EXPLORING TECHNOLOGY CHOICES IN INDUSTRIAL DECARBONISATION

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AGENDA

- Introduction
- Aim
- Swedish industry
- Modelling approach
- Scenario description
- Results and conclusions
INTRODUCTION

How to decarbonise the industry is one of the main challenges in order to limit global warming to well below 2°C. For Sweden see e.g. Krook-Riekkola & Sandberg 2018 in →

Industry can be described by: Large investments (easier to change parts instead of the whole site), many potential routes, integrated with the surrounding industries and energy system, new options that has not been fully tested: CCS, Biomass and/or Electricity → LARGE FLEXIBILITY and MANY POSSIBILITIES and big UNCERTAINTIES!

Process Integration Modeling

Comprehensive ESOM
AIM

To identify cost-efficient site-specific options and new process solutions when decarbonizing the industrial sector.
MODELLING APPROACH (I)

TIMES-Sweden Industry model
- A stand alone module of the TIMES-Sweden model. Starting to be merged/incorporated into TIMES-Sweden.

TIMES an energy system optimization model
- Suitable for analyzing large comprehensive energy systems, such as national energy systems.
MODELLING APPROACH (II)

Wants to capture:

• Process integration potentials
• Use of industry (site) specific energy- and material flows
• SITE SPECIFIC POTENTIALS – limiting process integration possibilities by site specific flows

→ Focus on industrial clusters/sites
MODELLING APPROACH (III)

- Optimized for process integration
  - Treats final energy and useful energy separately for all processes
SWEDISH INDUSTRY

- BIOMASS
- FOSSIL
- DERIVED HEAT
- ELECTRICITY
- Pulp & Paper
- Sawmills
- Other
- Mineral industry
- Chemical industry
- Iron & steel
- Other
### SCENARIO DESCRIPTION

All scenarios aim at reaching the Swedish net- or sub-zero GHG-emissions by 2045, but are limited to CO2-emissions and assumes a linear reduction from 2020 to 2045.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Central case</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biomass resources (B)</strong></td>
<td>• HIGH biomass availability for the industry (HIGH resource availability, LOW demand from other sectors) (B)</td>
<td>• Low biomass availability for the industry (LOW resource availability, HIGH demand from other sectors) (b)</td>
</tr>
<tr>
<td><strong>CCS (only storage solutions) (C)</strong></td>
<td>• Low storage acceptance and potential (equal to material based emissions) (C)</td>
<td>• High storage acceptance and potential (c)</td>
</tr>
<tr>
<td><strong>Electricity (E)</strong></td>
<td>• Reference price (E)</td>
<td>• High price (e)</td>
</tr>
<tr>
<td><strong>International fuel markets (F)</strong></td>
<td>• Fossil fuel price based on IEA New Policies (REF-level)</td>
<td>• Fossil fuel price based on IEA Sustainable Development (LOW-level)</td>
</tr>
<tr>
<td></td>
<td>• Reference CO2 price level</td>
<td>• Reference CO2 price level</td>
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<tr>
<td></td>
<td>• Biofuel price follows fossil fuel price (FT)</td>
<td>• Biofuel price follows fossil fuel price</td>
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<td>• High CO2 price level (Ft)</td>
</tr>
</tbody>
</table>
RESULTS

![Annual discounted cost graph with lines for different years and labels for biomass availability.]
RESULTS

High biomass availability

Low biomass availability

High ELC-price and CCS limit
RESULTS

![Graph showing energy production and input](image)

Legend:
- Green: Biofuel Prod.
- Blue: Biomass
- Black: Electricity
- Light Blue: Electricity prod.
- Orange: Fossil
- Red: Biofuel Exp

**INPUT**

**ENERGY OUTPUT**
Integrated biofuel or electricity production always utilized
- Minimizes cost by export or by replacing import
- Priorities investment in larger industries -> economy of scale

Unlimited CCS and high biomass availability leads to cheap electricity with natural gas (BECCS offsets remaining emissions).

**CONCLUSION:** Industrial biomass use is a multi-purpose tool of the energy system. Efficient use is crucial for reaching net-zero emissions.
HEAT PUMPS minimize steam supplied from biomass/black liquor in sawmills and pulp and paper industries (for drying applications).

CONCLUSION: Heat pumps are very important as they allow more biomass to be used where it is needed!
RESULTS-CCS

CCS/CCU [kt]

Capture

- Bio-ChP
- Bio-Fuel
- Fossil-ChP
- Bio-ChP
- Bio-Fuel
- Fossil-ChP

2045

Storage

- Bio-ChP
- Bio-Fuel
- Fossil-ChP
- PtG/PtL
- Storage

- Bio-ChP
- Bio-Fuel
- Fossil-ChP
- PtG/PtL
- Storage
BECCS combined with gasification-based fuel- or electricity production

No investment in CCS made for Mineral industries (e.g. Cement) in any scenario

CONCLUSION: CCS/-U required for reaching emission targets, but not necessarily at the site causing emissions!
INDUSTRIAL TECHNOLOGY CHOICES

IRON & STEEL

CHEMICAL

PtG-Hydrogen
ProductionProcess
Imp-fossil gas
Imp-Bio-SNG
PtL-methanol
ProductionProcess
NaturalGas-methanol
Imp. bio-methanol
Bio-methanol
IRON & STEEL: Uses gas or hydrogen for ore-based steel

CHEMICAL: Uses ethanol and methanol for olefin production

CONCLUSION: Industrial production technologies are chosen so that feedstock/fuel production can be adapted to the energy market
CONCLUSIONS

- The process-oriented modelling approach captures site specific integration possibilities very well – and is important for estimating potential benefits and costs when integrating new processes.

- Integrated production of biofuels very important to ensure an efficient use of biomass, which is key for reaching net zero target when the biomass availability is low. Heat-pumps are very important to further facilitate biofuel-production and overall biomass use.

- CCS/-U solutions required to reach the emission target. The most efficient way of mitigating non-energy related emissions is to combine CCS with gasification based production of biofuels and electricity.

- The industry has the possibility to become a facilitator of a sustainable energysystem through e.g. fuel production, but will most likely require new polices aimed at establishing competitive prices for biofuels and electrofuels.
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