Modelling alternative fuel production technologies for the future Danish energy and transport system

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How should we best value residual biomass resources?

The dependence on fossil fuels and lock-in effects in the infrastructure network have for long determined a slow pace in the transition to a transport sector based on renewable sources. While biofuels represent a possible alternative, biomass is a limited resource, which use is restricted by potential social, technical and environmental effects. Because residual biomass, e.g. straw in Denmark, inherently minimizes these negative impacts, it could lend itself to multiple options, including production of alternative transport fuels.

Current use of straw in 2015 (tons)

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Key Results

The bottom-up optimization model TIMES-DK covers the Danish energy system, allowing electricity and fuel exports, and it optimizes under the assumption of perfect foresight from 2010 through 2050. No primary imports of biomass are allowed for this study.

Objective function

\[
\min \sum_{r \in R} \sum_{y \in Y} (1 + d_{y,r})^{y-2010} \cdot Cost_{r,y}
\]

subject to

Resource bounds

\[
\sum_{r \in R} \sum_{y \in Y} y \cdot C_{r,y} \leq A_{r,y}
\]

set of regions

\[
y \geq 0, C_{r,y} \geq 0, r \in R, y \in Y
\]

set of resource commodities

Energy efficiency

\[
\sum_{r \in R} \sum_{y \in Y} \frac{y}{p_{r,y}} \leq B_{r,y}
\]

set of energy services

\[
p_{r,y} \geq 0, r \in R, y \in Y
\]

set of energy processes

Emission targets constraints

\[
\sum_{r \in R} \sum_{y \in Y} \frac{y}{e_{r,y}} \leq E_{r,y}
\]

input flow of commodity \( y \) in process \( p \)

\[
e_{r,y} \geq 0, r \in R, y \in Y
\]

CO2eq emissions from process \( p \)

Further work

- How does plant location affect the final use of straw?
- Geographical and temporal availability of biomass
- Transportation of biomass from the field
- What are the policy implications?
- Shaping the non-ETS CO2 quota market

Conclusions

- The analysis on the optimal use of straw suggests that a combination of technologies (BTL and biogas) is the most cost efficient while using straw for heat and power is the least attractive solution. However, the choice has a sensible impact only on the future configuration of the transport and heat sectors, with minor effects on the rest of the energy system.
- While uncertainty on cost and efficiencies of emerging technologies remains, further sensitivity analyses performed show no changes in the optimal combination associated with smaller or larger costs of investment and operation for the winning technologies.
- Given the current political debate on the optimal use of this undervalued resource, the analysis offers an objective and comprehensive comparison of the different options.

Methodology

Technological pathways

- AGR: Left on the fields
- BGA: Biogas
- CHP: Heat and power
- ETOH: Bioethanol 2G
- BTL: Biokerosene
- OPT: Optimal scenario

Biomass resource potentials in 2050 (PJ)

- Left on field; 50%
- Fodder; 16%
- Manure; 13.8
- Waste; 11%
- Hydrogen; 23%
- Electricity; 16%

Total Fuel Supply (2050)

- Synthetic Natural Gas
- Biokerosene G2 (Straw)
- Biodiesel G2 (Straw)
- BioNaphta (Woodchips)
- Bioethanol G2 (Sugarbeet)
- Liquid Petrol Gas

Further work

- How does plant location affect the final use of straw?
- Recovery of process heat in district heating network
- Geographical and temporal availability of biomass
- Transportation of biomass from the field

How do we measure costs and benefits within the agriculture sector?

- Soil carbon stock: direct and indirect land use changes
- Soil treatment: reutilization of process by-products
- Future food production and dietary developments

What are the policy implications?

- Shaping the non-ETS CO2 quota market

Literature