The +10 million tonnes study

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Will there be enough biomass for establishing a significant bio-refinery industry in Denmark?

• Will the production be sustainable?
  • Soil C, pesticides, nutrient leaching, biodiversity, eco system services etc..

• What about indirect land use change (iLUC)?

• What types of biomass can be available for which technologies?

Se the study at: http://biovalue.dk/media/TimioplanUKrevideret-1310-2016.pdf
Prerequisites:

- No reduction in Danish food and animal feed production
- No expansion of the agricultural area
- Must match the political desire for promotion of sustainability and a ‘greener’ society/economy
- Must not have negative environmental effects
- Be within the current regulatory framework
Land use in Denmark

Statistics Denmark, 2015
Biomass harvest in Denmark

- Wood from gardens and hedgerows
- Deciduous
- Coniferous
- Straw
- Grass and forage
- Root crops
- Legumes
- Grass seeds
- Oilseed rape
- Cereal

Statistics Denmark, 2010
Three Scenarios for 2020

**Business as usual (BAU):**
- No changes in crops or technologies
- Existing resources (straw, manure, oil seed rape oil etc.)

**Biomass optimised:**
- Straw rich grain varieties
- Increased straw harvest
- Less grain and oil seed rape
  - \( \Rightarrow \) high productive biomass crops (beets 19 t ha\(^{-1}\) DM)
- Fertilization of natural grasslands
- Road sides, aquatic weeds, catch crops etc.

**Environmentally optimised:**
- No straw removal from land with critical low carbon content
- Perennial biomass crops (grass 15 t ha\(^{-1}\) DM)
- No grain crop production in nitrate sensitive areas
- No fertilization of natural grasslands
- Increased afforestation
Danish agriculture and forestry can deliver 3-4 times more biomass for biorefineries in 2020.
Different biomass types for different conversion technologies

Gylling et al., 2013
Increased biomass utilisation can reduce nitrate leaching

<table>
<thead>
<tr>
<th></th>
<th>Change in nitrate leaching for Denmark (ton N y(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAU</td>
</tr>
<tr>
<td>Animal manure</td>
<td>-5.752</td>
</tr>
<tr>
<td>SRC</td>
<td>-248</td>
</tr>
<tr>
<td>New biomass crops substituting oil rapeseed</td>
<td>-3.142</td>
</tr>
<tr>
<td>New biomass crops substituting grain crops</td>
<td></td>
</tr>
<tr>
<td>Afforestation</td>
<td>-847</td>
</tr>
<tr>
<td>Additional catch crops</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-6.846</td>
</tr>
</tbody>
</table>

Will fulfil the demands of the EU Water Framework Directive

Jørgensen et al., 2013
Energy system scenarios were defined to analyse the effect on TOTAL Danish GreenHouse Gas emissions.

Reduction in Danish GHG emissions

% Reduction

- BAU
- BIO
- ENV

Gylling et al., 2016
The scenario effects on fossil fuel substitution and on Land Use Change (mio. T CO₂ eq.)

GHG reduction potential

Gylling et al., 2016
Average cost of supplying one tonne drymatter from field to biorefineries in different soil types areas

Cost per tonne dry matter (DM) in EURO

Clayey Soil | Sandy Soil

- Cereal straw
- Rape straw
- Willow
- Whole crop
- Maize-silage
- Grass low yield
- Grass high yield
- Beets

Gylling et al., 2016
## Employment effects - persons

<table>
<thead>
<tr>
<th>Sector</th>
<th>BAU</th>
<th>Biomass</th>
<th>Environment</th>
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</thead>
<tbody>
<tr>
<td>Agriculture, fisheries, extraction of raw materials</td>
<td>5978</td>
<td>8897</td>
<td>5448</td>
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<tr>
<td>Industry</td>
<td>1842</td>
<td>3558</td>
<td>2623</td>
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<tr>
<td>Energy and water supply</td>
<td>399</td>
<td>857</td>
<td>663</td>
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<tr>
<td>Building and construction</td>
<td>421</td>
<td>863</td>
<td>653</td>
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<tr>
<td>Trade, hotel and catering</td>
<td>823</td>
<td>1455</td>
<td>1020</td>
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<tr>
<td>Transport, postal service and telecommunications</td>
<td>879</td>
<td>1842</td>
<td>1401</td>
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<tr>
<td>Financial and business services</td>
<td>1607</td>
<td>2865</td>
<td>2016</td>
</tr>
<tr>
<td>Public and personal services</td>
<td>246</td>
<td>420</td>
<td>276</td>
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<tr>
<td>Associations, culture and refuse disposal</td>
<td>112</td>
<td>208</td>
<td>149</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12306</strong></td>
<td><strong>20965</strong></td>
<td><strong>14249</strong></td>
</tr>
</tbody>
</table>
What is needed to double productivity and halve environmental impact from Danish agriculture?

New crop production paradigm

- Annual crops -> perennial crops
- Improved application of cover crops
- Harvest green crops (maximum biomass & protein)
- Green biorefinery to produce food, feed, bioenergy & materials

Research and development

- Increase productivity of grasses and legumes
- Breeding for biorefinery quality (extractable protein, low ANF content)
- Biorefinery processes – protein extraction etc.
- Demonstration of new concepts (high production low emission crops, animal feeding, logistics & conversion)
- Optimized integration with bioenergy technologies (biogas, HTL, ethanol....)
Questions?

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