IEA Bioenergy

Task 38

Greenhouse Gas Balances of Biomass and Bioenergy Systems

Wood-based biodiesel in Finland: Market-mediated impacts on emissions

Juha Forsström[1], Kim Pingoud[1], Johanna Pohjola[2] and Terhi Vilén[3]

[1] VTT Technical Research Centre of Finland, P.O. Box 1000, FI-02044 VTT, Finland

[2] Finnish Environment Institute, Mechelininkatu 34a,P.O. Box 140, FI-00251 Helsinki, Finland

[3] European Forest Institute, Torikatu 34, 80100 Joensuu, Finland

Contact: Juha Forsström, juha.forsstrom@vtt.fi

Summary

A biodiesel strategy based on domestic forest biomass is analysed using an integrated modelling framework. A market-oriented approach is applied to estimate the potential impacts on greenhouse gas (GHG) emissions of achieving a national transport biofuel target (of 10% or 20% of total consumption) under the current climate and energy policy obligations. The cost-minimising adaptation of the energy system to achieve policy targets, the demand for wood biomass and emissions from the energy system including the transportation sector are assessed using an energy system model. The resulting response of the Finnish forests - their carbon (C) balance - to the increasing demand for wood biomass is estimated using a forest model.

The analysis demonstrates the importance of including market-mediated impacts in an assessment. The majority of adjustments toward the biofuel target take place among the energy producers participating in the EU Emission Trading Scheme (ETS), even though the transportation biofuel target is applied in the non-ETS sector. The ETS comprises more than 11,000 heavy energy-using installations in power generation and manufacturing industry and covers around 45 % of the greenhouse gas emissions in the EU. The demand for wood in biorefineries raises the wood price thereby weakening its competitive position against fossil fuels. As a consequence, wood is likely to be partly replaced by fossil fuels within the ETS sector for heat and power. In addition, biorefineries would increase the total use of electricity. Thus, fossil fuel carbon dioxide (CO_2) emissions in the ETS sector within the Finnish borders would increase.

Total cumulative emissions, including the non-ETS sector and the forest C balance, are slightly lower in the biodiesel scenarios than in the baselines. In transport and in the non-ETS sector in general, the decrease in emissions takes full effect immediately, whilst the decrease in C sink in the Finnish forests appears to be gradual. The impact on the C sink is fairly small because wood harvesting increases by less than the amount of wood used for biodiesel production due to diversion from use for electricity and heat.

The substantial increase in emissions from the Finnish ETS sector would not increase atmospheric emissions, because at the EU level, emissions in the ETS sector are capped. Any increase in ETS emissions in Finland has to be compensated by the purchase of emission allowances, and the corresponding emission reduction takes place elsewhere in the ETS area. This study's results indicate that introducing a target for forest-based transportation biofuels would impose an additional cost on the energy system.

Scope

The objective of the study (comprehensive report: Forsström et al. 2012) is to analyse the rationale of transportation biofuel targets from the perspective of GHG emission reductions and economic efficiency. The spatial system boundary comprises the national boundary, the energy system and forest biomass resources of Finland. In the study it is assumed that the imposed biofuel targets will be met using solely domestic forest biomass as feedstock without any biofuel imports to Finland. This was done to estimate the true impacts of increasing biomass demand on the forest C balance. The time interval considered is until 2050. Forest-based biodiesel is assumed to be produced in second-generation refineries which will be likely realised by 2020. The specifications of the Fischer-Tropsch refineries considered are based on the study by McKeough and Kurkela (2008). In the reference scenario only conventional fossil fuels are used in the transportation sector. The forest industry output – and its wood use - is the same in all cases. We also froze the amount of wood imports. Thus the variation in harvesting is due to the changes in wood fuel use. We assumed that the biowax producing refineries will be built into existing pulp and paper mills but the final processing of biodiesel will take place at an oil refinery. The pulp and paper mills already have all the facilities needed to procure and handle large amounts of wood, whilst the mills themselves can use the excess heat produced by the biorefinery process. These are crucial aspects of the economics of a biorefinery.

The driver of the system is the EU climate and energy policy and the targets for renewable energy (38 % for Finland), energy efficiency and the non-ETS emission reduction (Figure 1). In the reference scenario, the policy drivers are the same except that no targets on transport biofuels are set. The biofuel production changes the harvest level and the flows of wood fuel in the system. As a result, the forest C stock level and energy production based emissions follow different routes compared to that of the reference case. Adding up these changes reveals the true atmospheric GHG balance.

