IMPACTS OF TECHNOLOGY AVAILABILITY ON THE TRANSITION TO A NET ZERO INDUSTRY

Erik Sandberg

erik.sandberg@ltu.se

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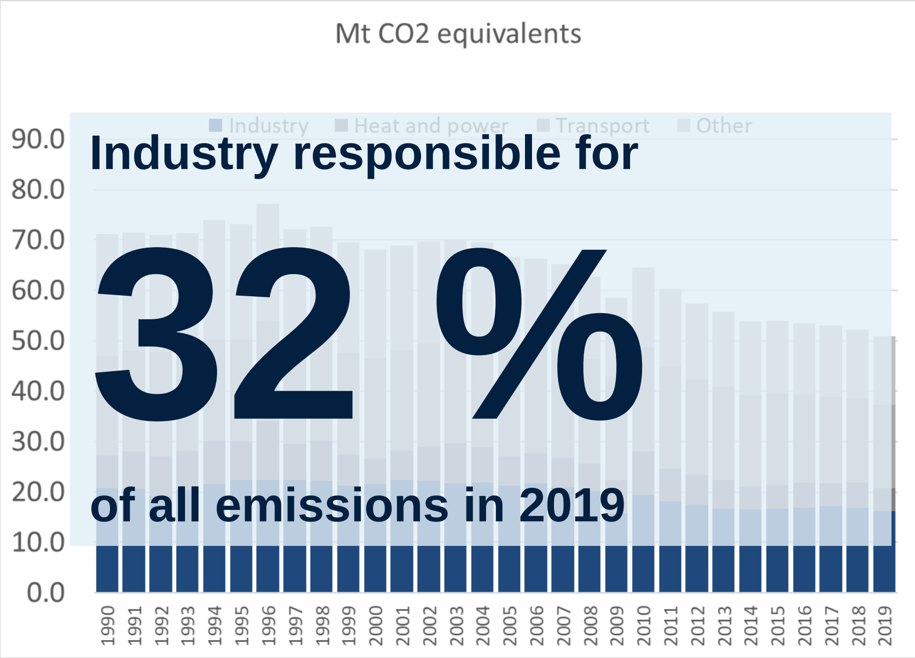
Outline

- Swedish industry
- Scope and aim
- Industry in TIMES-Sweden
- Scenario description
- Scenario results
- Conclusion

