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

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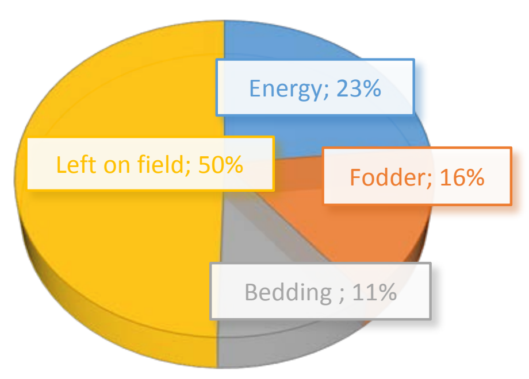
How should we best value residual biomass resources?

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)



Perspective	Parameters
Techno-economic	Investment cost - O&M cost - Fuel delivery cost Efficiency - Availability factor - By-products
Energy and transport system	Process heat recovery - Localization - Emissions
Agriculture sector	Avoided fertilizers - Carbon stock - LUC/ iLUC
Social	Employment effects - Livelihood impacts - Health

Methodology

Technological pathways		
AGR	Left on the fields	Main current use
BGA	Biogas	Anaerobic co-digestion with manure and biowaste
CHP	Heat and power	CHP plants and heat boilers
ETOH	Bioethanol 2G	Hydrolysis and fermentation
BTL	Bioalcohols and Biodiesel	Gasification + Fischer-Tropsch synthesis
OPT	Optimal scenario	Cost-optimal combination of technologies

