ETH zürich

Status of carbon capture and sequestration projects worldwide

Marco Mazzotti

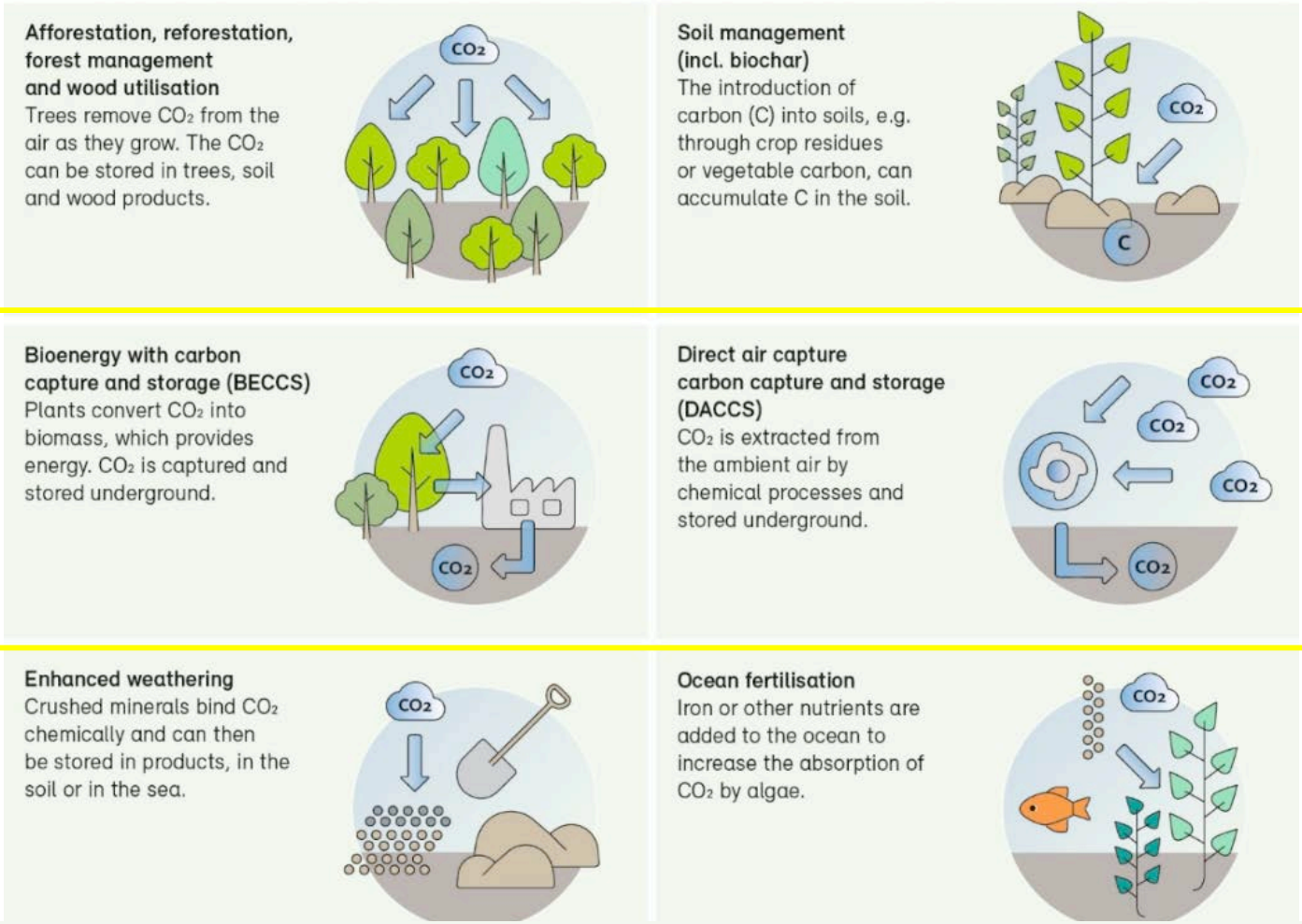
22 April 20201

EuChemS – The Carbon Element

Take-home messages

1. Counteracting climate change requires mitigating emissions as well as creating negative emissions

1. Possible approaches for negative emissions

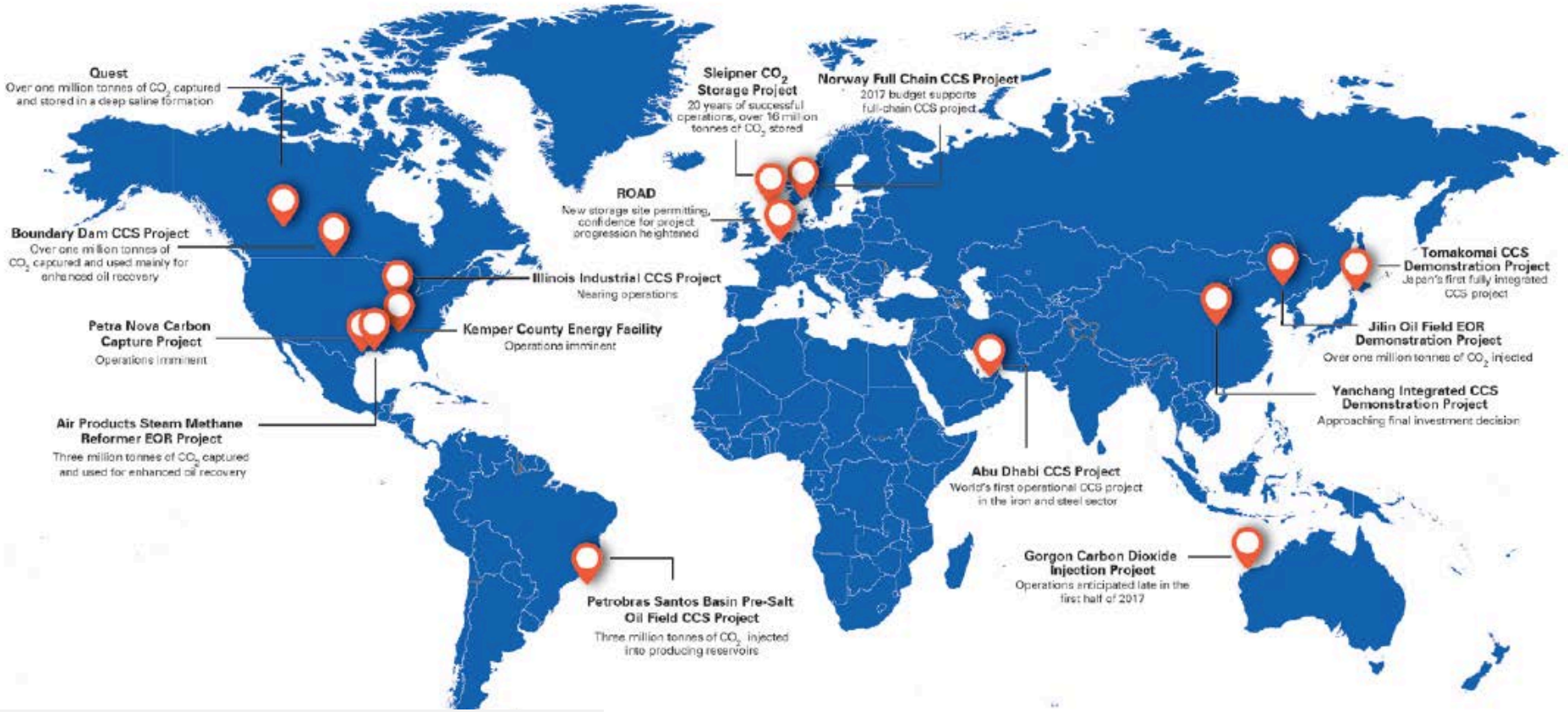


https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate-target2050/negative-emissionstechnologien.html

Take-home messages

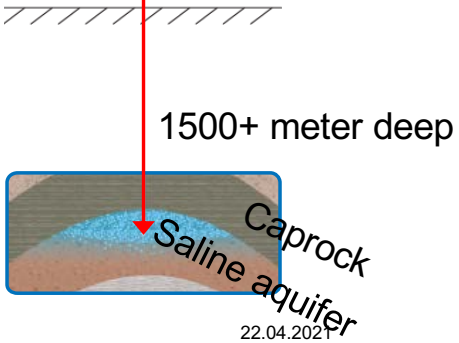
1. Counteracting climate change requires mitigating emissions as well as creating negative emissions
2. Point-source CO_2 capture is feasible across sectors, CO_2 storage will be accessible Europe-wide