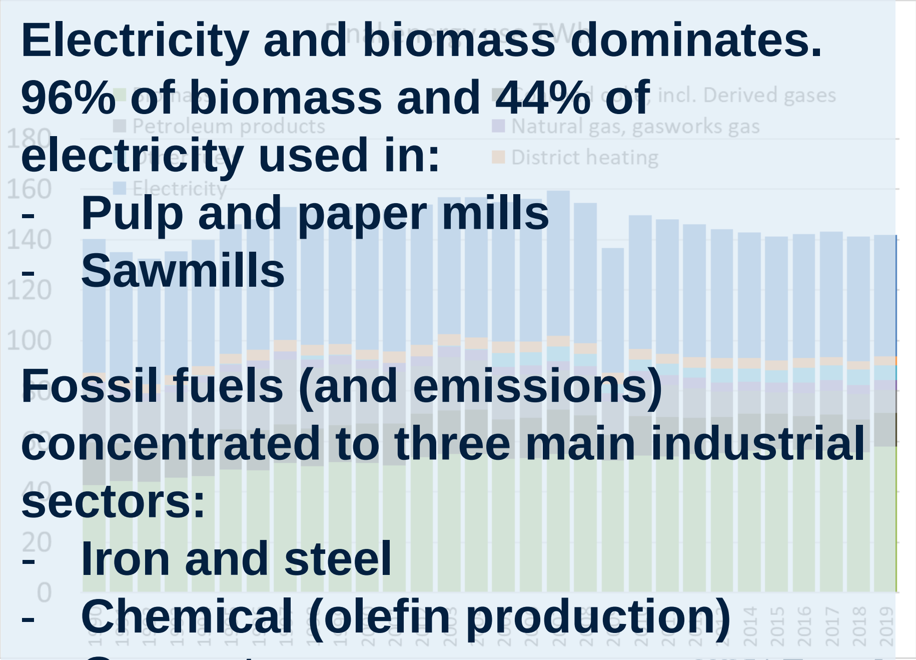
Swedish industry



Industry responsible for

32 %

of all emissions in 2019



Electricity and biomass dominates. 96% of biomass and 44% of electricity used in:

- Pulp and paper mills
- Sawmills

Fossil fuels (and emissions) concentrated to three main industrial sectors:

- Iron and steel
- Chemical (olefin production)
- Cement

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Hybrit and H2 green steel

Photografer: Åsa Bäcklin

Hybrit and H2 green steel plans:

- 5mt finished steel products by 2030
- Approximately 17mt DRI produced by 2045 (ramping production from 2035)

Using 55-70TWh electricity in northern Sweden

Production levels are included in the model. Hydrogen is not required.

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Scope and aim

Energy system modelling to assess how the availability of new technologies affects the transition to climate-neutral industry in Sweden under different net-zero CO_2-emissions policies

Achieved by: Scenario analysis using TIMES-Sweden, updated with an improved industrial representation, using TRL (technology readiness levels) to assess uncertainties regarding technology availability.

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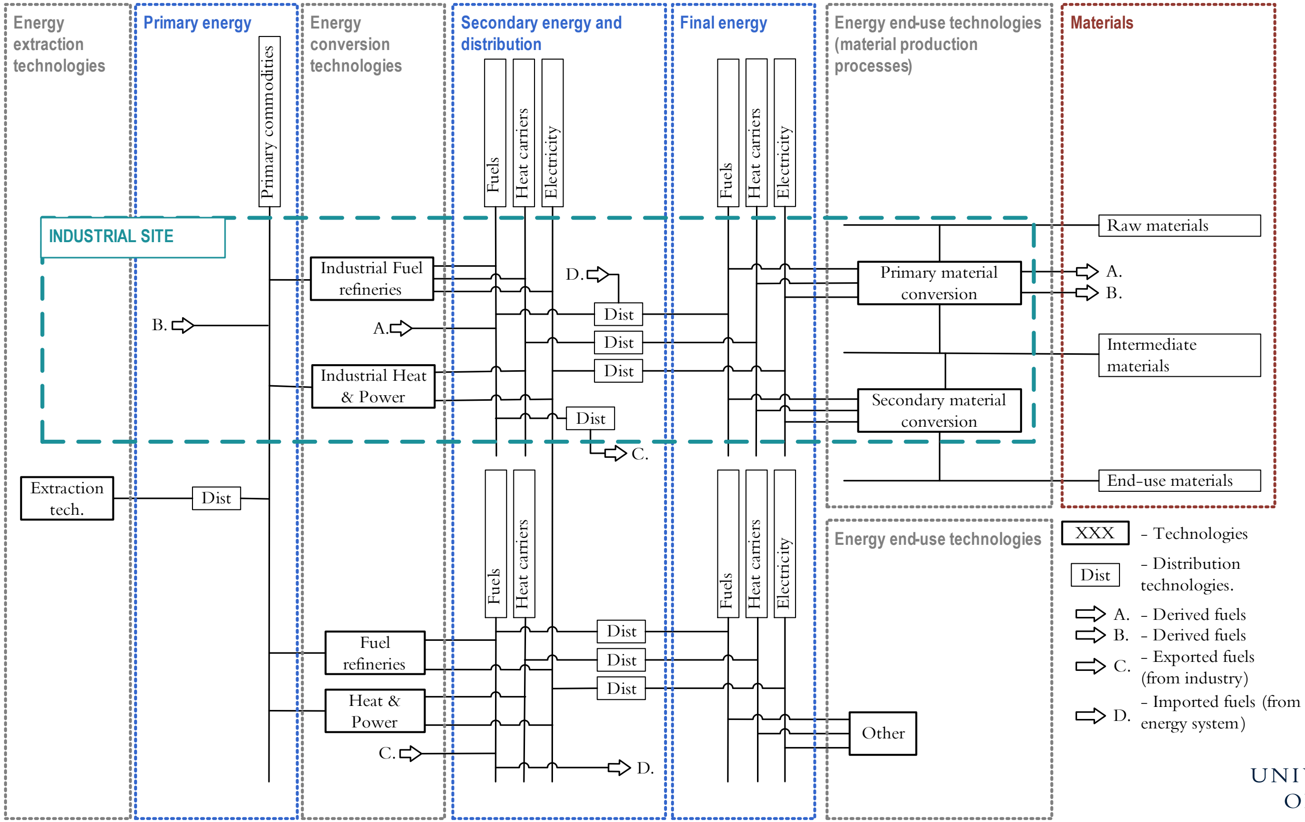
Industry in TIMES-Sweden



