# Energy from biomass: linkages between the energy and the agricultural sector in the EU until 2050

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*Abstract*

*Over the last decades traditional energy sources are increasingly replaced by energy from biomass and this trend is expected to continue into the future. Assessing the efficiency of bioenergy policies requires a comprehensive analysis of the interrelationship between agricultural and energy markets. This study analyzes the impacts of two alternative EU greenhouse gas emission mitigation scenarios on the utilization of biomass for energy production and the price of agricultural products. To this end, we combine the energy system model TIMES PanEU and the agricultural sector model ESIM. We establish a consistent interface between the models and run them in an iterative procedure where TIMES PanEU represents the demand side for energy crops and ESIM their supply side. According to our results, an extension of the mandatory reduction of emissions has strong biomass demand effects and affects the agricultural sector in its entirety. Due to the increased demand for energy crops, average crop prices in the EU increase by an estimated 30 percentage points in 2050. The expanded area use for production of energy crops inside the EU27 turns the EU from being a net exporter to a net importer for many important agricultural commodities.*

*Keywords: Biomass, bioenergy, energy system model, agricultural sector model.*

### 1. Introduction

Over the last three decades, energy prices have increased relatively to prices for agricultural products (World Bank, 2011). In reaction to this market development and due to regulatory policies in many countries which are motivated by a wide range of objectives, traditional energy sources are increasingly replaced by energy from biomass and this trend is expected to continue into the future. The potential supply of biomass for energy production has an impact on the future energy balance and demand for energy from biomass has an impact on agricultural markets. Moreover, the relationship between agricultural and energy prices is expected to strengthen further.

Apart from being driven by price incentives, the demand for biomass for energy as an energy source in the EU is driven to a large extent by policies which set mandatory targets for the share of renewable energy in final energy consumption, see, e.g., European Commission (2009). Other mandatory targets concern the reduction of greenhouse gas (GHG) emissions. In addition to these EU-wide policies, individual EU member states introduced additional policies, e.g., the German target to cover 20% of heat production in new housing with renewable or energy saving measures (EEWaermeG). This indicates that the importance of agricultural biomass as an energy carrier in the EU27 will increase further. At the same time, the degree of the efficiency and even the effectiveness of such policies is widely questioned (Searchinger et al,. 2008; Doornbosch and Steenblik, 2007; Wissenschaftlicher Beirat der Bundesregierung für Globale Umweltveränderungen, 2009).

Assessing the efficiency of bioenergy policies requires a comprehensive analysis of the interrelationship between agricultural and energy markets (e.g., European Environment Agency, 2006; Sachverständigenrat für Umweltfragen, 2007). Recent years spawned a number of studies analyzing this interrelationship employing a variety of methods.

Several energy system models have been applied to the analysis of renewable energy policies (e.g., Blesl et. al, 2008; International Energy Agency, 2008). The advantage of energy system models for the assessment of bioenergy policies is that they cover the whole energy system, from the production of primary energy to the consumption of final energy in the different end use sectors. Perfect competition among different technologies and pathways of energy conversion allow analyzing the optimal contribution of bioenergy to the achievement of different targets. On the other hand, such models do not depict the supply side of biomass explicitly and thus need to assume supply as given exogenously. Hence, no interaction between the agricultural and energy sectors takes place.

By contrast, agricultural sector models allow to depict supply of agricultural products as well as agricultural policies in high detail, but final demand for energy from biomass is mostly depicted in a very stylized manner. This can be explained by the partial equilibrium nature of the models which do not include important sectors which are closely linked to biomass demand, such as fossil energy sectors and fossil based energy demand. Banse and Grethe (2008), Rosegrant (2008) and OECD (2006) apply such models assuming a given biomass demand for energy. Furthermore, most of these studies only analyze effects of biofuel policies and neglect other sources of renewable energies.

An approach to analyze the two sectors and their interlinkages would be the integration of the energy system and the agricultural sector in one comprehensive model. Computable general equilibrium (CGE) models are suitable for such an approach, describing an economy as a whole. Kretschmer and Peterson (2010) give a broad survey about studies integrating bioenergy in CGE models. These integrated CGE analyses, however, come at a significant price, as quite some detail in depicting the agricultural sector as well as the energy system is typically lost. One attempt to overcome this lack in detail is to combine different model types with each other. Delzeit et. al (2010), e.g., link a CGE model with a regionalized agricultural sector model and a location model for biogas plants.

Following this latter approach, this study analyzes the impacts of two alternative EU environmental policies on the utilization of biomass for energy production and the price of agricultural products. To this end, we combine the energy system model TIMES PanEU and the agricultural sector model ESIM. We establish a consistent interface between the models and run them in an iterative procedure where TIMES PanEU represents the demand side for energy crops and ESIM their supply side.

The remainder of the paper is organized as follows. Section 2 describes the TIMES PanEU and ESIM models and the interface for the model combination. Section 3 introduces the two EU environmental policy scenarios and their implementation in the models. The results of the simulation experiments are presented in Section 4. Finally, Section 5 summarizes the study and concludes.

## 2. The Modeling System

### 2.1. The TIMES PanEU model

For the scope of the analysis, the Pan-European TIMES model (TIMES PanEU) was applied (Blesl et al., 2008; Kuder and Blesl, 2009; Blesl et al., 2010; Bruchof and Voß, 2010; Kober and Blesl, 2010). TIMES PanEU is a multi-regional model containing all countries of the EU27 and Switzerland, Norway and Iceland. The model minimises an objective function representing the total discounted system costs over the time horizon from 2000 to 2050. Perfect competition among different technologies and pathways of energy conversion is also assumed. TIMES PanEU covers, at the country level, all sectors connected to energy supply and demand, i.e. the supply of resources, the public and industrial generation of electricity and heat, and the end-use sectors industry, commercial, households and transport. In addition, both GHG emissions (CO2, CH4, N2O) and pollutant emissions (CO, NOx, SO2, NMVOC, PM10, PM2.5) are modelled.