2. Carbon dioxide Capture and Storage, CCS



2. CCS

- 120 MW net coal-fired power plant
- PCC of 1 Mt CO_2/y, with Cansolv amine scrubbing
- Storage in aquifer or for EOR
- Operational since October 2014
- Similar plant at Petra Nova, TX



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Direct Air Capture

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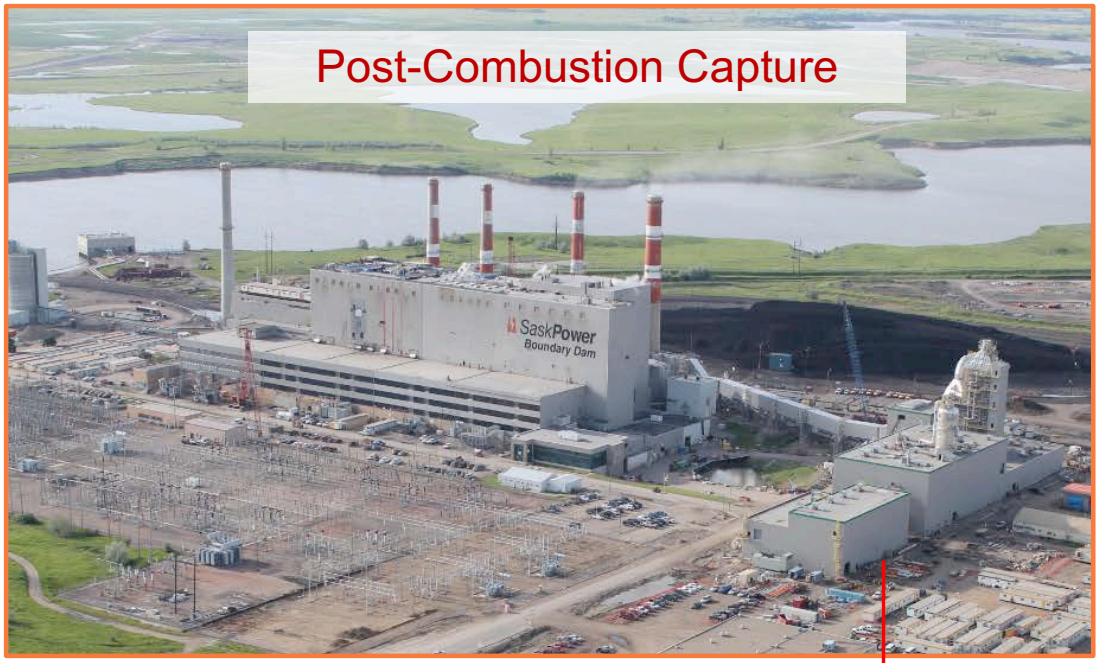
Post-Combustion Capture



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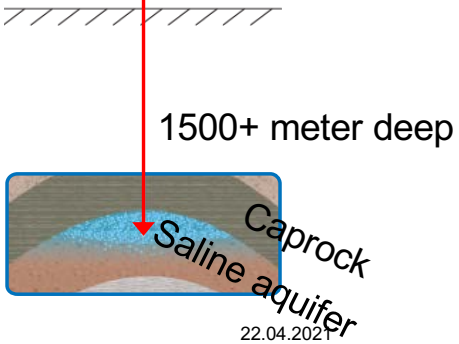

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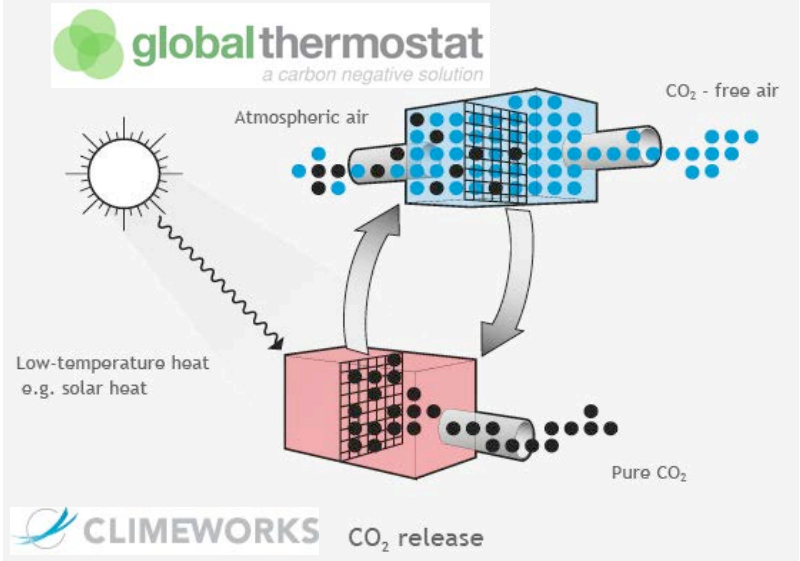

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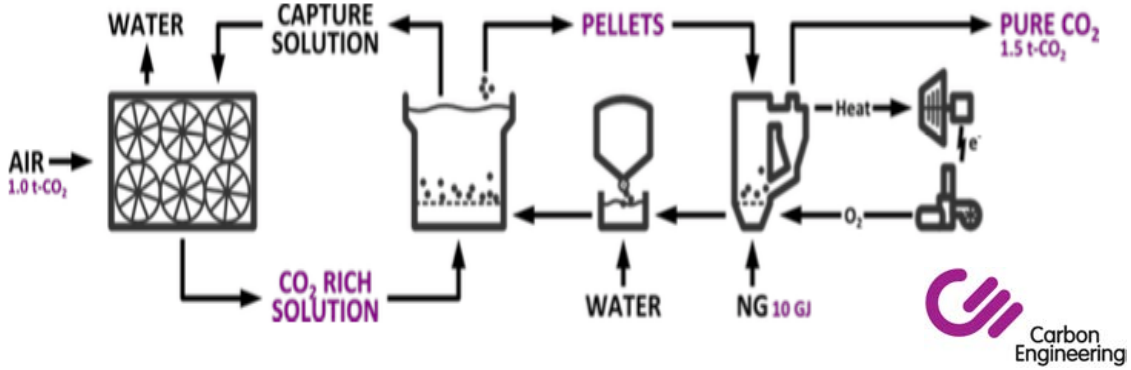
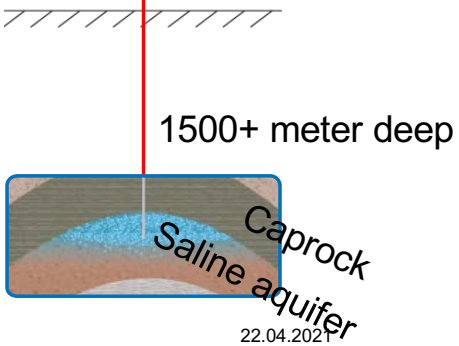
aBsorption + calcination (900°C)