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Industry in TIMES-Sweden

KEY FUNCTIONS

- **Improved representation of material flows and processes to produce these materials**
- **Included technology options allowing modelling of a fossil free industry**
- **Capture benefits of integrated (bio)fuel production (use of waste heat in industry)**

For detailed description see:

Sandberg (2020) - Capturing Swedish Industry Transition towards Carbon Neutrality in a National Energy System Model

http://ltu.diva-portal.org/smash/get/diva2:1373207/FULLTEXT01.pdf

For database with all included industrial technologies see:

Sandberg (2021) - TIMES-Sweden Industry Database v1.0.

https://doi.org/10.5281/ZENODO.5702722

TRL estimations

TRL = technology readiness level

TRL	Translation	Years required to reach TRL9
1-4	Lab scale	+25-50 (35)
5	Pre-pilot scale	+15-25 (20)
6	Pilot scale	+10-20 (15)
7	Demo scale	+5-10 (10)
8	Full scale	+0-5 (5)
9	Commercial scale (First-of-a-kind to mature)	+0 (0)

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Scenarios

- Two scenarios for achieving **Net-zero emissions**
  - Free offsetting (using negative emissions for offsetting fossil CO2 is allowed)
  - Restricted offsetting (using negative emissions for offsetting only allowed for process emissions)
- 5 versions of each scenario, varying the technology availability by TRL (technology readiness level)

	TRL ≥1	TRL ≥5	TRL ≥6	TRL ≥7	TRL ≥8
Free offsetting (FO) scenario	FO–TRL1	FO–TRL5	FO–TRL6	FO–TRL7	FO–TRL8
Restricted offsetting (RO) scenario	RO–TRL1	RO–TRL5	RO–TRL6	RO–TRL7	RO–TRL8

