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Methodology to assess EU Biofuel Policies: The CAPRI Approach

María Blanco, Marcel Adenäuer,
Shailesh Shrestha and Arno Becker

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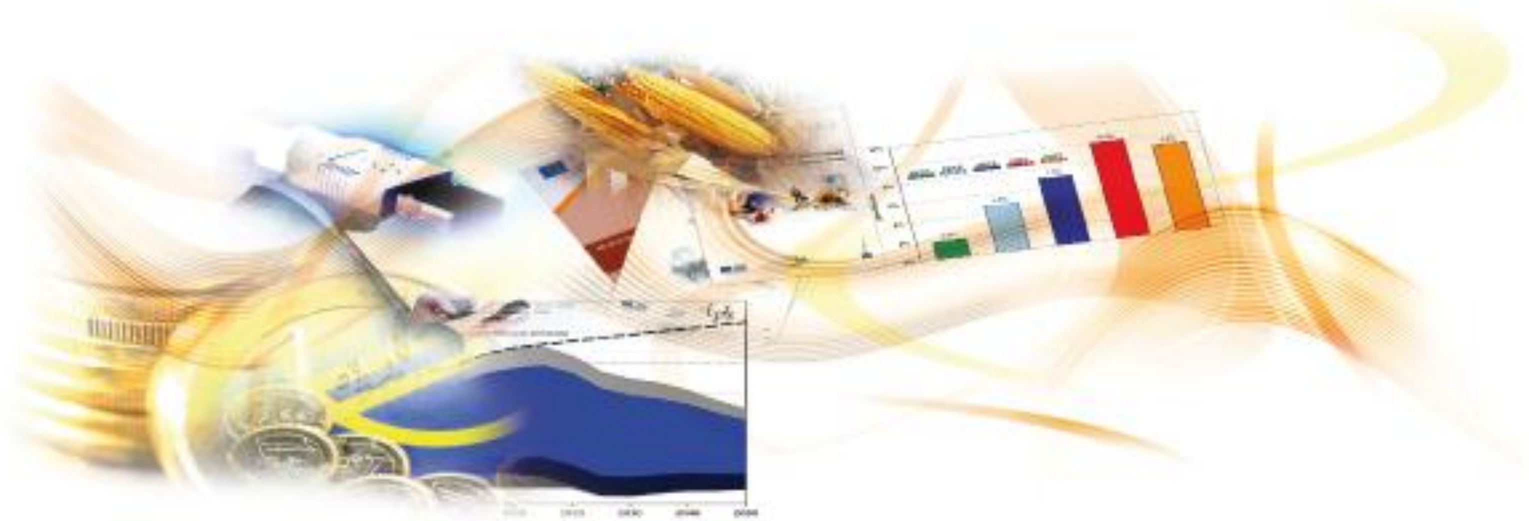

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Methodology to assess EU Biofuel Policies: The CAPRI Approach

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Executive Summary

Motivated by high fossil fuel prices and policy support, the production and use of biofuels are growing rapidly in many countries. At the current technological state, biofuels are mainly produced from agricultural feedstocks, such as cereals, sugar crops or vegetable oils. Thus, biofuel production and use create new links between agricultural and energy markets. While small in terms of energy supply, the development of the biofuel sector may have strong implications for both agriculture and the environment.

Accordingly, agro-economic models today need to simultaneously analyse agricultural and biofuel markets. Within this study, the spatial agricultural sector model CAPRI has been extended to include a behavioural market representation for biofuels and biofuel feedstocks. From the methodological point of view, the main enhancement of the model - compared to earlier versions of CAPRI - is the endogenous representation of biofuel markets (ethanol and biodiesel), meaning that biofuel supply and feedstock demand react flexibly to biofuel and feedstock prices and at the same time biofuel demand and bilateral trade flows react flexibly to biofuel and fossil fuel prices. This required an extension of the CAPRI database to include the necessary variables. This extension was based on many sources (the PRIMES and AGLINK-COSIMO models as well as EUROSTAT, F.O. Licht and national sources).

The estimation of the biofuel module relies on microeconomic theory and information derived from already existing modelling approaches. The OECD-FAO agricultural sector model AgLink-COSIMO (OECD, 2007 and 2008) is used to derive biofuel demand functions. The European energy sector model PRIMES (E3Mlab, 2011) is used to approximate total fuel demand functions.

The biofuel baseline, or reference scenario, is created based on statistical trend estimations and external expert knowledge. Baseline results presented in this report are for illustration purposes only, as the biofuel baseline is fully integrated into the CAPRI model and, therefore, updated yearly.

In this way, the biofuel module extends the advantageous features of the core CAPRI system (particularly its capability to analyse market effects at a very detailed spatial and agricultural product level) with a detailed representation of global biofuel markets, covering 1st and 2nd generation production technologies, biofuel by-products, bilateral biofuel trade and a link to global fuel markets.

CAPRI is now able to jointly assess biofuel and agricultural policies, including policy instruments defined at the Member State level. The CAPRI biofuel module allows for a detailed analysis of most relevant biofuel support instruments like consumer tax exemptions or quota obligations at European Member State and international level. Additionally, the model permits the analysis of scenarios regarding biofuel trade policies and the availability of 2nd generation technologies.

While most economic modelling systems analyse the impacts of biofuel policy developments on agricultural commodity markets and land use at aggregate spatial levels, the current study widens the analysis to consider regional effects within the EU as well as environmental impacts.

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List of Abbreviations

ACP	Africa, Caribbean, and Pacific
AgLink	Worldwide Agribusiness Linkage Program
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regionalised Impact Modelling System
CES	Constant elasticity of substitution
COCO	The Complete and Consistent CAPRI Data Base
COMEXT	External trade statistic division of EUROSTAT
COSIMO	Commodity Simulation Model
DDGS	Distillers Dried Grains with Solubles
DG-AGRI	Directorate General Agriculture and Rural Development
EBB	European Biodiesel Board
EBIO	European Bioethanol Fuel Association
ESIM	European Simulation Model
EU	European Union
EU10	10 EU Member States of the 2004 enlargement
EU12	12 EU Member States of 2004 and 2007 enlargements
EU15	15 EU Member States before the 2004 enlargement
EU2	2 EU Member States of the 2007 enlargement (Bulgaria and Romania)
EU27	27 EU Member States after the 2007 enlargement
EUROSTAT	Statistical Office of the European Communities
FADN	Farm Accountancy Data Network
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute
FOC	First Order Conditions
FQD	Fuel Quality Directive of the EU
GAMS	General Algebraic Modelling System
GDP	Gross Domestic Product
GHG	Greenhouse gas
GLOBIOM	Global Biomass Optimization Model
HC	Health Check
IEA	International Energy Agency
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IPTS	Institute for Prospective Technological Studies, Seville
MS	Member States
MTR	Mid-Term Review
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development
PRIMES	PRIMES energy system model
RED	Renewable Energy Directive of the EU
RFS	Renewable Fuel Standard of the US
SAPS	Single Area Payment Scheme
SFP	Single Farm Payment
SPS	Single Payment Scheme
toe	Tonne of oil equivalent = 10^7 kcal
TPES	Total primary energy supply
UAA	Utilised Agricultural Area
US	United States