The generation of electricity and heat in electric power plants, combined heat and power (CHP) plants, and heating plants is classified into public and industrial production. The model contains three different voltage levels of electricity (high, medium, and low voltage) and two independent heat grids (district heat and local heat).

In the transport sector the four areas of road transport, rail transport, navigation and aviation are modelled separately. In each of the transport modes, the model comprises a variety of alternative fuels (e.g. biofuels, methanol, natural gas, LPG, DME, hydrogen, electricity) and power trains (e.g. hybrid, plug-in hybrid, battery electric or fuel cell electric vehicles) that can be employed in order to achieve ambitious climate targets (Bruchof and Voß 2010).

The residential sector contains eleven demand categories: space heating, air conditioning, water heating, cooking, lighting, refrigeration, washing machine, laundry dryer, dishwasher, other electrics and other energy use. The commercial sector is represented by a similar reference energy system (RES) and consists of nine demand categories: space heating, air conditioning, water heating, cooking, refrigeration, lighting, public street lighting, other electrics, and other energy use.

The agriculture sector is described by a general process with a mix of several energy carriers taken as input and an aggregated demand of end use energy taken as output.

The industrial sector is divided into energy-intensive and non-intensive branches. While the intensive branches are modelled via a process oriented approach, the other industries are assumed to have a similar generic structure consisting of five energy services (process heat, steam, machine drive, electrochemical, and others). The energy-intensive industries consist, for example, of the iron and steel or the cement industry sub-sectors. In these sub-sectors, in addition to the use of different fuels or more efficient technologies, it is possible to use different production processes to reduce the CO2 emissions (e.g. electric arc furnaces can be used instead of blast oxygen furnaces or recycling processes in the aluminium and glass industries).

In the supply sector, all primary energy resources (crude oil, natural gas, hard coal and lignite) are modelled by supply curves with several cost steps. Three categories can be differentiated: discovered reserves (or developed sources), growth of reserves (or secondary and tertiary extraction), and new discoveries. In addition, eight bioenergy carriers are defined: mature forest, biogas, household waste, industrial waste and sugary, starchy, lignocellulosic and oil crops.

Due to its high degree of detail, TIMES PanEU considers country-specific particularities, e. g. decommissioning curves, potentials for renewable energy production and national carbon storage potentials. An interregional electricity trade is implemented in the model, so that exports and imports of electricity according to the existing border capacities are endogenous to the model. The model is technology oriented and characterised by a comprehensive database which contains various GHG mitigation technologies for all sectors of the energy system (including the different types of power plants with carbon capture and storage (CCS)), which provides a sound basis for the analysis presented here.

## 2.2. The European Simulation Model

ESIM (Banse et al., 2010) is a comparative-static, net-trade, partial equilibrium model of the European agricultural sector. It depicts the EU27 at the member state level and the EU common agricultural policies in great detail. As a world model it includes all countries, though in greatly varying degrees of disaggregation. Except for the EU27, some candidate countries and the US, all other countries are combined in an aggregate (the so-called "rest of the world”). Altogether ESIM contains 31 regions and 47 products and a high degree of EU policy detail including specific and ad valorem tariffs, tariff rate quotas, intervention and threshold prices, export subsidies, coupled and decoupled direct payments, production quotas and set-aside regulations. As ESIM is mainly designed to simulate the development of agricultural markets in the EU and accession candidates, policies are only modeled for these countries, i.e. for the US and the ROW production and consumption is depicted to take place at world market prices.

ESIM models the linkage between the fodder sectors and livestock and the processing of milk into dairy products. Finally, it also models the production of biofuels, in particular, biodiesel from oilseeds and plant oils and ethanol from wheat, corn and sugar. In addition, human demand for biofuels is modeled. Several biofuel policies are depicted, but the focus is on shifting overall biofuel demand to reach certain political quantitative targets, such as a given share in total transport fuel demand.

The production of biofuels is modeled as an isoelastic function of the respective biofuel price and the weighted net prices of the respective inputs. Net prices are defined as market prices minus the related value of feed output which is gluten feed in the cases of corn and wheat. The shares of feedstocks in bioethanol and biodiesel production are determined by a CES function based on net energy crop prices. Human demand for biofuels is a function of the respective biofuel price, the price of crude oil, and the tax rates on biofuels and on mineral oil.

### 2.3. Interface

The general idea of linking the two models is to endogenise demand and supply reactions of energy from biomass. This is accomplished by replacing the exogenous supply of biomass in the TIMES PanEU model with ESIM and the exogenous biomass demand in the stand-alone version of ESIM with TIMES PanEU. More specifically, TIMES PanEU assumes exogenous biomass prices thus neglecting the interdependencies with the level of of biomass usage for energy purposes. On the other hand, in ESIM demand for energy crops is exogenously and only fractionally depicted as merely demand for biofuels is taken into account. Due to the fact that crops used in biogas plants and especially lignocellulosic biomass played a minor role for the production of energy in the past, this widely used approach was sufficient. But as a major shift towards these energy sources is expected for the future, we establish this link between ESIM and TIMES PanEU.

The two different models are combined in an iterative procedure. TIMES PanEu and ESIM are linked via the repeated exchange of vectors of solution variables until convergence[1] is reached. Repeatedly, a vector of absolute demand changes for energy from biomass is generated by TIMES PanEU and exogenously added on the demand side in ESIM whereas a vector with the resulting price changes from this additional demand is given back to TIMES PanEU to calculate new demand quantities. This procedure is carried out until both models converge on these variables in the analysis of joint scenarios.

