CCS potensialet i svensk industri

Filip Johnsson

CCUS webinar #2 2022: "Hva skjer i Sverige"
April 21, 2022

The Swedish CCS context

- Targets on BECCS as a so-called **supplementary measure** for reaching **net-zero** GHG emissions by Year **2045** (and negative emissions thereafter). **EU-ETS** governing fossil emission sources.
- Swedish Energy Agency – National center for CCS

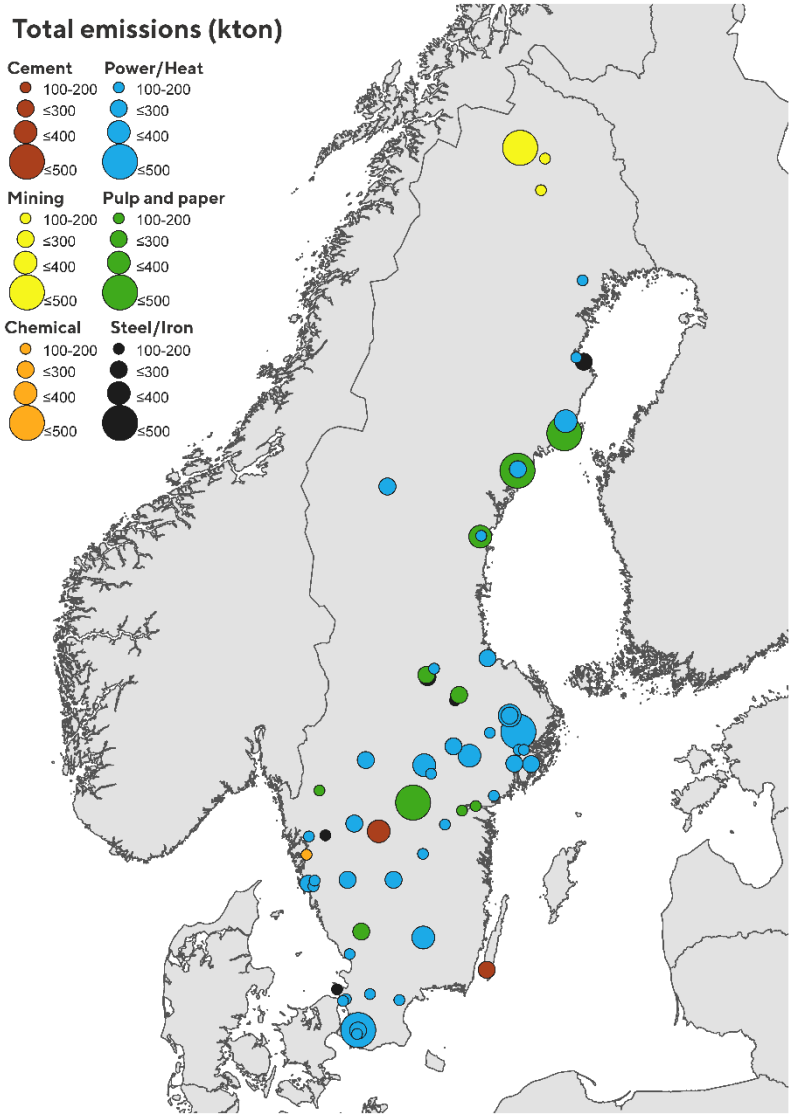
Swedish EPA

Swedish Energy Agency

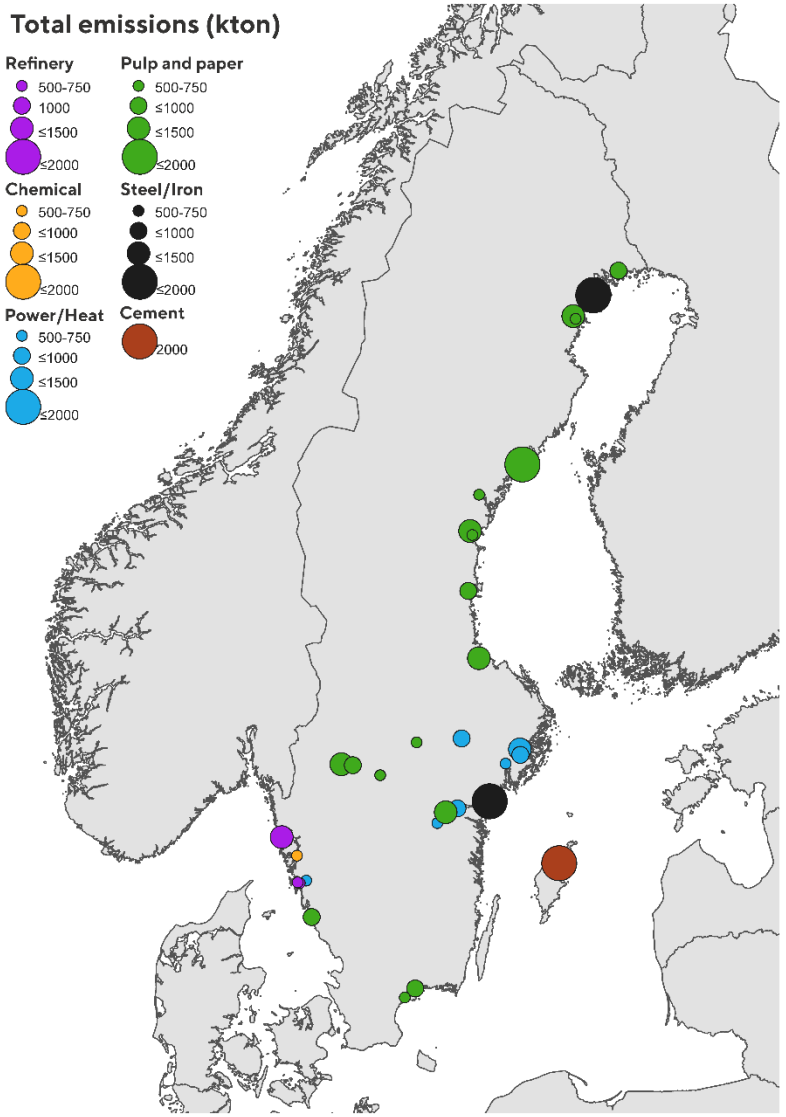
Energimyndigheten

Large point sources of CO_2

100 kt< CO_2 emissions < 500 kt/a



