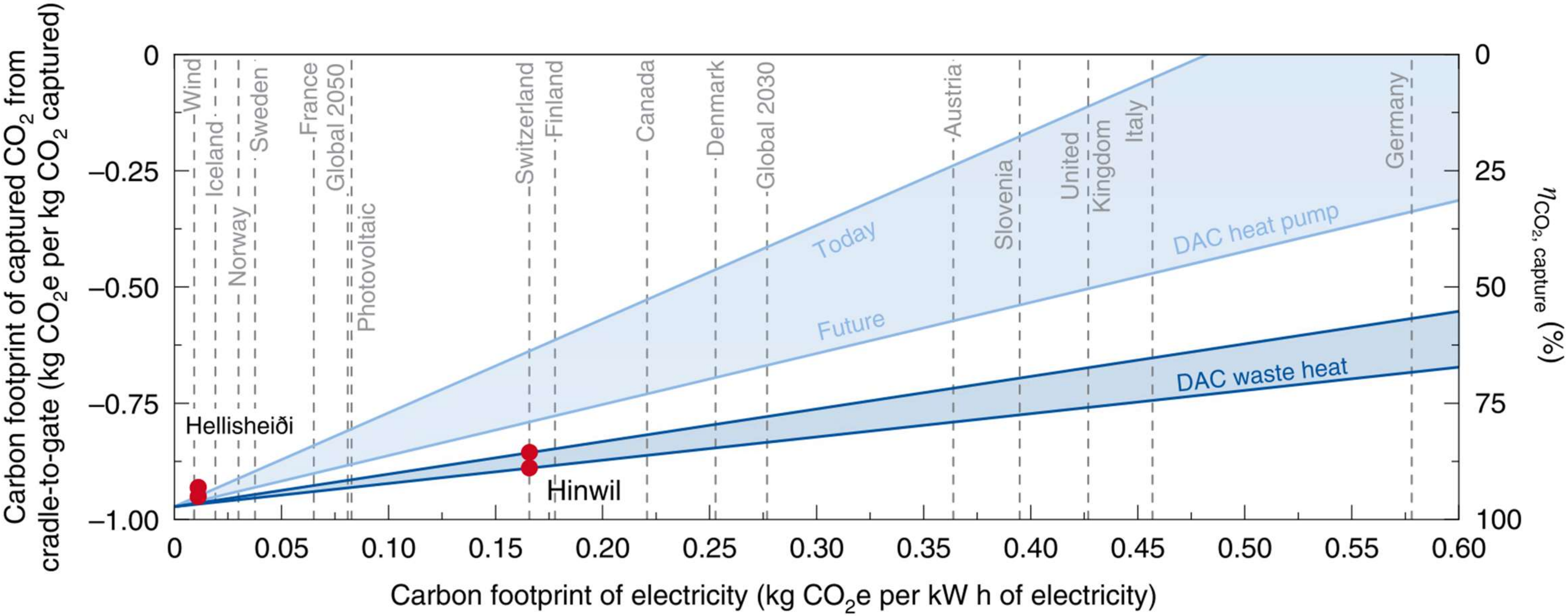
The Ugly: DAC is energy-intensive



Source: IEA 2022

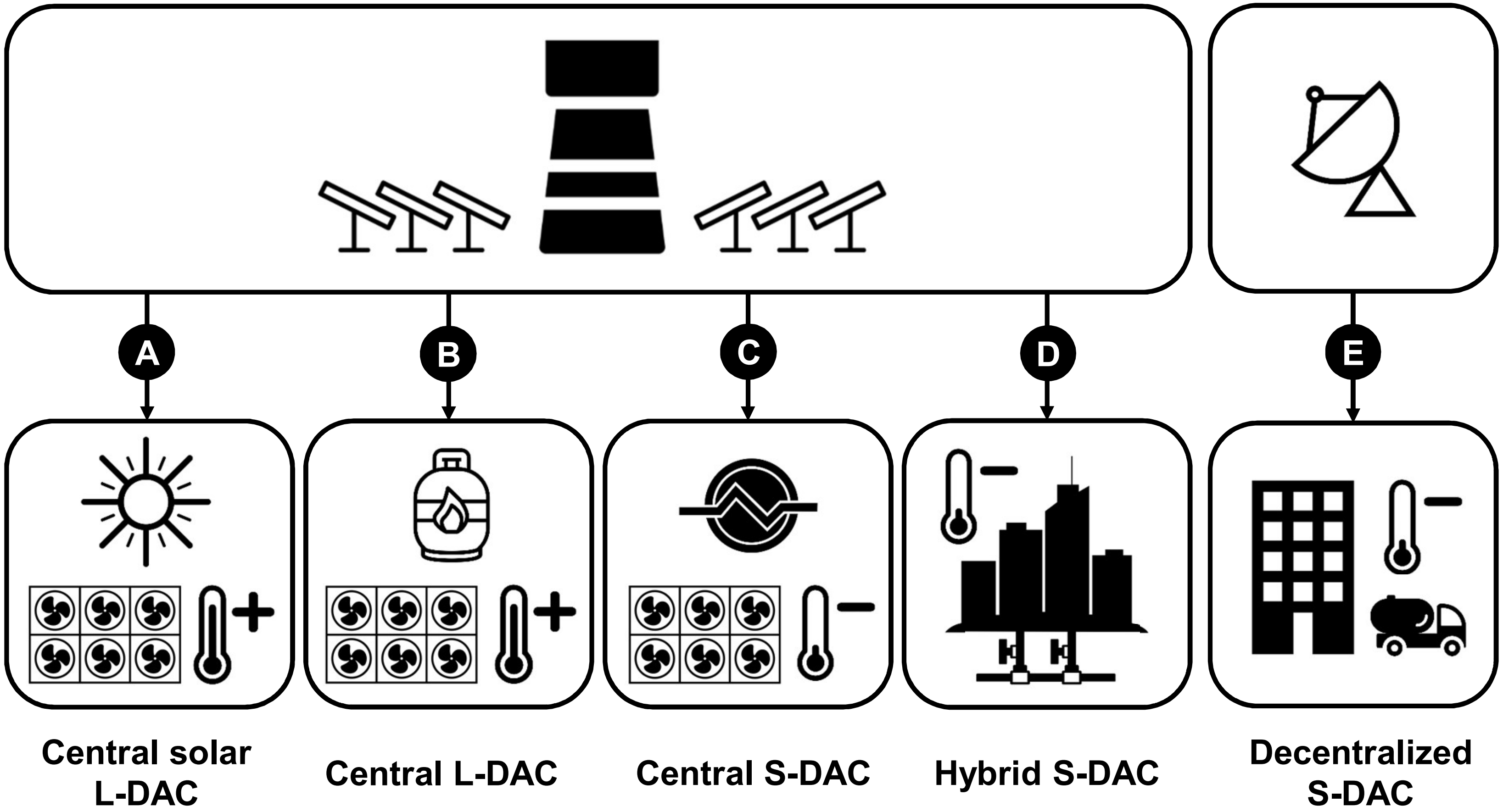


The Ugly: DAC is energy-intensive



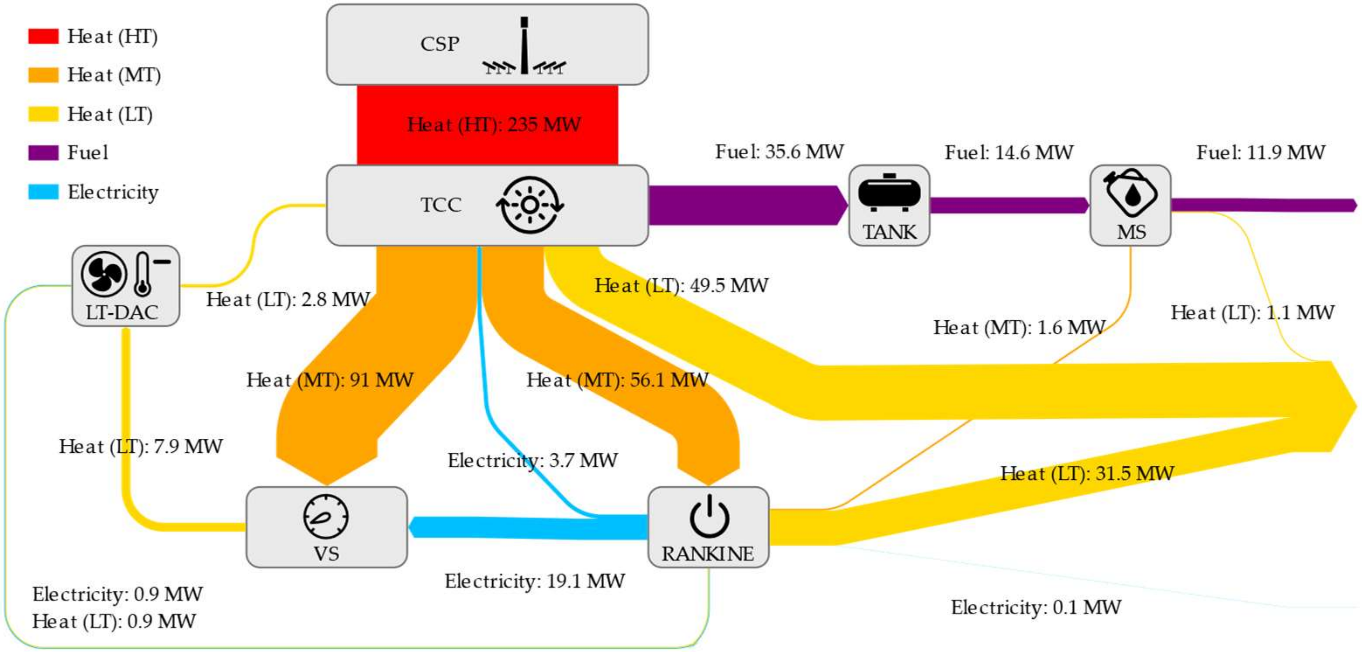