The study's approach is market-oriented. It focuses on the indirect impacts and energy system adjustments due to the changing relative competitiveness of different energy sources by using a cost-minimizing, detailed energy system model. The result is expressed as the change in cumulative emissions due to the biofuel targets across the entire energy and forestry sectors of Finland, and the result is also expressed, per tonne of fuel produced.

Methodology

The analysis utilizes an integrative framework covering direct and indirect impacts of the transportation biofuel targets on the GHG balance. An energy system model, EPOLA, evaluates the GHG emission impacts in the energy system while the forest resource model, EFISCEN, provides the estimates for changes in the C balance in forests. The

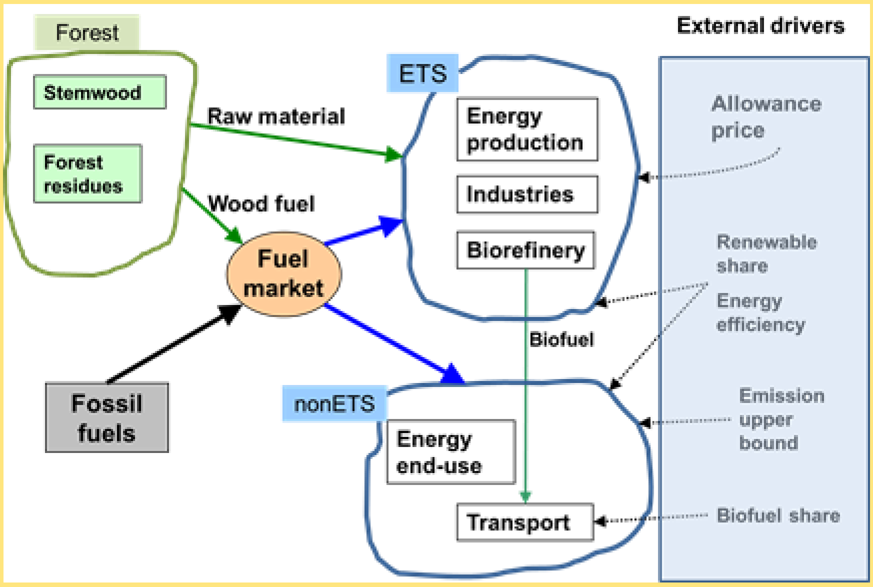

Figure 1: Linkages and material and information flows in the energy system model EPOLA. Fuel market is emphasized here to clarify the twofold role of wood: it is both raw material and fuel.

models are linked by wood demands that are obtained as results from the EPOLA model and given as inputs into the EFISCEN model. Thus so-called soft-linking is applied instead of solving the models simultaneously.

The EPOLA model is a version of the Energy Flow Optimisation Model (EFOM) (van der Voort et al., 1985) for Finland augmented with descriptions of forest industry processes. The model has been developed for energy policy assessment and comparison. It is an inter-temporal linear programming model in which the user defines the useful energy demands. The model covers the whole energy system from fuel supply and conversion to the demand sectors of energy. A wide range of existing and potential technologies are described. The emissions can be reduced in the model by replacing more fossil fuel intensive technologies with less intensive or C-free ones in existing plants, or by investing in less C intensive technologies and energy saving technologies.

The energy system is divided into two parts: the sectors that participate in emission allowance trading (ETS sectors) and the non-ETS sector covers the rest (see Figure 1). Biofuel production takes place in the ETS part of the system but biofuels are used in the non-ETS part. The economic rationale for adapting to externally set bounds differs in these sectors and the model structure reflects this division.