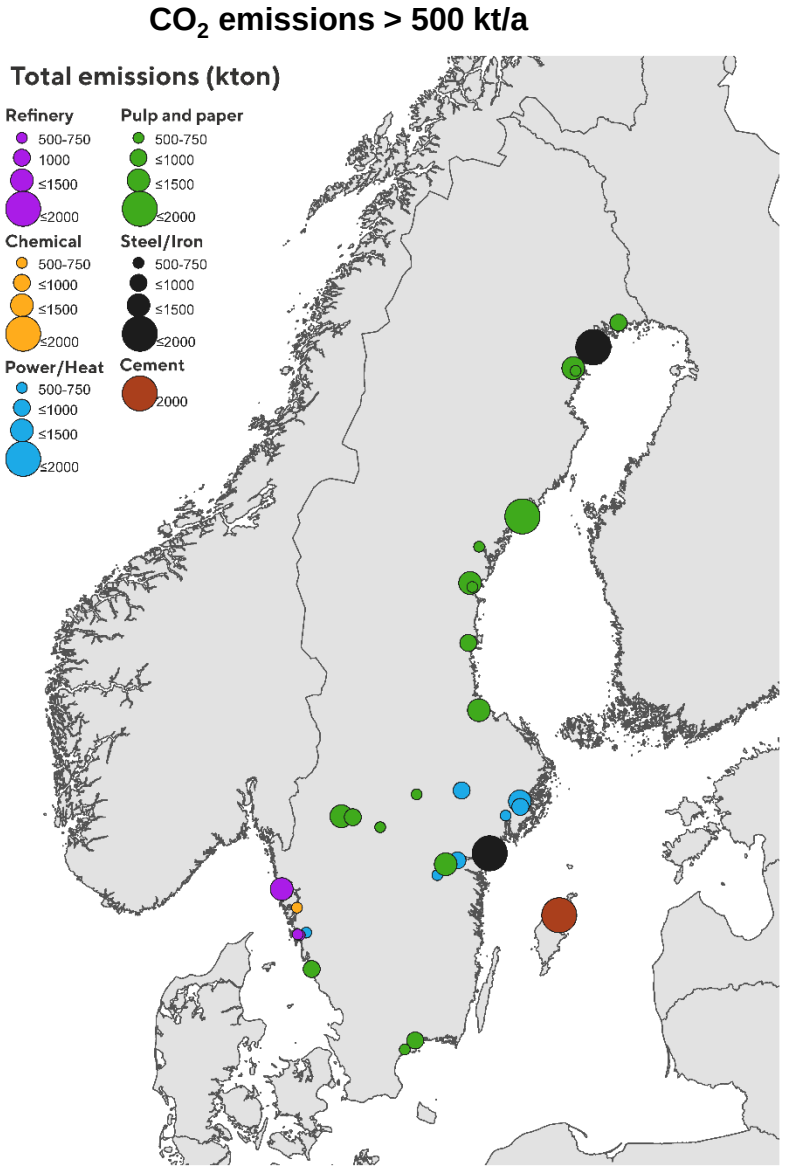
CO_2 emissions > 500 kt/a



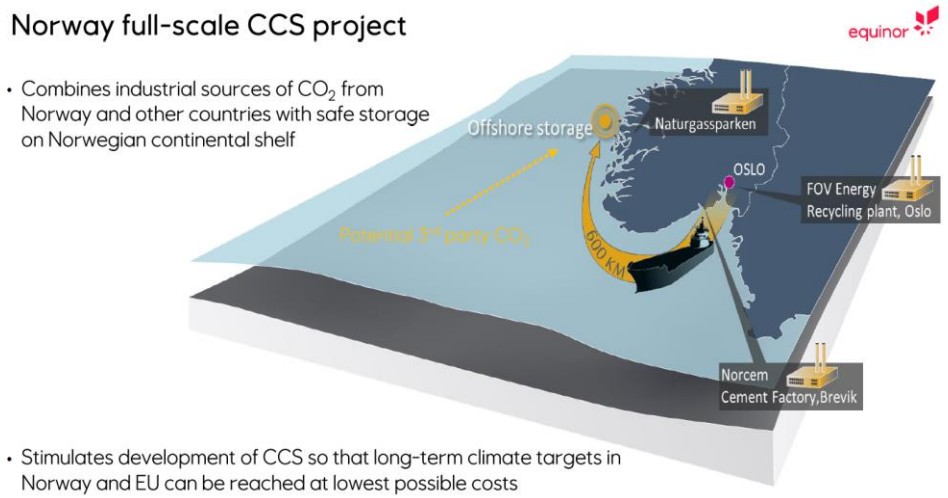
Johnsson & Kjärstad, 2018

Largest point sources of CO_2 > 500 kt/year

Many of the largest emission sources located at or near the coast
⇒ Facilitates transport (by ship)

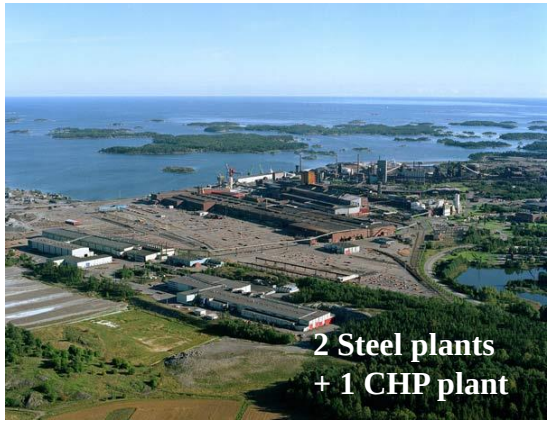


Large storage potential in North Sea



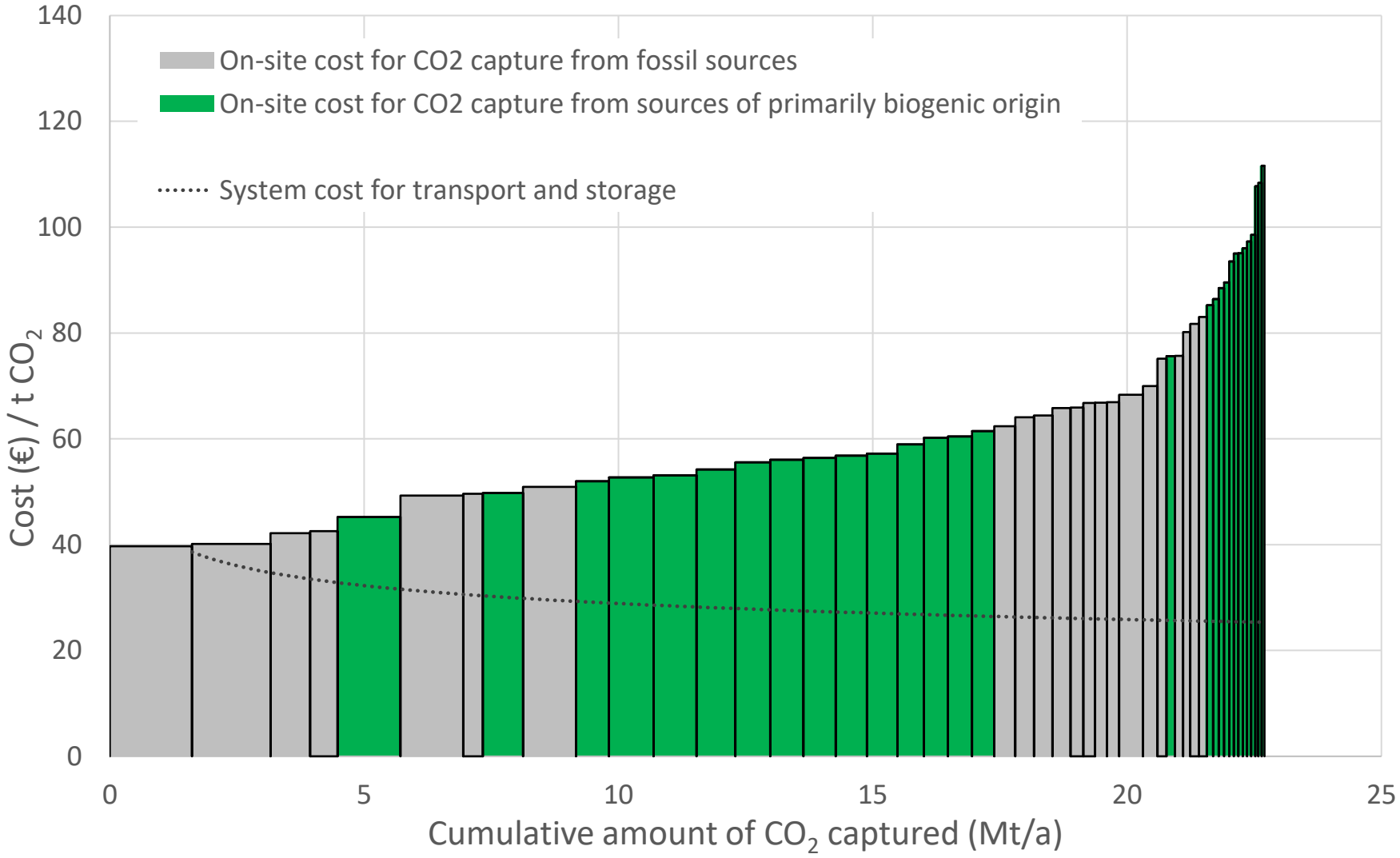
Johnsson & Kjärstad, 2018

CCS – 28 Large industrial point sources of CO_2 (>500 ktCO_2/year) Applying post combustion (MEA)



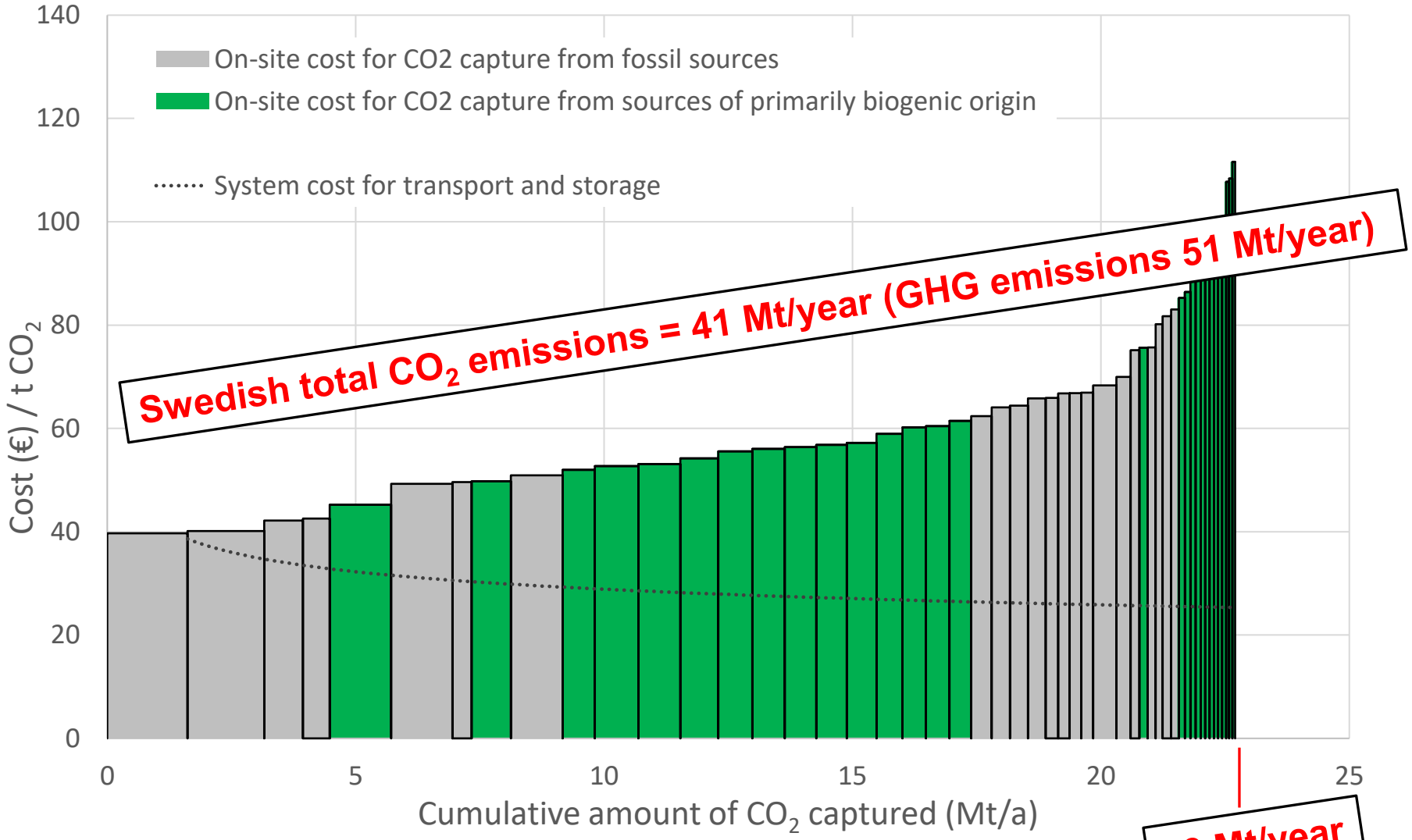
Biogenic and fossil feedstocks and fuels

