



CHALMERS
UNIVERSITY OF TECHNOLOGY

Carbon Capture and Storage from fossil (CCS) and biogenic (BECCS) feedstocks and fuels

Filip Johnsson

Department of Space, Earth and Environment

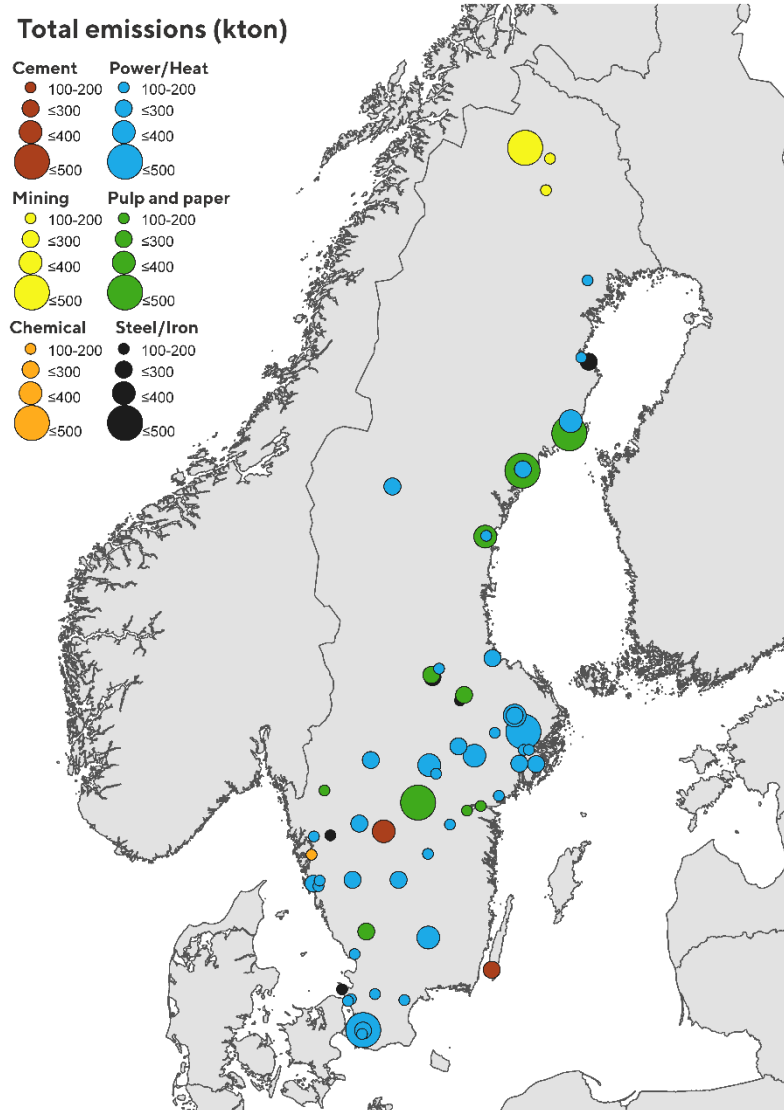
Chalmers University of Technology, S412 96 Göteborg, Sweden

BALTIC CARBON FORUM 2021

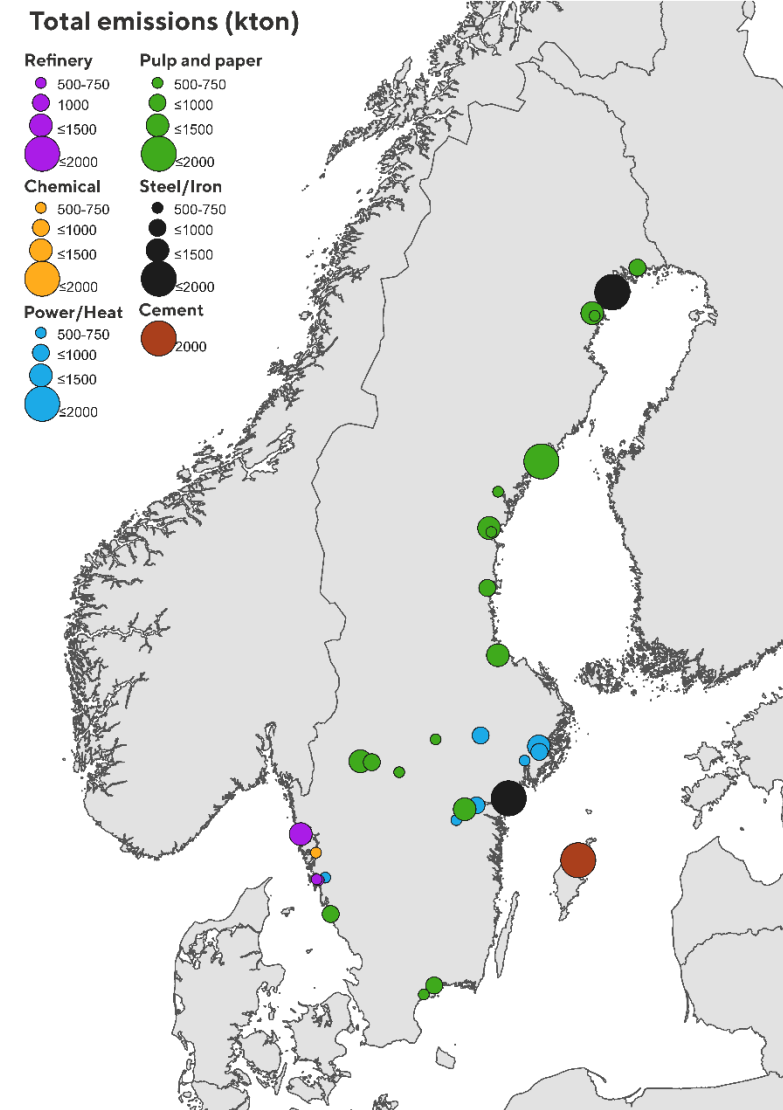
October 15, 2021

Large point sources of CO₂

100 kt < CO₂ emissions < 500 kt/a



CO₂ emissions > 500 kt/a



Large point sources of CO₂ > 500 kt/year

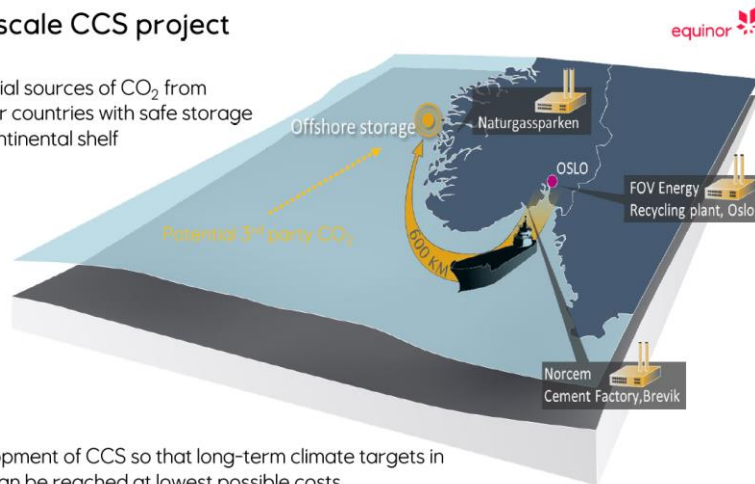
Many of the largest emission sources located at or near the coast