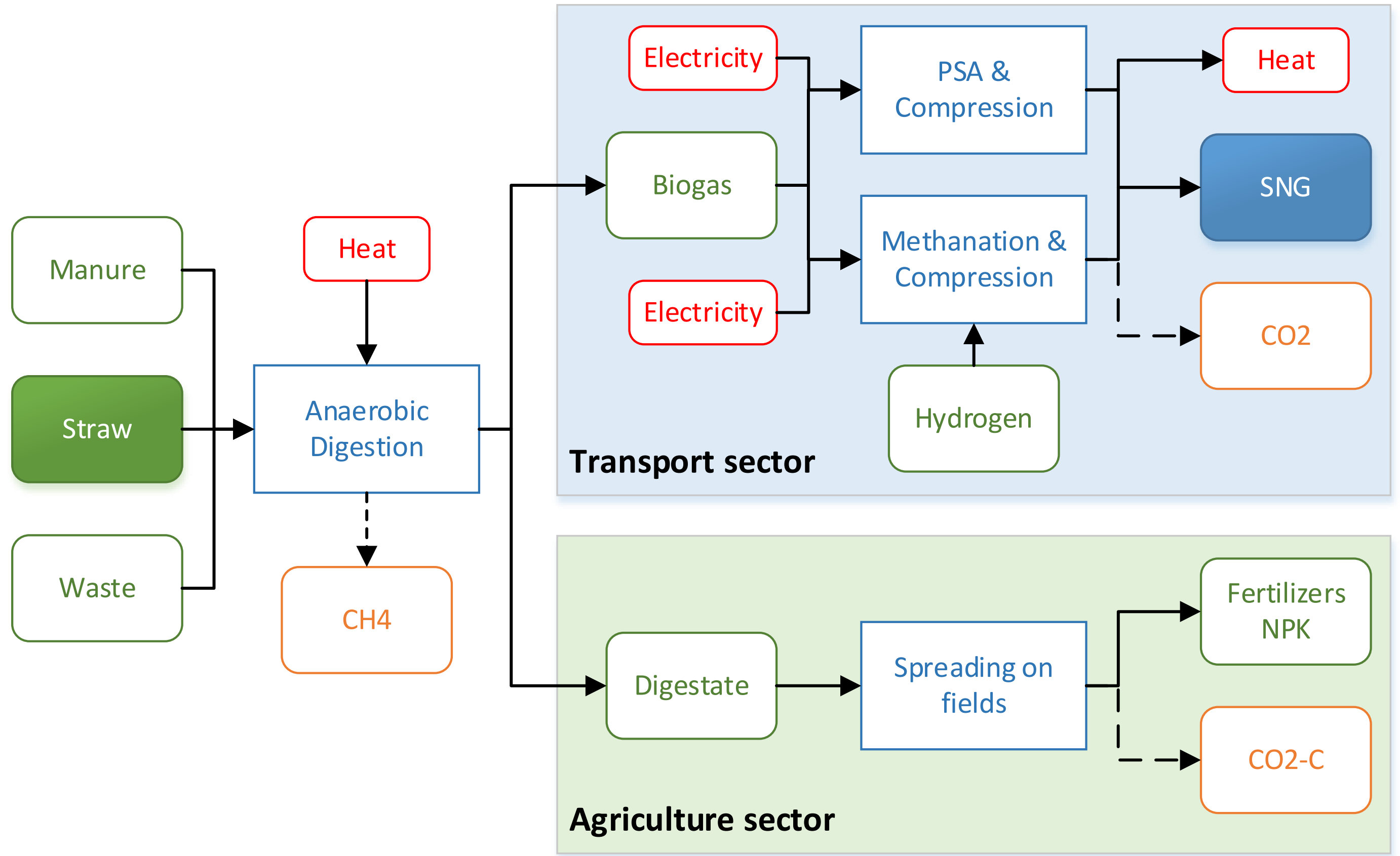


Figure Model for SNG production from anaerobic co-digestion of straw and subsequent biogas upgrade

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

$$\min \sum_{r \in R} \sum_{y \in Y} (1 + d_{ry})^{(y_0 - y)} \cdot Cost_{ry}$$

subject to

Resource bounds

$$\sum_{p \in P} x_{cp} \leq A_{cry} \qquad \forall\, c \in C, r \in R, y \in Y$$

Fulfilment of service demands

$$\sum_{p \in P} w_{sp} \geq D_{sry} \qquad \forall\, s \in S, r \in R, y \in Y$$