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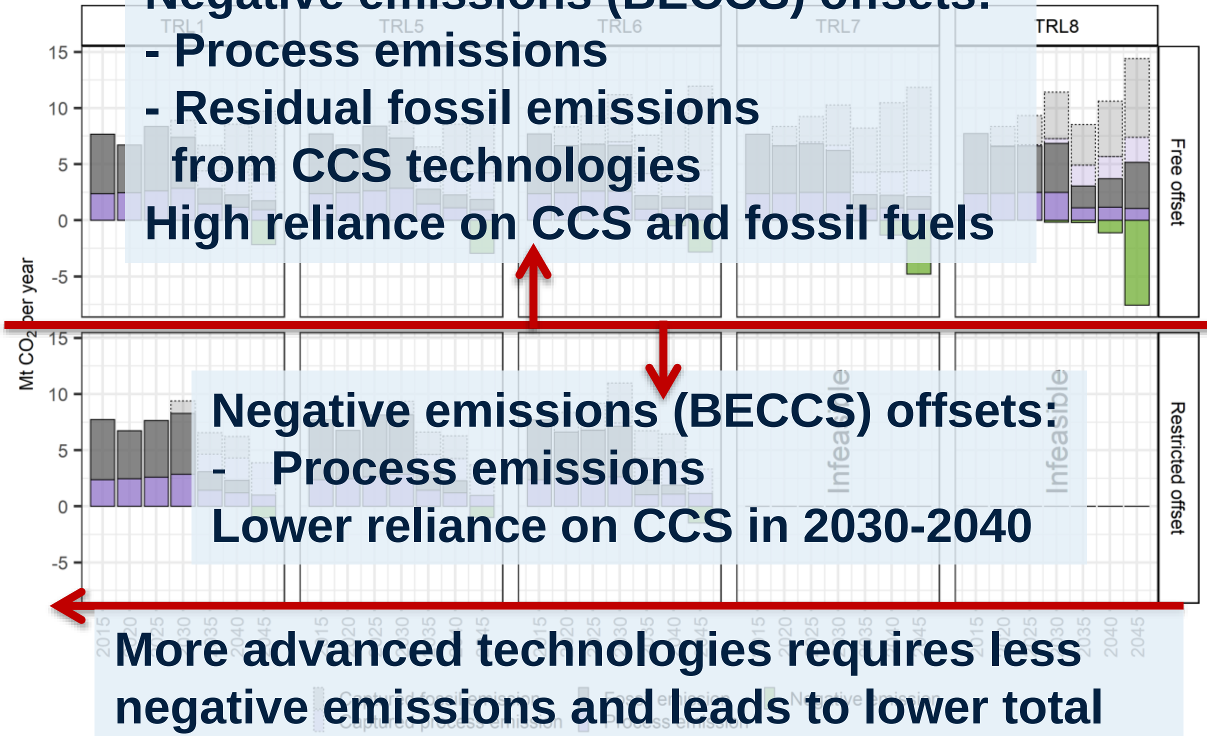
Scenario results (CO2)



Negative emissions (BECCS) offsets:
- **Process emissions**
- **Residual fossil emissions from CCS technologies**

High reliance on CCS and fossil fuels

Negative emissions (BECCS) offsets:
- **Process emissions**

Lower reliance on CCS in 2030-2040

More advanced technologies requires less negative emissions and leads to lower total CO2 captured