⇒ Facilitates transport (by ship)

Large storage potential in North Sea

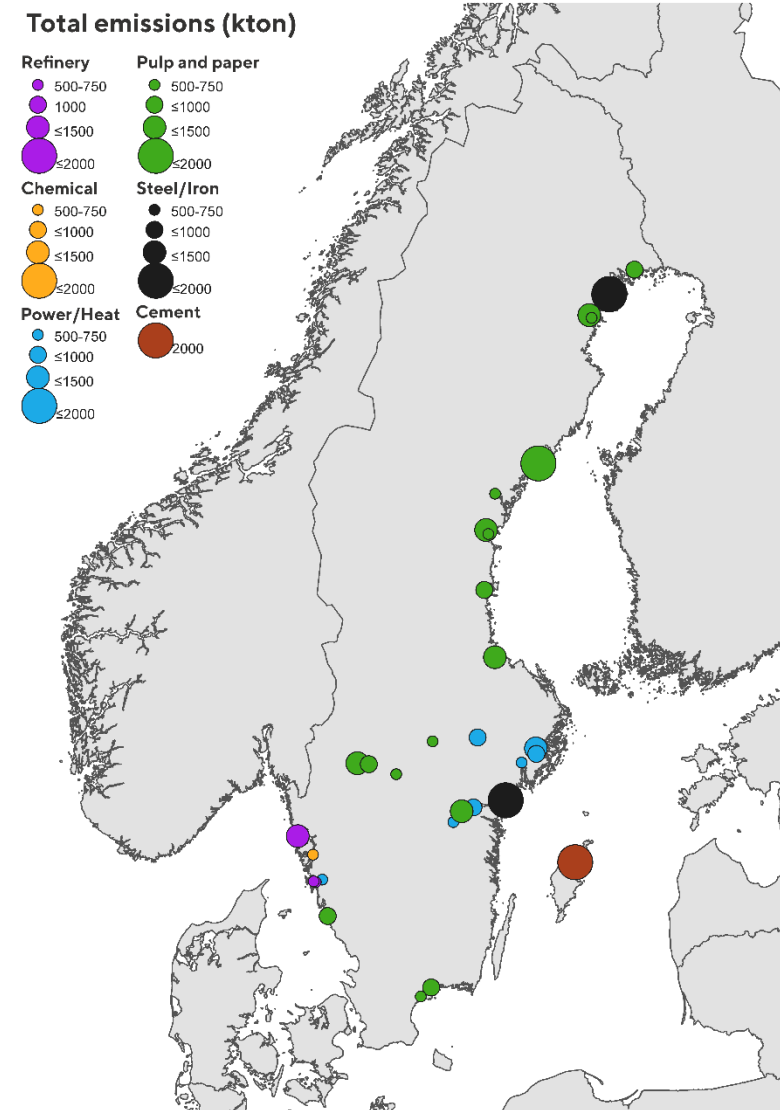
Norway full-scale CCS project

- Combines industrial sources of CO₂ from Norway and other countries with safe storage on Norwegian continental shelf



- Stimulates development of CCS so that long-term climate targets in Norway and EU can be reached at lowest possible costs

CO₂ emissions > 500 kt/a



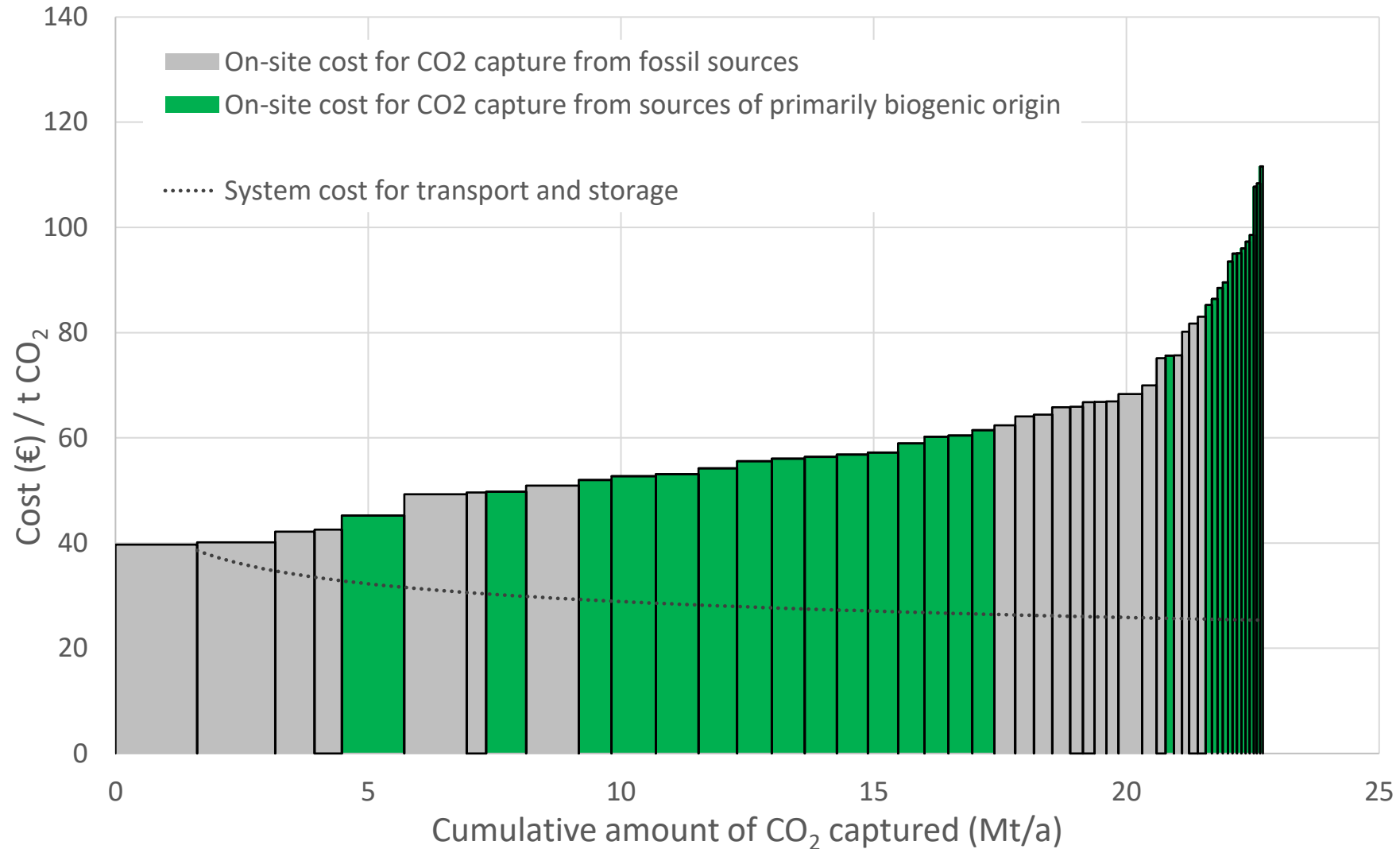
CCS – 28 Large **industrial** point sources of CO₂ (>500 ktCO₂/year) Applying post combustion (MEA)