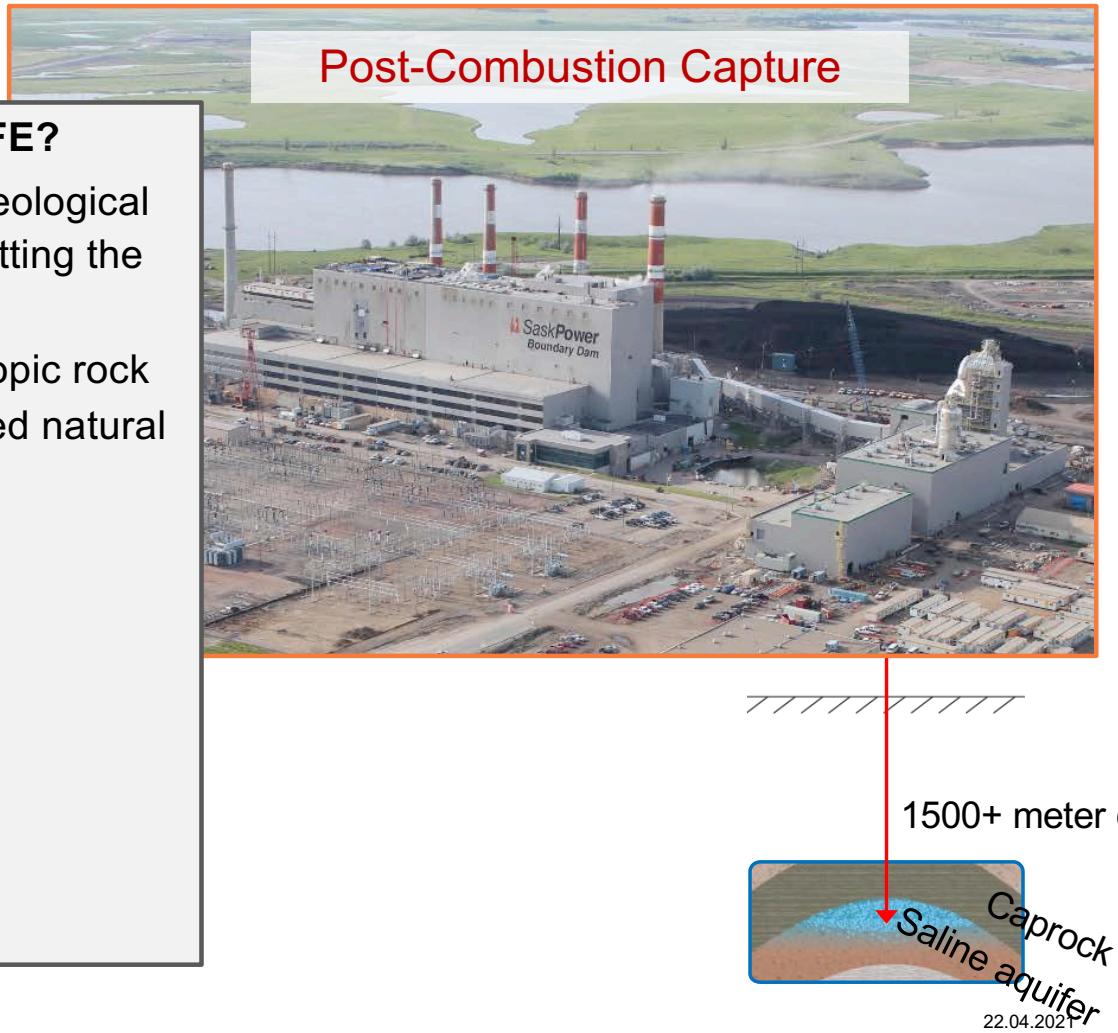




2. CCS

IS UNDEGROUND STORAGE OF CO_2 SAFE?

1. Climate protection: 'Putting CO_2 in deep geological formations is a lot safer and better than putting the same CO_2 into the atmosphere.'
2. Physical basis: 'CO_2 is trapped in microscopic rock pores by the same process that has trapped natural gas for millions of years.'



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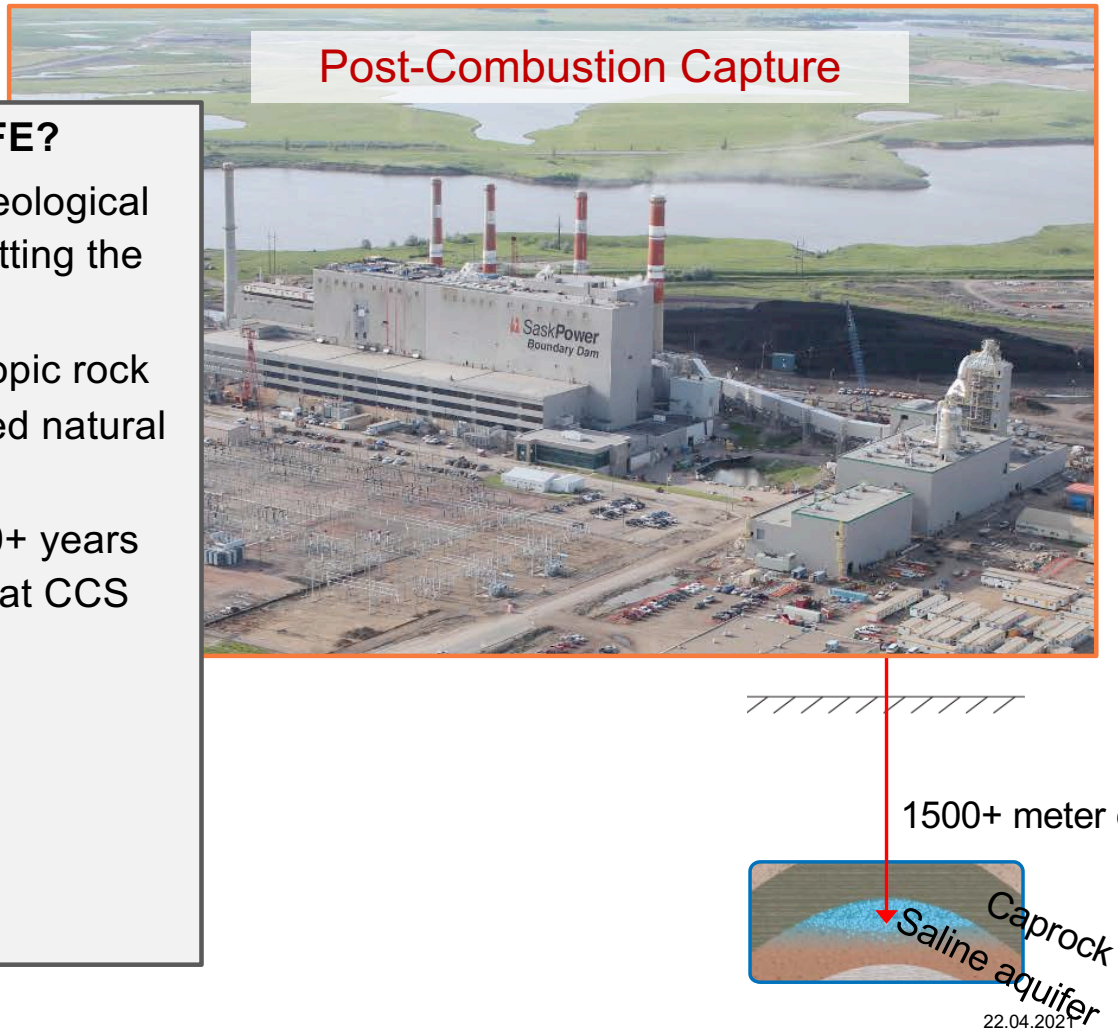
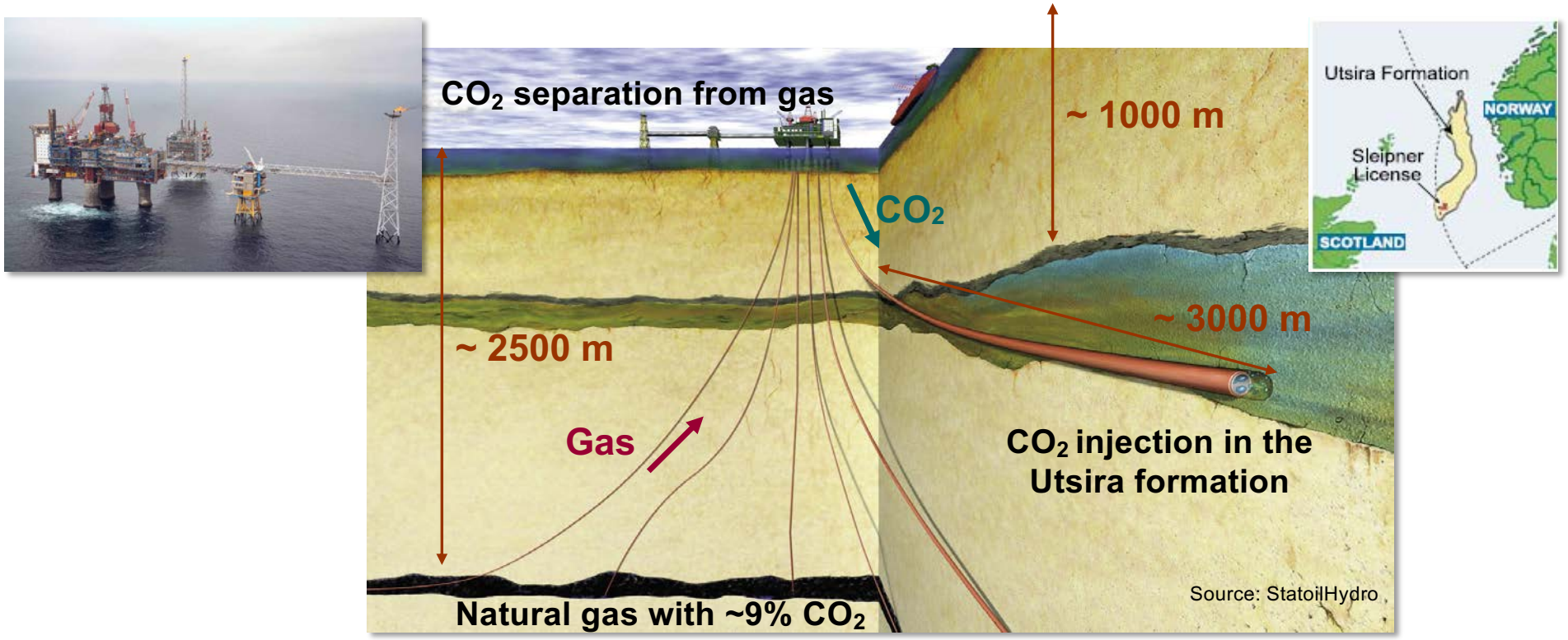


2. CCS at the Sleipner gas-field, Norway



- The world's first and longest lasting commercial storage project (since 1996, 20+ Mt CO_2 stored).

