Integrated assessment of the introduction of biofuels in the Danish Transport sector

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Introduction

During the last decade procedures and processes to support the integration of environmental issues in sector policies and sustainability issues in EU policy making have been developed to ensure increased policy coherence. Better regulation at EU and member state level is requested, and ex-ante impact assessment of policy alternatives is one of the methods implemented in the Commission policy making procedures, and is also implemented in some, but not all, member states (CEC, 2005). National ex-ante impact assessment systems have been implemented, but do not always give proper consideration of environmental aspects (Raggamby *et al*., 2007).

Targets for the introduction of biofuels in the transport sector in Denmark is now a 5.75 % share of fuels in 2010, phased in until 2012, and in 2020, 10% of the energy consumption in the transport sector should be covered by renewable energy. This paper presents the approach developed and some results from an integrated assessment of the introduction of biofuels in the transport sector in Denmark to reach these targets using biofuels. Based on forecasts for road traffic increase until 2030, estimations of road traffic energy demand, biofuel and biomass demand under different policy targets for biofuel mix are estimated. Options for meeting this demand under a strategy of self-sufficiency are discussed.

Background

Energy security and climate change considerations, and the subsequent need for decoupling from fossil fuel dependency, have targeted the production of energy from biomass as an important source for substitution. EU has through the Renewable Energy Directive (CEC, 2009) laid down targets for the use of renewable energy to reach 20% of the consumption in 2020, while the transport sector must reach a share of 10%. Recent legislation already supports this conversion in many countries, and incentives for national production exist. Required shares of biofuel mix lie in the range of 5-20 % to be reached at different years until 2020 (Petersen, 2008, pp. 389-390, Cushion et al., 2010, Ravindranath et al., 2009).

Biomass conversion to biofuels for transport is however heavily debated. The relatively low energy efficiency due to loss in the transformation process, in comparison to the use of biomass as fuel in combined power and heating plants has been highlighted (Teknologirådet, 2009), but it has been argued that side products from biofuel production, e.g. animal feed, and other side products should also be included in the calculations of energy efficiency. Another issue is the land competition which may result from land requirements exceeding the availability of land, which may threaten food security and impose indirect land use change (iLUC) with possible unwanted environmental impacts, such as loss of tropical forests (Cushion et al, 2010), and the ensuing carbon dept (Fargione, 2008, Searchinger 2008 and 2009). Yet another consideration is the environmental impact of biomass production from direct land use changes and crop substitution, which may be both positive and negative. Integrated studies, such as LCA studies, however, often focus on the greenhouse gas balances of biofuel conversion (Menichetti & Otto, 2009), while other environmental impacts are to some extent overlooked (Bringezu *et al.*, 2009). Approaches and methods for ex-ante integrated assessment of policy proposals to implement national bioenergy targets and to include land use change and environmental impacts are needed (Petersen 2008).

Fischer et al (2010) produced land use scenarios for Europe including Ukraine, anticipating up-keeping of current levels of self-sufficiency in food and feed production. They found the total availability of land for biofuel feedstock in 2030 to be between 44 million. ha and 72 million ha, depending on the environmental considerations and the priority to energy production (in 2000 the total cultivated land and pasture in Europe plus Ukraine was about 240 million ha). In this land use scenario Denmark figured with 289.000 ha for biofuel feedstock in 2030. The Danish agricultural organisation estimates a target of 100.000 ha cultivated with perennial energy crops in 2020 (and an additional 1 mio. tons of straw) (Landbrug og Fødevarer, 2009). A Danish study on behalf of the Danish Ministry of Food, Agriculture and Fishery (2008) estimated that the app. 100.000 ha used mainly for rape production in 2007 could be increased to 125.000 ha, and that 224.000 ha of other cropland could also be used for energy purposes. In addition, 57.000 ha set-aside and 115.000 ha low-lying grassland was included in the biomass for energy estimation, as well as 626.000 ha straw from crops and rape.

Data and methods

The overall method used is to compare scenarios for biofuel use in the road transport sector and the related demand for fuel production and agricultural products to a reference, where no biofuel is used. Consequences are quantified as differences between scenario and reference. Emphasis is on building the assessment methodology and system delimitations, while only using mainstream crops in the assessments. Two scenarios are produced – one compliant to the policy targets (HS1) and another reaching a 25% share in 2030 (the high scenario, HS2).

Reference forecasts

Two types of forecasts are used as reference for the impact assessments. The first is a forecast of the road traffic until 2030, while the second is a forecast of the agricultural area and the related land use in the same period.