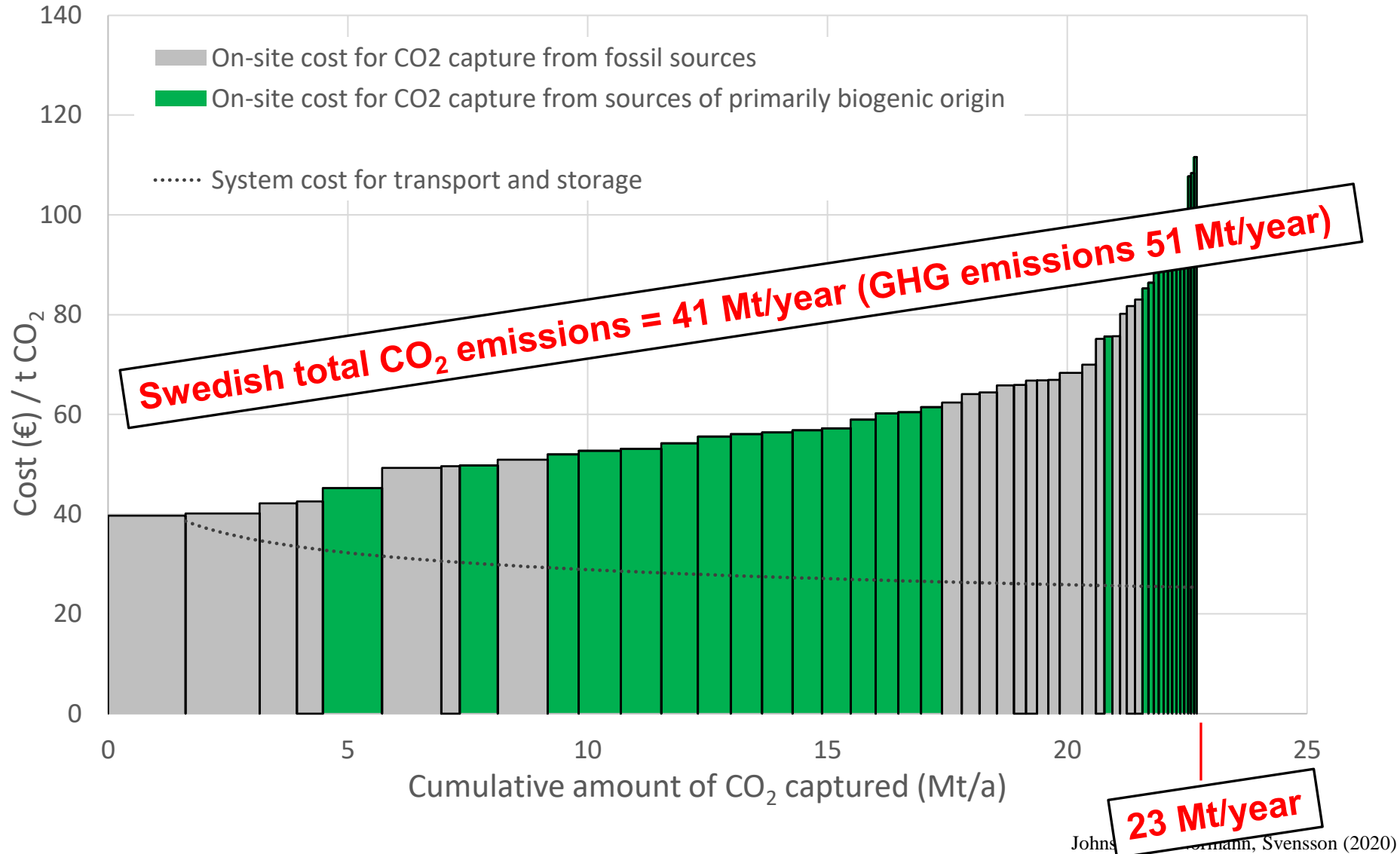
Biogenic and fossil
feedstocks and fuels



CCS – 28 Large industrial point sources of CO₂ (>500 ktCO₂/year)

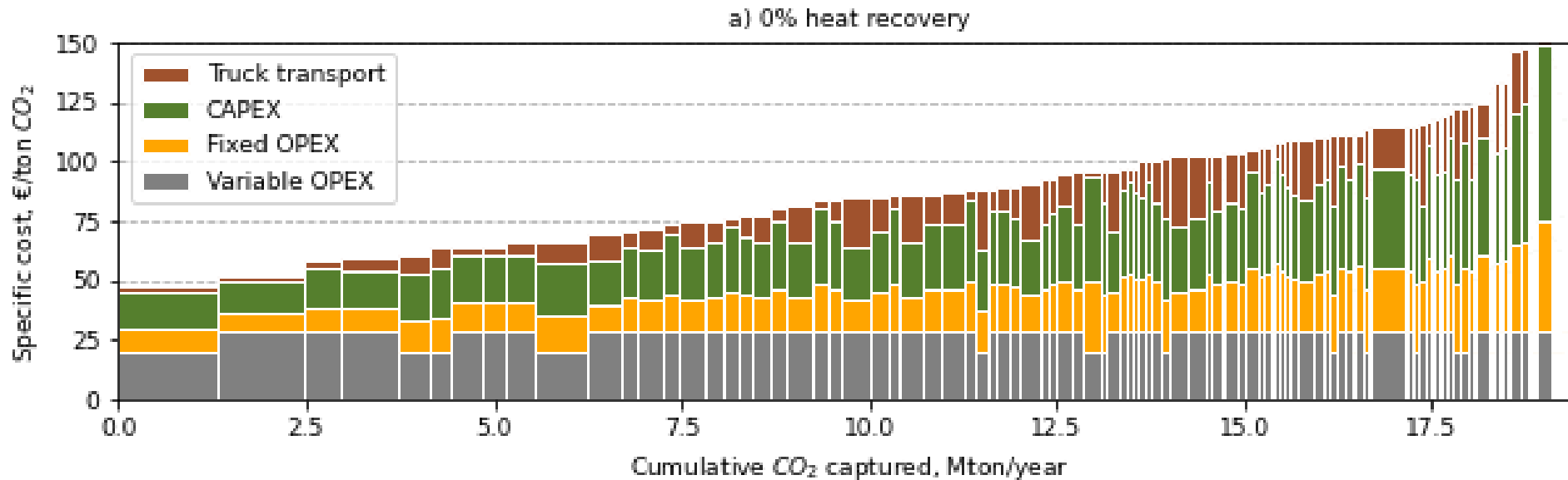


CCS – 28 Large industrial point sources of CO₂ (>500 ktCO₂/year)