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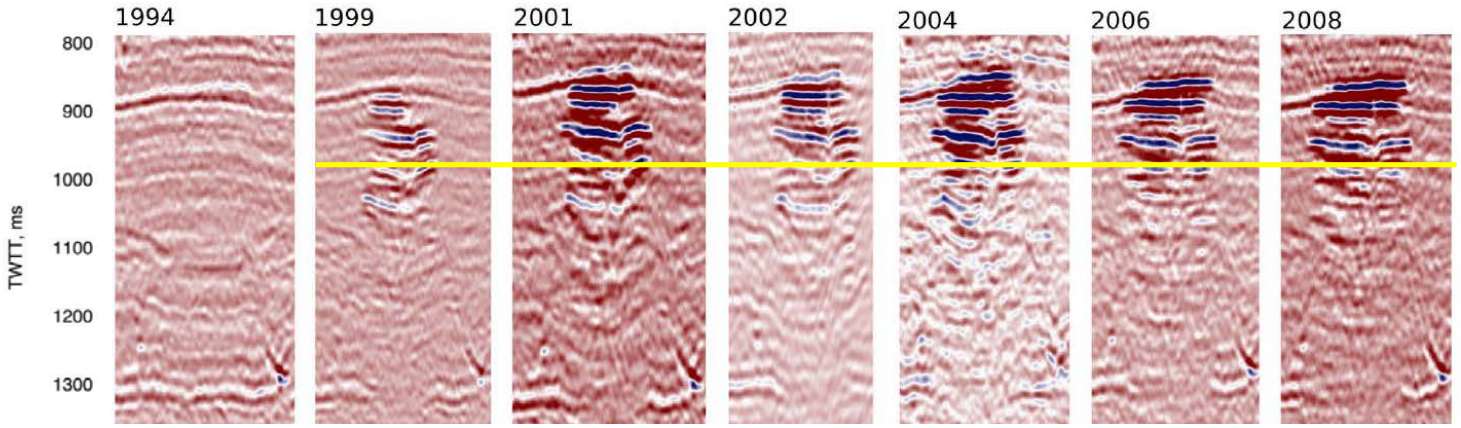
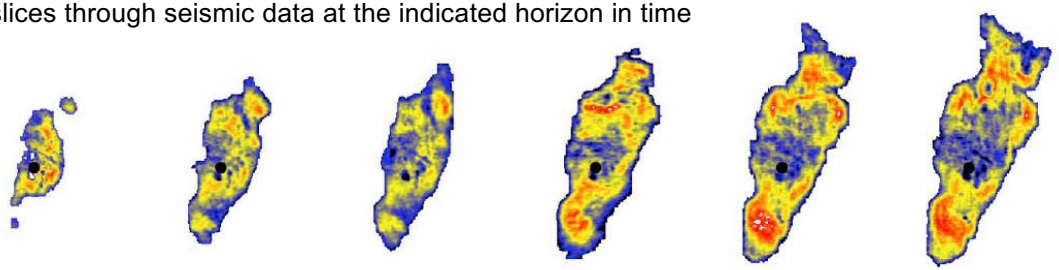


Top: vertical slices through seismic volumes

Bottom: horizontal slices through seismic data at the indicated horizon in time

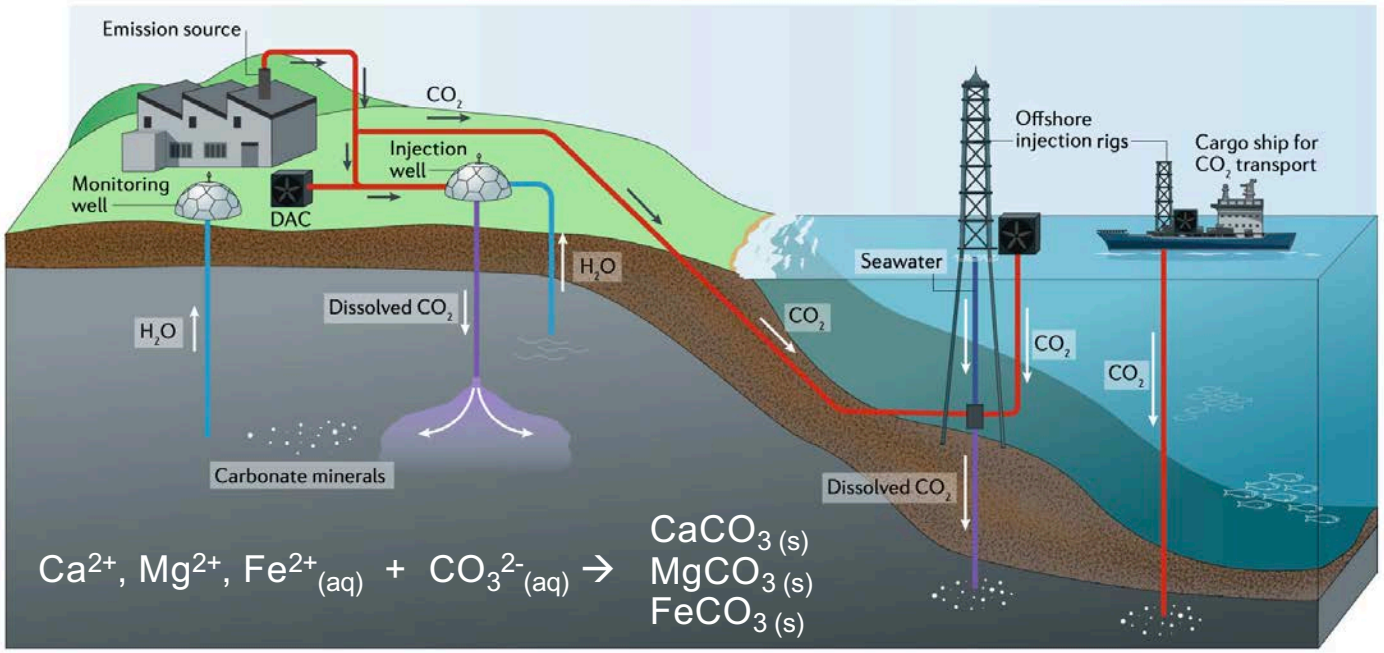


- 4D-Seismic, powerful monitoring technique, shows that CO_2 migration follows design specs.

Source: Boait et al. 2012. J Geophys Res 117. B03309.

2. CCS at the CarbFix project, Iceland

- The CarbFix pilot project undertaken in 2012 near the Hellisheiði geothermal power plant
- 230 t of CO_2 and CO_2-H_2S mixture in groundwater injected to a depth of ca. 500 m into basaltic rocks
- 25 t water per ton of gas injected
- 95% of the injected gas mineralized within 2 years (permanently stored)
- Project upscaled in 2014: it currently captures and stores 33% of the emissions of the Hellisheiði plant , i.e. 12 kt CO_2/y



Schematic of current and prospect CarbFix operation.

- ➢ CarbFix2 project couples DAC and mineral carbonation achieving a negative emissions pathway
- ➢ Moving offshore: the CarbFix2 project will inject CO_2 dissolved in seawater into submarine basalts

Snæbjörnsdóttir, S. Ó., et al. "Carbon dioxide storage through mineral carbonation." *Nature Reviews Earth & Environment* 1.2 (2020): 90-102.
Gunnarsson, I., et al. "The rapid and cost-effective capture and subsurface mineral storage of carbon and sulfur at the CarbFix2 site." *International Journal of Greenhouse Gas Control* 79 (2018): 117-126.