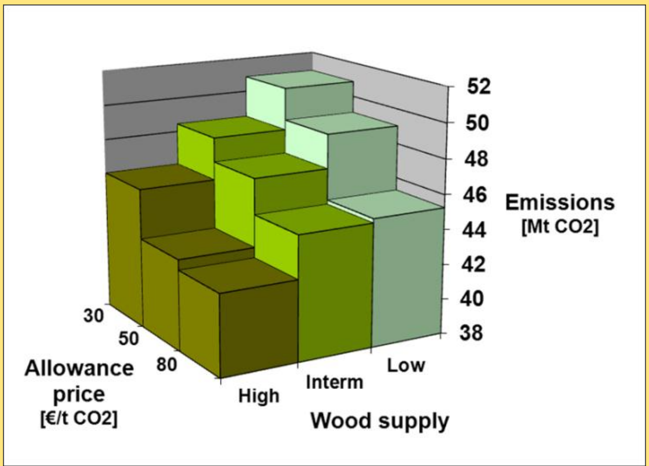

Figure 2: The surface of annual base-case emissions of the Finnish energy system in 2025. Forest C balance excluded. Allowance price (30, 50 and 80 €/t CO_2) and wood supply (high, intermediate, low) define the system state.

Results

We study the impact of the biofuel target on the cumulative net emissions to the atmosphere compared to the corresponding reference case in the period 2015-2050. The study considers three levels of biofuel share: 0% (the reference), and 10% and 20%. The main drivers that affect the results are the emission allowance price and wood supply situation. By varying these we obtain altogether 27 different cases. In addition to the biofuel target the other EU obligations (i.e. renewable energy and energy efficiency targets) are met in every case analysed.

First we construct the reference emissions scenario without a target for domestic biofuel production and consumption (illustrated for 2025 in Figure 2).

Domestic biofuel production increases the demand for wood. However, the increases in wood harvesting are smaller than the wood input to the biorefineries because the wood is mostly reallocated from other sectors, particularly at lower emissions allowance prices. Figure 3 shows that fulfilling the biofuel obligation leads to price-induced adjustments in fuel wood use in every sector of the energy system.

The increased harvesting decreases the forest C sink. Increasing the biodiesel target from 0% to 20% was estimated to decrease the C sink of Finland's forests maximally around 9 Mt CO_2/year when the emission allowance price was 50 €/t CO_2, but the positive sink was not threatened.

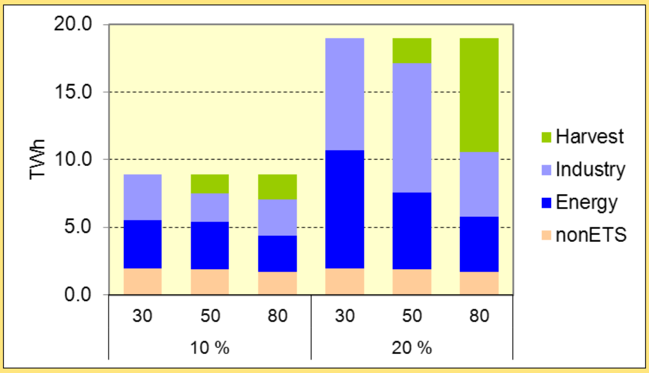

Figure 3: Wood procurement by biorefineries in the case of biofuel targets 10 or 20% with different prices of emission allowances (30, 50 and 80 €/ton CO_2) and intermediate wood supply in 2025. (Harvest = wood from additional harvesting; Industry = wood from reduced fuel wood use in industry; Energy = wood from reduced fuel wood use within large-scale heat and power production; nonETS = wood from reduced wood-use in the non-ETS sector).

Emission reductions come solely from biodiesel use. It is practically constant annually within each scenario, following the assumptions on future transport activity, technology change and demographic development. Emission increases come from two sources: First, increased harvests lead to smaller forest C sink. Market interaction through price increases contributes to preserving a higher sink level compared to a situation in which the demand is not linked to price. Second, the use of biofuel is implemented as a forced measure to reduce emissions in the non-ETS sector and makes some emission abatement measures of the reference case uneconomic.

Cumulating the net emission impact, the sum of reductions and increases, from the year 2015 onwards leads to the situation shown in Figure 4 (and 'Impact' row in Table 1). The net cumulative emissions are slightly reduced due to biofuel use. The reduction in emissions in the beginning reflects the immediate gains through biofuel use but later on, the decreasing sink dominates the net impact.

The biofuel target increases the emissions in the domestic ETS sector considerably (Table 1). The impacts of biofuel production on the ETS sector come across through the wood and fossil fuel markets. Fossil fuels or energy-saving investments, or both, substitute for wood compared to the 0% biofuel due to the higher price of wood. In addition, electricity demand increases due to increased processing which further increases emissions.