CCS – 28 Large industrial point sources of CO_2 (>500 ktCO_2/year)



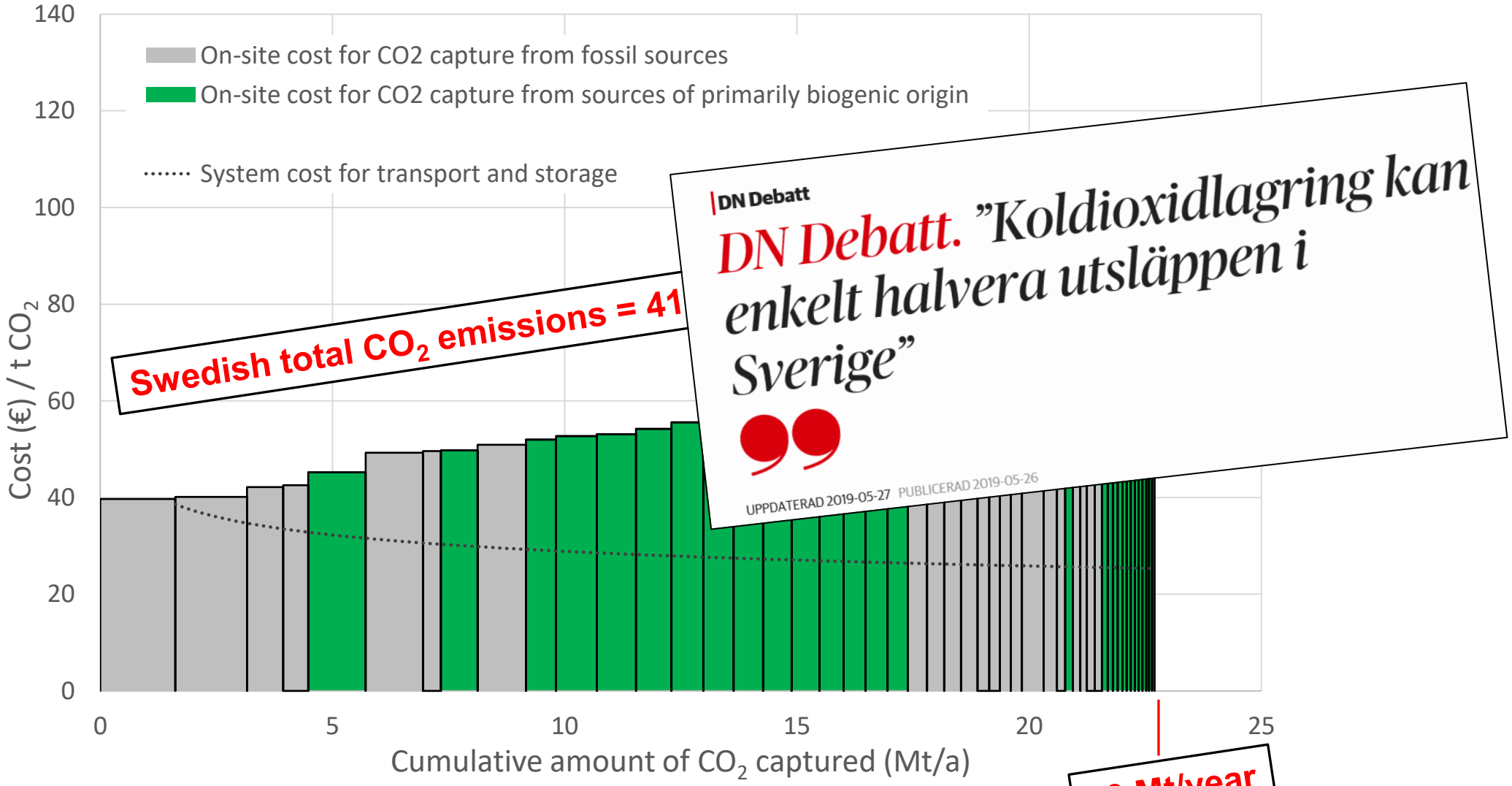
Johnsson, F. Normann, Svensson (2020)

CCS – 28 Large industrial point sources of CO_2 (>500 ktCO_2/year)



Johns[illegible]ormann, Svensson (2020)

CCS – 28 Large industrial point sources of CO_2 (>500 ktCO_2/year)



Johns[illegible]ormann, Svensson (2020)