TIMES PanEU generates demand for energy crops expressed in petajoule (PJ). The differences in demand for four categories of energy crops between the base year and the projection year are converted into physical units (expressed in tons) and then implemented as additional demand in ESIM. ESIM then simulates the corresponding prices which are injected into TIMES PanEU as relative price changes in relation to the base year. The system is solved in five year-steps over the time period of the scenarios to account for the recursive-dynamic structure of the TIMES PanEU model.

TIMES PanEU differentiates four different groups of energy crops: oilseeds, starchy crops, sugar crops and woody crops. ESIM contains a more disaggregated level of product groups. Table 1 shows the mapping of crops between the two models.

Table 1: Mapping of product groups of energy crops between TIMES PanEU and ESIM

| TIMES PanEU | ESIM |
|---|---|
| Oilseeds | Rapeseed, Sunflower, Soybeans |
| Starchy Crops | Corn, Wheat, Triticale, Rye, Barley, Grass, Silage maize, |
| Sugar Crops | White sugar |
| Woody Crops | Area (woody crops not explicitly modeled in ESIM) |

Source: own compilation.

The different product groups are treated differently when their demand is matched to ESIM; the procedure for each category is explained below. Factors applied for converting energy into physical units are provided in Table 2.

*Oilseeds*

TIMES PanEU provides information on both the demanded raw energy of oilseeds and the corresponding processed energy carrier, biodiesel. ESIM also depicts the production process of biodiesel. To account for the byproducts of biodiesel processing which can be used as

[1] We assume convergence when the difference in price and biomass demand changes is less than 1% between two iterations for all exchange variables.

animal feed, the energy equivalent of the oilseed demand expressed in biodiesel units is aggregated with the biodiesel imports in TIMES PanEU and added as biodiesel demand in ESIM. This allows accounting for the animal feed byproducts and their impact on the livestock sector. The second advantage of this procedure is that no *a priori* decision regarding the input composition of different oilseeds has to be made. ESIM chooses inputs on the basis of a CES function representing the biofuel processing technology.

*Sugar crops*

In TIMES PanEU, sugar crops are exclusively used as an input for bioethanol production. Again, to account for byproducts of ethanol production, demand for energy from sugar crops is converted to ethanol and added as such on the demand side of ESIM. Similar to the biodiesel processing, ethanol processing is represented by a CES function in ESIM. This implies that the particular mix of crops used in ethanol production is not necessarily identical to the input mix assumed in TIMES PanEU.

*Starchy crops*

Starchy crops in TIMES PanEU are used for the production of ethanol and biogas. The share of starchy crops that is used in ethanol processing is treated as processed ethanol when implementing it in ESIM, which uses wheat, corn and sugar as inputs. Again, this allows for the consideration of byproducts used as animal feed. As the processing of biogas is not explicitly depicted in ESIM, the remainder part of the starchy crops demanded in TIMES PanEU is added on the demand side of ESIM at the crops level. We assume that biogas crops consist of 75% silage maize, 15% wheat and 10% grass.

*Woody Crops*

*W*oody Crops represent short rotation coppice (e.g. poplar and willow) as well as grass energy crops (e.g. Miscanthus grass) and are not explicitly depicted in ESIM. In the base data period, no market exists for woody biomass from crop land and thus, no corresponding data are available. For the treatment in ESIM we assume that woody crops are non-tradable goods and thus have to be produced within the EU27 to meet European demand. Consequently, we reduce the available arable land in ESIM by the amount demanded for woody crops. To convert demand of energy units created in TIMES PanEU into a specific amount of hectare arable land, in a first step, energy units (PJ) have to be converted into physical units (tons) of biomass and, in a second step, assumptions have to be made regarding average yields per hectare (see Table 2). For price changes handed over to TIMES, a crop price index is used that depicts changes of the weighted average of all crops prices.

Table 2: Conversion factors

| Commodity | Conversion factor |
|---|---|
| Biodiesel | 37.2 GJ $t^{1}$ |
| Ethanol | 26.8 GJ $t^{1}$ |
| Wheat | 17.1 GJ $t^{1}$ |
| Corn | 19.3 GJ $t^{1}$ |
| Silage maize | 18.4 GJ $t^{1}$ |
| White sugar | 17.3 GJ $t^{1}$ |
| Gras | 17 GJ $t^{1}$ |
| Rapeseed | 26.5 GJ $t^{1}$ |
| Sunseed | 23.85 GJ $t^{-1}$ |
| Soybeans | 16.8 GJ $t^{-1}$ |
| Woody crops (energy content) | 18.4 GJ $t^{-1}$ |
| Woody Crops (average yield per ha) | 10 tons $ha^{-1}$ |

Sources: Kaltschmitt and Hartmann (2009), De Witt and Faaij (2008), Pradhan et al (2008), USDA National Nutrient Database (2011), DLG Datenbank Futtermittel (2011).

To facilitate the iteration process, some additional model adaptations and assumptions are made:

- In its stand-alone version, TIMES PanEU assumes a certain potential of area within the EU27 that can be used for producing energy crops without constraining self sufficiency of the EU27 in terms of food production (De Witt and Faaij, 2008) and that cannot be exceeded. This is necessary to prevent the model from demanding too much biomass as long as the model assumes fixed prices. To account for the full price effects of energy crop demand on agricultural commodities and to be consistent with the net trade model ESIM, these constraints had to be relaxed. To do so, import bounds for energy crops were abolished with an import price only marginally higher than the price for domestically produced energy crops[2]. Consequently, no restrictions apart from the price exist for demanding energy crops in TIMES PanEU any longer.
- TIMES PanEU uses varying member state specific prices for energy crops. With implementing relative price changes on top of the existing prices, price gaps among the member states would be broadened. To avoid such spreads, a weighted average price of all member states was used as a basis for the relative price changes. The resulting absolute difference is then added on top of the original member state specific prices, keeping absolute price differences among member states constant.

