Production of ammonia and nitrogen fertilizers based on biomass – research efforts in Sweden

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Outline of presentation

• Intro Sweden

• Studies of future production based on renewables:
  ➢ Techno-economic studies
  ➢ Life cycle assessment studies
Sweden

- 9.4 million people
- 449 964 km² (approx. same size as state of California!)
Sweden, land

- 3% urban area
- 53% forest
- 8% agriculture
- 9% mire
- 10% heathland, bare mountains
- 9% water
Sweden livestock

- 360,000 milk cows
- 180,000 beef cows
- 1.6 million swine
- 200,000 sheep
- 260,000 reindeers
Import of ammonia and N

At present: No production of ammonia in Sweden

<table>
<thead>
<tr>
<th></th>
<th>Metric Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anhydrous ammonia</td>
<td>136 500</td>
</tr>
<tr>
<td>Ammonia in water solution</td>
<td>14 700</td>
</tr>
<tr>
<td>Nitrogen in fertilizers (prilled calcium ammonium nitrate dominating)</td>
<td>148 100</td>
</tr>
</tbody>
</table>
Annual energy use in Swedish agriculture

Direct energy use 5.9 TWh

- Diesel: 48%
- Oil: 13%
- Electricity: 18%
- Solid biofuels: 20%
- Liquid biofuels: 1%

Indirect energy use 3.3 TWh

- Artificial fertilisers: 56%
- Imported fodder: 27%
- Transport of inputs: 4%
- Silage plastic: 7%
- Pesticides: 5%
- Seed: 1%
Nitrogen in crop GHG balance

Cultivation 1 kg winter wheat in Skåne (south Sweden)
Studies of future production based on renewables. In co-operation with:

- Lund University, dep of chemical engineering
- University of Minnesota, West Central Research and Outreach Center, Morris
Point of departure

N-fertilizers is a major contributor to fossil energy use and GHG in crop production

N-fertilizers are costly and the price fluctuates

Better utilization of renewable resources needed
Techno-economics, conclusions

• Production of ammonia from non-fossil sources can be expensive (or, fossil fuel is cheap at the moment)

• Biomass gasification most promising alternative
  - economy-of-scale effects
  - lower feedstock cost

• Results will soon be published in Environmental Progress & Sustainable Energy (Wiley) “Techno-Economic Assessment of Non-Fossil Ammonia Production” Authors: Tunå, Hulteberg, Ahlgren
Studied scenarios

- 3 MW Electrolysis
- 10 MW Electrolysis
- 5 MW Biogas from anaerobic digestion
- 10 MW Biogas from anaerobic digestion
- 50 MW Biomass gasification

Modeling performed in Aspen Plus
Biomass gasification - ammonia

- Circulating fluidized bed
- Steam reformer (800°C) + auto thermal reformer
- Ammonia synthesis modelled as three adiabatic reactors with recirculation. Pressure drop 3 bar, inlet temperature 427°C for each reactor
- Excess heat, for use in district heating grid, usable at levels down to 70 °C
Biomass gasification - ammonia

To the total bare-module cost, 18% contingency and 30% auxiliary added giving the overall investment cost

- Biomass 34 – 102 $/MWh
- Interest rate 5 – 12%
- Investment cost ±30%
Life cycle assessment

- Cradle to grave
- Cradle to gate
- Global warming potential
- Eutrophication
- Energy
- Land use
- etc

Energy and resources → Emissions → Manufacture → Use → Waste management

Raw material acquisition
Two types of LCA

<table>
<thead>
<tr>
<th>Attributional-LCA</th>
<th>Consequential-LCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing systems</td>
<td>Change-oriented</td>
</tr>
<tr>
<td>Average data</td>
<td>Marginal data</td>
</tr>
<tr>
<td>Allocation</td>
<td>System expansion</td>
</tr>
<tr>
<td>Only direct effects</td>
<td>Indirect (market induced) effects</td>
</tr>
</tbody>
</table>
ALCA – production of AN from renewables

Scenario 1

- Salix or straw production
- Pre-treatment
- Thermo-chemical gasification
- Gas cleaning and upgrading

- Natural gas extraction
- Injection on gas grid
- Ammonia production
- Nitric acid production
- Ammonium nitrate production

Reference

- Natural gas extraction
- Injection on gas grid
- Ammonium nitrate production

Scenario 2

- Ley and maize production
- Anaerobic digestion
- Cleaning and upgrading
- Injection on gas grid

- Dige-state

Salix (willow) in summer and winter
ALCA results – production of AN from renewables

- Production of ammonium nitrate granulates
- Based on gasification and anaerobic digestion
- From Ahlgren (2009)
- Attributional LCA
CLCA – production of AN from renewables

Integrate in existing CHP (Scenario 1)

- Forest residues
- Process
  - Nitrogen fertiliser
  - Heat
  - Surplus compared to existing CHP replaces marginal alternative
  - Marginal production
  - Compensating for reduced electricity output from CHP

Build a new thermal gasification plant (Scenario 2 and 3)

- Straw / Willow
- Process
  - Nitrogen fertiliser
  - Electricity
  - Replaces marginal alternative

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CLCA results – production of AN from renewables

<table>
<thead>
<tr>
<th>Product</th>
<th>kg CO2-eq/kg N</th>
</tr>
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<tbody>
<tr>
<td>Forest residues – integration in existing CHP</td>
<td>4.7</td>
</tr>
<tr>
<td>Straw – new thermal gasification plant</td>
<td>0.6</td>
</tr>
<tr>
<td>Salix – new thermal gasification plant</td>
<td>0.2</td>
</tr>
</tbody>
</table>

- Reduced electricity production
- Excess electricity
- Excess heat
- Nitric acid production
- Soil carbon emissions/uptake
- Biomass production and transport
Increasing interest for ammonia and nitrogen fertilizers based on renewables!

Biomass gasification seems like a promising alternative!

But questions remain on technology, scale, feedstock, etc

As with all modelling there are uncertainties, e.g. regarding economy and environmental impact

The next step…
References


Thank you!