VIEWLS: BIOFUEL IMPLEMENTATION SCENARIOS UP TO 2030 EXPLORED BY THE BIOTRANS MODEL

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ABSTRACT: Analysis of future prospects of biofuels using the BIOTRANS model indicate that conventional Pure Vegetable Oil and biodiesel, followed by bioethanol, remain the lowest cost biofuel options until 2020 with a gradually increasing market share for future biofuels based on lignocellulose. The model predicts rapid growth of advanced biofuels starting from 2010, such as bio-DME, biomethanol and Compressed-SNG, although the cost calculations have too large uncertainty ranges to indicate these as the 'winning' biofuels. Clear is that biofuels produced from more abundant and potentially much cheaper lignocellulosic feedstocks seem to be preferred over traditional conventional biofuels. Advanced biofuels can have a 2010 break-even oil price of 60 -100 $/bbl if technologies and bioenergy crops are developed to a sufficient scale. On the longer term, this break-even price could decrease to ca 40 $/bbl. Even under a supposed additional 20% biofuel Directive target for 2030, there is sufficient biomass potential for biofuels in Europe and in particular in the Central and Eastern European Countries. Given these results, the acceleration of advanced biofuel options may be more important for the realization of long-term biofuel goals in Europe than early penetration of first generation liquid biofuels as such.
Keywords: Biofuels, advanced conversion systems, land use

1 INTRODUCTION

Given the ambitious targets in the EU Biofuel Directive, there are still major uncertainties about the potentials in Europe for biofuel production, especially in the Central and Eastern European Countries (CEEC), and about the key biofuels for the short and long term. There is need for a cost efficient biofuel strategy for Europe in terms of biofuel production, cost and trade, and for an assessment of its larger impact on bioenergy markets and trade up to 2030. Key questions in this context are:
Under the European biofuel Directive, which combinations of biomass options and conversion technologies constitute the short-term and long-term least cost biofuel supply chain, taking into account all costs from biomass exploitation up to end-use conversion?
What is the potential for biomass production in CEEC countries, and what are the opportunities for bioenergy trade between CEEC and Western European Countries (WEC)?
What will be the average end-user costs of realising biofuel targets?
What is the impact of biofuels on overall GHG emissions in the transport sector?

Based on the biomass availability and associated costs within EU25, under different conditions, scenarios for biofuels production and cost can be constructed to address these questions, using quantitative modelling tools. The VIEWLS data on (future) biomass availability and conversion technologies are an excellent basis for such a modelling tool, assisting policy makers in developing a cost efficient biofuel strategy in Europe.

2 METHOD AND INPUT DATA

2.1 Method

The ECN BIOTRANS model was developed as a multi commodity network flow model. The model generates the lowest cost supply chain, from feedstock to end-use, for realising a specified demand for biofuels for the WEC and CEEC following the EU biofuels Directive, with a target of 5.75% biofuels market share in 2010 - the scope of the Directive. It is assumed that the Directives target is extended to 20% in 2030. Countries included in the model are the former EU15 (except Luxemburg), Poland, Hungary and the Czech Republic. The Accession Countries Romania and Bulgaria are included for biomass potentials but not for fuel demand.

The transport segments that have been incorporated in the model in each country are cars, buses and trucks. Given their characteristics, each biofuel replaces either gasoline or diesel, in blended or pure form. BIOTRANS contains the conventional, state of the art as well as the more advanced biofuels (see Table I). The same holds for the biomass input that includes, besides oil crops, residues etc., also higher energy density biomass such as lignocellulosic crops. The general structure is depicted in Figure 1.

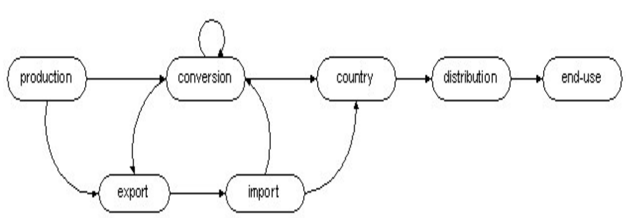

Figure 1: BIOTRANS model structure

Key inputs for BIOTRANS are
(1) regional costs and potentials of biomass resources,
(2) technology parameters on conversion processes including technological learning,
(3) transportation costs and
(4) infrastructure and vehicle adaptation costs.