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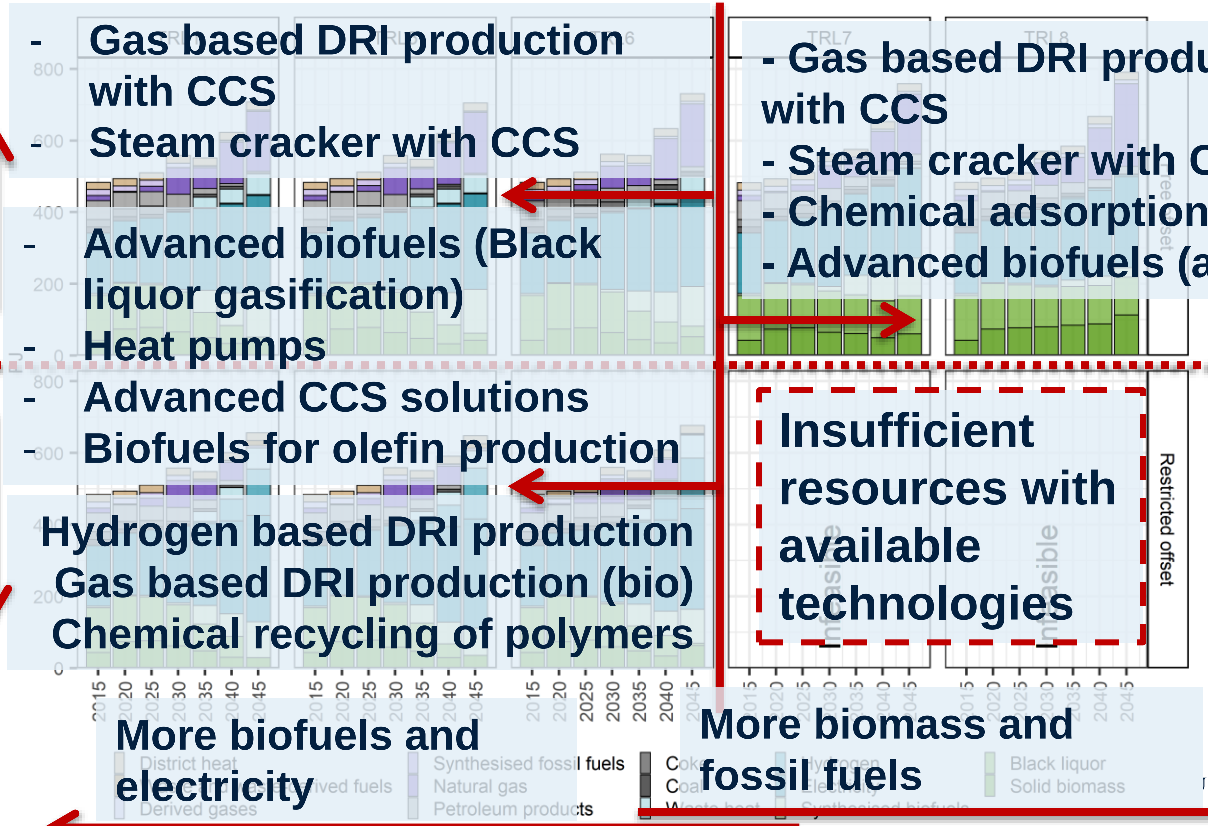
Scenario results (Final energy use)



More fossil fuels

- Gas based DRI production with CCS
- Steam cracker with CCS

- Advanced biofuels (Black liquor gasification)
- Heat pumps
- Advanced CCS solutions
- Biofuels for olefin production

More hydrogen

Hydrogen based DRI production
Gas based DRI production (bio)
Chemical recycling of polymers

- Gas based DRI production with CCS
- Steam cracker with CCS
- Chemical adsorption CCS
- Advanced biofuels (a few)