Source: Deutz and Bardow 2021

Synergies: solar fuels & DAC

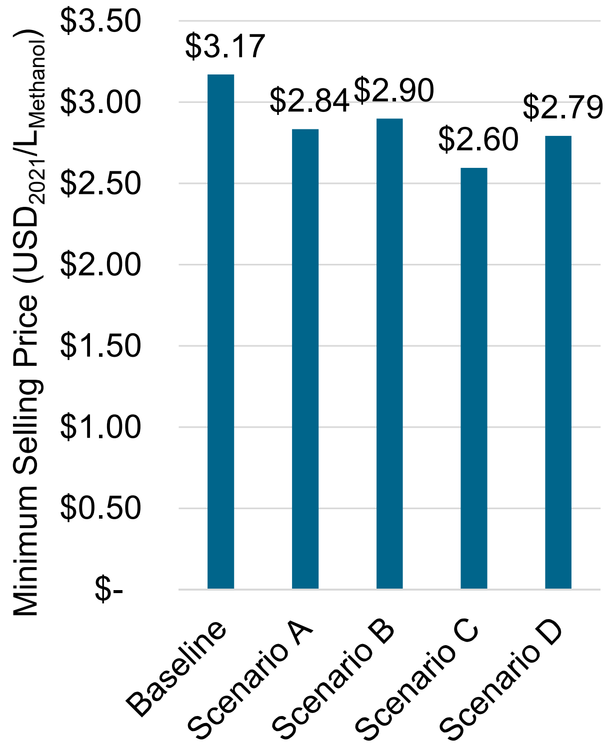


Source: Prats-Salvadó 2021

Synergies: solar fuels & DAC



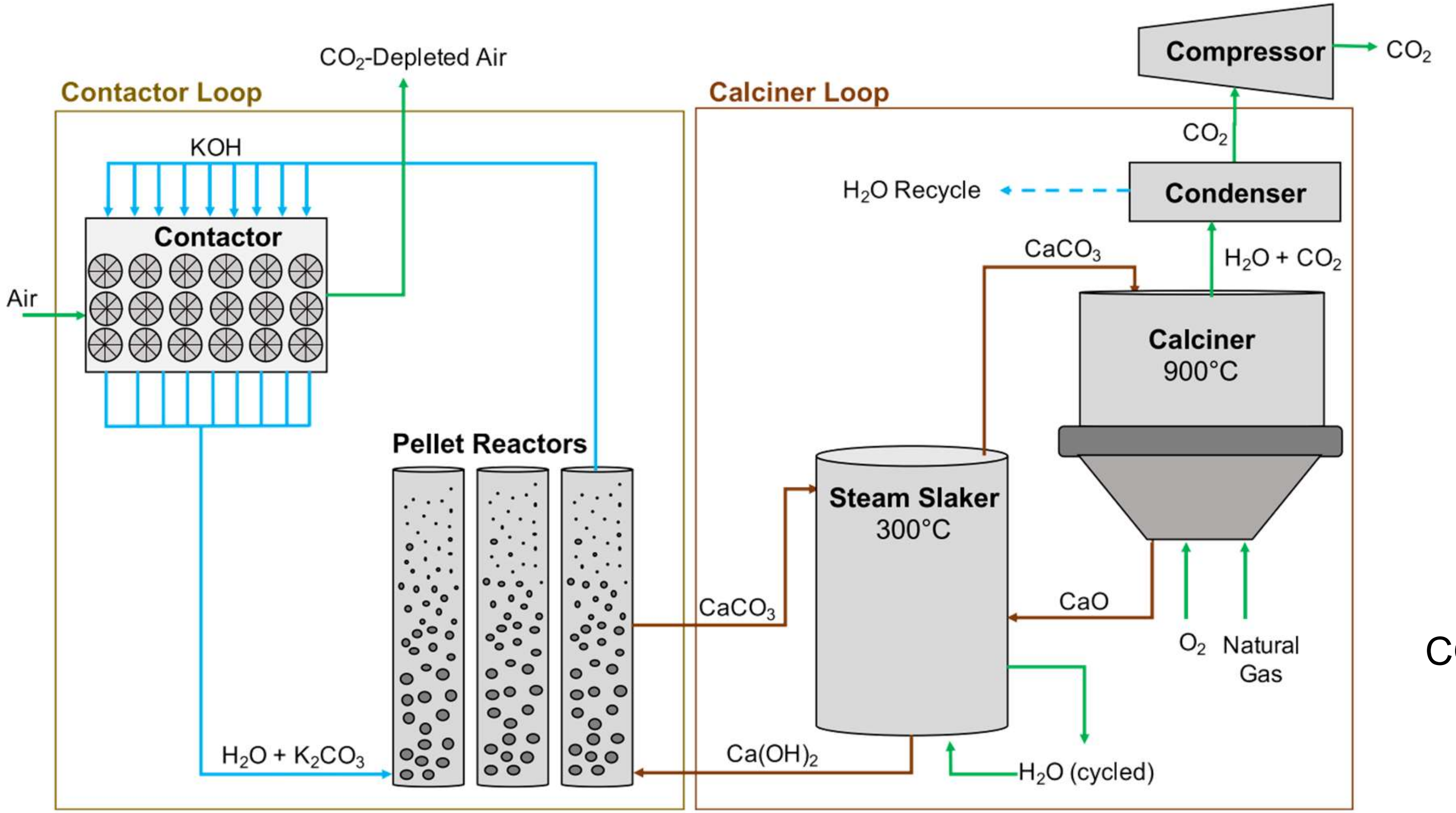
CSP: Concentrated solar power; TCC: thermochemical cycle, MS: Methanol synthesis, VS: Vacuum system; LT-DAC: Low-temperature DAC (a.k.a. S-DAC); HT: High temperature; MT: medium temperature; LT: low temperature