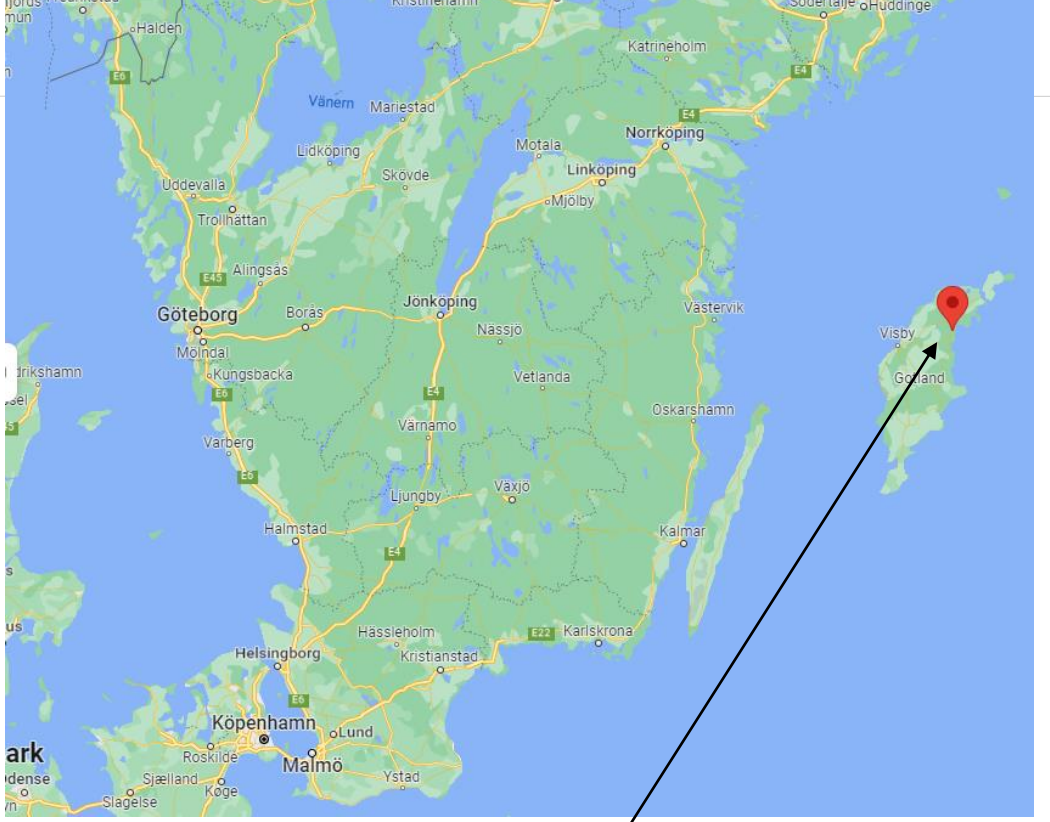
Cementa Slite

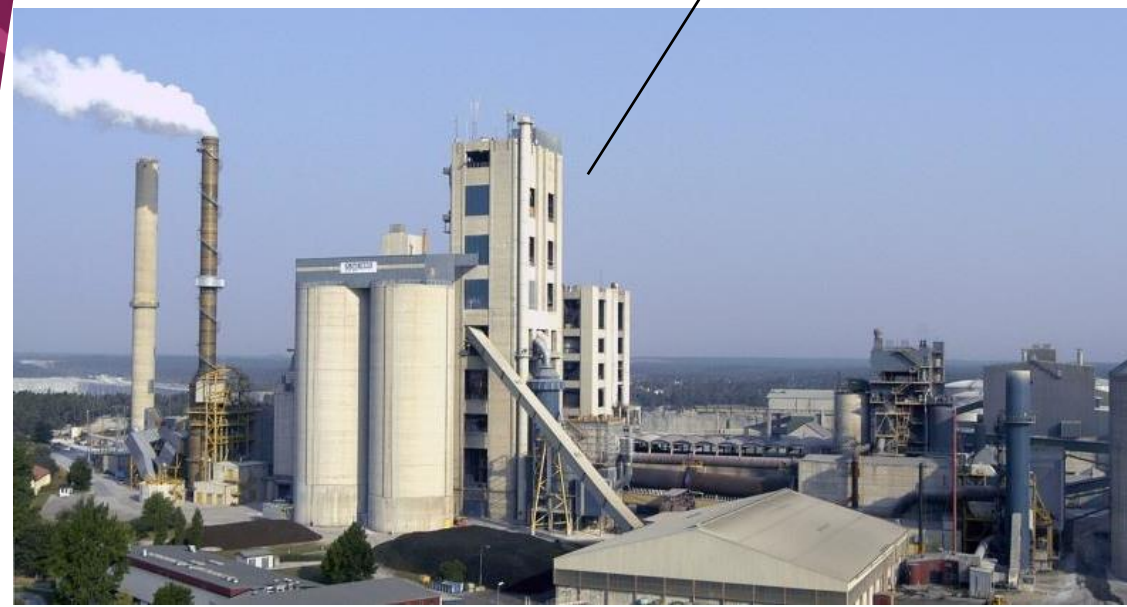
En av Europas största cementfabriker

1,5 Mt fossila CO_2 utsläpp

0,2 Mt biogena utsläpp

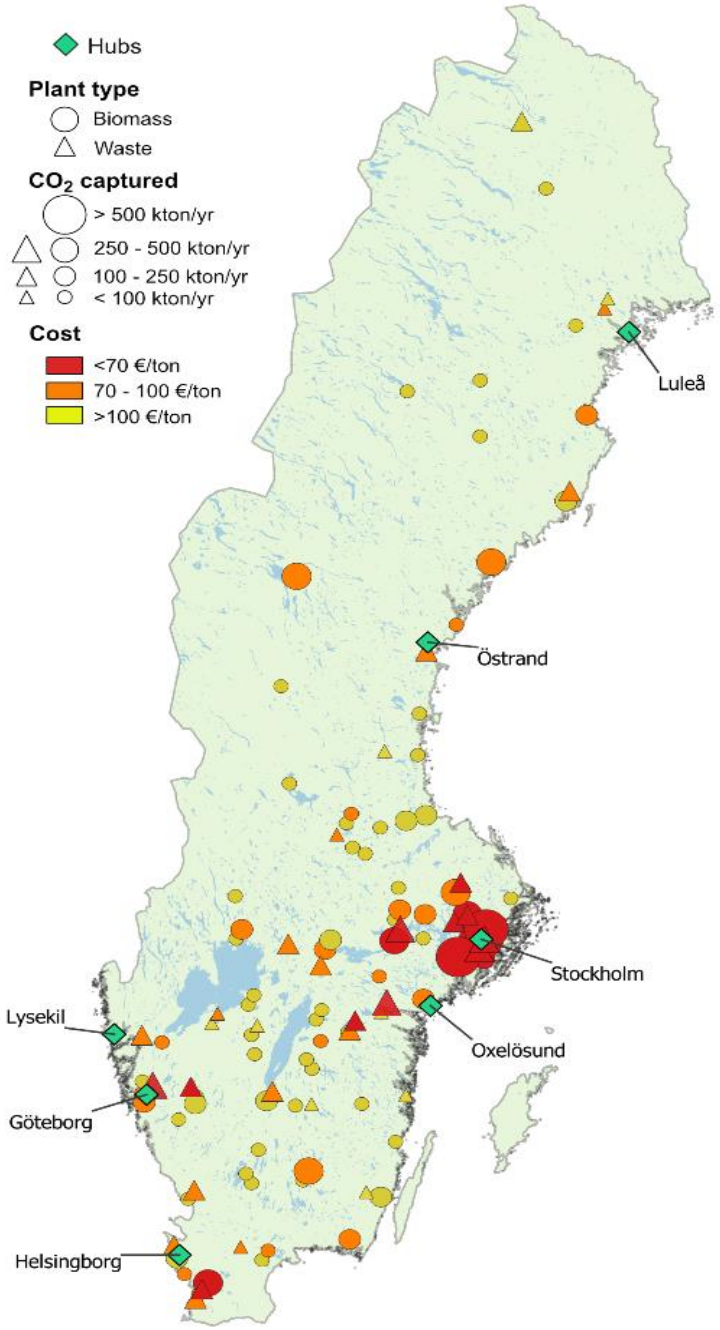
Mål: **Klimatneutralitet**/klimatpositiv **år 2030** med hjälp av CCS



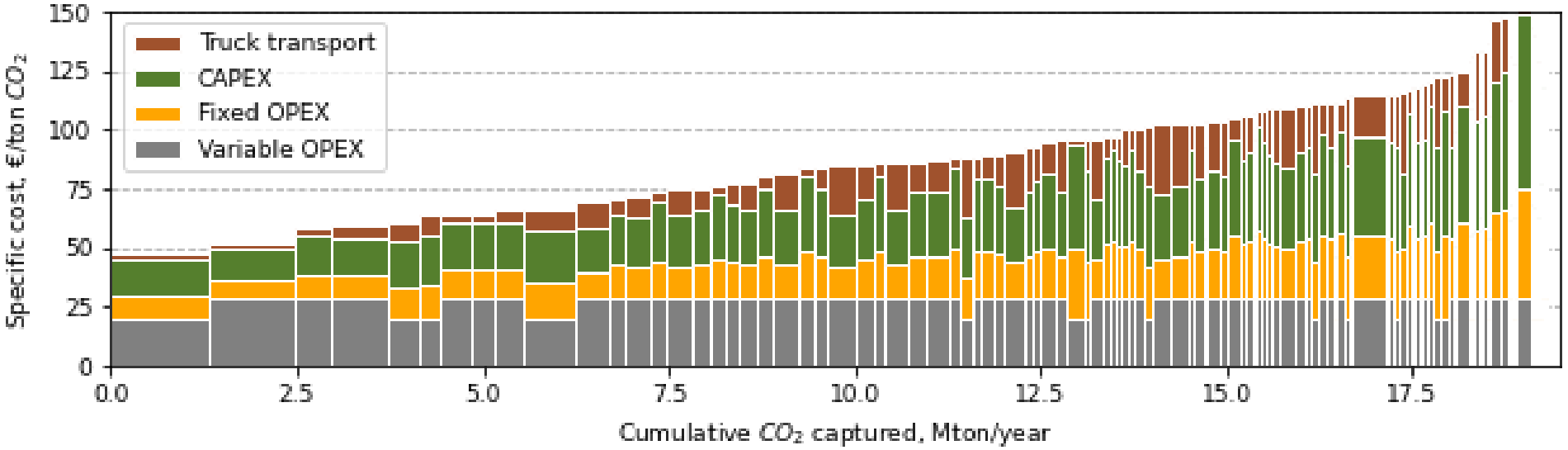


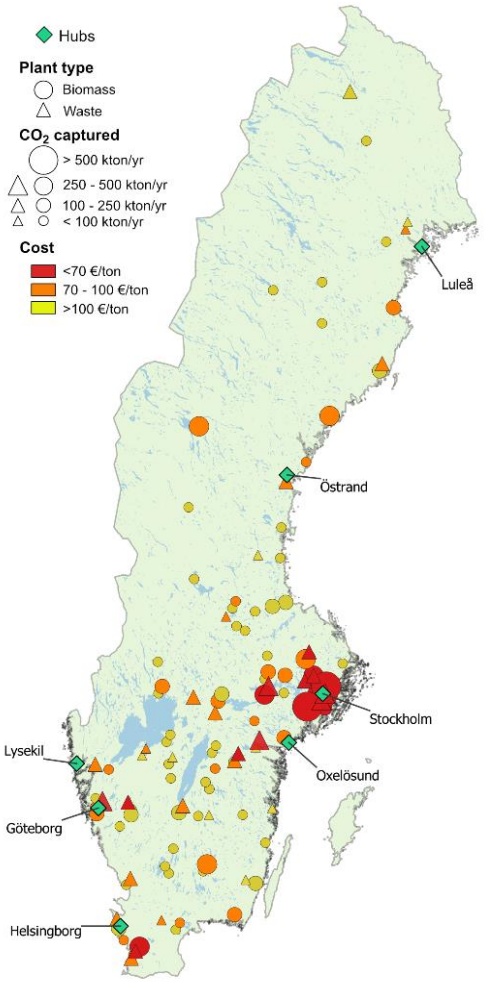
CCS på kraftvärmeverk

Ytterligare minst 10 Mt CO_2/år möjligt att avskilja



CCS on Swedish CHP plants in district heating systems
Mainly biogenic (but a significant fossil share in waste incinerators)