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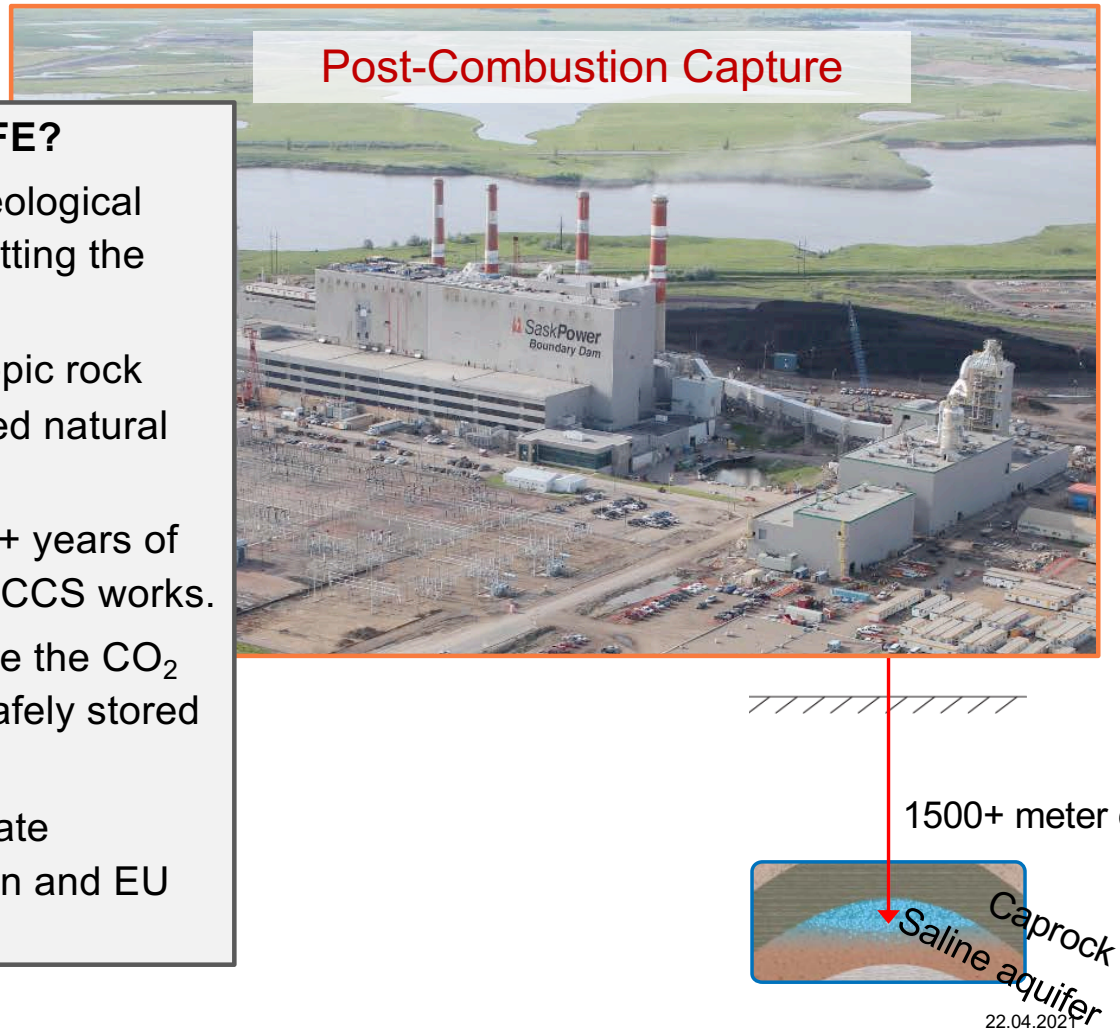
3. Operational experience: We know from 20+ years of operations at Sleipner and elsewhere that CCS works.
4. Geophysical monitoring: We can see where the CO_2 is (with some uncertainty) and show it is safely stored in the intended reservoir unit.
5. Regulatory compliance: We can demonstrate regulatory conformance with the Norwegian and EU CO_2 storage directives.



Take-home messages

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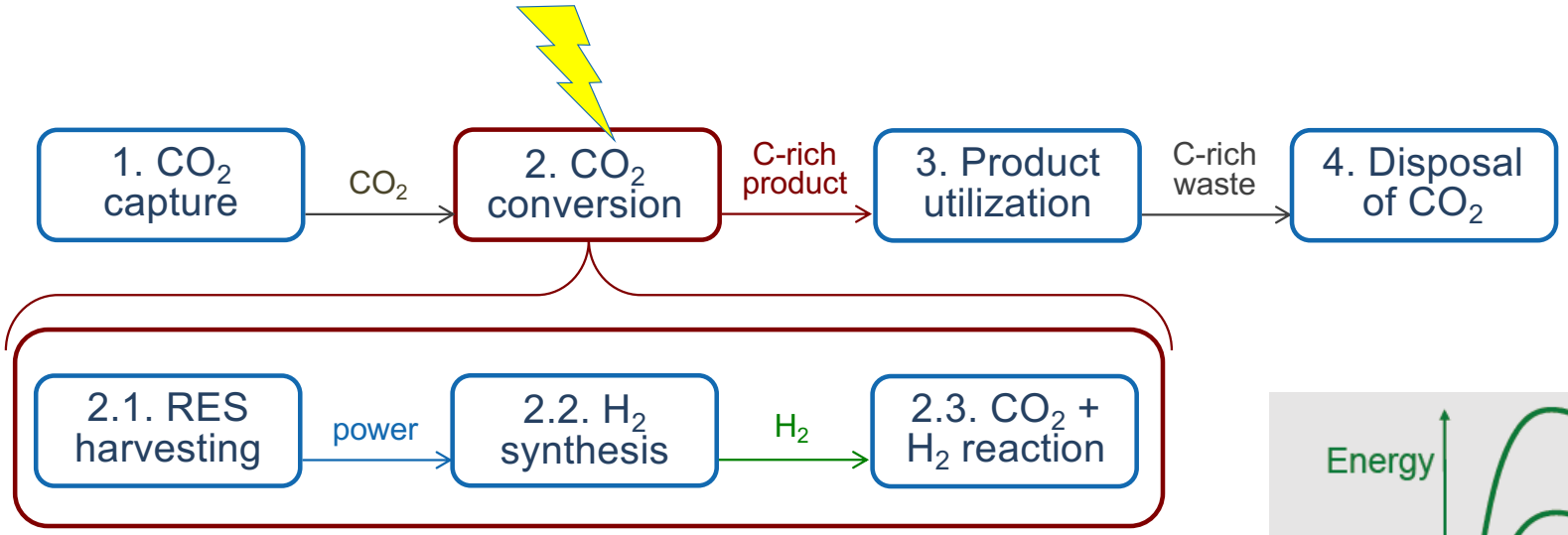
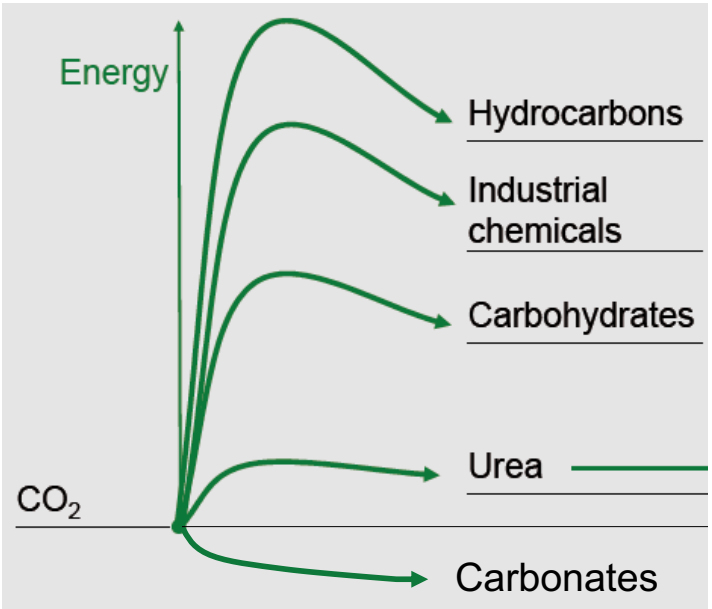
2. Point-source CO_2 capture is feasible across sectors, safe storage will be accessible Europe-wide
3. CO_2 utilization is very energy-intensive (thus requiring clean energy and system level analysis)

3. Carbon dioxide Capture and Utilization, CCU





The energy ground state of carbon is carbonate, CO_3^{2-} .