[2] The marginal top up for import prices is necessary to ensure that the model demands domestically produced biomass at first, which is necessary for technical reasons.

## 3. Scenarios

The focus of the analysis is on two EU greenhouse gas (GHG) emission mitigation scenarios which differ in their level of ambition. The ETS75 scenario assumes a continuation of the current EU emission trading system (ETS) and serves as reference scenario while the second scenario ("C75") assumes stronger EU climate change mitigation efforts.

The current EU emission trading system in the ETS75 scenario only limits the GHG emissions (CO2 and NO2) for public electricity and heat generation and energy intensive industries as well as, from 2012 on, the aviation sector. In contrast to the current EU-regulation 2009/29/EC (EU, 2009) which targets a reduction of GHG emissions of 21% in 2020 compared to 2005, the ETS75 scenario assumes a stronger target of 34%. This is the expected part of the ETS sectors in the 30% mitigation target considered in the EU commission communication 265 (European Commission, 2010). For the period from 2020 to 2050, the ETS75 scenario assumes a linear increase of mitigation targets to 75% compared to 2005. Further, in the ETS75 scenario all biofuel mandates of the EU are abolished after 2010.

The implementation of the scenarios requires additional assumptions for the two models. In order to establish an ESIM baseline up to the year 2050, assumptions about the future price developments are needed. To this end, ESIM is calibrated to the prices projected by Fisher (2009). Prices between 2006, ESIM's current base data year, and 2050 are assumed to develop linearly. The resulting world market price increase (between 3% and 16% in real terms depending on the commodity) is augmented by 10% to roughly catch price effects resulting from bioenergy demand in the rest of the world, as for his projections Fischer (2009) assumes a world without any agricultural crops used for biofuel production.

Moreover, we assume that all price policies and direct payments under the current Common Agricultural Policy of the EU will be liberalized linearly between 2010 and 2020. Starting from this situation, the ETS75 scenario is established in ESIM by adding the EU biomass demand for energy as given by TIMES PanEU.

Stronger EU climate change mitigation efforts are assumed in the scenario C75 which also enforces mandatory reduction in the non-ETS energy sectors. The target is set to 30% reduction in GHG emissions in 2020 compared to the Kyoto reference year (1990), corresponding to stricter targets the EU has envisaged for the case that other countries also commit to more ambitious targets (Council of the European Union, 2007). After 2020, the GHG mitigation target is linearly increased to reach 75% reduction in 2050 compared to the Kyoto reference year. Only for the subset of ETS sectors the additional limit of 34% reduction in 2020 is kept and then increased continuously each year by 1.74%. Otherwise, the spreading of the GHG mitigation across sectors depends solely on their respective mitigation costs given the particular energy and environmental policies at the time.

For the C75 scenario, we limit the area available for growing woody biomass to 30% of the total agricultural area covered by ESIM which is equivalent to about 25% of total agricultural area in the EU. This is because we assume a greater share would be unrealistic in terms of biodiversity, preferences for domestically produced food and landscape. Moreover, even 30% is only conceivable with a variety of woody crops adapted to the regional agronomic conditions.

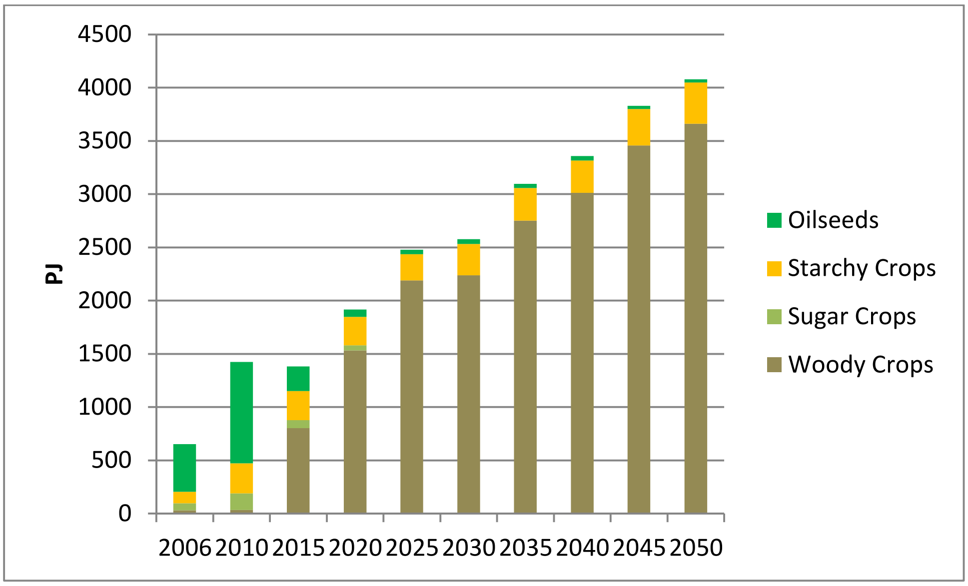
## 4. Results

### 4.1. The ETS75 scenario

Figure 1 displays the calorific values (in PJ) of the crop groups that are used in our reference scenario in the European energy sector. We find a clearly increasing demand for energy crops on aggregate, whereas single product groups develop differently.

