Consequential Environmental Assessment
Including Socio-Technical Change

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Introduction

• Life-cycle assessment (LCA) is not adapted to answer questions regarding strategic technology choice

• This can be done by taking socio-technical change into account

• For consequential LCA, then the question is which changes that should be included?
Definitions

• Attributional assessment
  – Reflecting the impact that a technology is responsible for at a certain point in time

• Consequential assessment
  – Reflecting the impact of changes related to decisions regarding a technology

• Retrospective and/or prospective
Ethanol in Sweden (1980-2020)

- We have studied the development of ethanol in Sweden, and how attributional LCA results change over time.
- This will be used to discuss which changes to include in consequential LCA used for strategic technology choice.

- Wheat pilot plant
- SSEU formed

**Ethanol vehicles**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Buses</td>
<td>2</td>
<td>4</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFVs</td>
<td></td>
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</tbody>
</table>

**Ethanol supply**

<table>
<thead>
<tr>
<th></th>
<th>Wheat (6 000 m3)</th>
<th>Sulphite (&lt;50 m3)</th>
<th>Sulphite (1 000 m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Import</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Attributional ethanol LCA (1990)

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
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<tbody>
<tr>
<td>GHG/fu (kg CO₂ eq./m³)</td>
<td>58</td>
</tr>
<tr>
<td>Total use (m³)</td>
<td>893</td>
</tr>
<tr>
<td>Total GHG (t CO₂ eq.)</td>
<td>52</td>
</tr>
<tr>
<td>Avoided GHG (t CO₂ eq.)</td>
<td>1 550</td>
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</tbody>
</table>
Ethanol in Sweden: 2nd period (1990-2005)

- Wheat pilot plant
- Government bill:
  - Wood research
  - Vehicle demos
- Tax exemptions
  - Wheat plant
  - EU import
  - Blending
- SSEU formed

Ethanol vehicles

<table>
<thead>
<tr>
<th>Year</th>
<th>Buses</th>
<th>FFVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>1990</td>
<td>32</td>
<td>350</td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td>&gt;3000</td>
</tr>
<tr>
<td>2000</td>
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Ethanol supply

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<td>Sulphite</td>
<td>(1 000 m3)</td>
</tr>
<tr>
<td>Sulphite</td>
<td>(10 000 m3)</td>
</tr>
<tr>
<td>Wheat (55 000 m3)</td>
<td></td>
</tr>
<tr>
<td>Sulphite (18 000 m3)</td>
<td></td>
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Import:

- Wine
- Sugar cane
## Attributional ethanol LCA (2005)

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<td>1 550</td>
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(Numbers in parenthesis represent different resources)
Ethanol in Sweden (scenario 2020)

- Wheat and wood ethanol: 500 000 m³ each
- Sugar cane ethanol: 200 000 m³
- Other alternatives (e.g. synthetic fuels)
- More efficient vehicles, hybrids, electric cars
- All petrol is E5, 20% of the cars are FFVs

(Assumptions based on socio-technical scenarios)
# Attributional ethanol LCA (2020)

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Consequential ethanol LCA

• A decision to invest in ethanol contribute to environmental impact related to the production and use of ‘one more unit of ethanol’, i.e. traditionally changes on the margin

• But which other changes could be included?
  – Co-evolution of ethanol technologies:
    • Changed resources and env. impact for ethanol production and use
  – Co-evolution with other alternatives:
    • Changed resources and env. impact for renewable transport fuels
    • Changed vehicles and transport systems (eventually)?
  – Rebound effects?
Co-evolution of ethanol technologies

Wheat pilot plant

SSEU formed

Government bill:
- Wood research
- Vehicle demos

Tax exemptions
- Wheat plant
- EU import
- Blending

- 1980
- 1985
- 1990
- 1995
- 2000
- 2005

By-product ethanol (market)
Wheat and wood (advocacy)
Domestic and imported (market)

Buses and FFVs (knowledge)
E5 and E85 (market)

And not least… Actors and legitimacy!
### Co-evolution of ethanol technologies

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Co-evolution with other alternatives

Wheat pilot plant
SSEU formed

Government bill:
- Wood research
- Vehicle demos

Buses

FFVs

Wood pilot plant
Brazilian import

1980
1985
1990
1995
2000
2005

Tax exemptions
Wheat plant
EU import
Blending

Methanol demos
(knowledge)

‘Alcohols’
(legitimacy)

Biofuels programme
(funding)

Tax exemptions
(market)

‘Clean vehicles’
(legitimacy)

Legitimacy!
Conclusions

- Which changes should be included in consequential LCA that will be used for strategic technology choice?
- Assessment of one ethanol technology and small changes might not be relevant
- Assessment of various ethanol technologies, or more general assessments of renewable transport fuels are needed, including contributions to socio-technical change
Thank you!

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Data used

- NTM, the Network for Transport and Environment (Blinge, 2006)
- Retrospective attributional LCA
- Energy allocation
- Different studies reviewed in Blinge (2006)
  - Sulphite ethanol
  - Wine ethanol
  - Wheat ethanol
  - Sugar cane ethanol
  - Wood ethanol (Arnäs et al. 1997)
Renewable transport fuels

- Various driving forces, shifting in influence through the years
  - Energy security
  - Agricultural policy
  - Air/water quality
  - Climate change
Socio-technical scenarios (until 2020)

- Co-evolution of various alternatives
- Illustrate the balance between:
  a. Legitimation through market formation for 1st generation renewable fuels
  b. Knowledge formation and expectations about 2nd generation renewable fuels
- Point out the risks of:
  - Lock-in of first generation renewable fuels
  - Lack of actors and legitimacy
- A successful scenario outcome used here…