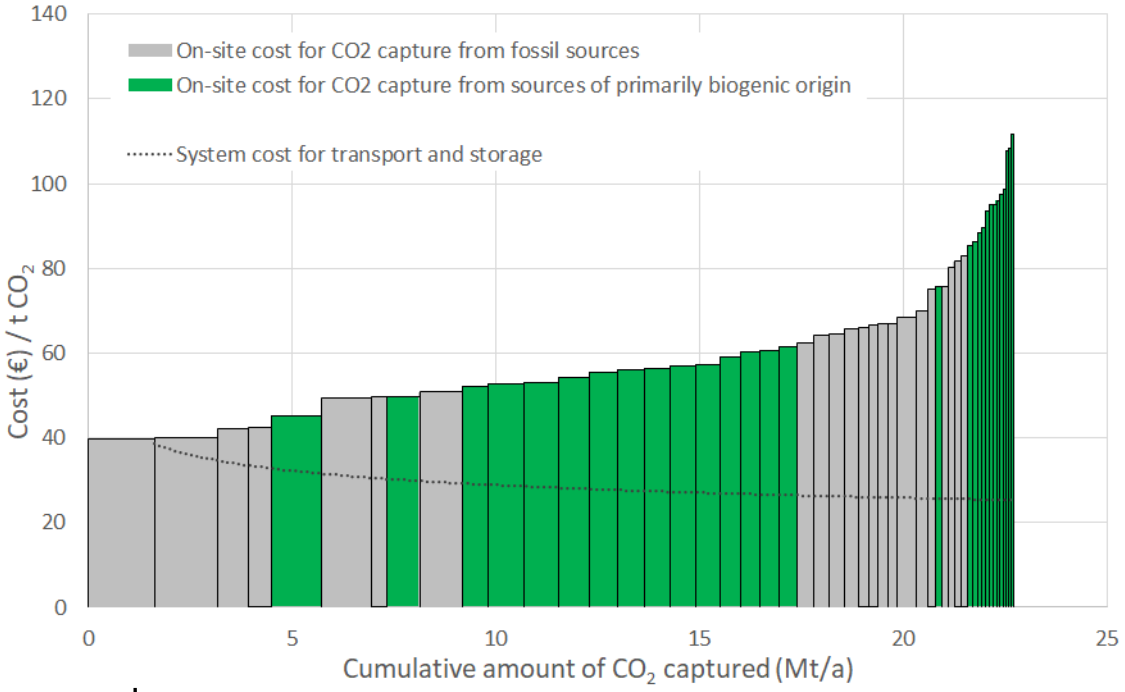


- One bar = one plant
- Carbon capture potential depends on extent of heat recovery from capture plant
- Storage costs not included

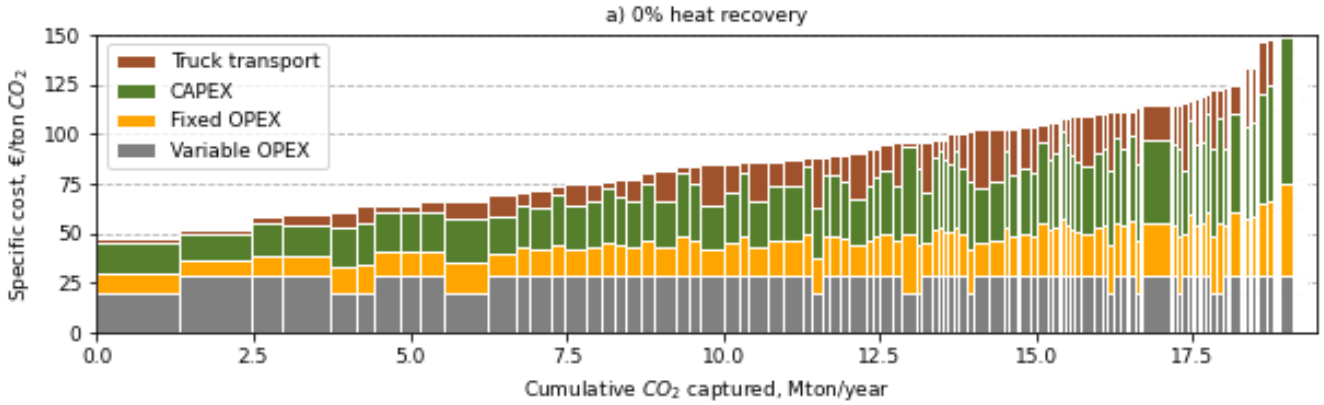
		Capture cost	**Local transport cost**		
CO_2 from plant	Carbon capture, compression & liquefaction	Transport to intermediate storage hub (truck)	Transport to final storage location	Storage

Included in cost estimation

CCS @
28 Large industrial point sources of CO_2 (>500 ktCO_2/year)
+ CHP plants of different sizes



Only transport to harbor included
Cost for transport and storage in North Sea estimated to 30-55 €/ton CO_2

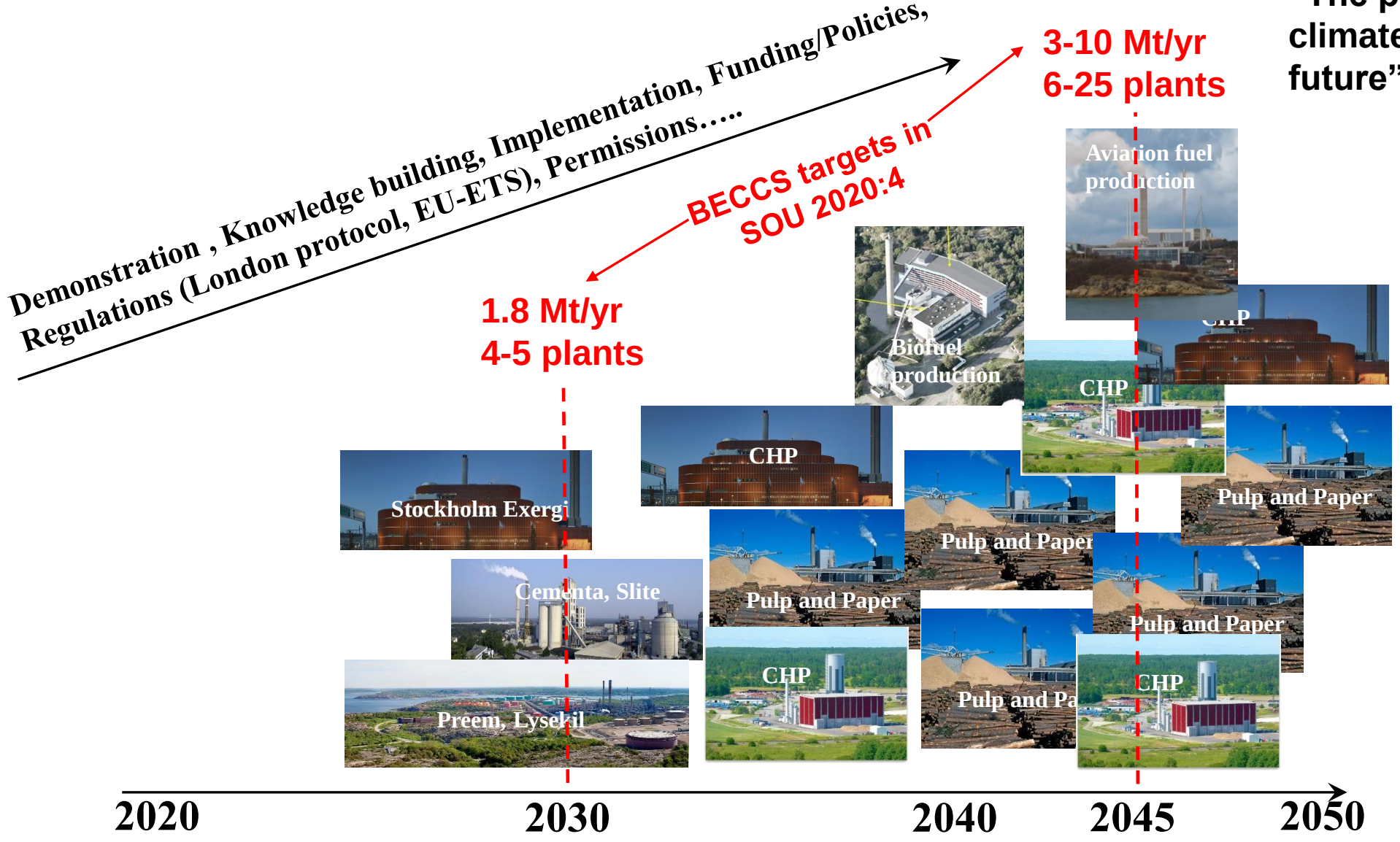


Around 35 Mt/year @ cost < 125 €/ton CO_2

Swedish total CO_2 emissions = 41 Mt/year (GHG emissions 51 Mt/year)

Timeline towards zero and negative emissions efforts must be accelerated

”The pathway to a climate positive future” (SOU 2020:4)



Timeline towards zero and negative emissions efforts must be accelerated

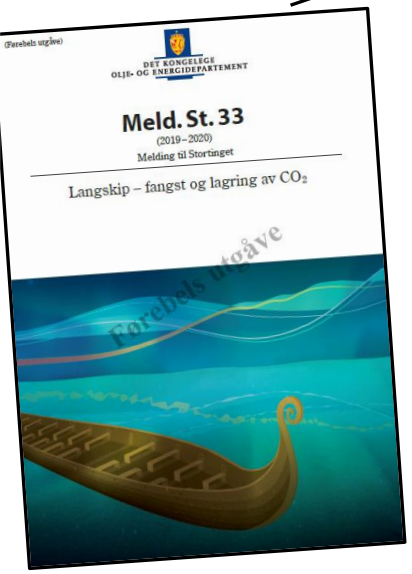
"The pathway to a climate positive future" (SOU 2020:4)

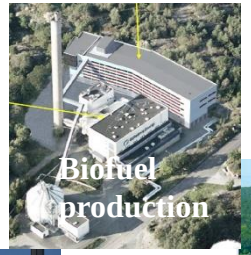
Demonstration , Knowledge building, Implementation, Funding/Policies, Regulations (London protocol, EU-ETS), Permissions…..