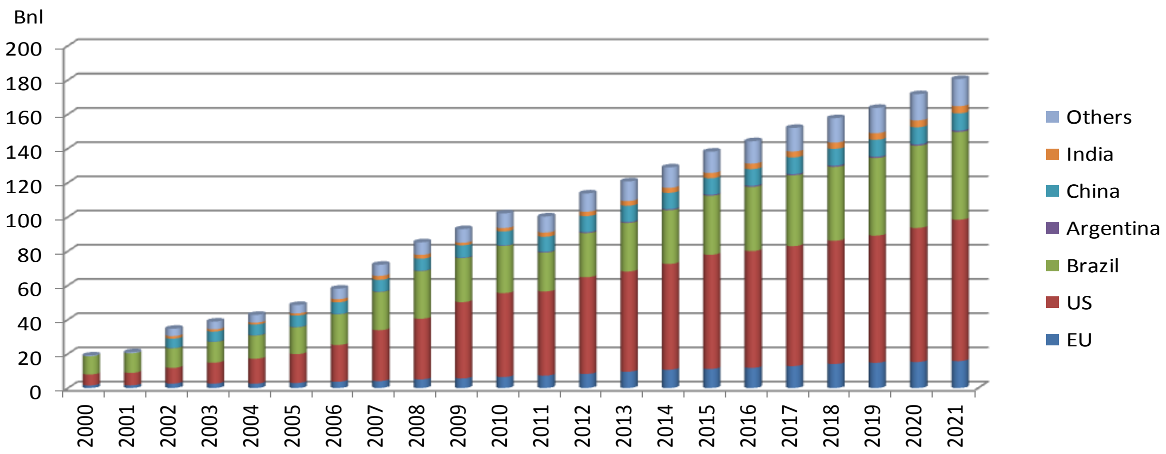
1 Introduction

The use of agricultural products as feedstock for biofuel production is growing rapidly in many countries primarily due to market forces and policy support. Mainly motivated by the desire to increase energy security and reduce greenhouse gas emissions in the transport sector, many countries have established policies to promote biofuels. As a result of these policy measures, as well as the foreseen scenario of high fossil fuel prices, biomass and biofuel markets are expected to grow substantially in the coming decades.

Global production of biofuels has been growing steadily over the last decade from 16 billion litres (Bnl) in 2000 to more than 100 billion litres in 2011. Today, biofuels provide around 3% of total road transport fuel globally (on an energy basis) and considerably higher shares are achieved in certain countries. Brazil, for example, met about 23% of its road transport fuel demand in 2009 with biofuels (IEA 2012).

Figures 1 and 2 depict global production data in the main producing regions as well as projections to 2021. In 2011, the main ethanol producing regions were the United States (US), Brazil and the European Union (EU). Production and use in the United States and the European Union are mainly driven by the policies in place, while in Brazil the growing use of ethanol is linked to the development of the flex-fuel vehicle industry (OECD-FAO 2012). As shown in Figure 1, global ethanol production is projected to almost double over the next 10 years (180 Bnl by 2021).

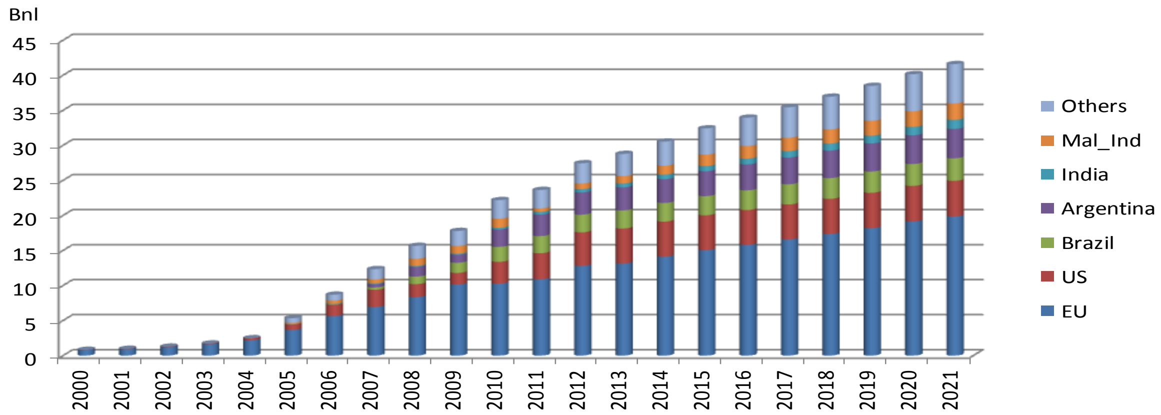
Figure 1: Global ethanol production and projections to 2021



Source: Based on data from OECD-FAO (2012)

With 46% of global production, the EU is the main producer of biodiesel, followed by the US, Argentina, Malaysia and Indonesia. Global production is projected to reach 42 Bnl in 2021 (from 24 Bnl in 2011) and the EU is expected to remain the main biodiesel producer (OECD-FAO 2012).

Figure 2: Global biodiesel production and projections to 2021



Source: Based on data from OECD-FAO (2012)

Up to now, almost all biofuels have been produced from agricultural feedstocks, such as cereals, sugar crops and vegetable oils. Thus, biofuel markets are closely connected to agricultural markets.

While small in terms of energy supply, the development of the biofuel sector has strong implications for both agriculture and the environment. On the one hand, there are concerns about the economic viability of biofuel production as in spite of high fuel prices the production of biofuels in recent years has been driven mainly by policy supports rather than by market forces (with the possible exception of ethanol production in Brazil).

On the other hand, the development of the biofuel sector also raises concerns about its impacts on land use and the environment. At the current state of technology, biofuels are mainly produced from agricultural feedstocks, meaning that an increase in biofuel production would further increase the competition for land and could have severe consequences on food prices. Also, the contribution of biofuels to reduce GHG emissions has been questioned in recent years because their production implies the use of significant amounts of fossil fuel. The strategic role of biofuels and the complex linkages between biofuel production, food markets and GHG emissions contribute to the debate surrounding public support. Therefore, the impact assessment of new biofuel policies becomes more crucial than ever before.

This study presents a methodological approach to assess the impacts of EU biofuel policies on the agricultural sector at both the global and regional levels. The CAPRI modelling system has been extended to integrate the links between agricultural and energy markets. The CAPRI model depicts a very detailed representation of EU policies at the MS level and since agricultural and trade policy developments are some of the important drivers for biofuel production and use, CAPRI allows a very detailed assessment of the effects on EU agriculture. CAPRI also captures a detailed regional disaggregation of effect, presenting results at the NUTS2 level. While most economic modelling studies analyse the impacts of biofuel developments on agricultural commodity markets and land use at aggregate spatial levels, the objective of the current study is to extend the analysis to consider regional effects within the EU as well as environmental impacts.

The structure of the document will be the following. Section 2 provides a brief overview of the evolution and economics of biofuel production. The main topics that make biofuels a strategic issue in agricultural and energy policies are presented. Furthermore, a review of selected economic models which already capture a biofuel market representation is presented. In Section 3, the overall CAPRI modelling system is described. Section 4 provides a thorough description of the modelling approach. The methodological construction and specification of behavioural functions for the biofuel market representation in the model (biofuel supply and biofuel feedstock demand, as well as the estimation procedures to derive approximating functions for biofuel and fuel demand) are summarized in this section. Section 5 focuses on the definition of the biofuel reference scenario (baseline). Section 6 provides an overview of the post-model analysis. The concluding Section 7 summarizes the main strengths and drawbacks of the methodology.

2 Biofuels background

2.1 Biofuels included in this study

Biofuels in this document is defined as liquid fuels (ethanol and biodiesel) for transport made from biomass. This should not be confused with bioenergy, which comprises biofuels, bioelectricity and bio-heat. Biofuels use has been modest for several decades but it increased rapidly in the last decade in response to concerns about rising energy prices and environmental impacts of fossil fuels use. The growing interest in biofuels during last few decades has been important in various technological developments with regards to the biofuel production. Biofuel production in recent years comprises several technological options, which can be grouped into: (i) conventional or first generation biofuels, and (ii) advanced biofuels, including second generation biofuels and other non-agricultural biofuels.

For convenience, we will keep apart biofuels produced from non-agricultural feedstocks. A detailed description of the technologies retained in this study is provided below.

First generation biofuels: Biofuel production under this technology comes from feedstocks which are the food crops used to produce biofuels. Ethanol is produced from starch crops such as cereals and sugar whereas biodiesel is produced using vegetable oils such as rape oil and palm oil. The advantage of this technology is that it has been available at the industrial scale for few decades now. A disadvantage of the technology is its dependence on the food crops. This means that the biofuel production under this technology competes with the crops demand for food. This would put more pressure on food demand of a growing population of the world today. In addition to that, savings on GHG emissions when replacing their fossil fuel equivalent can be limited or even negative as the production of crops has substantial GHG emissions in the process.