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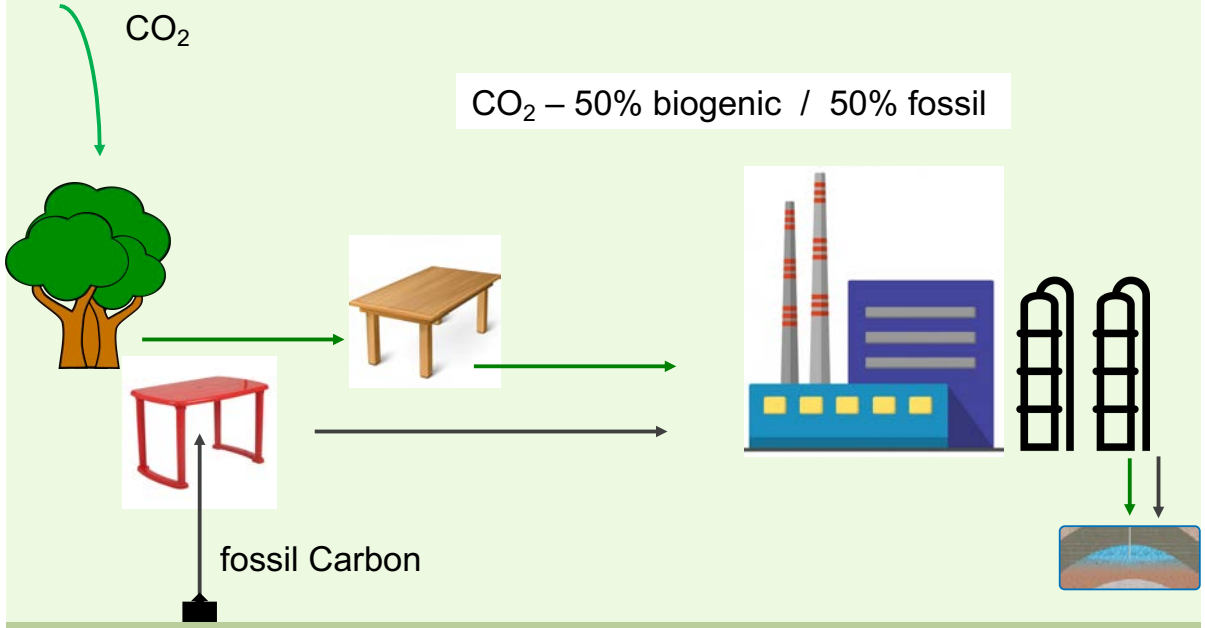
Waste-to-Energy Plants



- CO_2 emissions from European WtE plants are significant
- WtE plants enable sustainable cities: waste treatment, recycling, heat & power, CO_2 mitigation and CDR
- Biogas upgraders provide even more accessible biogenic CO_2

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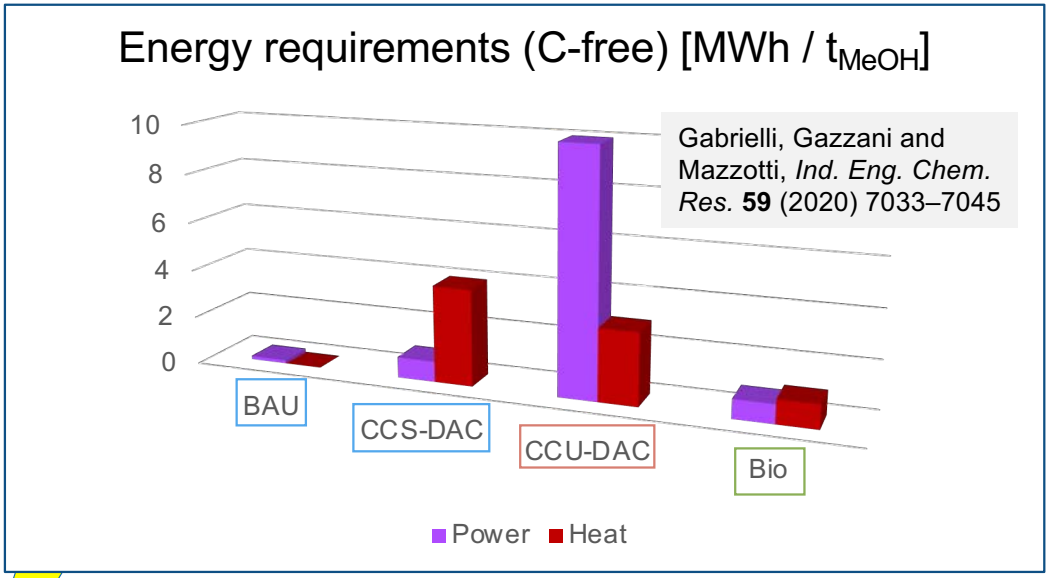
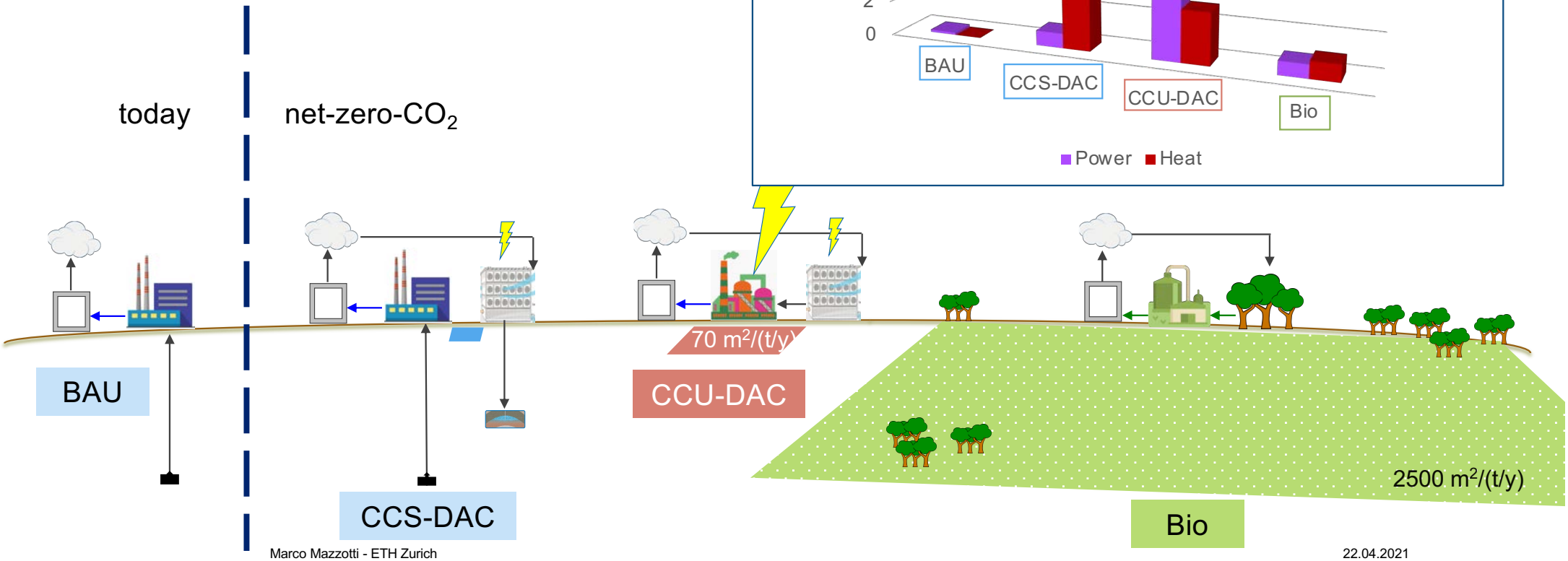
5. C-neutral Methanol