Table I: Biofuels in BIOTRANS

Conventional biofuels technologies of today:	**Advanced biofuels technologies of tomorrow:**
Pure vegetable oil (PVO)	Cellulosic bioethanol (enz. hydr.)
Biodiesel	Fischer-Tropsch Diesel
• from vegetable oils	Biomethanol (gasification)
• from used fats	Biodimethylether (DME, gasific.)
Bio-ETBE and Bio-MTBE	Substitute Natural Gas (SNG) by
Conventional bioethanol	• gasification, methanation
• from sugar crops	• anaerobic digestion
• from starch crops	Bio hydrogen (gasification)
	HTU-Diesel

2.2 Input data

This scope of this paper does not allow for presentation of the extensive datasets. Specific data can be found in [1]. Here we shortly discuss the data used for biomass resources and conversion technologies. For the *energy crops production potentials, p*Potential areas were generated per country by subtracting the total agricultural area by the prospected area needed for food, fodder and other agricultural crop production. This reasoning led to high potentials in Poland and Romania (each ca 11 Mha), Bulgaria and Hungary (each ca 4 Mha) and the Czech Rep., France, Germany and Spain (each ca 2 Mha).

The available land was categorised in suitability classes, potential yields were specified for each suitability class and for each country. Yields and costs were specified for four categories op crops: lignocellulosic (wood), herbaceous lignocellulosic (grasses), oil (oil seeds, soybean), sugar (beet, cane, etc.) and starch crops (wheat, maize, etc.). Energy crop yields and costs were calculated for Poland and the Netherlands (see Table II and Table III). For the other countries, yields and costs were related to these countries: WEC to the Netherlands, CEEC to Poland.

Table II: Typical energy crop yields (t/ha/yr)

Country	Land type	Ligno cell. crops	Herb. lignoc crops	Oil crops	Sugar crops	Starch crops
Netherlands	S	10.7	12.3	2.9	20.8	8.3
Poland	VS	10.6	12.1	2.7	13.6	7.2
Poland	S	7.9	9.0	2.2	11.3	5.4
Poland	MS	5.3	6.6	1.4	7.8	3.9
Poland	LS	1.8	1.8	0.7	3.7	2.4

*: Very Suitable, Suitable, Moderate Suitable, Less Suitable

Apart from energy crops, a wide variety of residual biomass streams was taken into account, ranging from forestry and wood processing residues to organic waste, manure and roadside hay.

The biofuels in BIOTRANS can be produced with a multitude of *conversion processes* and sub-processes, described in detail elsewhere [2]. Table IV gives an overview of the assessed costs and efficiencies of the most important processes. Some new technologies are expected to be available from 2010, and the corresponding performance parameters are based on expert judgement from various partners within the project. Costs are expressed either in €/GJ or €/ton product.

Table III: Typical energy crops costs (€/GJ)

Country	Land type*	Ligno Cell. crops	Herb. Lignoc crops	Oil crops	Sugar crops	Starch crops
Netherlands	S	3.3	3.0	10.0	4.3	4.3
Poland	VS	1.3	2.8	3.3	1.7	1.7
Poland	S	1.4	3.2	3.3	1.9	1.9
Poland	MS	1.5	4.3	4.8	2.7	2.7
Poland	LS	2.7	14.3	7.7	5.4	5.4

*: Very Suitable, Suitable, Moderate Suitable, Less Suitable

Implicitly, these cost assumptions include assumptions on future technological developments or break-troughs (efficiency improvements, up scaling) and on future policies (both R&D and implementation policies) that may bring down future costs. There are no explicit cost reduction parameters in the model such as endogenic and exogenic technological learning as a function of installed capacity and economies of scale, learning is modelled as a process over time.