Transport forecast. The forecast used in this study (Jensen & Winther, 2009) is based on a forecast made for a Danish Infrastructure Commission during 2006-2007 (Infrastrukturkommissionen, 2008). Two forecasts were set up based on alternative assumptions on oil prices, a low price assumption of 65$ pr barrel and one of 100$ pr barrel (the base case). The model used in the forecasts is a Danish econometric model. It uses the relationship between income (GDP) and variable costs on the one hand and car stock and annual mileage of a car on the other, and it is based on the historical relationship between these. The price of fuel is about 60 % of the variable costs. The projected traffic is estimated by multiplying the stock by the annual mileage per car.
Forecasts for busses and lorries is produced, based on constant yearly growth in traffic. Yearly growth is related to GDP and is based on analyses of the relationship between economic growth and traffic. Growth in GDP was set to 1.2 % pr year on average following the Danish Ministry of Finance (2005).
In the forecast with an oil price of 65$ pr barrel, traffic is estimated to grow by 1.4% p.a. 2005-2030 for cars and vans, 2.2% for lorries and 0.0% for busses – on average 1.4%. In the base case with an oil price of 100$ pr barrel traffic growth is reduced to 0.8% a year.
From these traffic estimates, energy consumption is estimated. It was assumed that no increase in fuel efficiency would take place[1]. Fuel consumption is thus directly related to traffic work. The

[1] A number of arguments support this assumption, including that fuel efficiency is implicitly incorporated in the price elasticity for small cars.

relative share of diesel and petrol cars was incorporated, as well as the effect of the fuel efficiency in already sold cars.
The resulting energy demand is shown in table 1 for the 100$ forecast, which is the forecast that will be used for the calculations of land use demand.

100 $ forecast	Fuel consumption TJ				
	2010	2015	2020	2025	2030
diesel	105.801	120.326	131.986	142.441	152.300
gasoline	55.211	48.599	47.837	48.695	50.213

Table 1: Estimated fuel consumption, based on road traffic forecast, assuming oil price, 100$

Agricultural land use reference scenario. This reference scenario (Larsen *et al*, in prep) is based on following presumptions: the agricultural land area will be reduced according to known reductions due to political environmental agreements (e.g. on afforestation and set-aside) and on estimated reductions due to development of urban areas and infrastructure. Moreover, the livestock/dairy sector develops as foreseen by the sector represented by the Agricultural organisation until 2015, and it stabilises after this towards 2030. This results in a reduction of the cultivated areas from 2.644.700 ha in 2008 to an estimated area in 2030 of 2.465.600 ha, i.e. a reduction of approximately 200.000 ha. The estimated area for roughage is almost constant in the period, while areas for concentrates increase. Consequently, the area for feed production takes up an increasing share of the cultivated area, and with a decreasing total agricultural area the remaining area – now used for fallow, high value seeds, regional products, and other crops are decreasing from 577.000 ha in 2008 to 267.000 ha in 2030. Given that high value seeds and regional products are continuously competitive, and that the present fallow area represents areas that will no be cultivated, the resulting "free" area now used for other crops descends from 371.000 ha to 107.000 ha in the scenario period.

Scenarios for introducing biofuels in the road transport sector

The policy scenario (HS1) implements the targets of 5.75 % biofuel use in 2010 and 10 % in 2020. The high scenario (HS2) use biofuel shares of 15 % in 2020 and 25 % in 2030. Second generation bioethanol are phased in from 2010, as illustrated in figure 1.

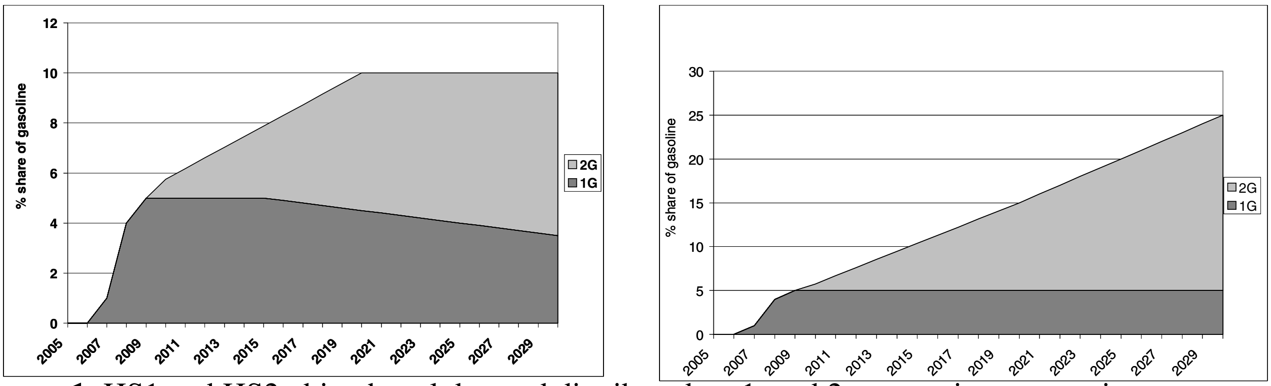

Figure 1: HS1 and HS2, bioethanol demand distributed on 1. and 2. generation conversion technology

The assumptions behind the development of the scenarios are:

- The shares of bioethanol and biodiesel are the same (implying that, as the number of diesel cars increases more than petrol cars, the biodiesel demand will increase more than the bioethanol demand.
- The agricultural products used are wheat (kernels) for bioethanol and rape (RME) for biodiesel, while wheat straw is used as raw material for second generation bioethanol production.