Second generation biofuels: This technology uses a wide range of agricultural by-products (such as straw), woody biomass as well as new energy crops such as miscanthus and willows to produce biofuels. The advantage of this technology thus is that the production under this technology does not compete with food demand for resources so has a lower repercussion of food and fodder demand. As the main resource of the technology comes from crop by-products, in principle the technology has lower environmental impacts than the first generation production. The energy generation potential from this technology is also greater than first generation biofuels. However, this technology is still under developmental stage and only future holds the full potential of this technology.

Non-agricultural biofuels: This includes biofuels produced from sources that are not directly originated from agriculture. For instance, biodiesel production from animal fat waste originating from food industries (old frying fat) or a recent technological developments regarding biofuel production from the use of aquatic vegetation such as algae can be grouped under this category. This technology does not compete for land with food crops and will be exogenously modelled.

2.2 Recent biofuel policies

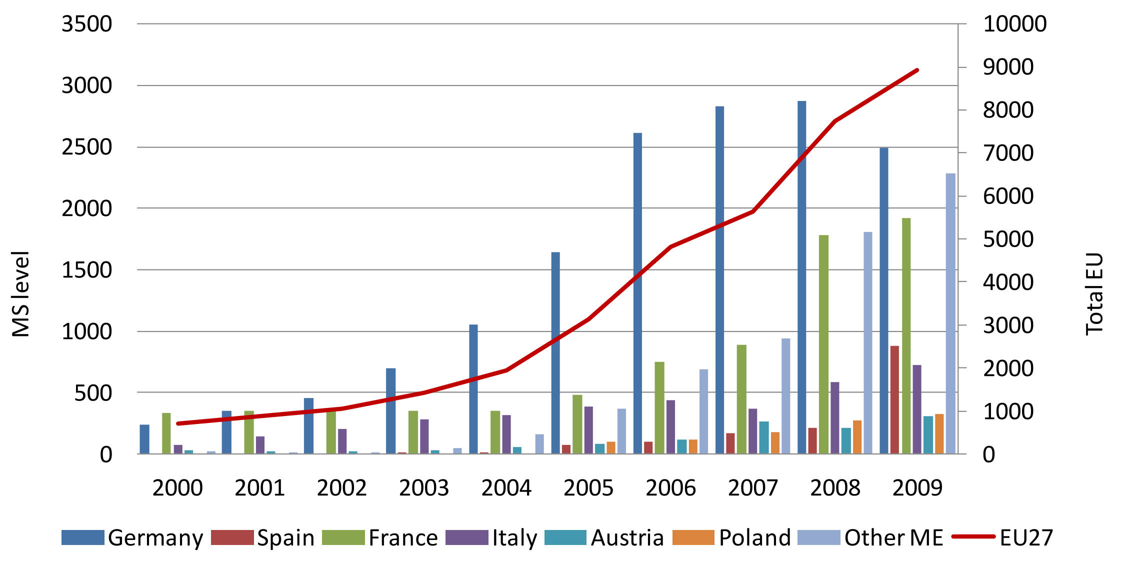
Many countries have initiated policy supports to promote biofuels as an alternative source of substitute for fossil fuel. In general, the main motivation behind these policy supports are: a) to reduce greenhouse gas emissions from the transport sector (climate change mitigation); b) to secure energy supply by reducing the oil import dependency of the transport sector (energy security); and c) to create an alternative outlet for farmers and the development of rural areas (rural development). The weighting of these motivations usually varies between countries and over time. In developing countries e.g. points b) and c) are dominating while point a) is more important in regulations of developed countries (OECD 2008).

Four broad groups of biofuel policy measures can be distinguished: (1) budgetary support, such as direct support to biomass supply and fuel tax exemptions for biofuel producers; (2) consumption targets (nonbinding) or mandates (binding), which set a minimum market share for biofuels in total transport fuel; (3) trade measures, in particular import tariffs; and (4) measures to stimulate productivity and efficiency improvements at various points in the supply and marketing chain (Blanco et al. 2010).

In the US, fuel-ethanol has been produced since the late 1970s and the first tax exemptions were set by the Energy Tax Act of 1978. The Renewable Fuel Standard (RFS) program established the first renewable fuel mandate in 2005, setting a minimum volume of biofuels to be used in the national transportation fuel supply. In 2007, the expanded RFS required the annual use of 9 billion gallons of biofuels in 2008 and expanded the mandate to 36 billion gallons annually in 2022, of which no more than 15 billion gallons can be ethanol from corn starch, and no less than 16 billion must be from cellulosic biofuels.

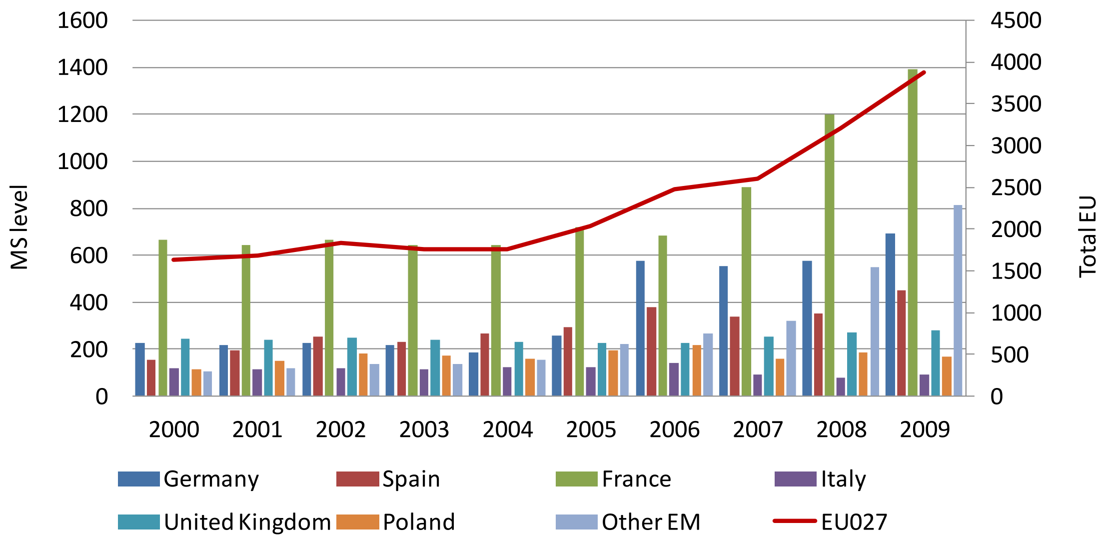
In the EU, although a discussion on using biofuel as an alternative source of fossil fuel had been taken place since early nineties, the main directive to promote biofuels and other renewable fuels in transport was formed in 2003 under the **Directive 2003/30/EC** and subsequent amendment **Directive 2009/28/EC** of the European Parliament and of the Council. The later Directive sets a target of 10% of renewable energy in total fuel consumption in transport by 2020. The Renewable Energy Directive (RED) provides the general framework while the implementation mechanisms (blending mandates, tax exemptions, and production incentives) are decided at the Member State (MS) level. This indicative target has been adopted by most Member States in their national biofuel objectives. A steep increase in the EU production of biodiesel and ethanol can be seen since these directives were introduced (Figure 3 and Figure 4). Both the RED and the Fuel Quality Directive (FQD) also establish environmental sustainability criteria that biofuels consumed in the EU have to comply with.

Figure 3: EU Biodiesel Production (1000 t)



Source: CAPRI database (several raw sources)

Figure 4: EU Ethanol Production (1000 t)



Source: CAPRI database (several raw sources)

Whereas some countries have established blending mandates (i.e. Brazil, the EU, and the US), others have set targets on biofuel consumption (i.e. Australia, China, India, Indonesia, and Malaysia). In addition to biofuel targets or mandates, some countries (the EU, the US, and Brazil) also provide production incentives (subsidies or tax credits) and tariffs for biofuels. The following table summarises biofuels policies in major producing countries and regions.