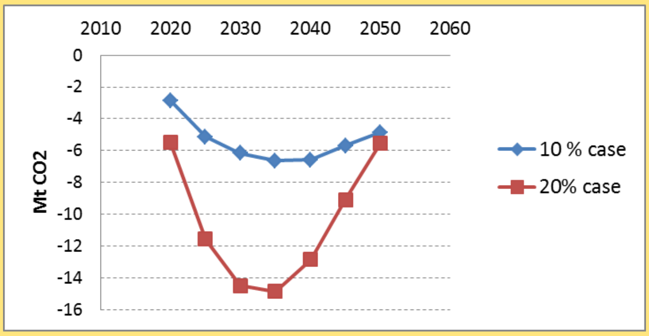

Figure 4: Net cumulative emission impact due to biofuel introduction and the forest C stock changes at the emissions allowance price 50€/t CO_2. Impact on ETS-sector emissions is not included. Each point in the curves represents the aggregated net amount from the year 2015 onwards. Both curves are on the negative side meaning that the emissions decrease.

The substantial increase in emissions from the Finnish ETS sector is not accounted for in the cumulative emissions to the atmosphere ('Impact'), because at the EU level, emissions in the ETS sector are capped. Therefore any increase in the ETS emissions in Finland has to be compensated by the purchase of emission allowances from abroad, and the corresponding emission reduction will be realized outside Finnish borders, creating additional costs to the Finnish economy.

In Figure 5 we compare yearly values of emissions impact per ton of biodiesel produced. In addition, we plot the emission impact in the ETS sector that reflects the increased demand of emission allowances – a purely economic consequence. The 10% and 20% biofuel share cases differ most in ETS sector where the easiest and cheapest measures are used-up already in the 10 % case so doubling the biofuel share doubles the emission allowance purchases per biofuel unit.

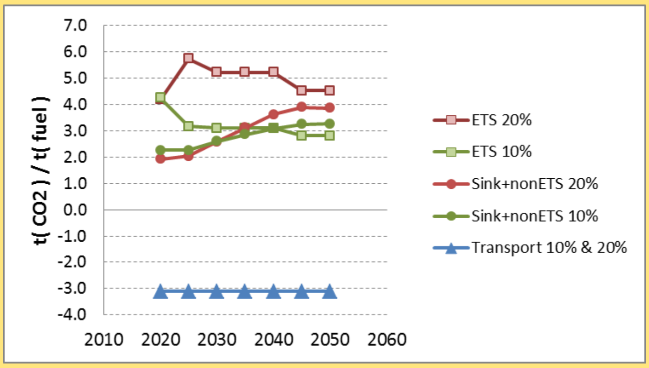

Figure 5: Average annual impacts of biofuel target on emissions per ton biofuel used in 10% and 20 % cases, compared with reference case. ETS describes the increased allowance purchases in the ETS sector. Sink+nonETS refers to the combined effect on forest sink and non-transportation part of the non-ETS sector. Transport refers to decrease in emission by replacing fossil fuel by biofuel.

Discussion and Conclusions

The aim of the study was to reveal the changes in the whole energy system caused by the introduction of a biofuels target in the transportation sector. The results demonstrate the direction of impacts under the EU policy drivers. Although transportation belongs to the non-ETS sector and the biofuel obligation directly affects emissions in the non-ETS sector, the impacts of introducing biofuels migrate to the ETS sector through fuel and energy markets. The production of wood-based biofuels increases electricity use and wood demand reducing the competitiveness of wood as a fuel.

Table 1: Cumulative emission differences between the 0% vs. 10% or 20% biofuel share cases [Mt CO_2] from 2015. Sum-ES refers to the energy system emissions, Impacts stands for emissions from the Forest plus non-ETS sectors only and Finland is the sum of all the emission differences within Finnish borders.