Figur 2a and 2b shows the relative distribution of energy from biodiesel and bioethanol respectively, for the two scenarios.

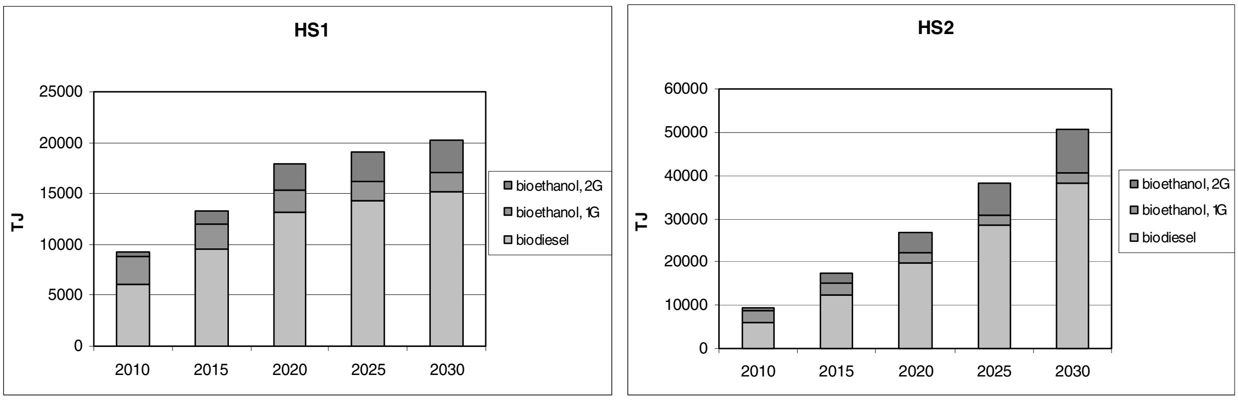

Figure 2: Distribution of biofuel shares in biodiesel, 1G bioethanol and 2G bioethanol

Results and discussion

Based on the estimated biofuel demand, the biomass demand and resulting land claims are estimated. In these estimates, it is anticipated that only 50% of the straw is used pr area unit, allowing for present uses of straw. The results are shown in table 2 and table 3.

table 2	HS1 area demand 1000 ha				
	2010	2015	2020	2025	2030
rape	129	202	280	302	323
wheat	44	38	34	31	28
straw with !	35	121	223	248	277

Table 2: land demand in HS1

table 3	HS2 area demand 1000 ha				
	2010	2015	2020	2025	2030
rape	129	265	420	604	808
wheat	44	39	38	39	40
straw w. 5C	35	223	408	620	853

Table 3: Land demand in HS2

The wheat and straw demand in HS1 could be met within the present land use, given that the “free” area is used for biofuels such that 25% (as much as rotation allows) is taken up by rape, and the remaining area is used for wheat and straw. Then only 8000 ha in HS1 and 20.000 ha in HS2 need to be found in the present wheat area, which takes up around 700.000 ha. Straw demand can also be met within the total wheat area. If the present rape area is used solely for biofuel, and 25% of the “free” area is used, land for rape will still be insufficient before 2020.

If the development in the car park allowed that this deficit could be covered by bioethanol, and given the same distribution among 1st and 2nd generation bioethanol, this would demand additional 20.000 ha wheat in HS1, and a total of 247.000 ha straw, which is fully available.

For HS2 the area for rape is almost three times as large, and if the deficit should still be covered by bioethanol this would claim around 30% of the present wheat area, while the straw would take up 80% of all wheat straw or 80% of the straw from all cereal production, given the 50% rule is still applied.

These estimates have not yet included the fodder, which can be retrieved as a side product from the bioethanol production and which will substitute some of the fodder demand, and thereby release more land for other production. Moreover, technological improvements and productivity increases can be expected. Eventually other agricultural strategies with less dominance of dairy and meat production would also free areas for e.g. biofuels.

Conclusion

The scenarios presented show that the policy targets for biofuel implementation cannot be fully met for the RME part. If 25% the diesel share could be interchanged to bioethanol, it would be possible to realise in terms of land availability, given that 2G technology is soon available, and under present agricultural strategies. Higher share of biofuel use will need to be based on higher shares of bioethanol to RME fuels or on larger changes in agricultural strategies.

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