Table 1: Biofuel policies in major producing countries and regions

Country	Current production (2011)	Mandate or target	Production incentives	Trade policy
United States	49.2 Bnl ethanol 3.7 Bnl biodiesel	Mandate: 36 billion gallons of biofuels by 2022, of which no more of 15 billion gallons come from conventional sources and no less of 16 billion gallons come from cellulosic ethanol.	Tax credit of US$0.45/gallon ($0.12/litre) for ethanol blenders and US$1.00/gallon ($0.26/litre) for biodiesel blenders from agricultural feedstocks.	Ethanol tariff of US$.54/ gallon ($0.143/litre) plus ad valorem duty of 2.5 %. Ad valorem duty of 1.9 % on biodiesel.
European Union	7.2 Bnl ethanol 10.9 Bnl biodiesel	Mandate: minimum of 10% of transport fuel from renewable fuels by 2020.	Member States can apply tax reductions on biofuels as well as provide production incentives.	Specific tariff of €0.192/litre of under-natured ethanol and €0.102/litre of denatured ethanol. Ad valorem duty of 6.5 % on biodiesel.
Brazil	22.7 Bnl ethanol [sugar cane] 2.5 Bnl biodiesel [soya]	Blending mandate for ethanol of 20–25%. Biodiesel use mandate set at 5% (B5) since 2010 (proposal to increase to up to 10% by 2020.	Tax incentives on fuel ethanol and biodiesel. Tax incentives on flex-fuel vehicles.	Ad valorem duty of 20% on ethanol imported from outside the Mercosur area (temporarily in the list of exceptions). Ad valorem duty of 14% for biodiesel.
India	1.08 Bnl ethanol [molasses] 0.24 Bnl biodiesel [jatropha]	Indicative 20% target for blending for both ethanol and biodiesel by 2017.	Minimum price mechanisms for feedstocks Tax incentives for ethanol or biodiesel.	Ad valorem duty of 28.6% both on ethanol and biodiesel.
China	2.3 Bnl ethanol	E10 for 2020 (12.7 Bnl ethanol)	Production subsidies on ethanol	Ad valorem duty of 5% on

	[maize and wheat] 0.6 Bnl biodiesel [waste and residues]	Target of 2.3 Bnl biodiesel consumption in 2020 Target of 15 per cent of fuel consumption to be non-fossil fuel by 2020	and biodiesel.	denatured ethanol (30% until 2009) and 40% on undenatured ethanol.
Thailand	0.5 Bnl ethanol [sugar cane] 0.7 Bnl biodiesel [palm oil]	Ethanol: E20 mandatory since 2008. Biodiesel: B2 mandatory since 2008 and B5 since 2012.	Tax exemption for ethanol. Investments subsidies for ethanol plants. Soft loans for biodiesel.	No export duties on processed palm oil or biodiesel.

Source: Compilation from several sources, including Mitchel 2011, Blanco et al. 2010, U.S. Department of Agriculture, Global Agriculture Information Network (GAIN) biofuels reports, various countries and years.

2.3 Review of previous modelling exercises

There is a growing literature analysing the impact of biofuels and biofuel policies on agricultural markets and the environment. Several theoretical models have been developed for studying the effect of biofuels on agricultural markets (e.g. Gardner, 2007; de Gorter and Just, 2008, 2009). For example Gardner (2007) developed a vertical market integration model of ethanol, by-product, and corn markets to analyse the welfare effects of corn and ethanol subsidies in the US. De Gorter and Just (2008, 2009) extended the Gardner's model by incorporating ethanol in the aggregate fuel market. They showed that market power up streaming the input market and down streaming the corn-processing sector may have important implication of how biofuels and biofuel policies impact agricultural markets.

Theoretical work provides important insights on how biofuels and biofuel policies operate and on the interlinkages in the energy-biofuel-food system. To quantify impacts, some studies employ econometric tools to investigate relationships between biofuels and food prices (Tyner and Taheripour 2008a and 2008b, Ciaian and Kancs 2011) or between biofuels and land use (Diermeier and Schmidt 2012; Giuseppe et al. 2012).

However, the most widely used approaches for analysing biofuel developments are partial and general equilibrium models. These models have richer theoretical structure and are able to capture induced feedback effects and market inter-linkages as well as simulating new polices for which past observed data are not available. Partial and general equilibrium models have been widely used to simulate biofuel policies and biofuel market developments (Arndt et al. 2008, Birur et al. 2008, and Blanco-Fonseca et al. 2010).

Several Computable General Equilibrium (CGE) models analyse the trade-offs between food, feed and fuels and their impact on global agricultural markets. One of the CGE models that have incorporated a biofuel market representation is the well-known *GTAP* model (Global Trade Analysis Project). The GTAP Energy (GTAP-E) version first developed by Burniaux and Truong (2002) covers biofuel markets and the new GTAP Biofuel model (GTAP-BIO) is an additional extension of GTAP-E focusing at biofuels. The *MIRAGE* CGE model has also been adapted to assess biofuel policies.

Banse et al. (2008) use a modified GTAP-E model with endogenous land supply to analyse the impact of the EU biofuel directive on agricultural markets. The GTAP-BIO version is initiated by Birur et al. (2008), who incorporate biofuels into the GTAP database, differentiating three biofuels, ethanol from grains, ethanol from sugar crops, and biodiesel from vegetable oils. To allow for analysing land competition, they disaggregate land endowments by Agro-Ecological Zone (AEZ). Keeney and Hertel (2009) use the GTAP-BIO version to assess the agricultural land use impacts of mandate driven ethanol demand increases in the US. Hertel et al. (2010) use a

GTAP model that incorporates by-products to conduct an ex-ante analysis of biofuel policies in the US and the EU. They evaluate the individual and combined impacts of EU and US biofuel policies on global markets.

Al-Riffai et al. (2010) use a modified version of the MIRAGE model to estimate the impacts on global agricultural production and the environmental performance of the EU biofuels policy. Their study pays particular attention to the land use change (LUC) effects, and the associated emissions, of the main feedstocks used for first-generation biofuels production. Using an updated version of the MIRAGE model, the study by Laborde (2011) places the focus on the estimation of specific feedstock LUC effects.

General equilibrium models offer a more encompassing assessment of the impacts of biofuel market developments because intersectoral linkages are explicit in these models. The disadvantages of general equilibrium analyses are the aggregation of biofuel feedstocks in a few sectors and the lack of realistic representation of agricultural policies. Furthermore, these models usually do not distinguish between 1st and 2nd generation technologies. Partial equilibrium models, on the contrary, have limited capability to address intersectoral linkages but provide more disaggregated feedstock coverage and enhanced capability to simulate agricultural policies as well as to cover different biofuel processing technologies.

Among the partial equilibrium models of the agricultural sector that include a representation of biofuel and biofuel feedstock markets, we distinguish *AgLink-COSIMO* (the OECD-FAO agricultural sector model), *FAPRI* (Food and Agricultural Policy Research Institute), *ESIM* (European Simulation Model), *GLOBIOM* (Global Biomass Optimization Model) and *IMPACT* (International Model for Policy Analysis of Agricultural Commodities and Trade). With the exception of the IMPACT model, all mentioned models include a behavioural representation of biofuel markets.

In the IMPACT model (Rosegrant et al. 2008), biofuels demand is exogenous and determines demand for biofuel feedstocks, which is derived using fixed conversion coefficients. Therefore, biofuel scenarios are modelled as a demand shock for agricultural commodities based on exogenously given biofuel production quantities. This approach does not allow for considering market feedbacks.

The FAPRI model has a strong focus on the US and, therefore, pays particular attention to the ethanol market. This model has been used to estimate the impact of various scenarios of biofuel expansion in the US on agricultural prices and land use (Fabiosa et al. 2010).

AGLINK-COSIMO models ethanol and biodiesel markets worldwide, while assuming exogenous prices for fossil fuels (OECD 2008). Several production technologies are considered: 1st generation biofuels, 2nd generation biofuels and biofuels from non-agricultural sources. AGLINK-COSIMO covers biofuel by-products and their linkage to the feed market. The EU is modelled as two regions (EU-15 and EU-12 respectively), although biofuel demand and supply functions are modelled only at aggregate EU-27 level, meaning that fuel and biofuel taxes are set at uniform rates across the EU (Blanco-Fonseca et al. 2010). Net trade flows are endogenous.