Table IV: Costs and efficiencies of key conversion processes in BIOTRANS

Conversion process	Intro	Cost Unit	Costs per cost unit O&M	Costs per cost unit Inv.	Yield Unit	Yield ratio
CFB-gasification	2010	ton	9	180	GJ	0.74
CO_2 removal (Hydrogen)		GJ	0.08	2.8	GJ	0.95
CO_2 removal (SNG)		GJ	0.02	0.6	GJ	0.95
Cold-Pressing		ton	31	30	ton	0.38
Crushing, Fermentation, Distillation		ton	15	125	ton	0.2
Digestion		GJ	1.6	16	GJ	0.5
DME-synthesis		GJ	0.3	6.8	GJ	0.79
EF-gasification	2010	GJ	0.4	10	GJ	0.77
ETBE-synthesis		ton	32	320	ton	2.1
FT-synthesis		ton	15	300	GJ	0.64
Hydro Deoxygenation		ton	15	450	ton	0.87
Hydro-cracking		GJ	0.1	2.5	GJ	1
Hydrogen-compression		ton	1.7	48	ton	1
Hydrothermal-treatment	2010	ton	40	320	ton	0.44
Indirect-gasification	2010	ton	9	180	GJ	0.76
Biomethanol synthesis		ton	6.8	136	GJ	0.72
Methanation		GJ	0.3	7	GJ	0.83
Milling, Heating, Fermentation , Distillation		ton	40	300	ton	0.31
MTBE-synthesis		ton	42	460	ton	2.8
SNG-compression		ton	0.2	6	ton	1
Steam-reforming		ton	0.6	20	GJ	0.85
Size reduction, Hydrolysis, Fermentation, Distillation	2010	ton	20	140	ton	0.25
Transesterification-oil seed		ton	33	100	ton	0.99
Transesterification-used-fat		ton	30	100	ton	0.96

3 RESULTS

3.1 Lowest cost biofuel mix

The development of the lowest cost fuel mix over time in BIOTRANS is summarized in Figure 2. PVO is the lowest cost conventional biofuel option compared to biodiesel and bioethanol (which does not enter into the market at all), even with the necessary cost of vehicle adaptation. The PVO is almost solely used in trucks and buses. While biodiesel currently dominates biofuel markets in practice, key message of this analysis is that in order to reach the 5.75% target in 2010 a 100% use of PVO and biodiesel exclusively for the diesel fleet of vehicles would be more cost-efficient than the use of E-05 bioethanol for the petrol fleet.

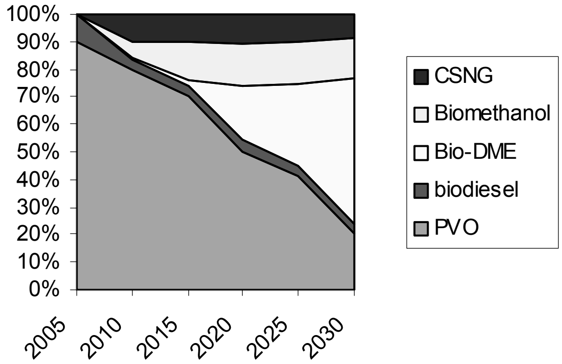

Figure 2: Lowest cost fuel mix

In BIOTRANS, the fraction of PVO in the biofuel mix decreases after 2010 in favour of advanced biofuels. This because, in order to achieve increasing biofuel targets, less attractive potentials (less suitable land for crop production) for PVO and biodiesel would have to be used, leading to higher costs for these fuels. The use of advanced biofuels, with related crops with higher energy potential per ha, then becomes economically attractive, if the conversion technology is also available. In 2010 and beyond, this development results in the increasing market penetration of Bio-DME, Biomethanol and CSNG. Due to projected conversion cost reductions of some 20% - 30% per decade, these become the lowest cost options of the advanced fuels, all based on biomass gasification. FT-Diesel and bioethanol are close to competitive but BIOTRANS is radical in selecting the lowest cost options to build the required amount of biofuel in a given year. Note that the cost reduction assumptions for the different fuel conversion technologies have uncertainties as they are in the R&D, or at best in the pilot phase, which makes extrapolation regarding cost reductions, up scaling and economies of scale rather speculative. Therefore, the data are not sufficiently reliable to indicate the 'winner' biofuels.