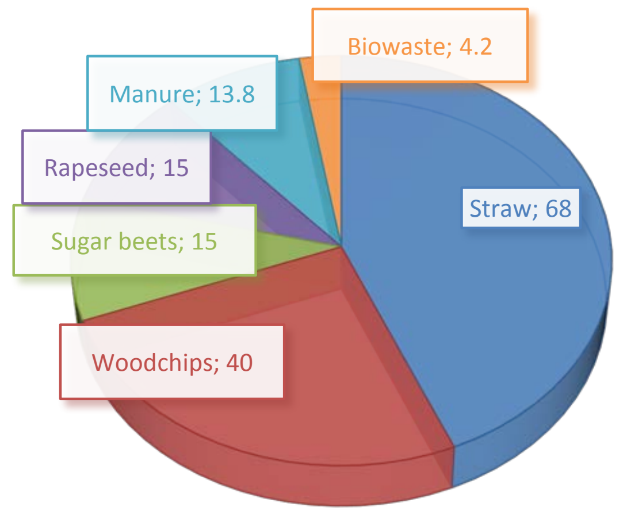
Emission targets constraints

$$\sum_{p \in P} Emis_p \leq Target_{ry} \qquad \forall\, y \in Y, r \in R$$

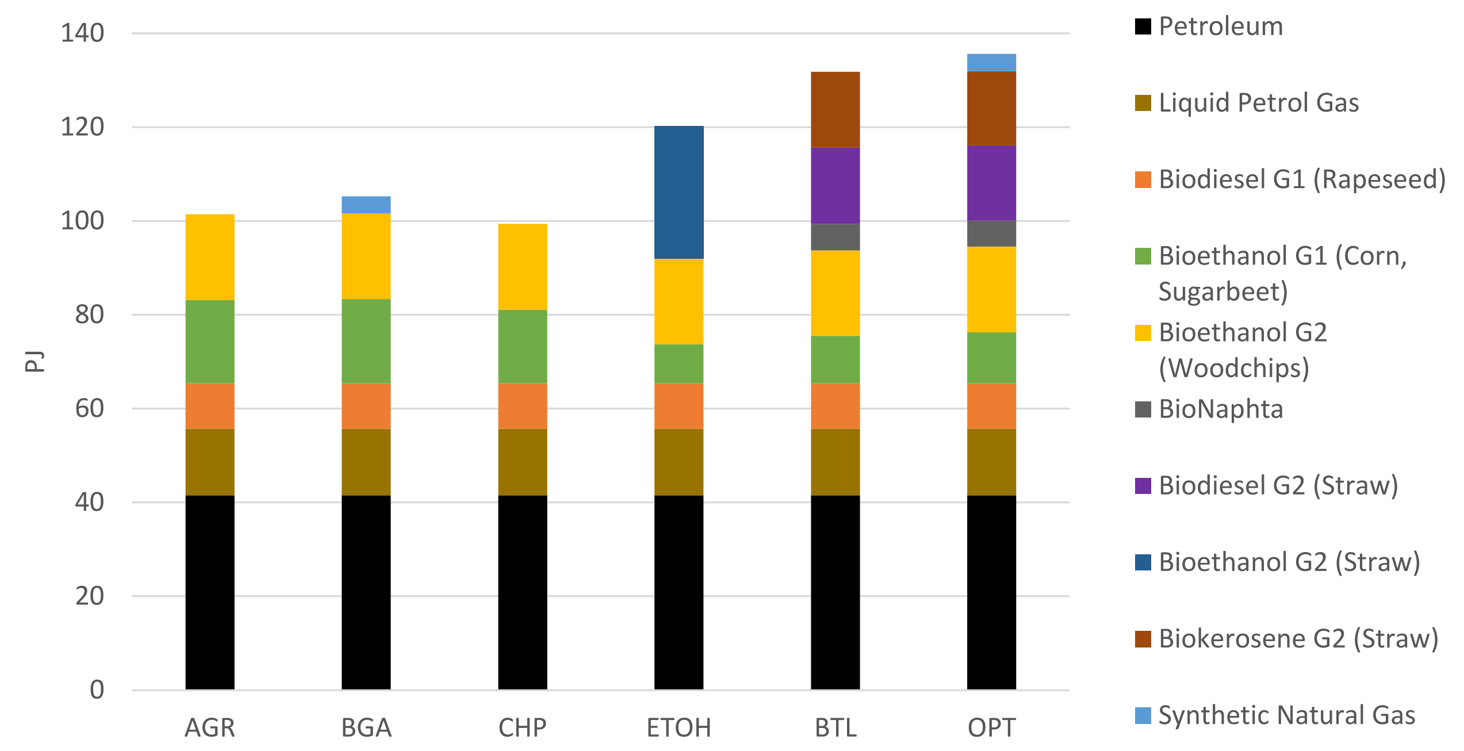
R: set of regions
Y: set of years with y_0 reference year
d_{ry}: discount rate with $r \in R$ and $y \in Y$
$Cost_{ry}$: total cost in year $y \in Y$ and region $r \in R$

C: set of resource commodities
S: set of energy services
P: set of energy processes
A_{cry}: availability of resource $c \in C$, with $r \in R, y \in Y$
D_{sry}: demand for service $s \in S$, with $r \in R, y \in Y$
$Target_{ry}$: emission target in region $r \in R$, year $y \in Y$
x_{cp}: input flow of commodity $c \in C$ in process $p \in P$
w_{sp}: output flow of commodity $c \in C$ in process $p \in P$
$Emis_p$: CO_2eq emissions from process $p \in P$