The ESIM model includes explicit supply and demand functions for ethanol and biodiesel (Banse and Grethe 2008). Fossil energy prices are taken as exogenous. Only 1st generation technologies are modelled. ESIM distinguishes three feedstocks for ethanol (wheat, maize and sugar) and other three for biodiesel (sunflower, rape and soy oil). Biofuel by-products are also modelled. ESIM models each EU Member State individually and incorporates a wide range of EU agricultural domestic and trade policies (Blanco-Fonseca et al. 2010). However, the non-European country differentiation in ESIM is very limited (apart from the US and Turkey, all other countries are aggregated in the rest of the world block).

GLOBIOM is a PE model of the global forest, agriculture and biomass sectors (Havlik et al. 2010). Global regions are aggregated in 28 regions, four of them covering the EU. Biofuel by-products are not covered.

Compared to the PE models presented above, the CAPRI model has two distinctive features:

(1) A higher spatial differentiation in the EU. With the exception of ESIM, all the above mentioned PE models represent the EU as a block. CAPRI models agricultural markets not only at the MS level but also at the regional level (NUTS2 regions).
(2) A bilateral trade representation for biofuels and biofuel feedstocks. All the above mentioned PE models use a net trade approach. On the contrary, CAPRI allows for bilateral trade flows for all products included in the market model.

Since EU biofuel policy instruments are defined at the MS level and biofuel trade is a crucial issue when evaluating biofuel policies (biofuels can be transported at relative low costs per unit and production costs vary strongly between countries), the CAPRI model is particularly well suited to address biofuel-agriculture feedbacks.

Previously to the methodological development presented in this report, biofuel markets were not endogenously modelled in CAPRI. Rather, biodiesel and ethanol targets were set exogenously and the resulting feedstock demand was incorporated by adding a new position (biofuel processing demand) to the CAPRI demand system (Britz and Leip 2008). Fixed biofuel conversion coefficients were used to estimate the biofuel processing demand resulting from exogenously given biofuel production quantities, as well as the by-products produced. Several agricultural feedstocks were considered both for ethanol and for biodiesel, but the demand shares for these products were assumed to be fixed. The model allowed simulating shocks of biofuel feedstock demand and analysing changes in production, demand, imports, exports and prices for agricultural products resulting from those shocks.

Whereas biofuel supply and demand were left exogenous, an upgrade of the simplified feedstock demand handling was introduced in 2008 to overcome the problem of fixed feedstock demand shares (Britz and Witzke 2012). In order to develop a first behavioural system for biofuel feedstock demand, a simplified processing sector for biofuels was introduced. This version of the model was used to analyse the implications of the EU biofuel policy (Blanco-Fonseca et al. 2010).

3 Integration of biofuel markets in CAPRI

3.1 Overview of the CAPRI methodological approach

CAPRI (**C**ommon **A**gricultural **P**olicy **R**egionalised **I**mpact Modelling System) is a comparative-static, spatial, partial equilibrium model specifically designed to analyse CAP measures and trade policies for agricultural products within the European Union (Britz and Witzke, 2012). CAPRI models agricultural commodity markets worldwide, whilst providing a detailed representation of the diversity of EU agricultural and trade policy instruments. It consists of two interlinked modules, a supply module for European countries and a global market module, such that production, demand, trade and prices can be simulated simultaneously and interactively[1]. The supply module is composed of separate, regional, non-linear regional programming models. These regional programming models are based on a model template assuming profit-maximizing behaviour under technological constraints, most importantly in animal feeding and fertilizer use, but also constraints on inputs and outputs such as young animal, land balances and set-aside (Jansson and Heckelei, 2011). The supply module currently covers all individual Member States of the EU-27 and also Norway, Turkey and the Western Balkans broken down to about 280 administrative regions (NUTS2 level) and more than 50 agricultural products. The market module is a global spatial multi-commodity model depicting 77 countries in 40 trade blocks. Based on the Armington approach (Armington, 1969), products are differentiated by origin, enabling bilateral trade flows to be captured.

3.2 Extension of the CAPRI modelling system to cover biofuel markets

In this study, the CAPRI system was extended to cover global biofuel markets with a detailed focus on Europe. Compared to the previous version of CAPRI, several improvements had been made with this extension. The earlier version of CAPRI did not include endogenous biofuel production. Instead, the demands for ethanol and biodiesel were set exogenously, and the model determined the consequences for supply, demand, trade (in feedstocks only, as trade in biofuels was not modelled) and prices of agricultural primary and secondary products. In contrast, the new CAPRI biofuel module includes a global representation of biofuel markets, with endogenous supply, demand and trade flows for biofuels and biofuel feedstocks.

In a previous study (Blanco et al. 2010) which used the earlier version of CAPRI, both the baseline and counterfactual scenarios were constructed to meet the EU27 2020 biofuel demands (first- and second-generation) obtained from AGLINK. In the current version of CAPRI, biofuel demand is determined endogenously and depends on the price ratio between fossil fuel and the corresponding biofuel.

The development of the biofuel module in CAPRI covered 5 steps.

- Implementation of new variables into the model required for the biofuel market representation.
- Building an ex-post database which includes all market balance positions for biofuels and biofuel feedstock in each EU MS and non-European region.
- Specification and calibration of behavioural functions for biofuel supply and feedstock demand as well as fuel and biofuel demand and global biofuel trade.

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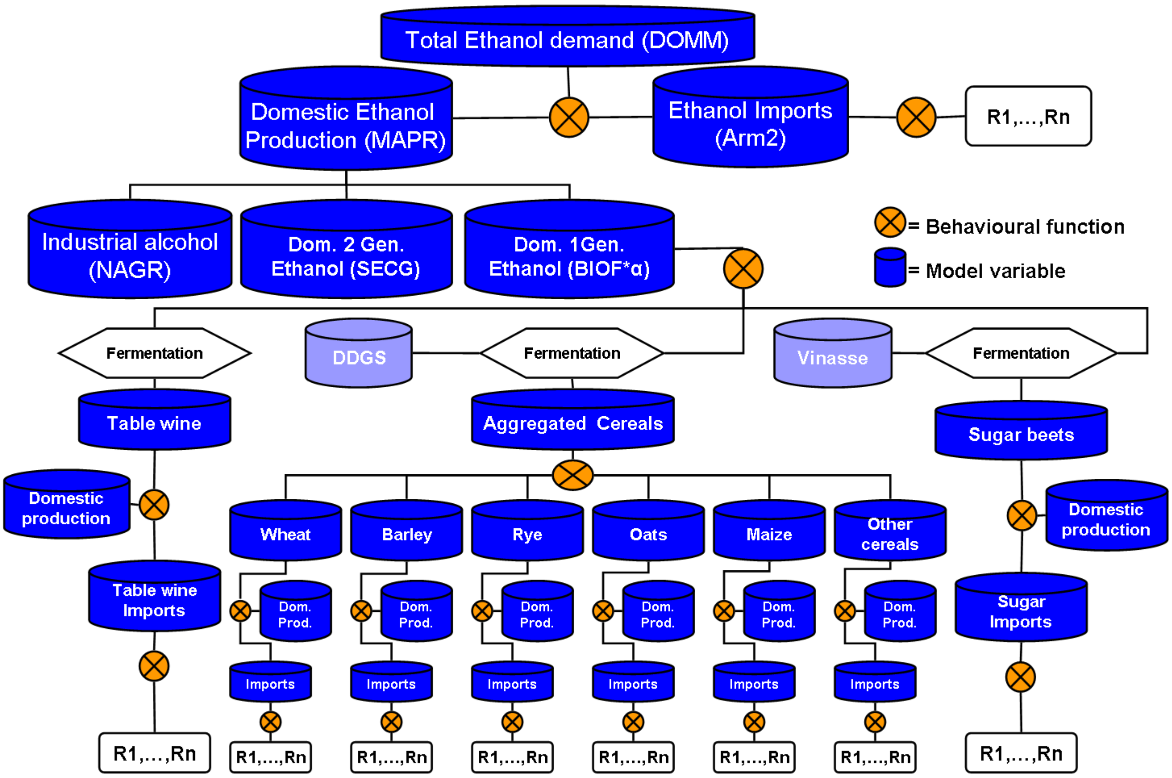
[1] More detailed model information is available online at www.CAPRI-model.org.