While the energy extracted from starchy crops is constant over time, the quantities of oilseed- and sugar-based energy declines. In the base year, energy from sugar already has a relatively small share while oilseeds dominate the other energy crops. Oilseed demand even increases until 2010 but after the abolishment of the European biofuel mandates demand for first generation biofuels decreases sharply and with it demand for biodiesel and oilseeds. From 2015 on woody crops start to gain importance and immediately become the major biomass source for energy. Constantly growing in production, more than 3,500 PJ of woody crops are used in the European energy sector by 2050. The area corresponding to the 2050 level of woody crop production represents roughly 11% of total arable land available in the EU27. At this time, sugar crops have vanished and oilseeds only make up a negligible share of the energy biomass. The only other noteworthy energy biomass besides woody crops are starchy crops.

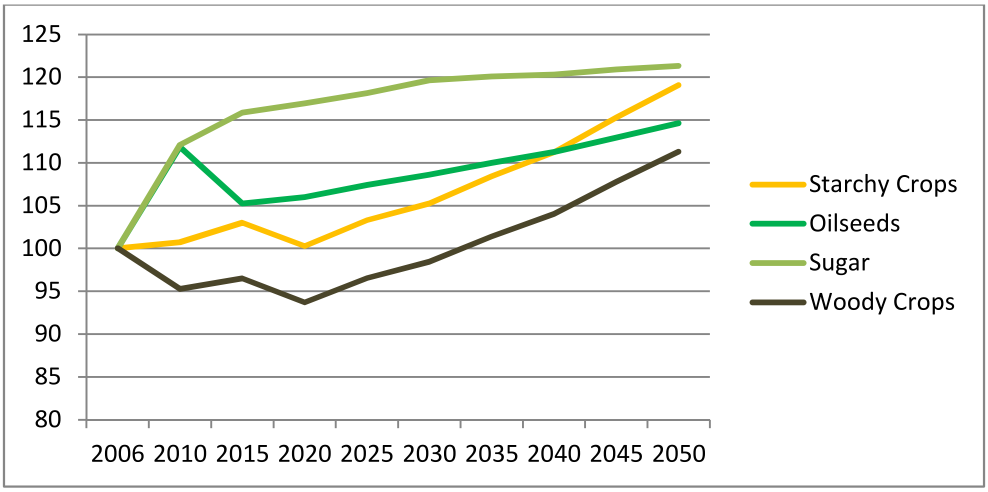
Figure 1: Energy crop demand in the ETS75 scenario for EU27




Source: own compilation.

Figure 2 presents the development of real price indices of the different energy crops in Europe. As ESIM does not explicitly depict woody crops as a commodity, the price is represented by the price index of all crops. In the first years of the projection period, the price index decreases which can partly be explained by the liberalization of the European agricultural market which is realized over the period until 2020. The effects of abolishing the European biofuel mandates are obvious in the real price of oilseeds (and to a lower extent the price of ethanol) which drops sharply after 2010. But over the total projection period all real prices show increasing trends.

Figure 2: Real price index for energy crops in the EU27 (2006 = 100) in the ETS75 scenario




Note: the real sugar price is represented by its real world market price as sugar used for ethanol production is not affected by the European sugar market regime.

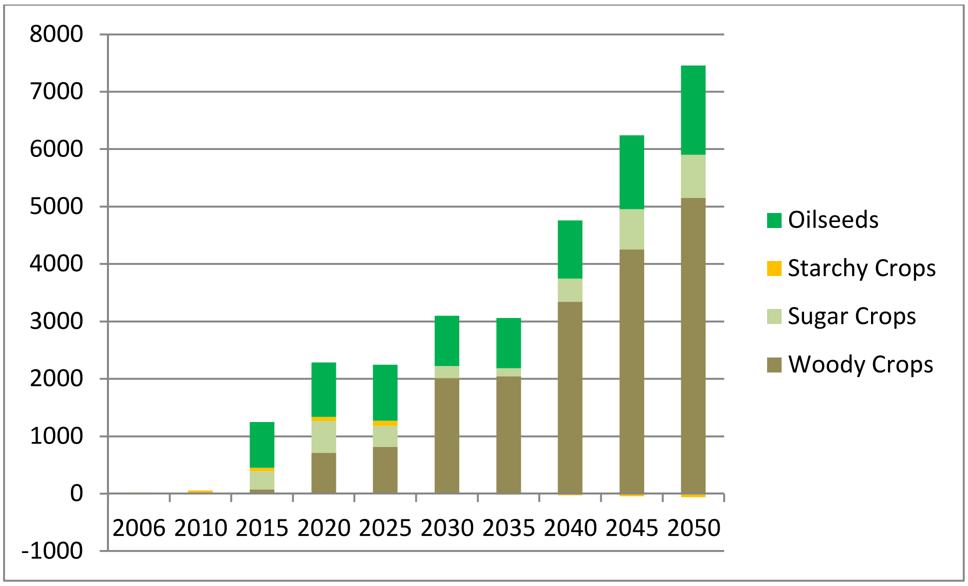
Source: own compilation.

### 4.2. The C75 scenario

In the more ambitious greenhouse gas reduction scenario C75, where the EU reduces 75% of its GHG emissions by 2050 compared to 1990 not only in the ETS but in all sectors, demand for energy from biomass increases significantly (see Figure 3). With an additional 7,400 PJ in 2050 demand almost triples in relation to the ETS75 scenario. As in the ETS75 scenario, woody crops become the dominating source of energy from biomass in 2050 and provide 8,800 PJ for use in the energy sector. This corresponds to a land area of 47 million hectare or 25%[3] of total available arable land in the EU27 which have to be cultivated with woody crops. In the unrestricted model solution this extreme share would have been even greater, but we exogenously restricted the area available for the production of woody crops to 25% of total arable area (see above).

Beside woody crops, also energy production from oilseeds and sugar increases but to a much lesser extent. Solely the demand for starchy crops does not change. This can be explained by the fact that the bulk of the additionally imported ethanol in this scenario is assumed to be produced from Brazilian sugar cane.

