The value of CO_2 point source capture for the energy-industry system transition

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2.5% lower annual system cost in 2050 with point source capture

3.8 b€ saved over 2020–2050 (0.9% of total system cost)

8–13% cheaper e-Fischer-Tropsch liquids and e-methanol

≈100% of CO_2 for e-fuels from point sources in 2050 (14.6 $MtCO_2$)

93.8% of CO_2 from biomass plants with capture and pulp & paper mills

Background & motivation

Nordic challenge: long cold winters, high heating demand and energy-intensive industry (44% of Finland's final energy use).

Unavoidable CO_2 remains: pulp & paper mills, biomass plants, waste incinerators and cement calcination emit biogenic or process CO_2.

Opportunity: this CO_2 can feed Power-to-X: e-Fischer-Tropsch liquids (e-FTL), e-methanol and e-methane for aviation, shipping and chemicals.

Gap: in 1067 studies of ≥95% renewable systems, DAC is the CO_2 source in 57% and point source capture (PSC) in 34%; industrial PSC appears in only two.

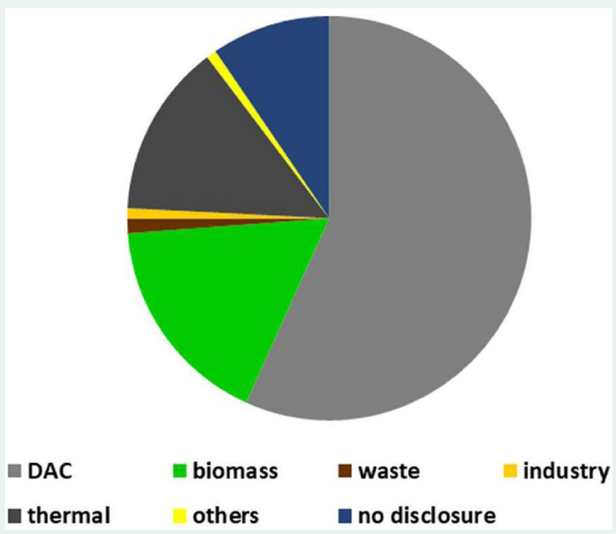

Fig. 1 CO_2 sources assumed for CO_2-to-X in 100% renewable energy system studies.

Methods: LUT-ESTM & scenarios

Model: LUT Energy System Transition Model: linear optimisation minimising total annual system cost at hourly resolution, 2020–2050 in 5-year steps.

Scope: ~160 technologies across power, heat, transport, industry and fuel synthesis; Finland split into 7 regions.

CO_2 capture technologies: DAC, Pulp&Paper industrial PSC, Cement mill PSC, Biomass PP PSC, Biomass CHP PSC, Wastes incinerator PSC.
Heat flows: 3 temperature levels – High temperature, medium and low temperature.

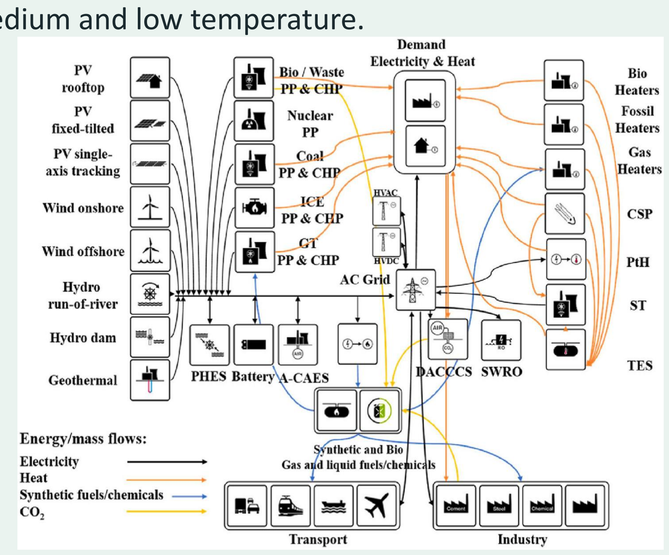

Fig. 2 Schematic of the LUT Energy System Transition Model.

Both scenarios: supported onshore wind in eastern Finland, fixed e-fuel demand.

BPS-WF-PSC
DAC plus PSC from pulp & paper, biomass PP/CHP, waste incinerators and cement, no restrictions.

BPS-WF-noPSC
Identical, but CO_2 PSC is excluded: DAC is the only CO_2 source.

CO_2 capture assumptions

CO_2 source (reference plant)	Captured CO_2, 2030 [kt/yr]	Capex 2030 → 2050 [€/(t/yr)]
Pulp & paper mill avg. Finnish mill, ~607 kt pulp/yr	1,170	119 → 86
Biomass power plant 200 MWel	2,500	90 → 65
Biomass CHP plant 125 MWel / 262 MWth	2,000	98 → 71
Waste incinerator 78 MWel / 120 MWth	540	158 → 114
Cement plant 4,000 t clinker/day	900	131 → 95
Direct air capture low-temperature solid sorbent	scalable	338 → 199

Post-combustion capture, 90% capture rate, CO_2 purity >99%. Capex falls with technology learning.

Results: energy system impact

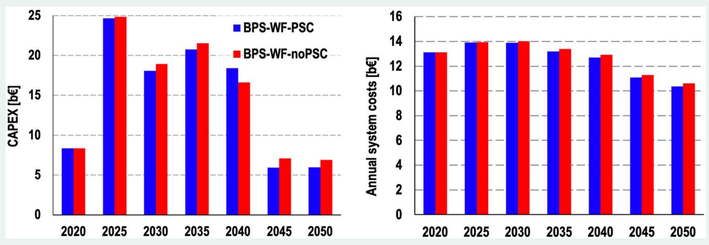

Fig. 4 Capex (left) and annual system costs (right), BPS-WF-PSC vs BPS-WF-noPSC.