- Construction of a reference scenario (baseline) by trend estimates based on the database and external expert knowledge.
- Integration of socioeconomic and environmental indicators.

The first step stated above is described briefly in this section whereas the latter four steps will be addressed in more detail in the following sections. The core advantage of the CAPRI biofuel module is that biofuel supply and feedstock demand react flexibly to the price ratio of biofuel and feedstock prices as well as biofuel demand and bilateral trade flows react flexibly to biofuel prices and further relevant drivers.

Figure 5: Construction of the ethanol market implemented in CAPRI



Basically two biofuel product markets are covered in the model; Ethanol (BIOE) and Biodiesel (BIOD). For total domestic ethanol production, three technology pathways are covered as shown in Figure 5; 1st generation ethanol ($BIOF_E$) - differentiated in wheat, barley, rye, oats, maize, other cereals, sugar and table wine, 2nd generation ethanol (SECG), and non-agricultural ethanol (NAGR).

A similar technological pathway for biodiesel production can be observed as shown in Figure 6. The three production pathways for biodiesel are; 1st generation biodiesel ($BIOF_D$) produced from vegetable oils (rape oil, sunflower oil, soya oil, and palm oil), 2nd generation biodiesel (SECG); and non-agricultural biodiesel (NAGR).

Figure 6: Construction of the biodiesel market implemented in CAPRI

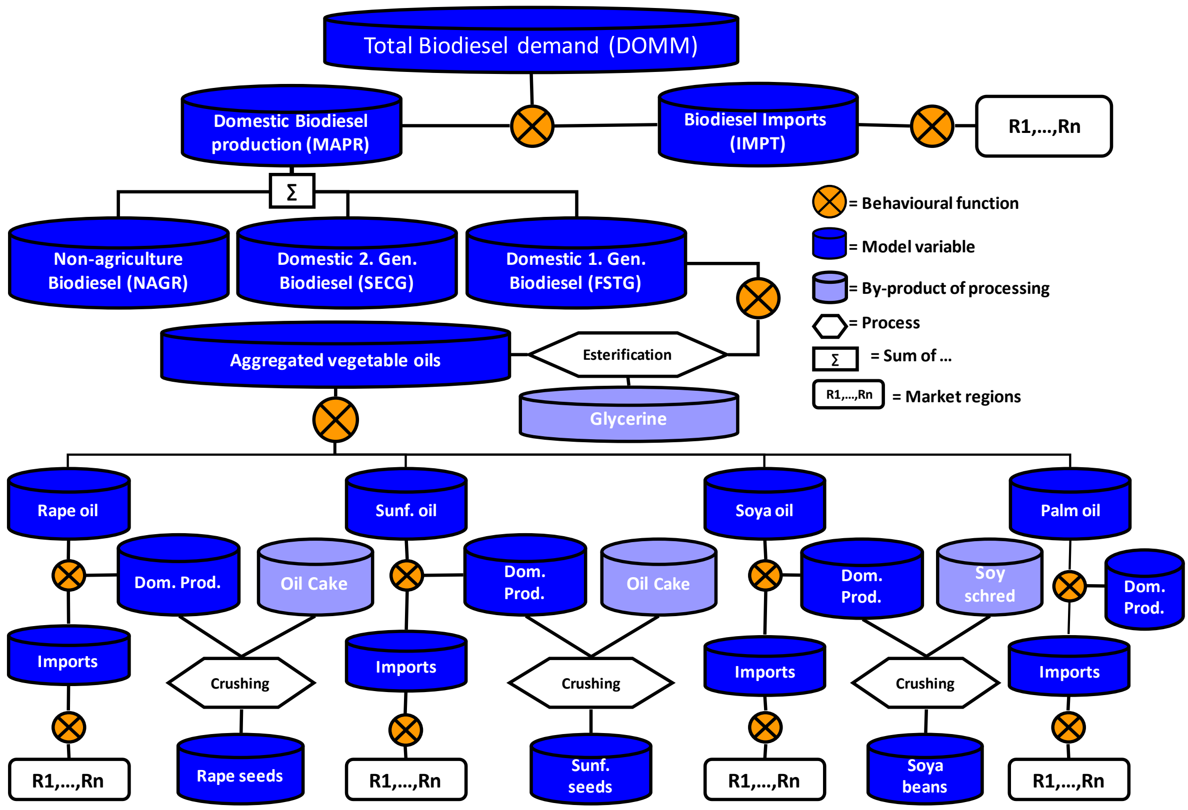
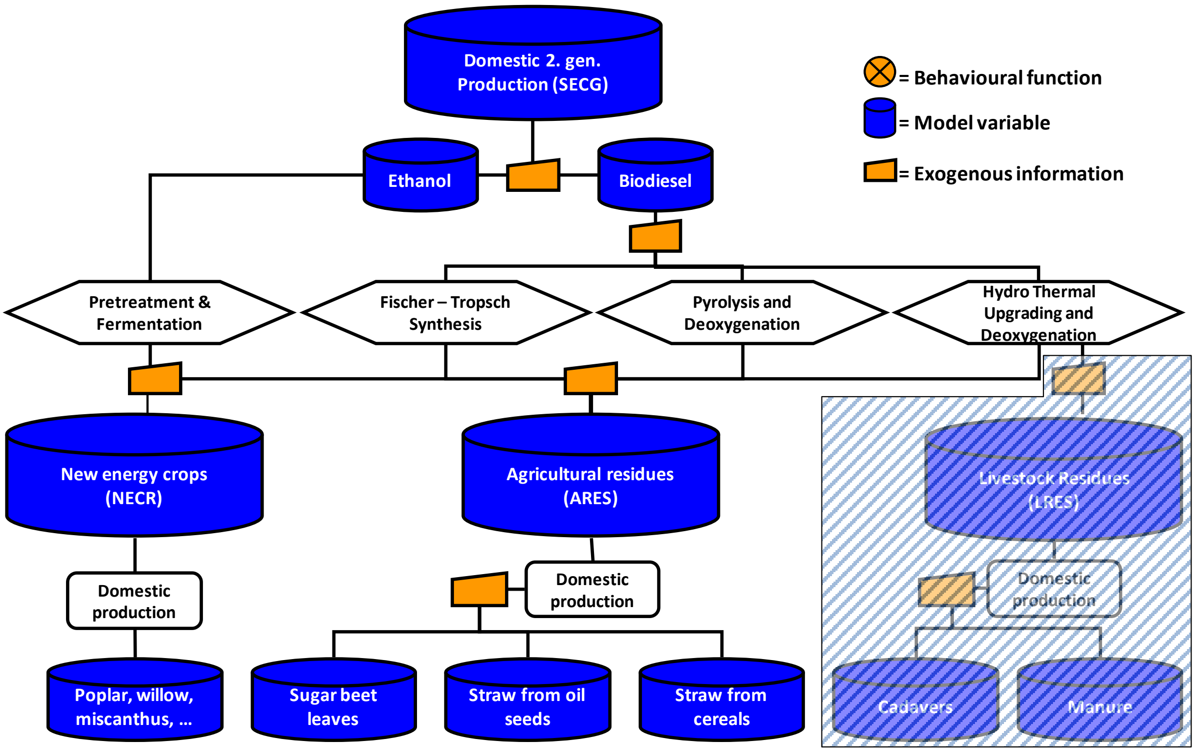


Figure 7 provides a schematic diagram of the process of 2nd generation biofuel production in CAPRI. Two different product aggregates are introduced in the CAPRI product list to cover feedstock for 2nd generation biofuel processing: (1) a product aggregate for agricultural residues (ARES) which covers straw from cereals/oil seed production and sugar beet leaves and (2) a product aggregate for new energy crops (NECR) which cover herbaceous and woody crops like poplar, willow and miscanthus. The use of residues from livestock production, which covers manure and cadavers, is not included explicitly in the second generation processing as this source is assumed to have only a marginal importance for biofuel processing. However, biofuels produced in this processing path will show up under the aggregate on non-agricultural biofuels. Furthermore, the demand shares for the single agricultural residues are provided exogenously in the model meaning that there is no economic draw back that influences crop allocation decisions based on demand for e.g. straw based ethanol. This assumption was based on the observation that the potential of ARES resulting from the activity levels of cereals, oilseeds and sugar beet production in the base and projection year is high enough[2] that even in a high second generation scenario (50% of biofuel demand in EU should be stemming from 2nd generation biofuel processing) could only generate a demand of up to 10% of the actual potential. The demand share for new energy crops in the second generation production quantities is also provided exogenously in the model. However, as the production of new energy crops require agricultural land, the available agricultural land for the production of other agricultural products is reduced accordingly with the yield information collected for NECR.