Figure 3: Differences in energy crops demand between the ETS75 and the C75 Scenario in the EU27



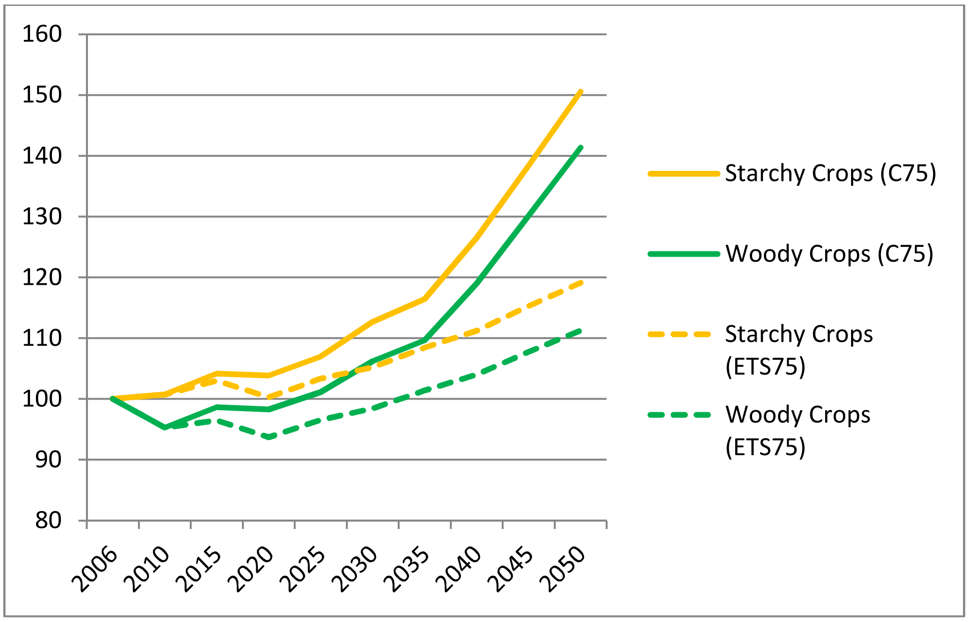

Source: own compilation.

Compared to the baseline scenario, real prices increase considerably more during the projection period (see Figure 4 and Figure 5). The dashed lines in these figures represent the real price indices of the ETS75 scenario. Real prices for woody crops (equivalent to the crop price index) and starchy crops show the strongest increases in the years from 2020 on (after

[3] This figure relates to the maximum area available in ESIM. As in ESIM not all the agricultural commodities are depicted (e.g. vegetables are missing) the share might be a little smaller in reality.

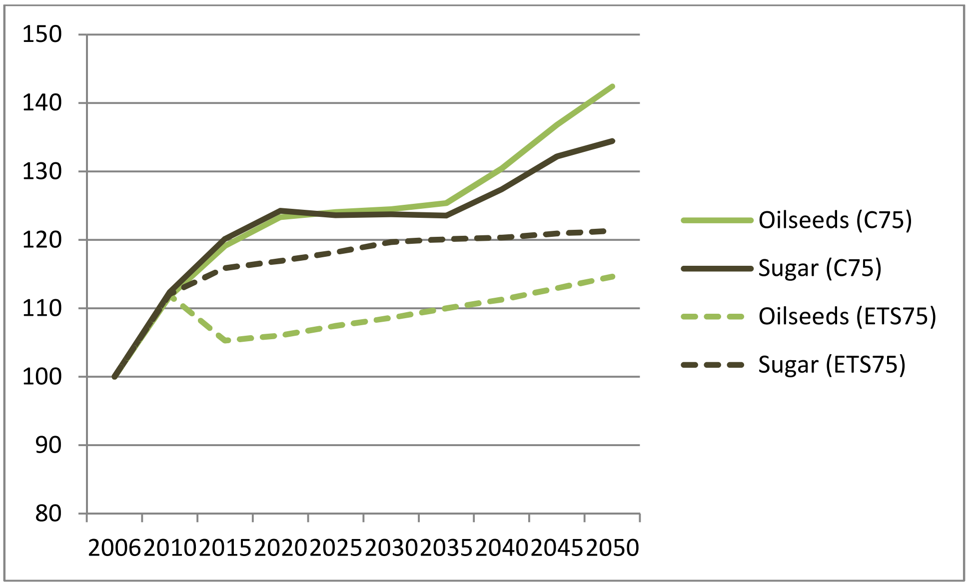
the period of overlaying price effects due to market liberalization). This can be explained by the fact that both indices contain prices of non-tradable goods, e.g. silage maize, which tend to react stronger to increasing competition for arable land than prices for tradable goods do. As in the base year virtually no tariffs on oilseeds are applied and the world market price applies for sugar beet for ethanol production in the EU, liberalization of the agricultural sector has only very limited effects on their prices.

Figure 4: Comparison of real price index for starchy and woody crops in the EU27 (2006 = 100)




Source: own compilation.