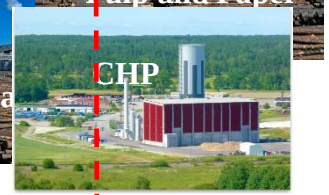
BECCS targets in SOU 2020:4

1.8 Mt/yr
4-5 plants

3-10 Mt/yr
6-25 plants

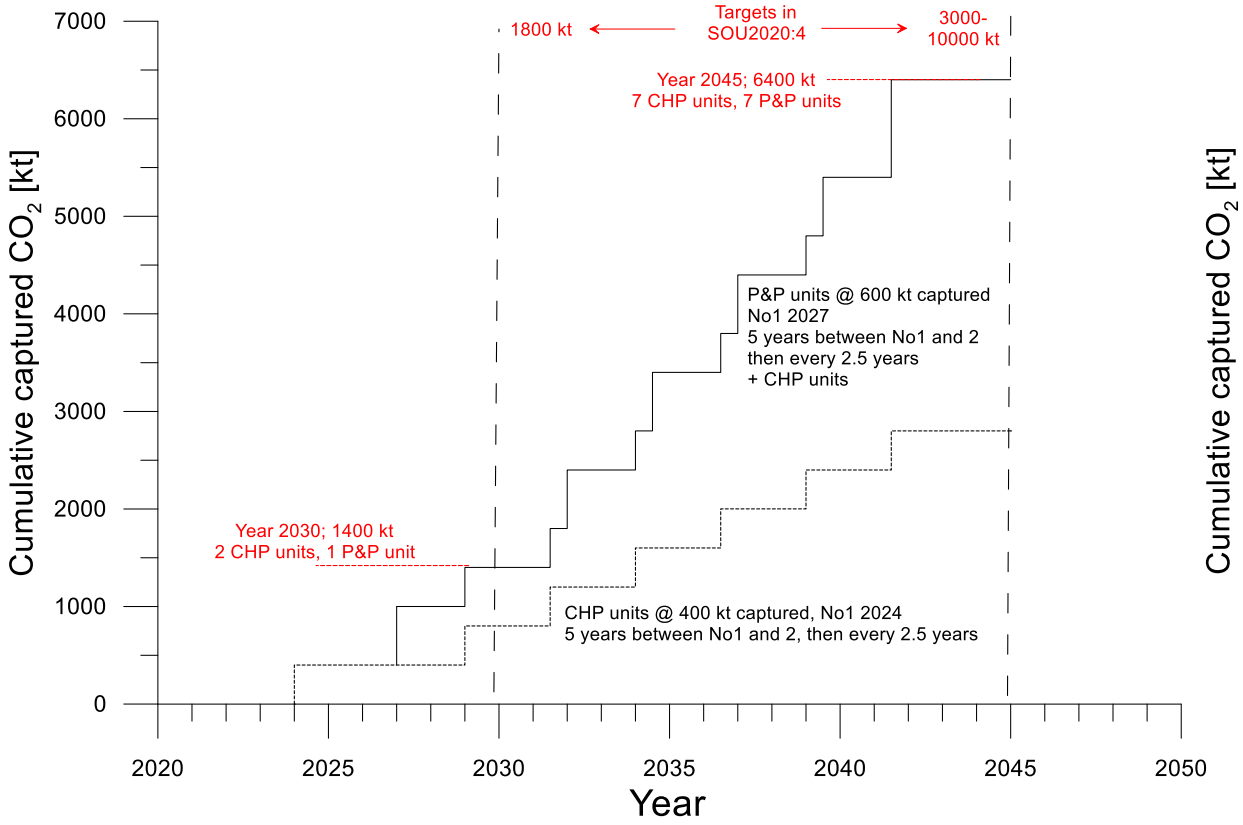


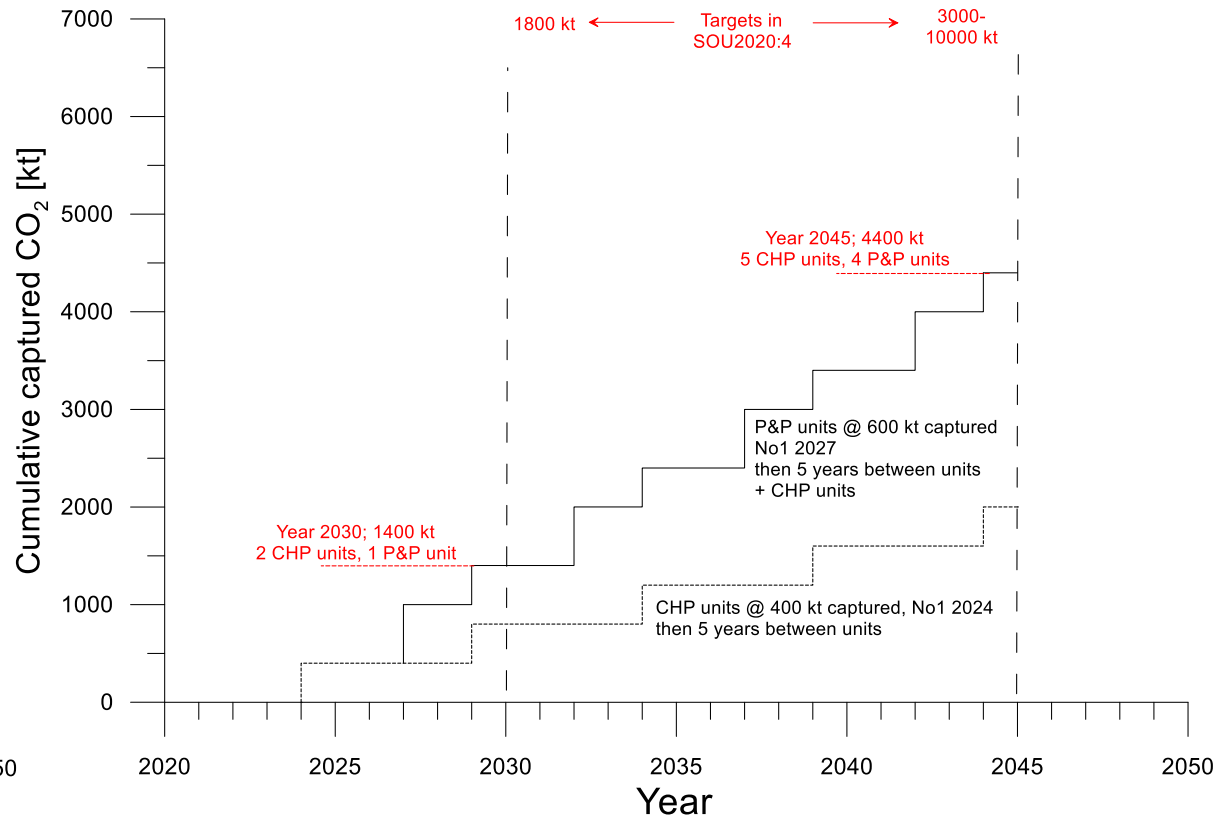




2020 2030 2040 2045 2050

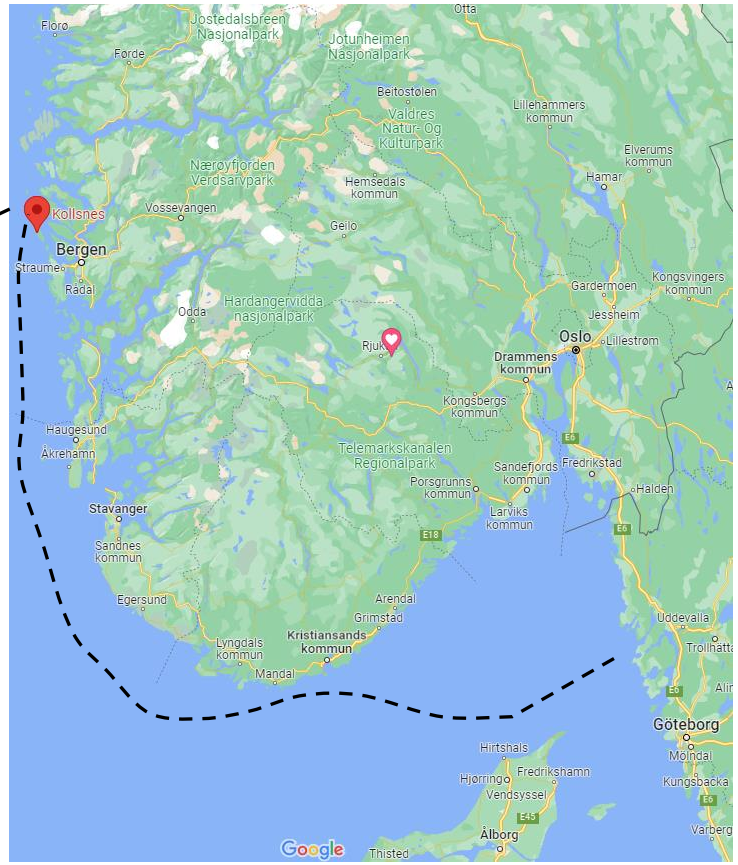
Two schematic BECCS ramp-up scenarios for Sweden