Biomass resource potentials in 2050 (PJ)

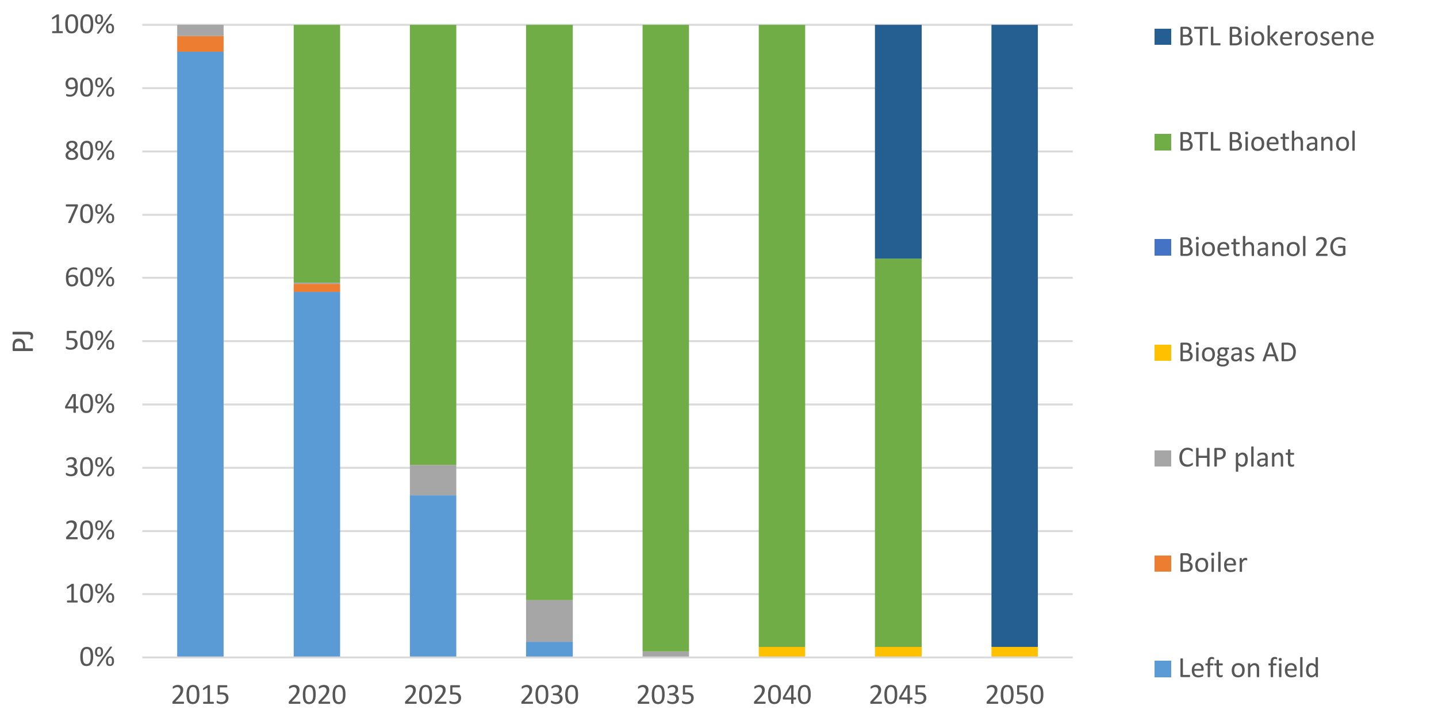


Total Fuel Supply (2050)



- *Green Growth 2020*: Use of 50% manure for biogas production by 2020
- *EU RED*: Min share of 10% renewable energy in transport by 2020
- *National targets*: 100% renewable (fossil CO_2 neutral) industrial, residential and transport sectors by 2050

Technology Roadmap



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 unutilized resource, the analysis offers an objective and comprehensive comparison of the different options.

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 CO_2 quota market

Literature

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