[2] In the CAPRI baseline we observe about 60 million ha cereals producing about 200 million tons of straw. This would be equivalent to about 30 million litres of ethanol.

Figure 7: Consideration of 2nd generation biofuel production and related feedstock



4 Description of the CAPRI biofuel module

4.1 Construction of a biofuel database

The availability of biofuel market data is still very limited due to the fact that this market has mainly developed within the last few years. Thus, different data sources had to be consulted to build a sufficient database. This creates heterogeneity in variable notation as well as consistency in data which requires adjustments to ensure completeness and consistency and to derive closed market balances. The main data sources used for the development of the biofuel database were; F.O. Licht, AgLink 2010 baseline, PRIMES 2010 baseline (used in the EC4MACS interim Assessment, www.ec4macs.eu), EBIO, EBB and EUROSTAT (all updated in Winter 2011). Apart from data for market balance positions, conversion coefficients for the 1st and 2nd generation biofuel processing as well as the technology parameters for the 2nd generation feedstock production including the usability rates for agricultural residues and average yields for new energy crops were also collected. This ex-post database was used to estimate trends for the projection year (2020). However, given the very short ex-post horizon (2002 - 2005) of biofuel data, the baseline projections were mainly fed by expert knowledge. Main sources in this case were the AgLink 2010 and PRIMES 2010 baselines which provide projections of domestic use and supply of biofuels for the single EU27 countries (PRIMES) and non-European countries (AgLink). This kind of expert knowledge was also fed into the trend estimation system of CAPRI.

4.1.1 Production

In the following section the different identified and used data sources will be described for each market balance position. There is no differentiation made between fuel- or non-fuel (undenatured or denatured) on the production, import and export positions of ethanol as they cover aggregated ethanol quantities. But the consumption position of ethanol is differentiated in fuel-ethanol consumption and non-fuel-ethanol consumption. Hence data on fuel and non-fuel production and consumption of ethanol was required. In the case of biodiesel this differentiation is not used as biodiesel is only produced for fuel purposes and no additional demand beside fuel use exists.

For the acquisition of ex post biofuel production quantities in European and non-European countries the following data sources were consulted:

- European Bioethanol Fuel Association (EBIO)
- European Biodiesel Board (EBB)
- EUROSTAT: PRODCOM
- Base-year data from the PRIMES model (status 2010)
- OECD agricultural model AgLink-COSIMO database (status 2010)
- F.O. Licht

Table 2 provides an overview of the production data from different data sources used in this study. As described above, one can observe that different variable definitions are used to describe ethanol production. In the case of biodiesel this problem doesn’t exist as there is only one definition of production quantities. In the case of ethanol EBIO and PRIMES production data covers only fuel-ethanol quantities whereas F.O. Licht and PRODCOM differentiate between undenatured and denatured ethanol. The AgLink-Cosimo database does not distinguish between these sub-products but introduced a new differentiation between ethanol produced from agricultural sources and ethanol produced from non-agricultural sources. To achieve consistency among the different sources for ethanol production, the collected data were consolidated. From this procedure it got obvious that the PRIMES production data (fuel-ethanol production) is largely consistent with EBIO data.

Table 2: Overview on data sources utilized for biofuel production

Source	Variables covered	Time period	Regional coverage
EBIO	**Fuel ethanol production**	**2004 - 2008**	**Sel. EU MS**
EBB	**Biodiesel production**	**2003 - 2007**	**EU MS (EU 27)**
EUROSTAT-PRODCOM	**Sold volume:** **Biodiesel (code: 20595990)** **Undenatured ethanol (code: 20147400)** **Denatured ethanol (code: 201474500)**	 **2007 - 2008** **1995 - 2008** **1995 - 2008**	 **Sel. EU MS** **Sel. EU MS** **Sel. EU MS**
PRIMES	**Fuel ethanol production** **Biodiesel production**	**2000 - 2007** **2000 - 2007**	**Sel. EU MS** **EU MS (EU27)**
Aglink-Cosimo	**Ethanol production from agr. crops** **Ethanol production from non-agr. inputs** **Biodiesel production**	**2000 - 2008** **2000 - 2008** **2000 - 2008**	**EU27 agg. + OECD Members** **EU27 agg. + OECD Members** **EU27 agg. + OECD Members**
F.O.Licht	**Undenatured ethanol production** **Denatured ethanol production** **Biodiesel production**	**2000 - 2008** **2000 - 2008** **2003 - 2008**	**Sel. EU MS + non-EU countries** **Sel. EU MS + non-EU countries** **Sel. EU MS + non-EU countries**

Furthermore, the AgLink-Cosimo aggregate for ethanol produced from agricultural and non-agricultural sources is consistent with the F.O. Licht aggregate for denatured and undenatured ethanol. These consistencies allow for defining the production activity variable (MAPR) for ethanol which covers the whole ethanol production quantity (undenatured and denatured ethanol, regardless of its origin) in a certain country and year. Therefore the F.O. Licht production data for ethanol was taken as the base dataset as it covers explicitly European as well as non-European countries complemented with PRIMES data for the EU. In the case of biodiesel the PRIMES dataset was taken as the base whereas F.O. Licht data was taken into consideration to amend non-European production. It was abandoned to consider only fuel-ethanol production as a significant share of non-fuel ethanol quantities are also produced from agricultural products. This fact was proved by comparing the increase in global ethanol production in certain countries with the amount of industrial use of agricultural products which was already part of the COCO database in CAPRI. A significant link was observed between both positions which allows for the assumption that a significant share of the industrial use position in the COCO database already covered biofuel processing demand quantities in the past. Thus the differentiation between fuel- or non-fuel use and denatured or undenatured chemical status has no consequence on the production side. However, this will be important and incorporated in the calculation of ethanol demand. The differentiation of non-agricultural or agricultural ethanol is of course important as it indicates that not the whole ethanol production quantities are produced from agricultural products. To consider this fact in CAPRI the AgLink-Cosimo data on non-agricultural ethanol was used to calculate the supply share of non-agricultural ethanol. The resulting compiled production data set went through the standard consistency and completeness steps of COCO and was integrated into the biofuel-database as displayed in Table 3.