Figure 5: Comparison of real price index for oilseeds and sugar in the EU27 (2006 = 100)

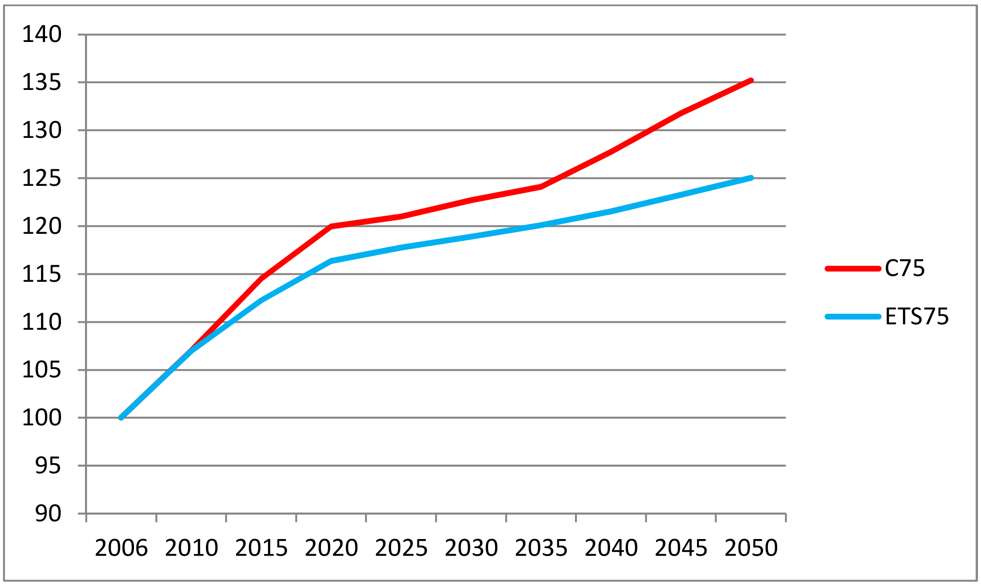



Note: the sugar price is represented by its world market price as sugar used for ethanol production is not affected by the European sugar market regime.

Source: own compilation.

The increased European energy crop consumption has considerable effects on real world market prices. In 2050 the real crop price index lies 10% higher than in the ETS75 scenario (Figure 6).

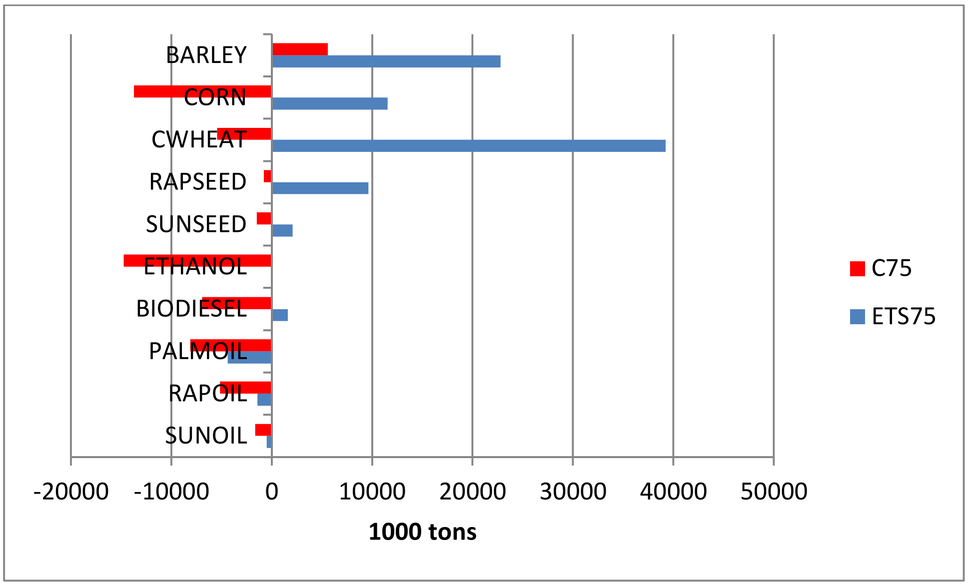
Figure 6: Comparison of world market price reactions (crop price indices 2006 = 100)




Source: own compilation.

Figure 7 shows that higher European demand for energy crops is increasingly satisfied by additional imports. While in the reference scenario the EU27 is a huge net exporter for arable crops and even exports biodiesel, the reverse is true for the C75 scenario. In particular, ethanol and biodiesel as well as their feedstocks are imported in larger quantities. These additional European demand triggers the world market prices to increase. With relatively low price elasticities of human demand in Europe, food consumption is virtually not reduced. Instead, the (via woody crops) displaced European production is sourced out to the world market or removed from the export market.

Figure 7: Net exports of selected products in the EU27 in 2050




Source: own compilation.

## 5. Summary and Conclusion

This paper analyzes the impacts of alternative environmental policies of the EU on energy and agricultural markets. To facilitate this analysis, we establish a consistent interface between the energy system model TIMES PanEU and the agricultural sector model ESIM. The procedure runs the models iteratively until convergence is reached in the solution variables. The basic idea is to replace the exogenous supply side of energy crops in TIMES PanEU by ESIM and the demand side of energy crops in ESIM by TIMES PanEU to account for the existing interlinkages between the agricultural and energy sectors.

From a methodological point of view, the feedback between the two models clearly has an impact on the results. The stand-alone version of TIMES PanEU used restrictions on the maximum usage of energy crops (measured by the maximum available area inside the EU) to keep the model within the range of realistic solutions. This implicitly excluded imports. In the combined model system, these restrictions were abolished (except for woody crops as they are assumed as being non-tradable) so that demand for energy crops is completely determined by prices and imports are part of the solution. Under the C75 scenario the previous domestic potentials are clearly exceeded. Thus, the iteration process impacts on the final demand for energy crops.

We ran two common GHG emission mitigation scenarios with the ESIM-TIMES-PanEU modeling system. Results should be understood as hinting at an order of size of effects, as projecting for a period of more than 40 years is subject to severe limitations. Especially, structural and technological changes that are likely to occur with the introduction of a new technology (woody biomass) over such a long time are impossible to depict with the chosen approach.