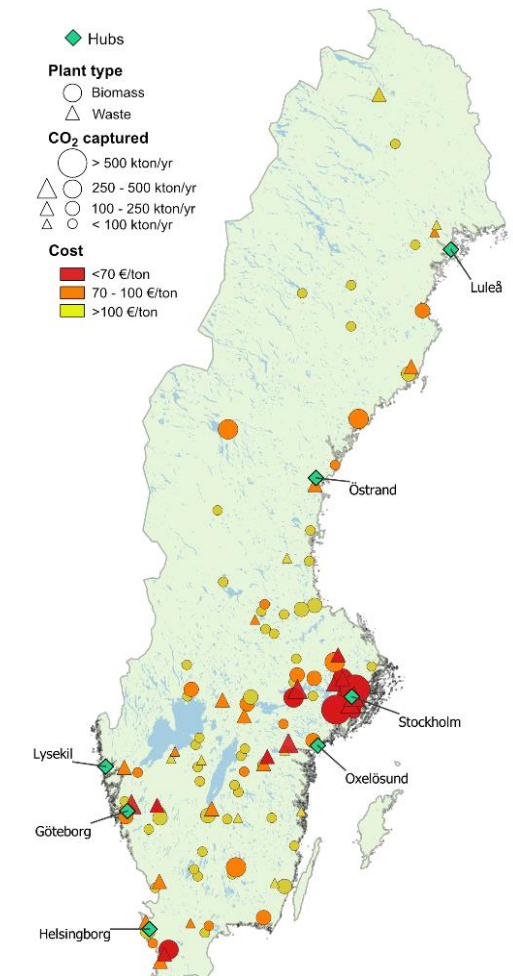
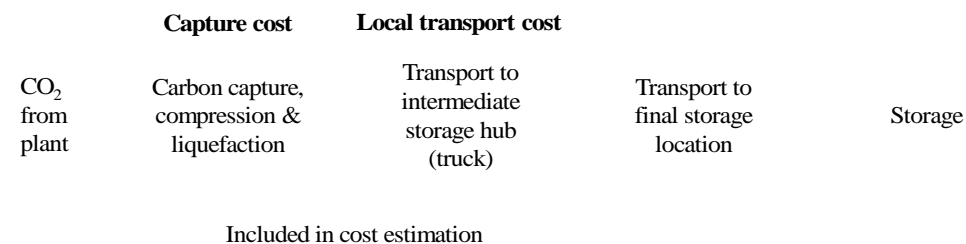


CCS on Swedish CHP plants in district heating systems

Mainly biogenic (but a significant fossil share in waste incinerators)

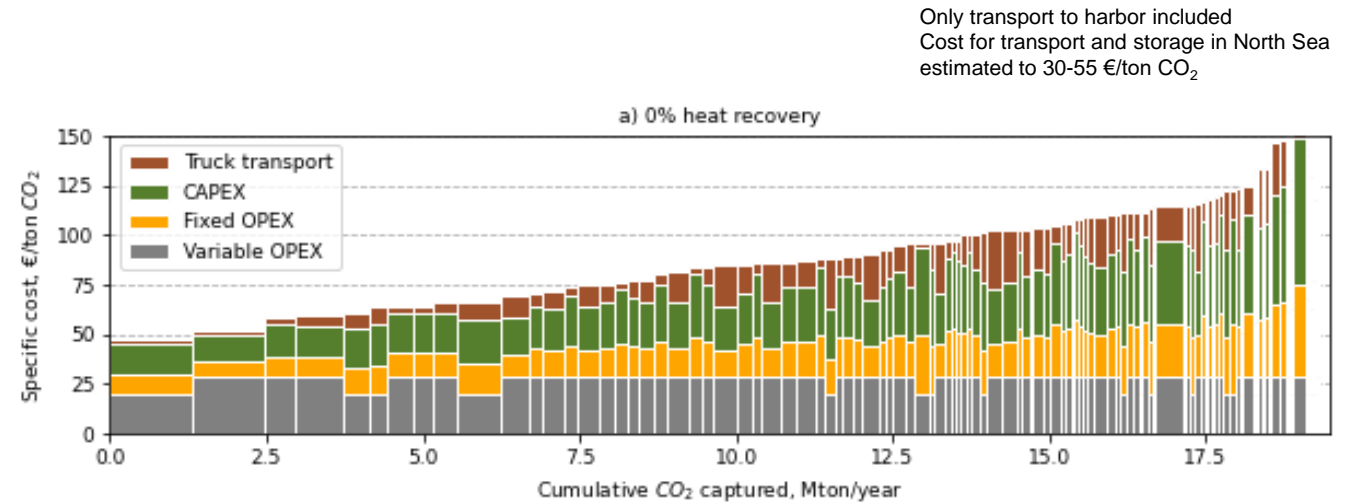
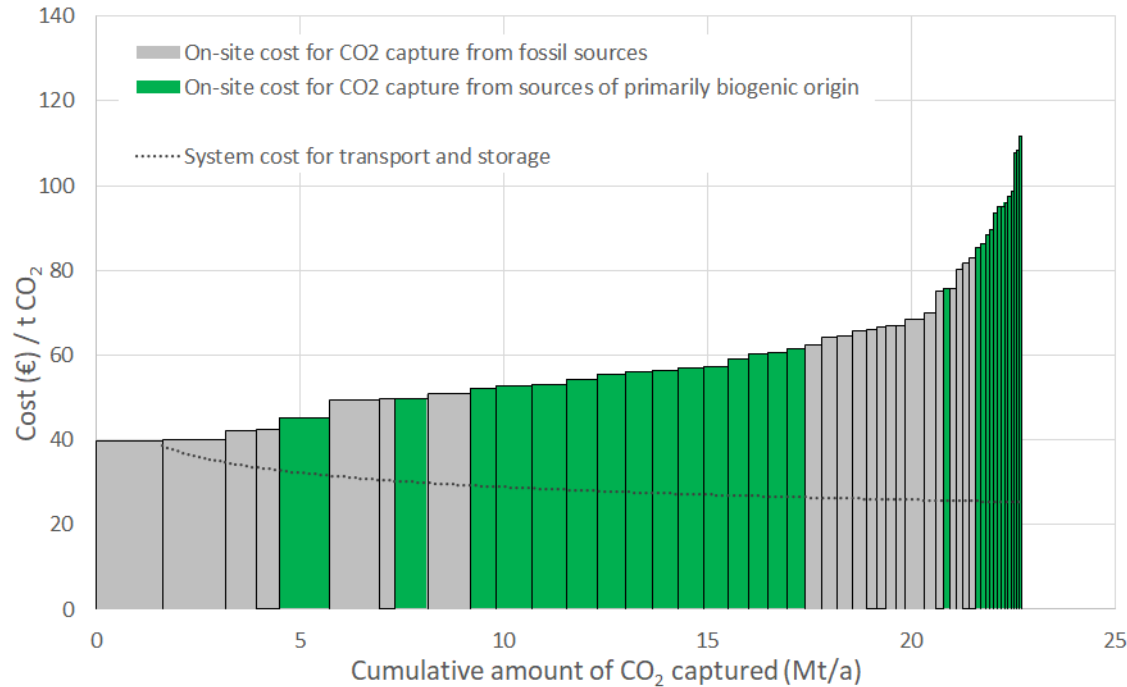