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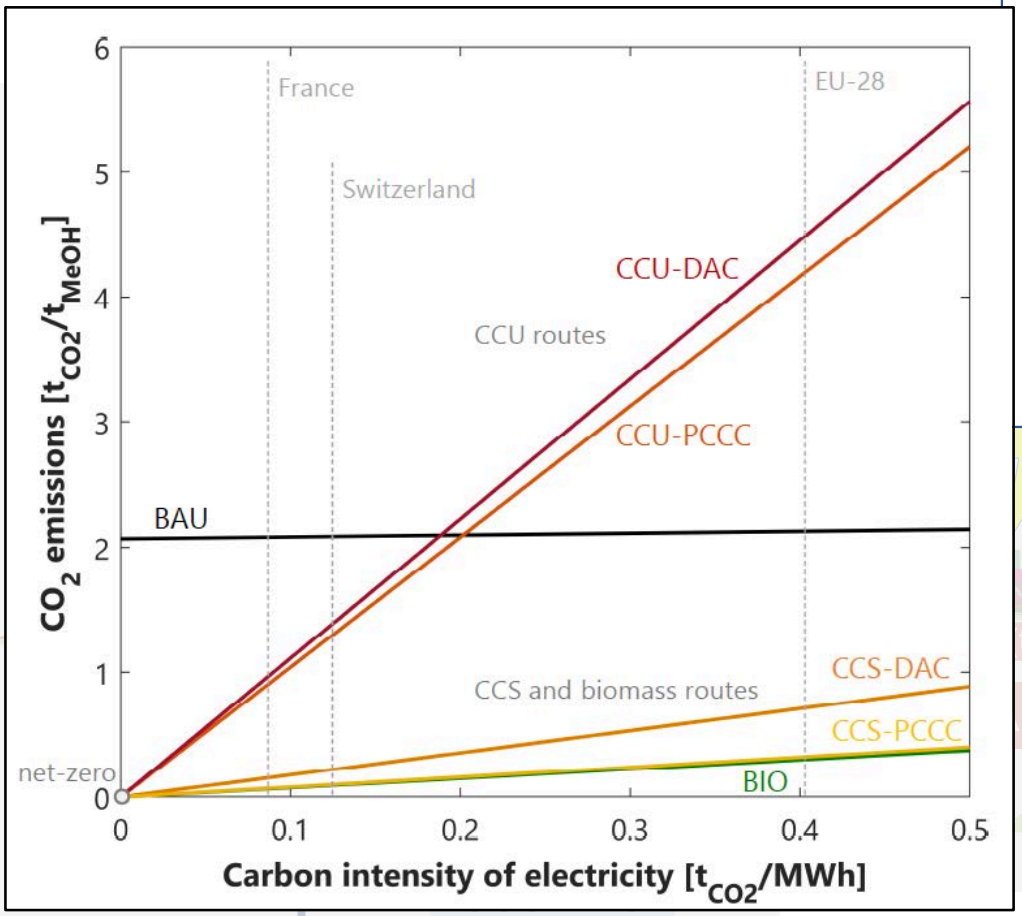

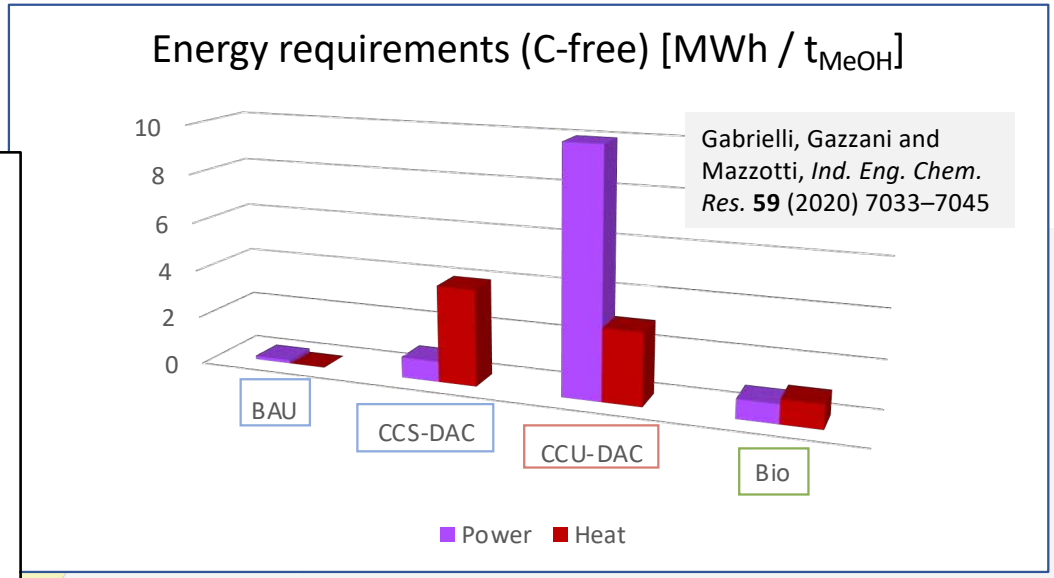

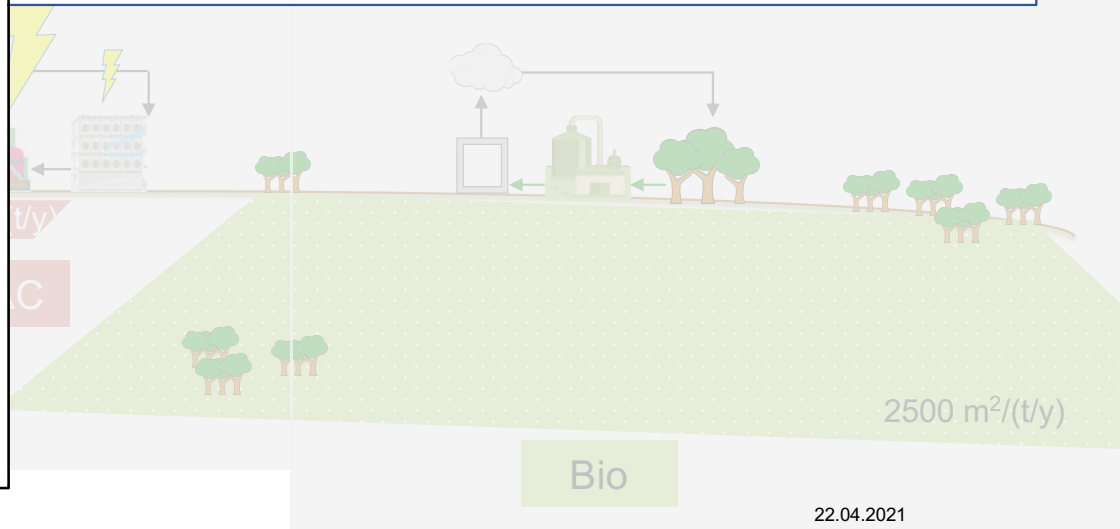

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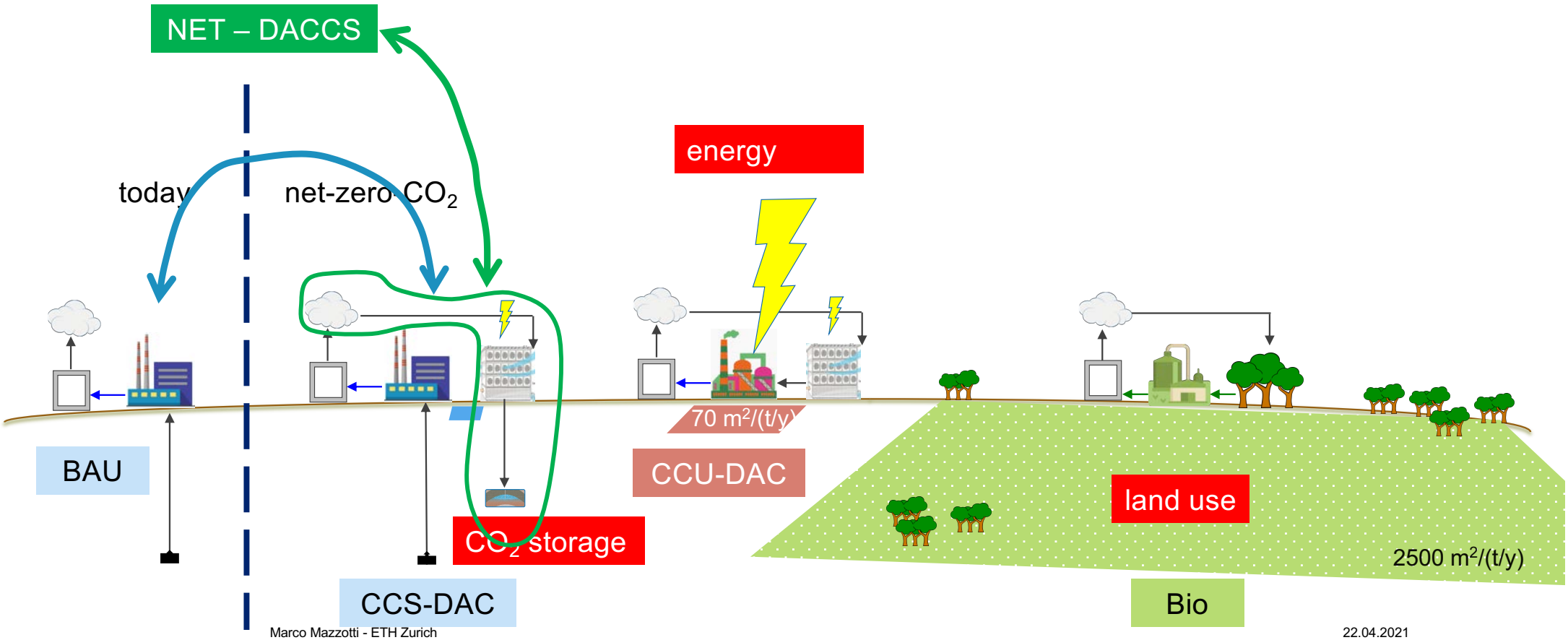
Becattini, Gabrielli, and Mazzotti,
Ind. Eng. Chem. Res. (2021)
https://doi.org/10.1021/acs.iecr.0c05392