According to our results, an extension of the mandatory reduction to the non-ETS energy sectors has strong biomass demand effects and affects the agricultural sector in its entirety. Due to the increased demand for energy crops, average crop prices in the EU increase by an estimated 30 percentage points in 2050. This has also effects on world market prices which increase by 10 percentage points more in the C75 scenario compared to the ETS75 scenario. The expanded area use for production of energy crops inside the EU27 turns the EU from being a net exporter to a net importer for many important agricultural commodities.

These results clearly show that European GHG emission mitigation policies cannot be considered in isolation from other parts of the world. The huge net imports under the C75 scenario question strongly the efficiency and also the effectiveness in general of such policies. Even if the major share of energy crops is produced within the EU (as woody crops in our scenarios) world market prices are heavily affected which also might raise concerns about food security issues.

## References


Banse, M., Grethe H. (2008): Effects of the New Biofuel Directive on EU Land Use and Agricultural Markets. Contributed paper at the EAAE-Seminar Modelling Agricultural and Rural Development Policies, Seville, Spain, January 31 – 1 February.

Banse, M., Grethe, H., Nolte, S., Deppermann, A. (2010): European Simulation Model (ESIM) in the General Algebraic Modelling System (GAMS): Documentation of the Model Code. Hohenheim and Brunswick.

Blesl, M., Kober, T., Bruchof, D., Kuder, R. (2008): Beitrag von technologischen und strukturellen Veränderungen im Energiesystem der EU-27 zur Erreichung ambitionierter Klimaschutzziele. Zeitschrift für Energiewirtschaft 4/2008: 219-229.

Blesl, M., Kober, T., Bruchof, D., Kuder, R. (2010): Effects of climate and energy policy related measures and targets on the future structure of the European energy system in 2020 and beyond, Energy Policy 38(10), 6278–6292.

Bruchof, B., Voß, A. (2010): Analysis of the Potential Contribution of Alternative Fuels and Power Trains to the Achievement of Climate Targets in the EU-27, Paper presented at the International Energy Workshop 2010, Royal Institute of Technology (KTH), Stockholm, Sweden, 21-23 June 2010 [available at www.kth.se/polopoly_fs/1.61926!B1_Bruchof .pdf].

Council of the European Union (2007): Presidency Conclusions – Brussels, 8/9 March 2007.

De Witt, M.P., Faaij, A.P.C. (2008): Biomass Resources Potentials and Related Costs, Assessment of the EU-27, Switzerland, Norway and Ukraine, Refuel Working Package 3, final report.

Delzeit, R., Gömann, H., Holm-Müller, K., Kreins, P., Kretschmer, B., Münch, J., Peterson, S. (2010): Analysing Bioenergy and Land Use Competition in a Coupled Modelling System:

The Role of Bioenergy in Renewable Energy Policy in Germany, Kiel Working Paper No. 1653.

DLG Datenbank Futtermittel (2011): http://www.dlg.org/futtermitteldatenbank.html.

Doornbosch, R., Steenblik, R. (2007): Biofuels: Is the Cure Worse than the Disease? OECD Document SG/SD/RT(2007)3. OECD, Paris.

EU (2009): The European Parliament and the Council, Amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community. 2009/29/EC, 23 April 2009.

European Commission (2009): Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC. Brussels.

European Commission (2010): Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2010) 265 final. Brussels.

European Environment Agency (2006): How Much Bioenergy Can Europe Produce without Harming the Environment? Study on behalf of the European Commission. Copenhagen.

Fischer, G. (2009): World Food and Agriculture to 2030/50: How do climate change and bioenergy alter the long-term outlook for food, agriculture and resource availability?, Paper prepared for the FAO Expert Meeting on “How to Feed the World in 2050,” FAO, Rome, 24-26 June 2009. Final draft produced August 2009.

International Energy Agency (2008): Energy Technology Perspectives 2008 - Scenarios and Strategies to 2050. Paris.

Kaltschmitt, M., Hartmann, H. (2009): Energie aus Biomasse – Grundlagen, Techniken und Verfahren, Springer, Berlin, Heidelberg.

Kober, T., Blesl, M. (2010): Analysis of potentials and costs of storage of CO2 storage in the Utsira aquifer in the North Sea, Final Report, the Fossil Energy Coalition Network (FENCO ERA-NET) project [available at www.fenco-era.net/lw_resource/datapool/__pages/pdp_142/UTSIRA-FENCO-ERA_NET-Final_report.pdf].

Kretschmer, B., Peterson, S. (2010): Integrating bioenergy into computable general equilibrium models — A survey, Energy Economics 32 (2010): 673–686.

Kuder, R., Blesl, M. (2009): Effects of a white certificate trading scheme on the energy system of the EU-27, Paper presented at the 10th International Association for Energy Economics European Conference: Energy, Policies and Technologies for Sustainable Economies, Hofburg Congress Center, Vienna, Austria, 7-10 September 2009 [available at www.aaee.at/2009-IAEE/uploads/fullpaper_iaee09/P_471_Kuder_Ralf_21-Aug-2009,%2013:15.pdf].

Pradhan, A., Shrestha, D. S., Van Gerpen, J., Duffield, J. (2008): The Energy Balance of Soybean Oil Biodiesel Production: A Review of Past Studies, American Society of Agricultural and Biological Engineers, Vol. 51(1): 185-194.

Sachverständigenreat für Umweltfragen (2007): Klimaschutz durch Biomasse. Sondergutachten. Berlin.

Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Tun-Hsiang, Y. (2008): Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land Use Change. Science 319: 1238–1240.

USDA National Nutrient Database (2011), http://www.nal.usda.gov/fnic/foodcomp/search/.

Wissenschaftlicher Beirat der Bundesregierung für Globale Umweltveränderungen (2009): Welt im Wandel: Zukunftsfähige Bioenergie und nachhaltige Landnutzung.

World Bank (2011): http://databank.worldbank.org/ddp/home.do.