- One bar = one plant
- Carbon capture potential depends on extent of heat recovery from capture plant
- Storage costs not included



CCS @

28 Large **industrial** point sources of CO₂ (>500 ktCO₂/year) + **CHP plants** of different sizes



Around 35 Mt/year @ cost < 125 €/ton CO₂
Swedish total CO₂ emissions = 41 Mt/year (GHG emissions 51 Mt/year)

The policy is the challenge

- **BECCS: No incentives** for carbon removal – there must be a system for monitoring, verifying, and accounting for carbon removals
 - EU: Upcoming legislative proposal on **carbon removal certification**
 - A **reversed auctioning** system has been proposed in Sweden
- **CCS**
 - **EU-ETS** for fossil fuel emissions – at present around **60€/ton of CO₂** i.e., getting closer to CCS cost. Yet, free allocation will continue with phase out starting in Year 2026 (over a 10-year period)
- Urgent to get started to comply with Swedish targets...

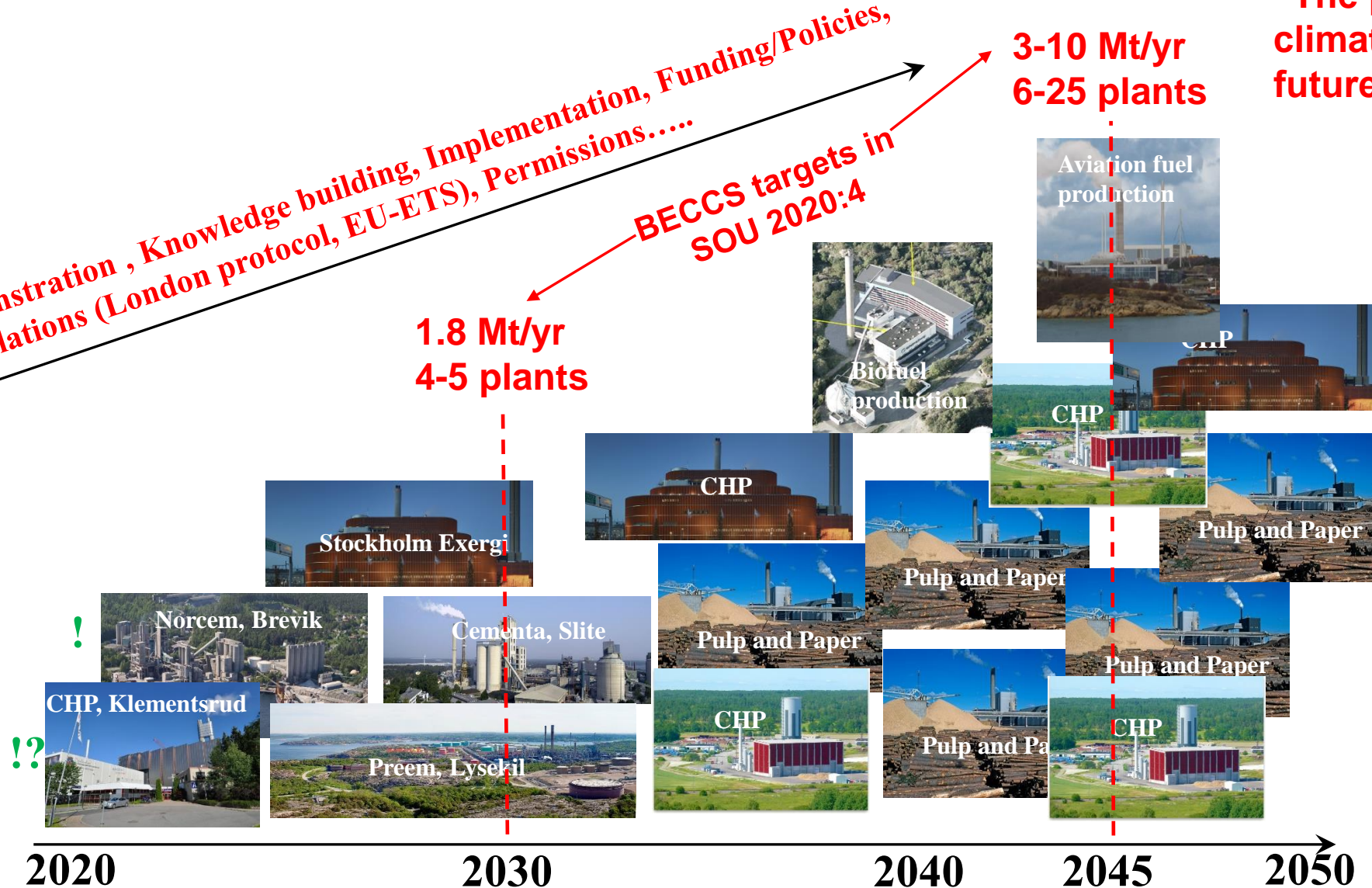


Timeline towards zero and negative emissions efforts must be accelerated

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

BECCS targets in SOU 2020:4


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



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

**1.8 Mt/yr
4-5 plants**

**BECCS targets in
SOU 2020:4**



Bio

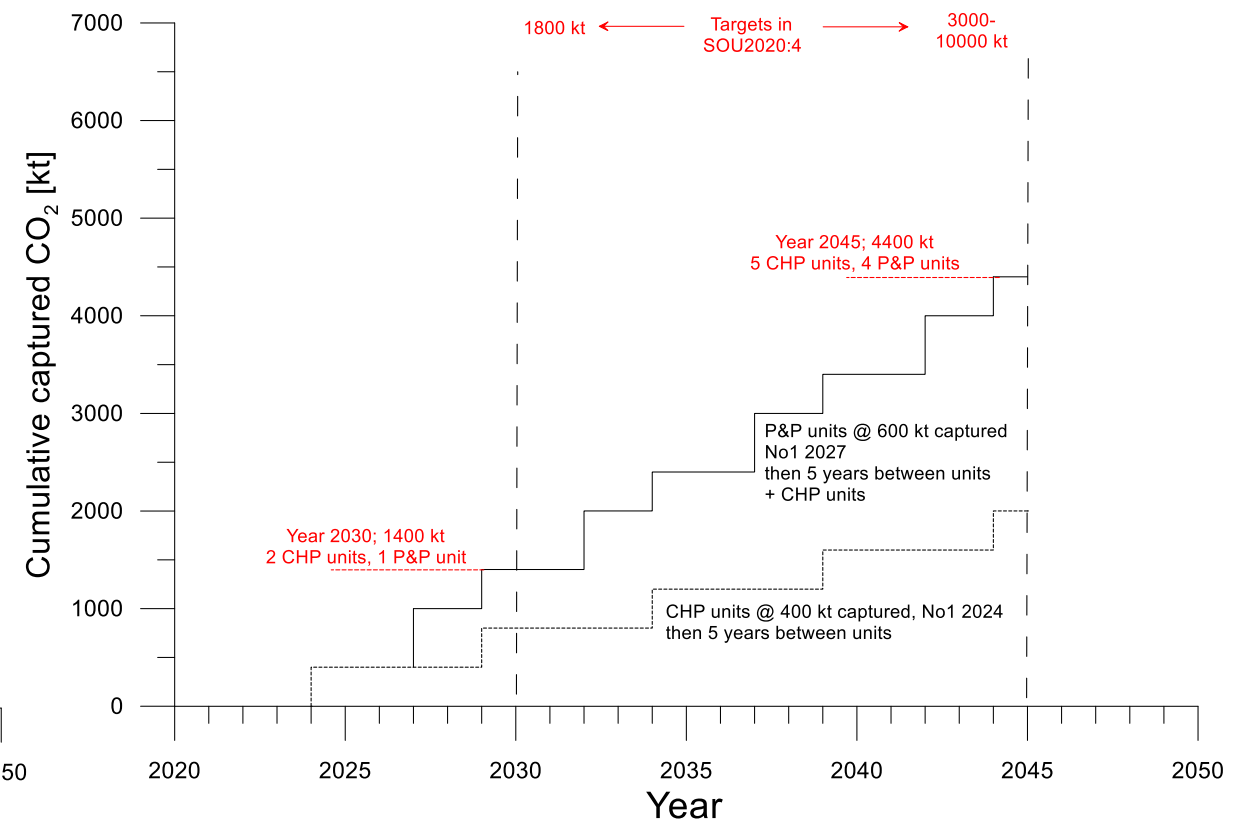
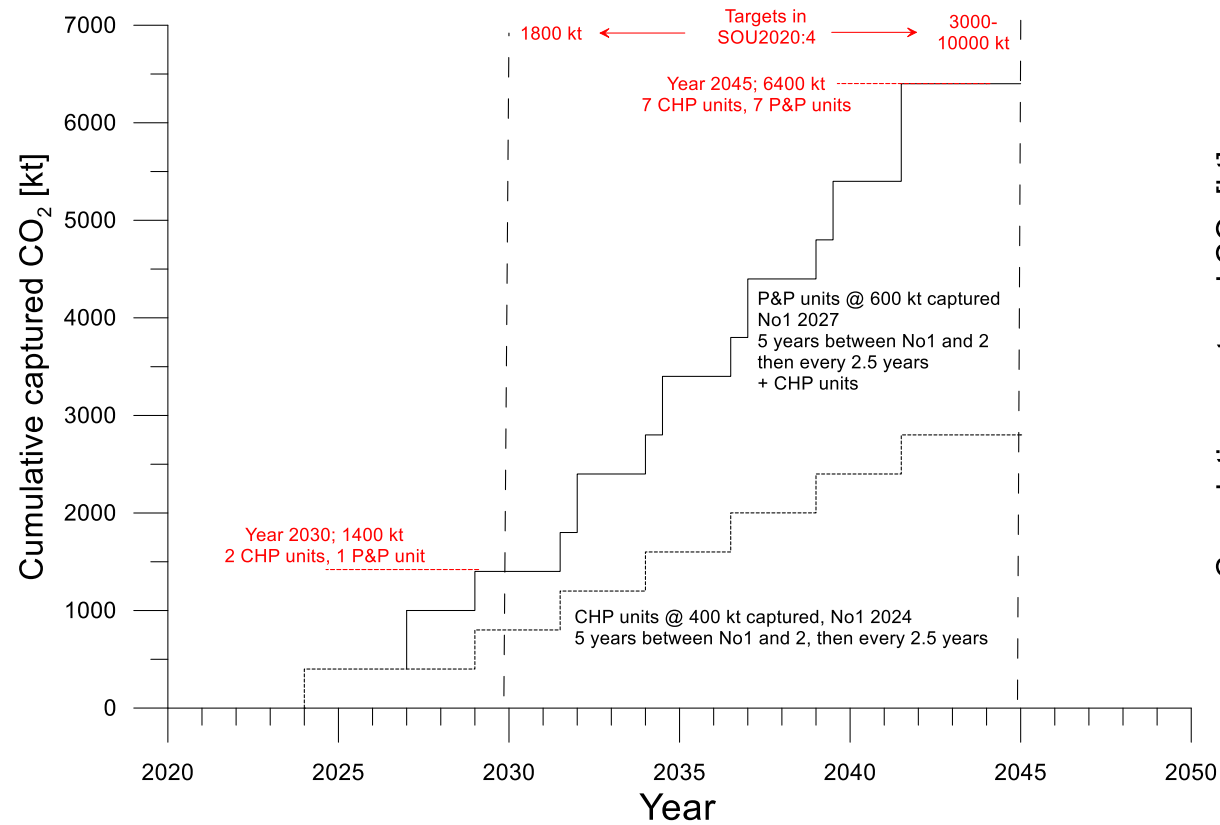
**BECCS targets in
SOU 2020:4**