Peak and decline: annual cost peaks in 2030 (nuclear and wind build-out), then falls 24% by 2050.

PSC is cheaper in every period: −2.5% in 2050.

Lower investment: e-fuel synthesis incl. CO_2 capture is 75% lower in 2050 with PSC (55% over 2020–2050).

Levelised cost	2030 PSC	2030 noPSC	2050 PSC	2050 noPSC
e-FTL [€/MWh]	155	174	128	141
e-methanol [€/MWh]	175	144	87	95
Electricity [€/MWh]	–	–	33.2	32.6
Final energy [€/MWh]	–	–	42.3	43.3

Results: CO_2 supply

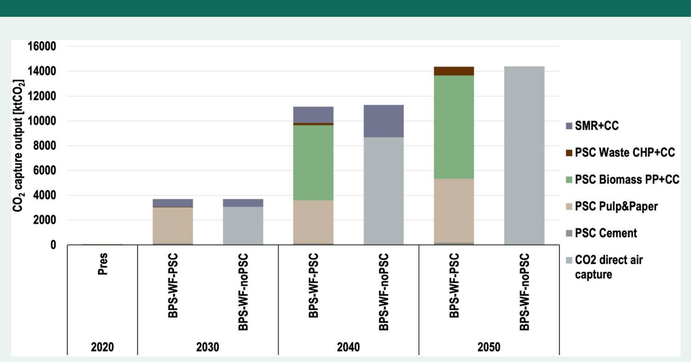

Fig. 3 CO_2 captured for fuel synthesis by source, 2020–2050.

With PSC, almost all CO_2 comes from point sources: 14.6 $MtCO_2$ in 2050 versus 0.6 $ktCO_2$ from DAC.

Biomass plants with capture supply dispatchable power and CO_2 together; pulp & paper mills dominate in 2030.

Same CO_2 demand in both scenarios (fixed e-fuel demand).

Regional effects

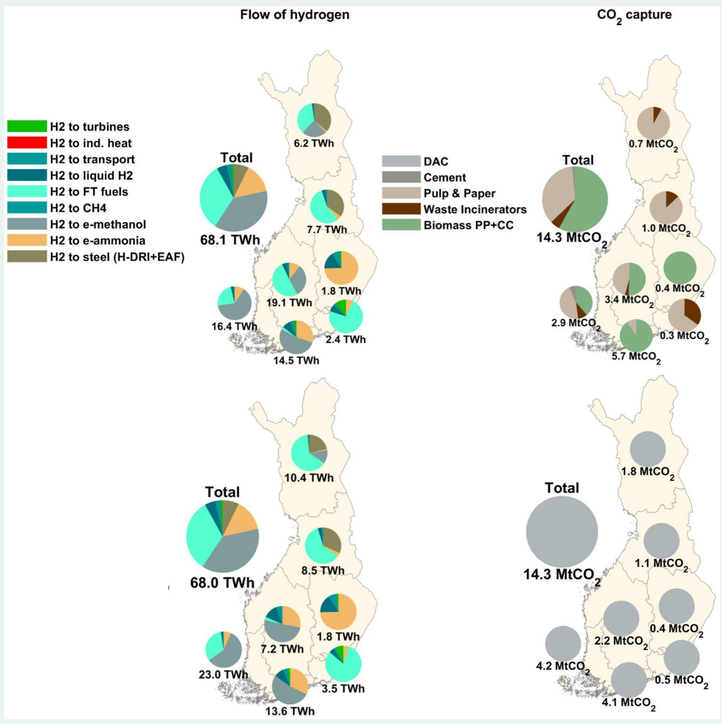

Fig. 5 Hydrogen flows (left) and CO_2 capture (right) by region in 2050: BPS-WF-PSC (top), BPS-WF-noPSC (bottom).

DAC-only: e-fuel plants sit where wind is best, e.g. Southwest Finland.

With PSC: e-FTL and e-methanol shift towards CO_2-rich regions (Centre-West, South), despite higher electricity costs.

Regional planning of CO_2 capture and e-fuel synthesis matters.

Outlook, robustness & limits

Untapped potential: industrial CO_2 potential is 25.0 Mt; only 6.0 Mt (industrial) + 8.3 Mt (biomass PP) are used. The remaining 49.4 $MtCO_2$ could yield 187 TWhth e-methanol or 190 TWhth e-FTL for export.

Energy system: wind + solar PV supply 93% of 109 GWel capacity in 2050; e-ammonia costs ~6% more with PSC.

Sensitivity: +58% DAC cost leaves results unchanged; +4–62% PSC cost lifts DAC to only ~4% of CO_2; system cost rises 0.4–1.0%.

Limits: no CO_2 or H_2 trade between regions, two scenarios, Finland as an isolated system, deterministic.

Barriers: CO_2 transport networks, permitting, and EU rules counting non-biogenic point-source CO_2 only until 2036.

Conclusions

Cost: PSC cuts annual system costs by 2.5% and e-FTL / e-methanol costs by 8–13% versus DAC-only.

Sources: biomass plants with capture and pulp & paper mills are the key CO_2 suppliers.

System: primary energy demand and power and heat generation barely change.

Policy: use PSC early to scale electrolysers and FTL synthesis; plan CO_2 infrastructure and permitting; DAC becomes important later, DACCS in the long term.

More information Q&A:

Zoom:

Teams:

Galimova T., Satymov R., Bogdanov D., Khalili S., Breyer C. (2026). The value of CO_2 point source capture for the energy-industry system transition. Energy 360, 141587. doi:10.1016/j.energy.2026.141587 (open access, CC BY 4.0)
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