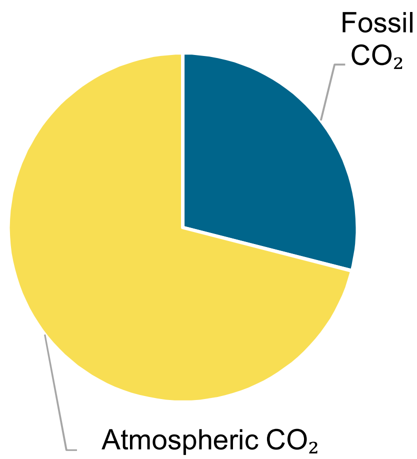


Environmental assessment on-going

Source: Prats-Salvadó 2022

Synergies: solar energy & L-DAC

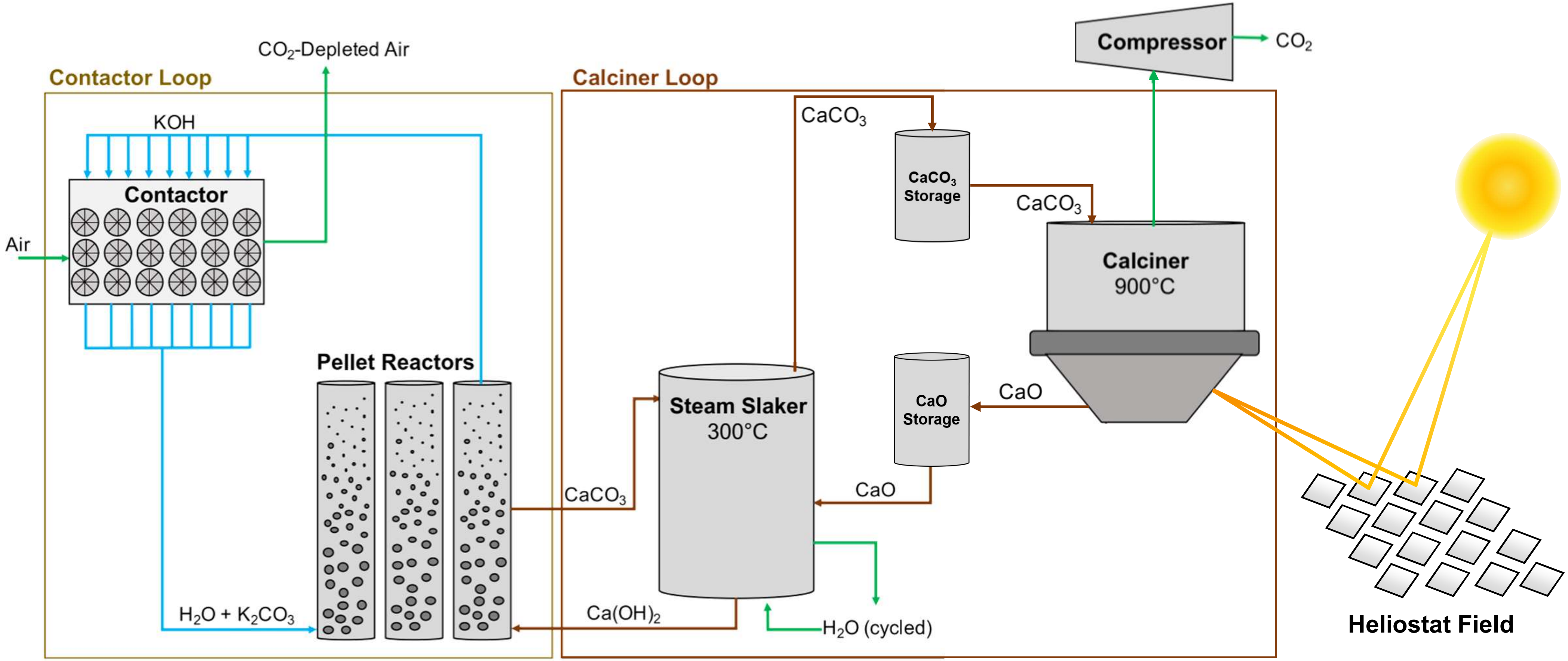




CO_2 mostly limited to CCS

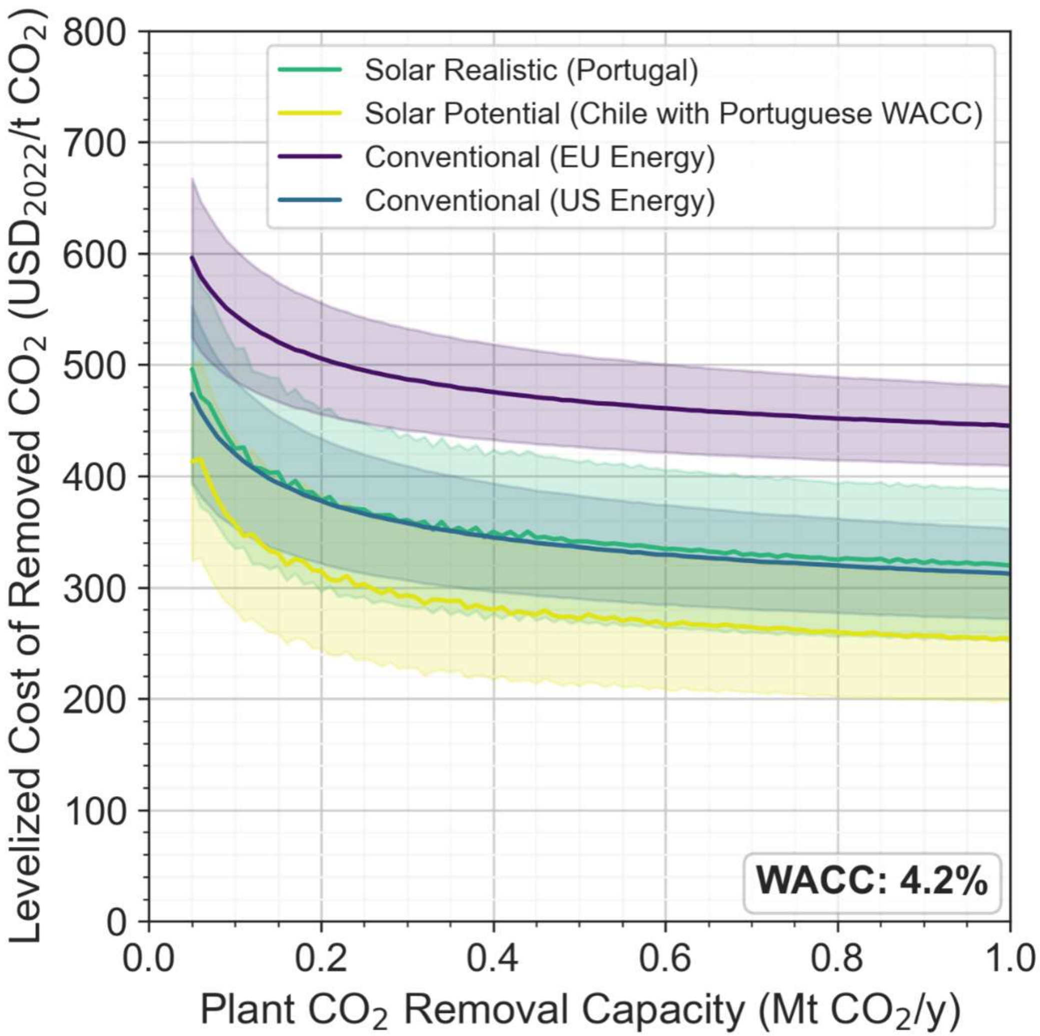
Sources: Fasihi 2019, McQueen et al. 2021