1.8 Mt/yr
4-5 plants

3-10 Mt/yr
6-25 plants



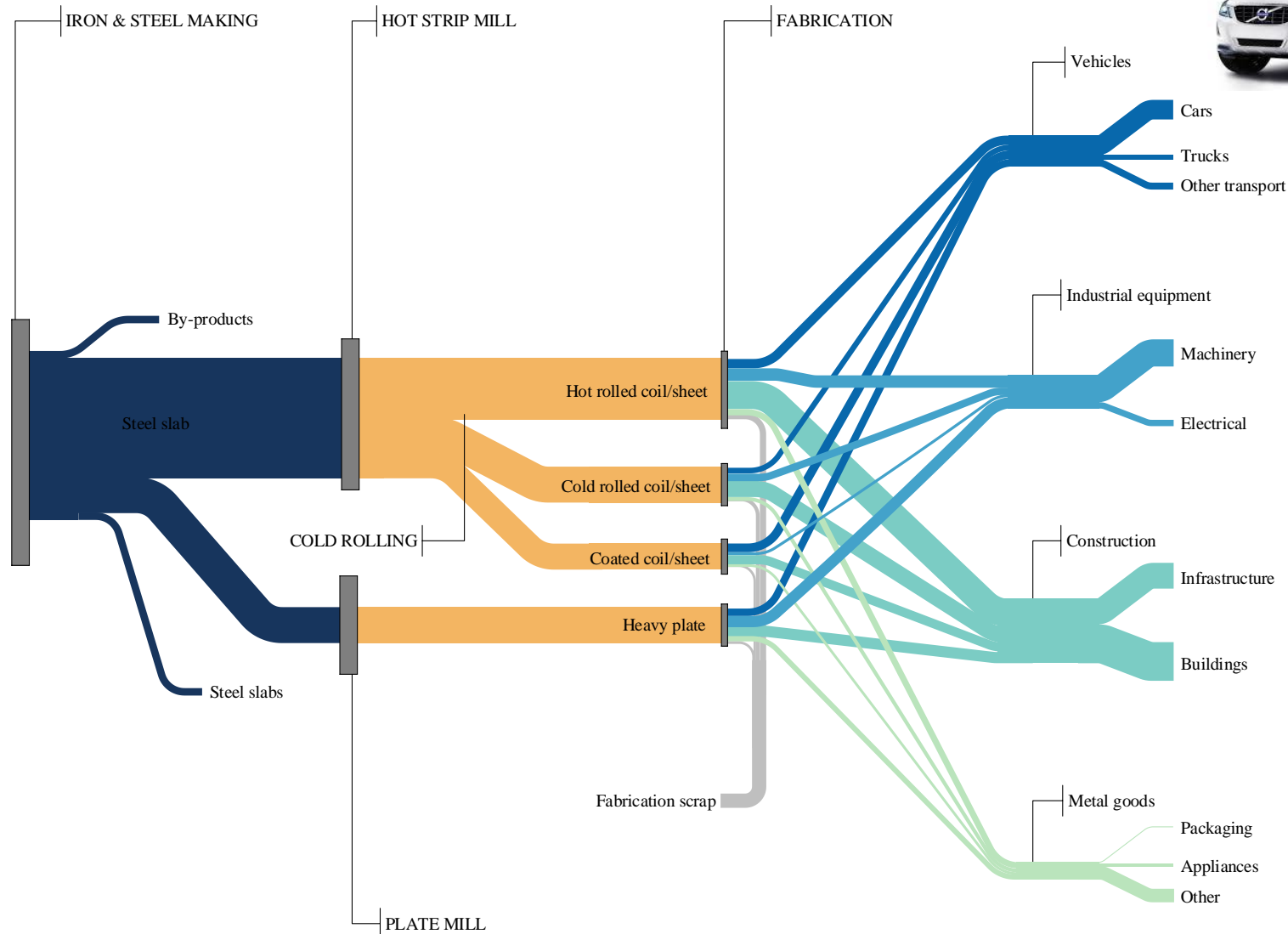
Two schematic BECCS ramp-up scenarios



The cost is the challenge!
Typically > 100 €/tonne CO₂
Is that expensive for society?

Supply and value chain analysis

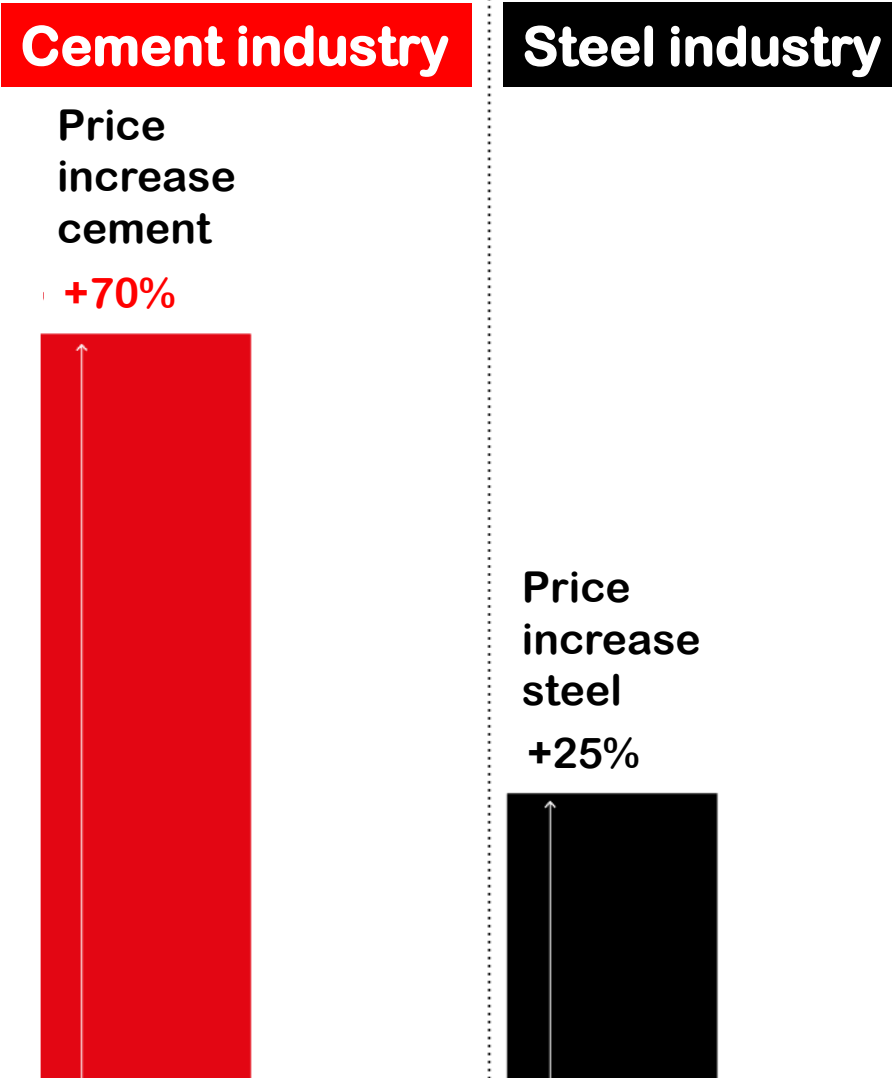
Steel to car



Example - Nordic basic material industry (Cement & Steel)