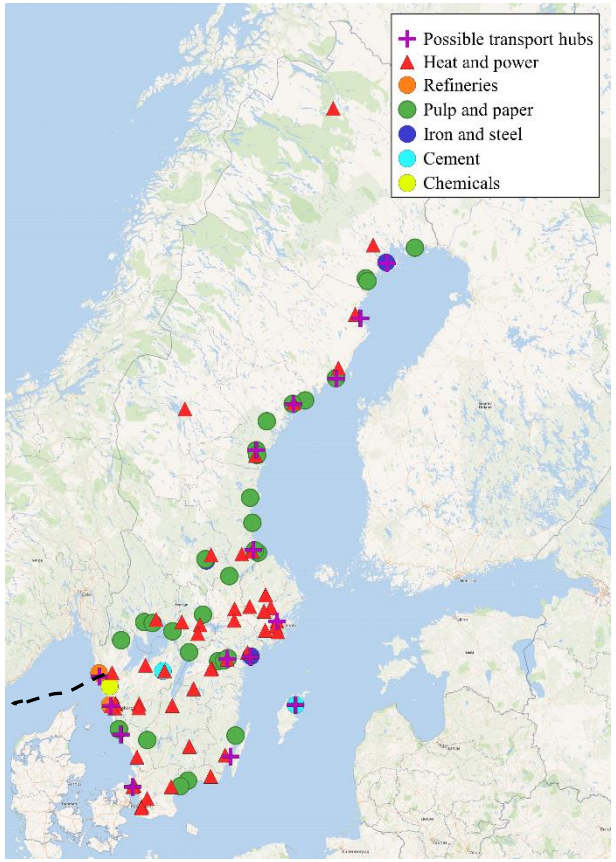




Fuss & Johnsson (2021)

Transport and storage infrastructure – optimization project (part of ZEROC project)



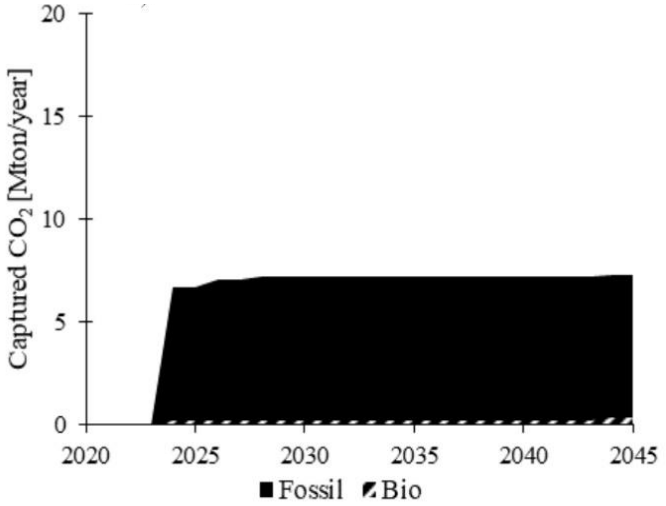


- Optimizing system of:
  - Capture
  - liquefaction
  - truck transport to hub
  - ship transport (to Kollsnes)
- Emission sources > 100 kt/year

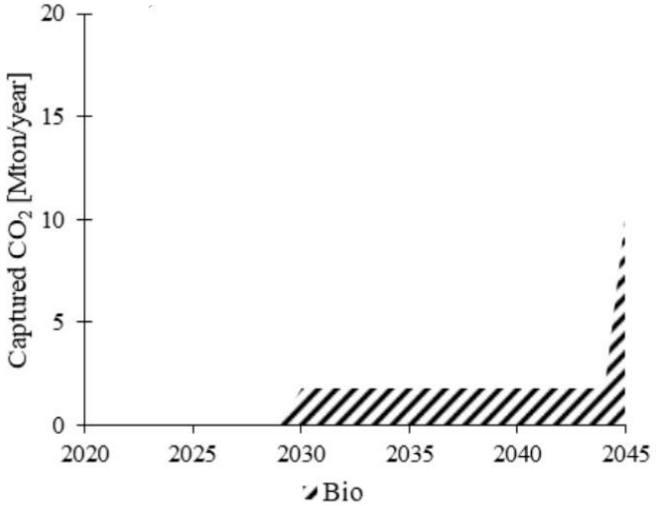
(Work in progress)

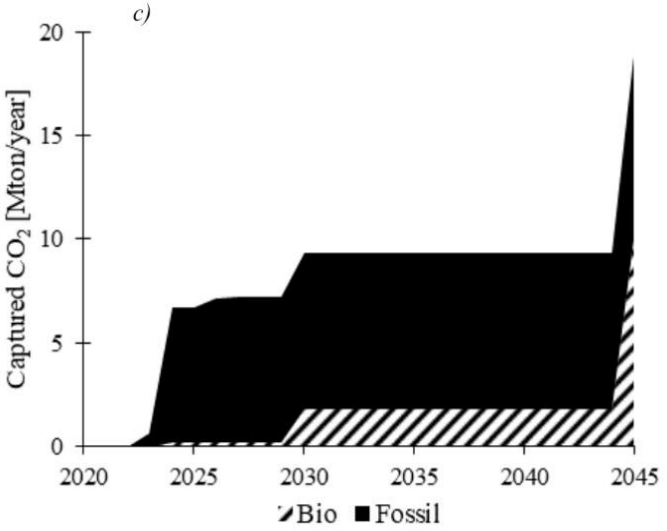
Transport and storage infrastructure – optimization project (part of ZEROC project – work in progress)

a) Fossil – EU-ETS prices ramped up according to IEA WEO (net zero by 2050)

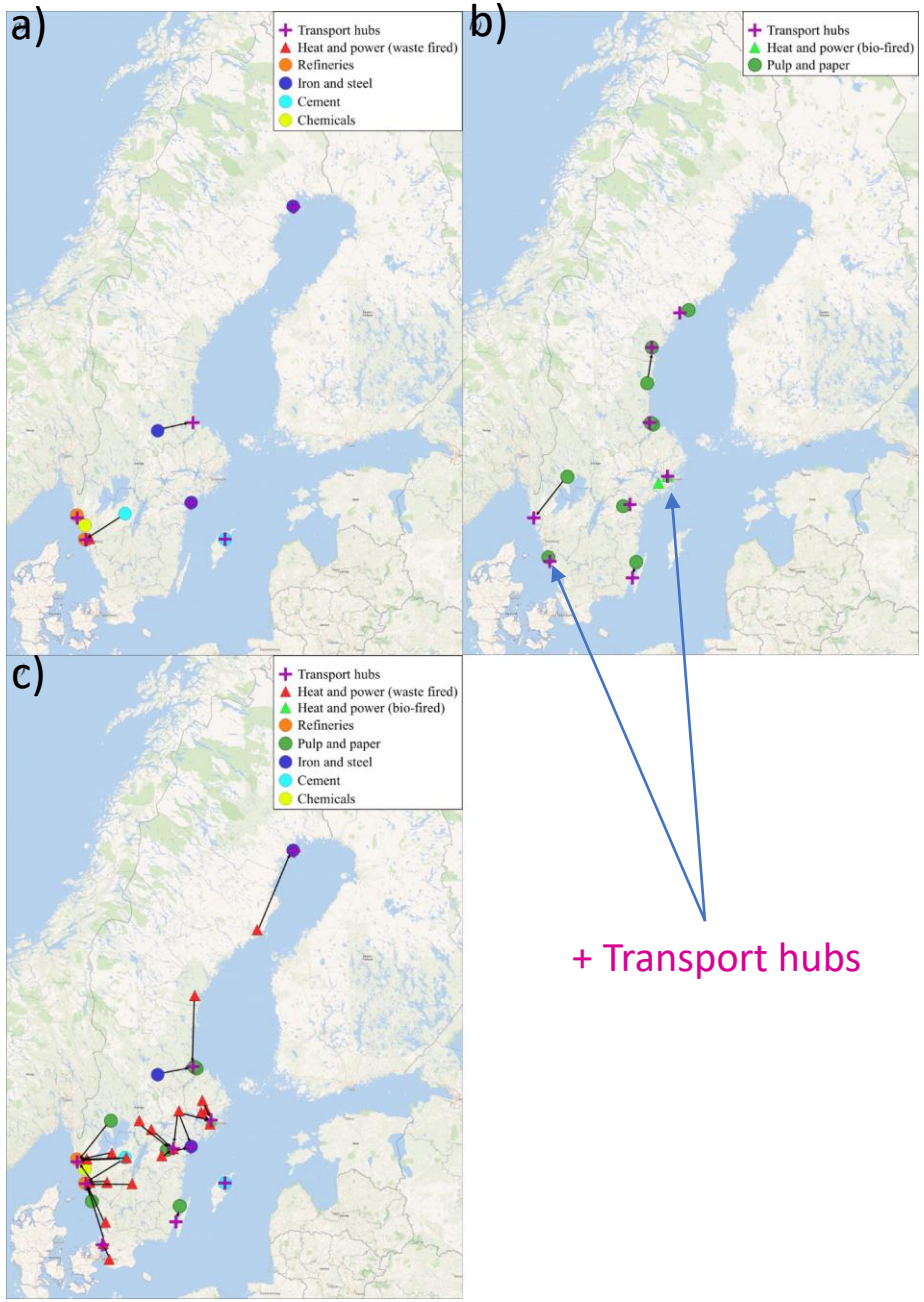


b) Biogenic – Swedish targets 1.8 Mt/yr 2030 & 10 Mt/yr 2045





c) Biogenic & fossil as above, combined



In summary

- **Large potential** for CCS and BECCS in Sweden (“CDR forerunner”)
- Generally **favorable conditions** (coastal locations, large point sources of fossil and biogenic emissions, “access” to Norwegian storage infrastructure)
- Seems to be **broad consensus** on prospects of BECCS and CCS (with proposed targets on BECCS to 2030 and 2045)
- The **challenge is financing** – EU-ETS and to incentive negative emissions – Swedish state as buyer (through **reversed auctioning system** = governmental guarantee).