3.2 The average costs of the biofuel mix

The average costs of the biofuel mix are depicted in Figure 3. The slight increase in fuel mix cost is a net effect of several developments. On one hand, crop prices decrease due to the replacement of oil crops by cheaper and more energy efficient woody biomass. On the other hand, conversion costs increase due to the growth of advanced biofuel technologies. Although fuel costs of advanced biofuels are higher than those of PVO and biodiesel, these technologies will enter the market, since the conventional biofuels will become more expensive due to the use of less attractive land in order to meet increasing biofuel targets beyond 2010. Another relevant result is that until 2030, Europe has sufficient domestic biomass potential to fulfil the needs, although some of the most suitable areas in the CEEC become exhausted.

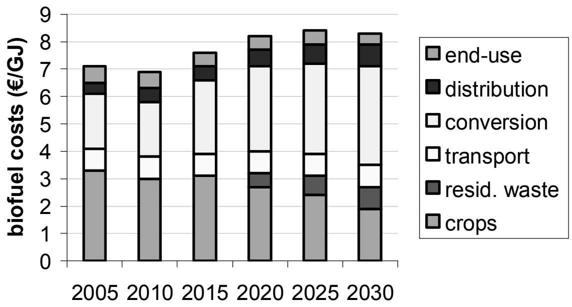

Figure 3: Average cost of the biofuel mix

In the far future, typical 8 €/GJ projected costs of advanced biofuels can be reached, provided that:

(1) The development and up scaling of advanced biofuel technologies, based on e.g. gasification, is successful, meaning available on time, with sufficient production volume, product quality, and economies of scale.
(2) The cheap woody biomass potential in the CEEC becomes and remains available at low prices.
(3) The advanced biofuels meet their fuel specifications.

If these conditions are met, then biofuels will be able to compete with fossil fuels at cost of around 7 €/GJ, an oil price of 40 USD/bbl. This makes a high biofuels scenario a serious option for Europe in view of security of supply.

3.3 Greenhouse Gas (GHG) impacts

From Life Cycle Analyses it can be concluded that PVO and biodiesel are not GHG neutral. According to the VIEWLS WP2 survey, the emission reduction per driven km relative to the replaced fossil fuel is only ca. 45%. For the advanced biofuels this reduction is much higher (85-90%). Assessing the net GHG impacts of the biofuel development targets, it is therefore interesting to evaluate the effect of excluding PVO(and biodiesel) as options from the base case fuel mix in favour of advanced biofuels (see Table V).

Table V: Reduction of CO_2-equivalents emissions for the whole transport sector in the EU

	Biofuels target		
	2010 (5.75%)	2020 (15%)	2030 (20%)
Base Case	2%	9%	15%
Excluding PVO	5%	12%	17%
Excluding PVO and Biodiesel	5%	13%	18%

Because in 2010 the fuel mix mainly consists of PVO and biodiesel, the effect on CO_2 emission reductions of replacing these by advanced biofuels, which have a much higher CO_2 emission reduction, is the strongest. In 2030, this effect is relatively small, since advanced biofuels already have a large market share of 76% in the base case.

3.4 Costs of individual biofuels

In Figure 4, the costs, and their components, of the individual biofuels is compared for the year 2010. It is assumed here that the target of 5.75% is strictly fulfilled by one biofuel, which puts stringent requirements on biomass supply.

For PVO and biodiesel, the fuel costs strongly depend on crop costs. For biofuels of the future, the conversion costs dominate as lignocellulosic crops and agro and forestry residues are supposed to become available at prices around 1.5 - 2.0 €/GJ. However, factors such as supply constraints, limited land availability, water management issues, competition with food crops or with biomass for stationary applications, these crop may well go up in the longer term.