Synergies: solar energy & L-DAC



Sources: Fasihi 2019, McQueen et al. 2021

Synergies: solar energy & L-DAC



Take home messages

DAC as carbon source: carbon-neutral, less invasive, more scalable

Cost of DAC: one order of magnitude higher than alternatives

DAC is energy intensive and requires relatively low carbon energy

DAC can (and should) be integrated into carbon utilization technologies

Thanks for your attention!

Enric Prats-Salvado
Institute of Future Fuels
(DLR)

Linkedin

References

Climeworks (2023). Available online at https://climeworks.com/.

Deutz, Sarah; Bardow, André (2021): Life-cycle assessment of an industrial direct air capture process based on temperature–vacuum swing adsorption. In Nat Energy 6 (2), pp. 203–213. DOI: 10.1038/s41560-020-00771-9.

Fasihi, Mahdi; Efimova, Olga; Breyer, Christian (2019): Techno-economic assessment of CO2 direct air capture plants. In Journal of Cleaner Production 224, pp. 957–980. DOI: 10.1016/j.jclepro.2019.03.086.

Hanna, Ryan; Abdulla, Ahmed; Xu, Yangyang; Victor, David G. (2021): Emergency deployment of direct air capture as a response to the climate crisis. In Nature Communications 12. DOI: 10.1038/s41467-020-20437-0.

IEA - International Energy Agency (2023). Available online at https://www.iea.org/.

International Energy Agency (2022): Direct Air Capture: A key technology for net zero. Edited by IEA Publications. France.

Küng, Lukas; Aeschlimann, Silvan; Charalambous, Charithea; McIlwaine, Fergus; Young, John; Shannon, Noah et al.: A Roadmap for Achieving Scalable, Safe, and Low-cost Direct Air Carbon Capture and Storage. The Research Centre for Carbon Solutions (RCCS), RMI, Carbon Removal Partners Ltd.

McQueen, Noah; Gomes, Katherine Vaz; McCormick, Colin; Blumanthal, Katherine; Pisciotta, Maxwell; Wilcox, Jennifer (2021): A review of direct air capture (DAC): scaling up commercial technologies and innovating for the future. In Prog. Energy 3 (3), p. 32001. DOI: 10.1088/2516-1083/abf1ce.

National Academies of Sciences, Engineering, and Medicine (2019): Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. DOI: 10.17226/25259.

Prats-Salvado, Enric; Monnerie, Nathalie; Sattler, Christian (2021): Synergies between Direct Air Capture Technologies and Solar Thermochemical Cycles in the Production of Methanol. In Energies 14 (16), p. 4818. DOI: 10.3390/en14164818.

Prats-Salvado, Enric; Monnerie, Nathalie; Sattler, Christian (2022): Techno-Economic Assessment of the Integration of Direct Air Capture and the Production of Solar Fuels. In Energies 15 (14), p. 5017. DOI: 10.3390/en15145017.

UNEP (2017): The emissions gap report 2017. A UN Environment synthesis report. Nairobi, Kenya: United Nations Environment Programme (UNEP). Available online at http://hdl.handle.net/20.500.11822/22070.