Mistra Carbon Exit

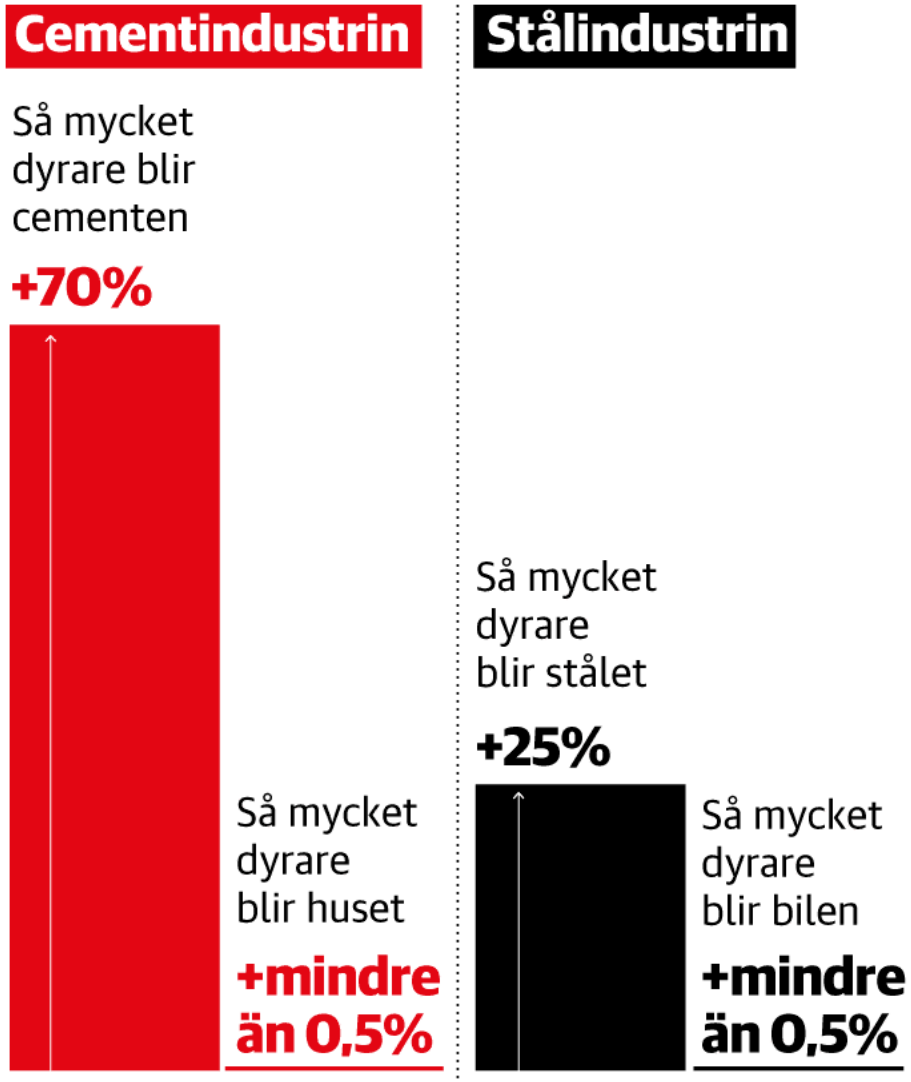
DN DEBATT

DN Debatt. ”Billigt för konsumenterna att klimatanpassa industrin”

UPPDATERAD 2022-01-03 PUBLICERAD 2022-01-02

https://www.dn.se/debatt/billigt-for-konsumenterna-att-klimatanpassa-industrin/

Höga kostnader för producenter, låga för konsumenter



Rootzén and Johnsson
Energy Policy 98 (2016) 459–469
Climate Policy 17, 6, (2017) 781-800
See also (in Swedish)
http://www.dn.se/debatt/plan-saknas-for-att-minska-basindustrins-klimatpaverkan/

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- **Large potential** for CCS and BECCS in Sweden ("CDR forerunner")
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- Seems to be **broad consensus** on prospects of BECCS and CCS (with proposed targets on BECCS to 2030 and 2045)
- The **challenge is financing** – EU-ETS and to incentive negative emissions – Swedish state as buyer (through **reversed auctioning system** = governmental guarantee).
- CCS part of an **overall mitigation portfolio** – (*cf.* roadmaps developed by the Building and Construction sector within Fossil Free Sweden initiative)
- **Not obvious** that **CCS** is always **preferable** – CCS can be used in cases where energy from oxidation of C is the cheapest way of covering process energy. Alternatives to carbon source should always be investigated (e.g. hydrogen based steel).

Projects

- **Mistra Carbon Exit** project assesses roadmaps towards climate neutrality for Building and Construction industry https://www.mistracarbonexit.com/
- **CCS in the district heating sector** https://energiforsk.se/program/bio-ccs-i-fjarrvarmesektorn/ (in Swedish)
- **ACCSESS** Providing access to cost-efficient, replicable, safe and flexible CCUS https://cordis.europa.eu/project/id/101022487
- **ZEROC** –Transition to a zero-carbon industry in Norway and Sweden https://www.sintef.no/en/projects/2019/zeroc-transition-to-a-zero-carbon-industry-in-norway-and-sweden-process-solutions-and-supporting-infrastructure/
- **FUTNERC** - Transformative change towards net negative emissions in Swedish refinery and petrochemical industries
- **Fossil Free Sweden** initiative - National initiative to make Sweden the first fossil-free welfare nation in the world https://fossilfrittsverige.se/en/start-english/

Some publications

- Zetterberg, L., Johnsson, F. Möllersten, K., Incentivizing BECCS—A Swedish Case Study (2021) *Frontiers in Climate*, 3:685227. DOI: 10.3389/fclim.2021.685227
- Fuss, S., Johnsson, F. The BECCS Implementation Gap–A Swedish Case Study (2021) *Frontiers in Energy Research*, 8, art. no. 553400 DOI: 10.3389/fenrg.2020.553400
- Johnsson, F., Normann, F., Svensson, E. Marginal Abatement Cost Curve of Industrial CO2 Capture and Storage – A Swedish Case Study (2020) *Frontiers in Energy Research*, 8, art. no. 175, DOI: 10.3389/fenrg.2020.00175
- Garðarsdóttir, S.Ó., Normann, F., Skagestad, R., Johnsson, F. Investment costs and CO2 reduction potential of carbon capture from industrial plants – A Swedish case study (2018) *International Journal of Greenhouse Gas Control*, 76, pp. 111-124.
- Rootzén, J., Johnsson, F. Managing the costs of CO2 abatement in the cement industry (2017) *Climate Policy*, 17 (6), pp. 781-800.
- Rootzén, J., Johnsson, F. Paying the full price of steel – Perspectives on the cost of reducing carbon dioxide emissions from the steel industry (2016) *Energy Policy*, 98, pp. 459-469.
- Beiron, J., Normann, F., Johnsson, F., "A techno-economic assessment of CO2 capture in biomass and waste fired combined heat and power plants - A Swedish case study", submitted for journal publication
- Biermann, M., Ali, H., Sundqvist, M., Larsson, M., Normann, F., Johnsson, F. Excess heat-driven carbon capture at an integrated steel mill – Considerations for capture cost optimization (2019) *International Journal of Greenhouse Gas Control*, 91, art. no. 102833, DOI: 10.1016/j.ijggc.2019.102833
- Martinez Castilla, G., Biermann, M., Montañés, R.M., Normann, F., Johnsson, F. Integrating carbon capture into an industrial combined-heat-and-power plant: performance with hourly and seasonal load changes (2019) *International Journal of Greenhouse Gas Control*, 82, pp. 192-203. DOI: 10.1016/j.ijggc.2019.01.015
- Biermann, M., Normann, F., Johnsson, F., Skagestad, R. Partial Carbon Capture by Absorption Cycle for Reduced Specific Capture Cost (2018) *Industrial and Engineering Chemistry Research*, 57 (45), pp. 15411-15422. DOI: 10.1021/acs.iecr.8b02074
- "Partial capture from refineries through utilization of existing site energy systems", Proc. 15th Greenhouse Gas Control Technologies Conference, 2021 http://dx.doi.org/10.2139/ssrn.3820101
- Biermann, M. et al. (2022) 'The role of energy supply in abatement cost curves for CO2 capture from process industry – a case study of a Swedish refinery', Submitted for publication..