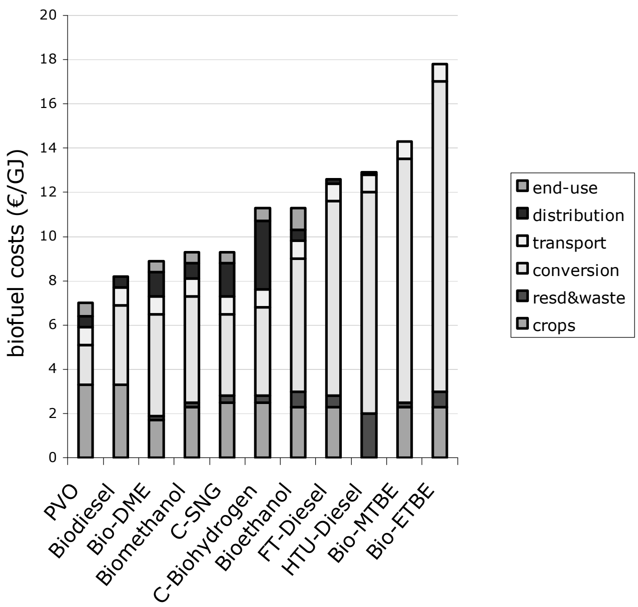

Figure 4: Costs of individual biofuels in 2010

The 2010 costs range from 7 €/GJ for PVO to 18 €/GJ for Bio-ETBE. In the light of competition with fossil fuels these figures would compare to break even oil-prices ranging from 40 USD/bbl up to 100 USD/bbl.

End-use (adaptation) cost are in general relatively low, 0,5 €/GJ. This because in BIOTRANS niche fleets of buses and trucks are built, of which the conversion costs are relatively low. For cars the conversion cost, where applicable, would be 1 to 2 €/GJ higher.

Bioethanol, in 2010, is produced from a mix of sugar, starch, and residues and waste resulting in a total price of 11.3 €/GJ. From a pure European perspective, would bioethanol be required in the fuel mix, it would simply be cheaper to import bioethanol from Brazil (produced from sugar cane) at a total price (transport included) of 8 €/GJ. At the same time, there might be a (European) future for lignocellulose based bioethanol, although BIOTRANS predicts slower technological progress for bioethanol than for other advanced biofuels.

4 DISCUSSION, CONCLUSIONS

According to BIOTRANS, conventional biofuels, primarily PVO, remain the lowest cost options until 2020 with a gradually increasing market share for future biofuels based on lignocellulose. The model predicts rapid growth of advanced biofuels starting from 2010, in particular bio-DME, biomethanol and compressed-SNG, although the cost calculations have too large uncertainty ranges to indicate these as the ‘winning’ biofuels. Advanced biofuels can have a 2010 break-even oil price of 60 -100 $/bbl if technologies and bioenergy crops are developed to a sufficient scale.

In the far future (2030), typical 8 €/GJ projected costs of advanced biofuels are comparable to fossil oil price around 40 $/bbl. This makes a high biofuels scenario a serious option for Europe in view of security of supply. However, this very low future cost level requires successful, on-time development and up scaling of advanced biofuel technologies such as gasification, sustained low-price availability of woody biomass in the CEEC, and fuel specification achievement by the advanced biofuels.

Even under a supposed additional 20% biofuel Directive target for 2030, there is sufficient biomass potential for biofuels based on lignocellulose in Europe and in particular in the CEEC, although some of the very cheap areas in the CEEC become exhausted.

The BIOTRANS results indicate that present Directives and regulations induce penetration of first generation biofuels, based on traditional starch, sugar and oil crops. In the long term however, biofuels produced from more abundant and potentially much cheaper lignocellulosic feedstocks seem to be preferred, also because of their significantly better CO_2 balance. The acceleration of these advanced options may even be more important for the realization of long-term biofuel goals in Europe than early penetration of first generation liquid biofuels as such. This requires that a lignocellulose-based feedstock supply system is developed, and corresponding advanced technologies for the conversion to almost GHG neutral biofuels become further developed.

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