6. Net-zero-CO_2-emissions chemicals (or jet fuels)



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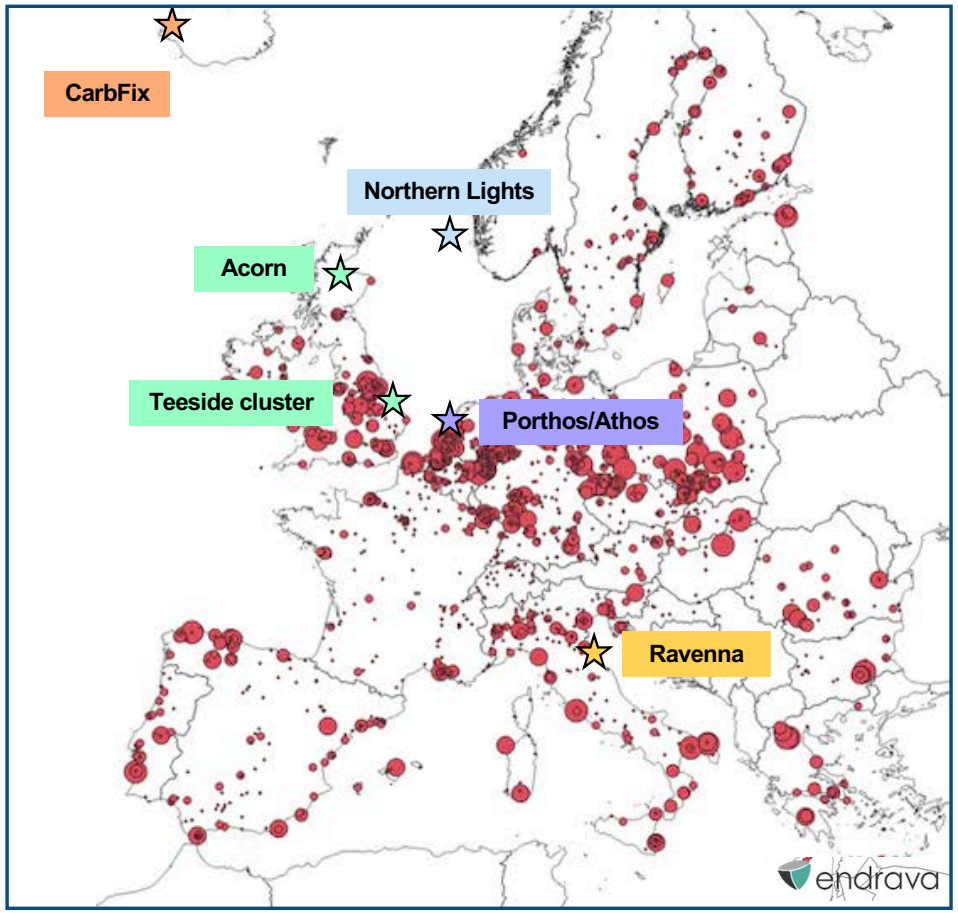
7. There is a pressing need for a Europe-wide CO_2 network, serving all CO_2 sources and CO_2 sinks

7. CO_2 sources and sinks across Europe



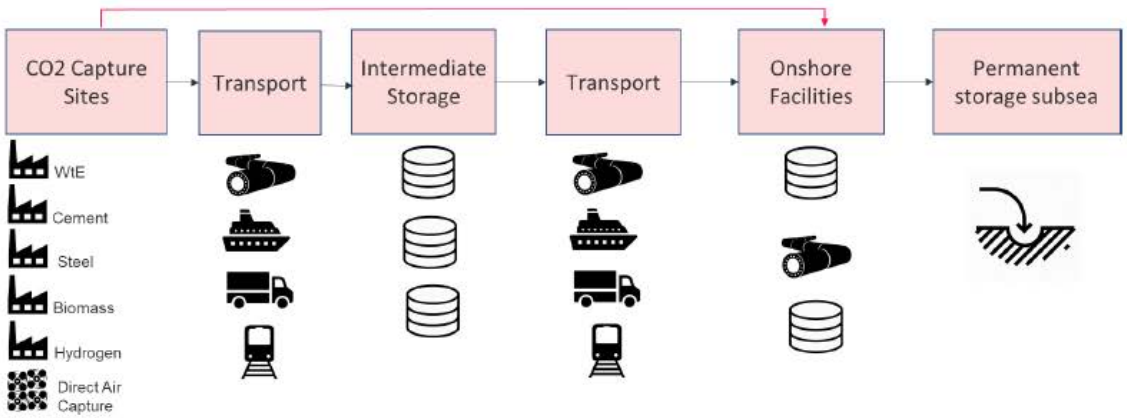
Sectors with the largest potential

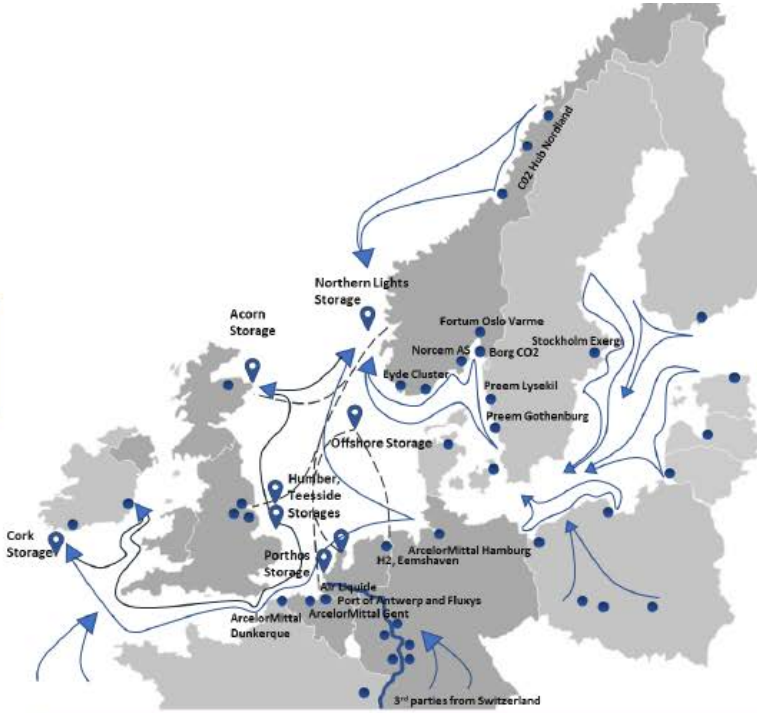
- Waste incineration / WtE
- Cement
- Biomass and biofuel
- Refineries
- Steel
- Natural gas
  - Hydrogen
  - Electricity
- DAC

- Order of magnitude: hundreds of millions of tons CO_2 in 2050

7. Scenario for a European CO_2 network

Small ships, large ships, pipelines, inland transport
CO_2 from many industries and countries
Storage initiators in Norway, Netherlands, UK
Storage in more countries later





- The first, indispensable element of a CO_2 ecosystem in Europe
- CO_2 captured from sources (fossil and biogenic) and from air
- CO_2 transported through a Europe-wide CO_2 network
- CO_2 delivered to temporary sinks (CCU) and to permanent sinks (CCS)
- CO_2 network interconnected with NG grid and H_2 network

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