Insufficient resources with available technologies

More biofuels and electricity

More biomass and fossil fuels

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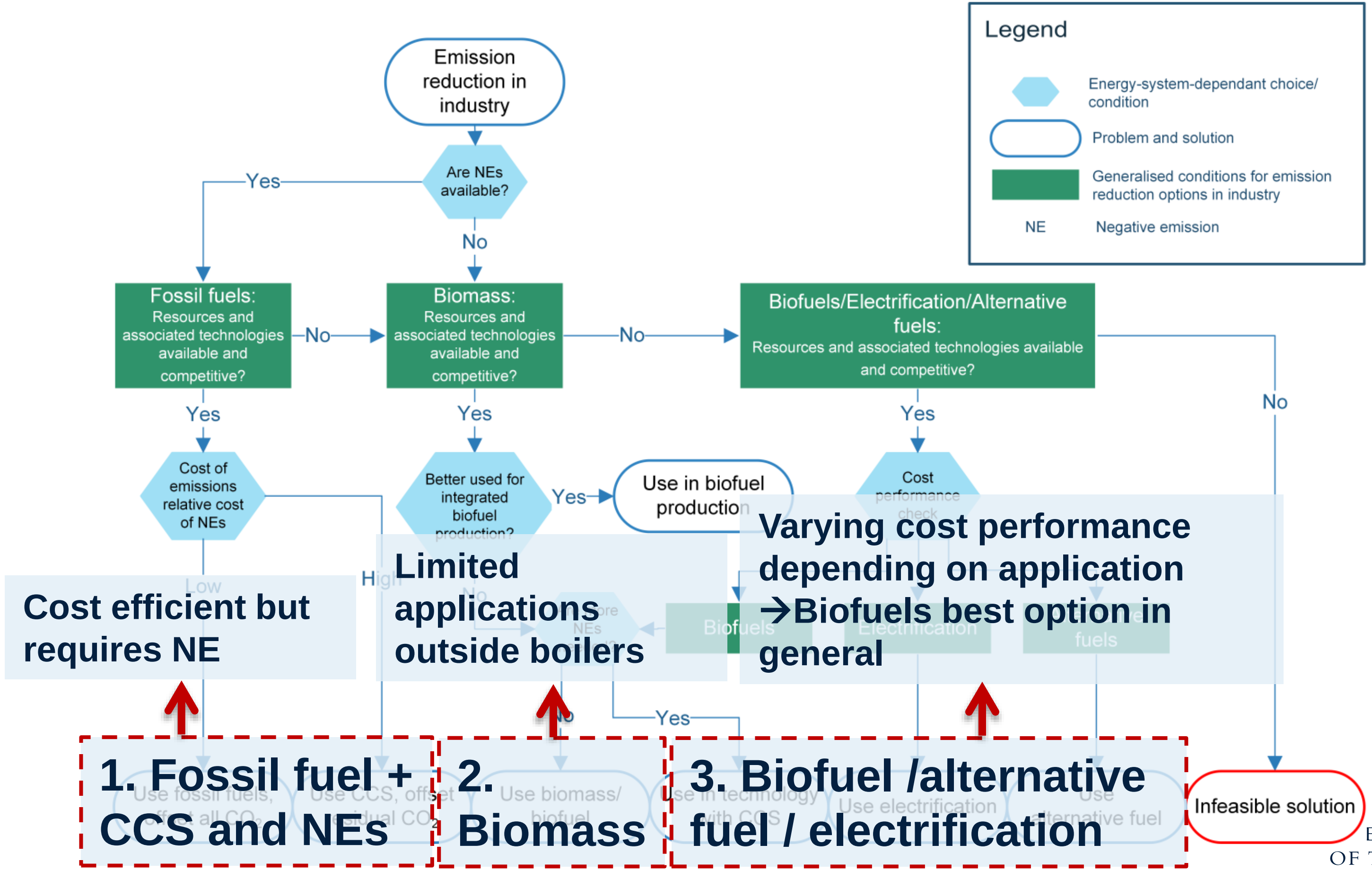

Cost efficient but requires NE

Limited applications outside boilers

Varying cost performance depending on application →Biofuels best option in general

1. Fossil fuel + CCS and NEs

2. Biomass

3. Biofuel /alternative fuel / electrification

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Some comments

- CCS is preferable but requires efficient solutions (e.g., oxyfuel or membrane assisted CCS) and sufficiently cheap sources of negative emissions – requires similar technology development as renewable options
  - Chemical adsorption CCS using MEA is an emergency solution in most cases (the required additional boilers and high energy demand makes for a costly solution)
- Low cost NEs via BECCS – possible since the cost of carbon separation is carried by the production of biofuels or materials (separation is core part of the process)

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Some comments

- Hydrogen electrolysis is the primary back stop technology
- Biofuels are more efficient than using fuels from power-to-X
- Direct electrification is preferred, as it is in general more efficient than using fuels from power-to-X
- Competitiveness of direct electrification vs biofuels are unknown due to the scarcity of biomass
- Biomass availability in Sweden provides a competitive advantage, uses domestically could be questionable.

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Conclusions

- CCS with fossil fuels most cost efficient
  - Faces similar uncertainties in technology development as renewable alternatives
  - Continued lock-in of fossil fuels, needs negative emissions
- Advanced biofuels and large scale electrolysis required to reach feasible solutions with limited carbon offsetting
- Sector coupling is key for efficient use of biomass
  - Strengthens as more technologies become available
  - Heat pumps and integrated biofuel production are key

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