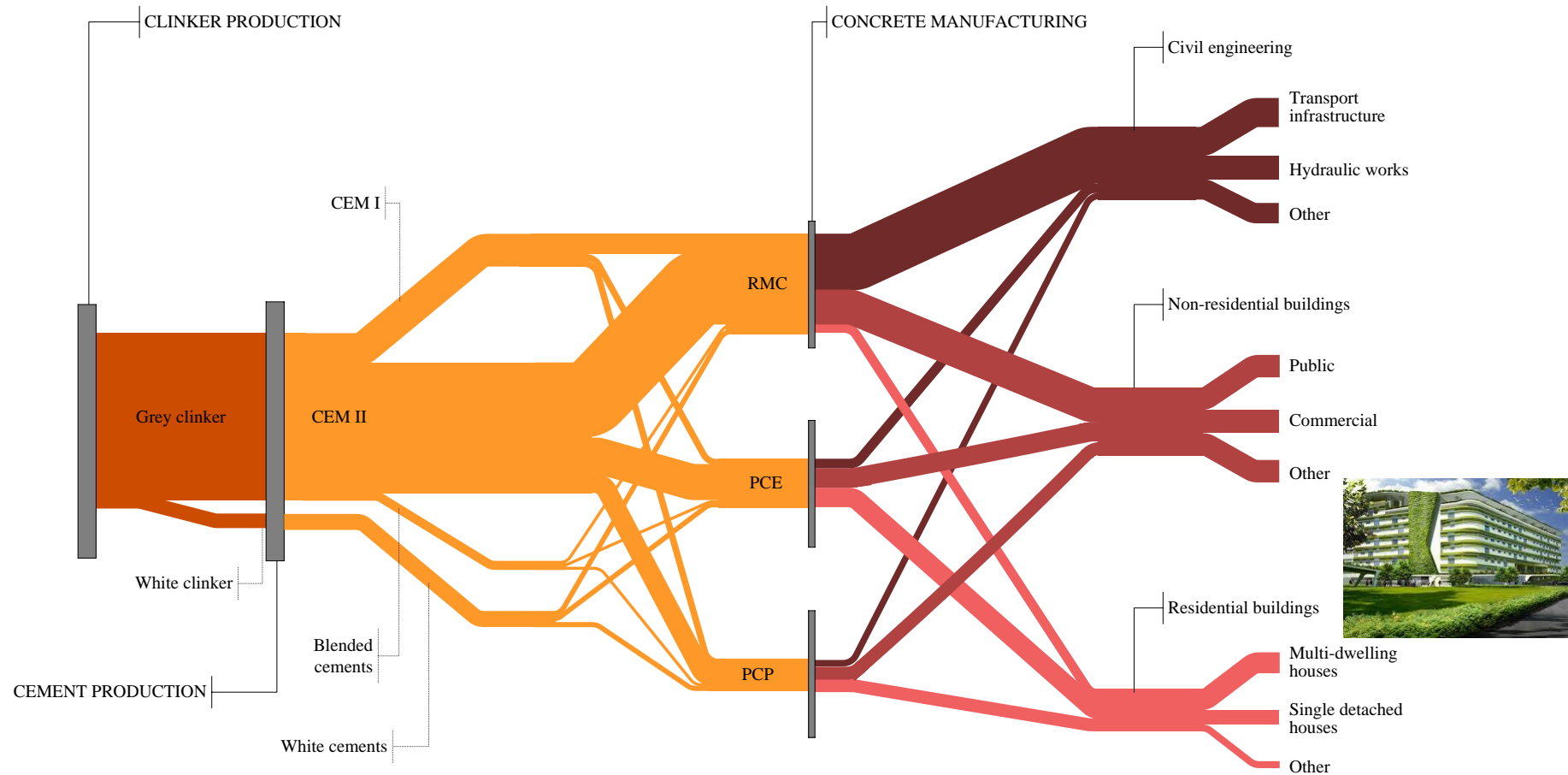
Measures to comply with Year 2050 targets $>100\text{€}/\text{ton CO}_2$

EU-ETS $\sim 60\text{ €}/\text{ton CO}_2$



Supply and value chain analysis

Cement (and steel) to building

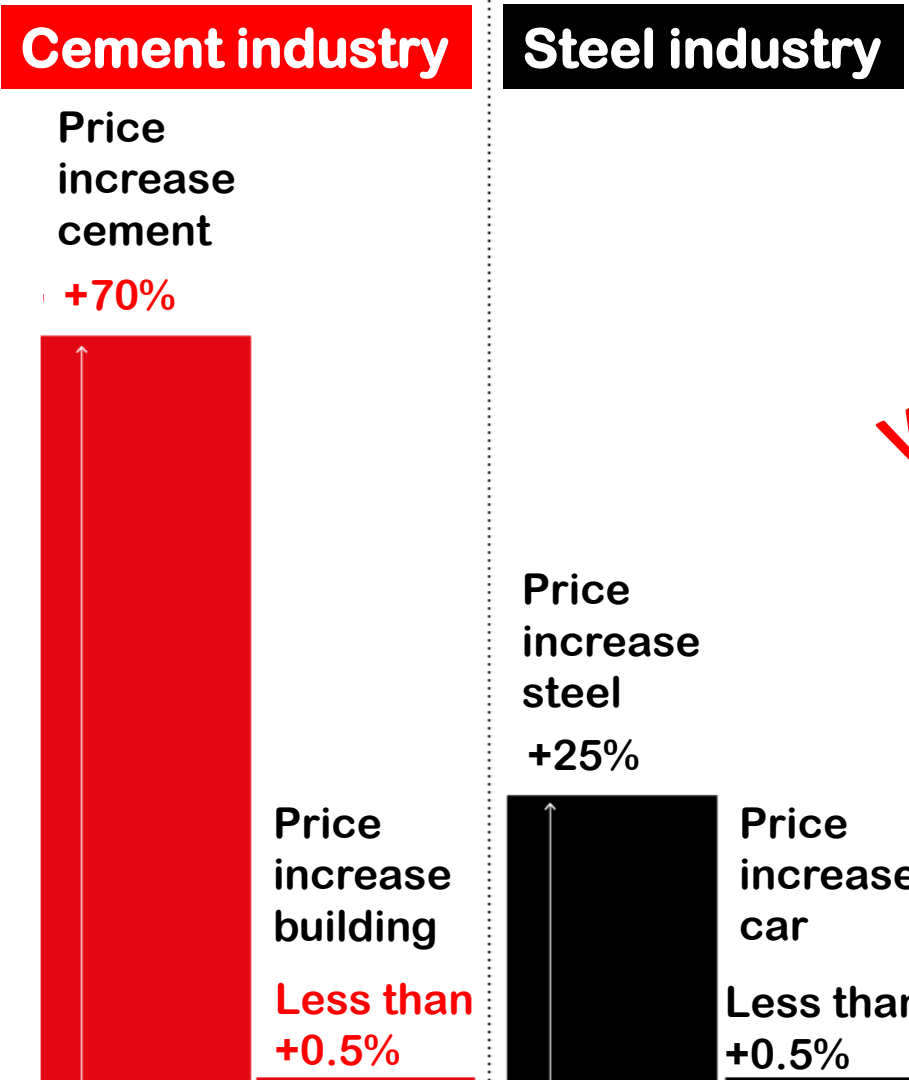


Example - Nordic basic material industry (Cement & Steel)

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/>

Measures to comply with Year 2050 targets >100€/ton CO₂

EU-ETS ~60 €/ton CO₂



In summary

- **Large potential** for CCS and BECCS in Sweden
- 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 establish incentives for negative emissions
 - **Voluntary markets** may be a complementary possibility – value chain approach
 - **Procurement** practices
 - **EU carbon removal certificates**
- CCS part of an **overall mitigation portfolio** – (*cf.* roadmaps developed by the Building and Construction sector within Fossil Free Sweden initiative)
- Not obvious what is the **best use of biomass** – implications on BECCS and associated policies for carbon dioxide removals (CDR) + controversy over forest management

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)
- **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/>
- **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.