		2020	2025	2030	2035	2040	2045	2050
10 % case								
Forest C-balance	1	0.4	1.2	2.7	4.8	7.4	10.3	13.1
nonETS	2	-3.2	-6.4	-8.9	-11.5	-14.0	-16.0	-18.0
ETS	3	9.6	16.7	23.7	30.7	37.7	44.0	50.3
Sum-ES	2+3	6.3	10.3	14.8	19.2	23.7	28.0	32.3
Impact	**1+2**	**-2.8**	**-5.1**	**-6.2**	**-6.6**	**-6.6**	**-5.7**	**-4.9**
Finland	1+2+3	6.7	11.5	17.5	24.0	31.1	38.3	45.4
20% case								
Forest C-balance	1	1.3	5.5	12.5	22.0	33.8	46.9	59.8
nonETS	2	-6.8	-17.1	-26.9	-36.8	-46.7	-56.0	-65.3
ETS	3	18.9	44.7	68.2	91.7	115.2	135.6	155.9
Sum-ES	*2+3*	12.1	27.6	41.2	54.9	68.6	79.6	90.6
Impact	**1+2**	**-5.5**	**-11.6**	**-14.5**	**-14.8**	**-12.8**	**-9.1**	**-5.5**
Finland	1+2+3	13.4	33.1	53.7	76.9	102.4	126.5	150.4

Harvesting of logging residues and other energy wood increases only slightly, as most wood available at a competitive price is already utilized in the base cases to meet the 38% target for renewables. The biofuel target therefore largely reallocates wood from energy production and industry into biorefineries. The forest model simulations show that the additional wood demand due to biodiesel production would weaken the terrestrial C sink in Finland for the next 40 years when examined with respect to the baseline with no bio-diesel. Finnish forests would still remain as a net C sink, but neglecting the sink change in the present accounting framework can be considered a principal C leakage mechanism. However, because of the adjustments in the ETS sector, the decrease in forest sink is much less than if the demand would be fulfilled by additional harvest only.

The increased emissions in the domestic ETS sector do not imply climate impacts under the present climate policy framework, with fixed emission reduction targets at the EU level. Instead, the issue is largely transformed into an issue of cost-effectiveness to meet the targets. The additional costs are mainly due to the investments in biodiesel plants and buying additional emission allowances. There would be upward pressure on the price of emission allowances due to the increased demand.

References

Forsström, Juha; Pingoud, Kim; Pohjola, Johanna; Vilén, Terhi; Valsta, Lauri; Verkerk, Hans 2012. Wood-based biodiesel in Finland. Market-mediated impacts on emissions and costs. VTT Technology 7, VTT, Espoo. 47 p. + app. 1 p. http://www.vtt.fi/inf/pdf/technology/2012/T7.pdf

McKeough, P. and Kurkela, E. 2008. Process evaluations and design studies in the UCG project 2004–2007. VTT: Espoo. VTT Research Notes 2434. 45 p. http://www.vtt.fi/inf/pdf/tiedotteet/2008/T2434.pdf.

Nabuurs, G. J., Schelhaas, M. J. and Pussinen, A. 2000. Validation of the European Forest Information Scenario Model (EFISCEN) and a projection of Finnish forests. Silva Fennica, 34, pp. 167–179

Sallnäs, O. 1990. A matrix growth model of the Swedish forest. Studia Forestalia Suecica, 183. 23 p.

Schelhaas, M. J., Eggers, J., Lindner, M., Nabuurs, G. J., Pussinen, A., Päivinen, R., Schuck, A., Verkerk, P. J., van der Werf, D. C. and Zudin, S. 2007. Model documentation for the European Forest Information Scenario model (EFISCEN 3.1.3). Alterra rapport 1559. EFI Technical Report 26.

van der Voort, E. et al. 1985. Energy supply modelling package EFOM-12C. European Commission, DG-XII, EUR 8896 EN/II, Brussels.

IEA Bioenergy (www.ieabioenergy.com) is an international collaborative agreement, set up in 1978 by the International Energy Agency (IEA) to improve international cooperation and information exchange between national bioenergy research, development and demonstration (RD & D) programs. IEA Bioenergy aims to achieve a substantial bioenergy contribution to future global energy demands by accelerating the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas (GHG) emissions from energy use.

IEA Bioenergy Task 38 (www.ieabioenergy-task38.org) brings together research work of national programs in all participating countries on GHG Balances for a wide range of biomass systems, bioenergy technologies and terrestrial carbon sequestration. Emphasis is placed on the development of state-of- the-art methodologies for assessing GHG balances; demonstrating the application of established methods, supporting decision-makers in implementing effective GHG mitigation strategies. As one example of work, case studies have been conducted by applying the standard methodology developed by Task 38. The case studies have assessed and compared GHG balances of different bioenergy and carbon sequestration projects in the participating countries, and this Austrian case study is one example.