Table 3: Production quantities of biofuels in European Member States (2002-2010)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
BL00000 ***BIOE***	0	0	0	0	0	0	0	110.71	117.91
BL00000 ***BIOD***	0	0	0	0.98	25.3	162.78	276.3	407.68	396.62
DK00000 ***BIOE***	14.5	14.2	14.5	16.26	16.12	12.89	13.94	13.94	13.94
DK00000 ***BIOD***	9.8	40.97	70.06	69.58	81.6	86.7	130.34	136.12	127.86
DE00000 ***BIOE***	225.62	216.78	185.33	259.36	574.46	555.2	576.15	694.46	668.3
DE00000 ***BIOD***	459	700.7	1055.7	1644.32	2608.76	2832.2	2875.38	2488.22	2987.41
EL00000 ***BIOE***	0	0	0	0	0	0	0	0	0
EL00000 ***BIOD***	0	0	0	3.06	41.19	98.88	108.01	76.89	71.21
ES00000 ***BIOE***	252.27	230.95	266.35	293.6	376.55	338.35	351.25	448.73	392.01
ES00000 ***BIOD***	0	6.12	13.26	74.46	100.98	171.36	211.14	876.18	816.91
FR00000 ***BIOE***	667.01	643.32	644.66	717.45	684.93	890.33	1200.01	1393.56	1321.26
FR00000 ***BIOD***	358.68	351.41	354.96	482.16	747	889.44	1778.7	1919.82	1824.2
IR00000 ***BIOE***	0	0	0	0	0	5.42	7.74	1.55	1.08
IR00000 ***BIOD***	0	0	0	4.9	3.93	3.06	23.52	16.82	25.11
IT00000 ***BIOE***	120.06	115.36	120.87	124.65	139.36	91.67	77.42	90.25	86.72
IT00000 ***BIOD***	205.92	278.46	313.6	388.08	438.06	370.26	583.1	726.53	782.32
NL00000 ***BIOE***	0	0	0	6.42	11.84	11.33	7.02	0.05	0.03
NL00000 ***BIOD***	0	0	0	0	17.64	83.3	98.98	316.54	311.62
AT00000 ***BIOE***	6.45	6.45	5.42	5.53	9.67	20	68.9	145.04	96.33
AT00000 ***BIOD***	24.5	31.36	55.86	83.3	120.54	261.66	208.74	303.8	292.99
PT00000 ***BIOE***	0	0	0	0	0	0	0	0	0
PT00000 ***BIOD***	0	0	0	1.02	89.18	81.6	263.14	249.32	234.92
SE00000 ***BIOE***	78.64	80.58	84.61	119.36	113.73	97.61	114.42	192.59	180.81
SE00000 ***BIOD***	0.98	0.98	0.98	0.98	12.74	61.74	96.04	97.02	101.97
FI00000 ***BIOE***	0	0	0	0	0	0	38.71	3.22	2.07
FI00000 ***BIOD***	0	0	0	0	0	0	83.3	215.6	181.19
UK00000 ***BIOE***	249.8	240.26	229.47	224.52	225.62	253.16	272.43	278	353.11
UK00000 ***BIOD***	3.06	8.82	9.18	50.05	188.16	153	188.16	134.26	108.04
CY00000 ***BIOE***	0	0	0	0	0	0	0	0	0
CY00000 ***BIOD***	0	0	0	0.98	0.98	0.98	8.82	8.91	6.7
CZ00000 ***BIOE***	0	0	0	12.14	22.54	37.05	71.7	100.7	94.82
CZ00000 ***BIOD***	0	0	59.27	130.34	104.86	59.78	101.92	160.72	151.55
EE00000 ***BIOE***	0	0	0	0	0	0	0	0	153.82
EE00000 ***BIOD***	0	0	0	6.86	0.98	0	0	23.52	39.3
HU00000 ***BIOE***	37.74	37.18	41.81	46.2	66.57	80.57	119.84	116.15	85.16
HU00000 ***BIOD***	0	0	0	0	0	7.14	102.9	130.34	119.74
LT00000 ***BIOE***	0	0	0	6.53	14.33	16.1	15.46	24.15	73.86
LT00000 ***BIOD***	0	0	4.9	6.86	9.87	25.59	64.68	96.17	90.12
LV00000 ***BIOE***	0	0	9.48	9.69	9.69	14.25	15.72	12.08	7.79
LV00000 ***BIOD***	0	0	0	4.9	6.86	9.18	29.4	43.12	54.8
MT0000 ***BIOE***	0	0	0	0	0	0	0	0	0
MT0000 ***BIOD***	0	0	0	1.96	1.99	1.02	0.98	0.98	0.68
PL00000 ***BIOE***	182.99	171.88	157.13	194.2	216	159.55	186.59	166.81	704.3
PL00000 ***BIOD***	0	0	0	98	115	178.5	269.5	325.36	296.43
SI00000 ***BIOE***	0	0	0	0	0	0	0	0	0
SI00000 ***BIOD***	0	0	0	7.84	10.78	10.78	8.82	8.82	17.6
SK00000 ***BIOE***	0	0	0	0	0	23.23	75.75	91.36	102.57
SK00000 ***BIOD***	0	0	15.13	76.44	80.36	46.92	143.08	103.02	95.76
BG00000 ***BIOE***	0	0	0	0	0	0	0	0	0
BG00000 ***BIOD***	0	0	0	0	3.92	8.82	11.22	25.5	53.91
RO00000 ***BIOE***	0	0	0	0	0	0	0	0	0
RO00000 ***BIOD***	0	0	0	0	9.8	35.28	63.7	28.42	39.98

Source: COCO database in CAPRI model

4.1.2 Consumption

For the acquisition of ex post biofuel consumption quantities the following data sources were consulted:

- EUROSTAT
- Base-year data from the PRIMES model (status 2010)
- OECD agricultural model AgLink-COSIMO database (status 2010)
- F.O. Licht

Table 4 provides an overview about covered consumption data within the different data sources used in the analysis. In comparison to the data availability for production quantities, information on consumption quantities of ethanol and biodiesel in European and non-European countries is more limited. In addition regarding ethanol demand, the same problem occurs as already described for the production data. Demand information for ethanol can be described as fuel-ethanol consumption and non-fuel ethanol consumption. Furthermore, there is also variation in the aggregation in different dataset; PRIMES covers only European Member States, AgLink covers only the EU27 aggregated and OECD member countries and only F.O. Licht includes detailed information for both, European and non-European countries, but only for selected ones. From this it follows that the required consumption position was fractional incomplete. As it is necessary to distinguish fuel- and non-fuel ethanol demand (to clearly differentiate the impacts of an increase in fuel ethanol consumption against other usages) further gaps result from these moderate data sources.

Table 4: Overview on consulted data sources for the acquisition of biofuel consumption data

Source	Variables covered	Time coverage	Regional coverage
EUROSTAT	**Biofuel consumption:** **Ethanol** **Biodiesel**	 **2005 - 2007** **2005 - 2007**	 **EU MS** **EU MS**
PRIMES	**Biofuel consumption** **Ethanol** **Biodiesel**	 **2000, 2005** **2000, 2005**	 **EU MS** **EU MS**
Aglink-Cosimo	**Fuel ethanol consumption** **Non-fuel ethanol consumption** **Biodiesel consumption**	**2000 - 2008** **2000 - 2008** **2000 - 2008**	**EU27 agg. + OECD Members** **EU27 agg. + OECD Members** **EU27 agg. + OECD Members**
F.O.Licht	**Fuel ethanol consumption** **Non-fuel ethanol consumption** **Biodiesel consumption**	**2000 - 2008** **2000 - 2008** **2003 - 2008**	**Sel. EU MS + non-EU countries** **Sel. EU MS + non-EU countries** **Sel. EU MS + non-EU countries**

In general, consumption data of European and non-European countries for fuel ethanol and non-fuel ethanol were taken from F.O. Licht as this data source provides the most extensive country and time coverage and is predominantly consistent with the fuel-ethanol consumption quantities offered by PRIMES, EUROSTAT and AgLink-Cosimo. To fill in the still existing gaps within the consumption position the following assumptions were made within the COCO procedure to achieve data completeness:

If information on production and trade flows was available in a respective year and country, the consumption of ethanol was taken as the production of ethanol minus exports plus imports.

If no information on fuel-ethanol consumption was available at country level but available at an aggregated level, the EU27 average share of non-fuel ethanol consumption (provided by AgLink) was used to calculate non fuel ethanol consumption and consequently fuel consumption.

Biodiesel consumption quantities for European countries were taken from the PRIMES model because the F.O. Licht dataset was incomplete for the required ex post time period. The biodiesel consumption data available from F.O. Licht were predominantly consistent with the PRIMES dataset where overlaps exist. Furthermore the PRIMES data was chosen as this data source contains ex post data for 2000 and 2005 as well as estimates for 2010 and allowed for an interpolation of the intermediate years. Biodiesel consumption data for non-European countries were taken from F.O. Licht as PRIMES does not cover non-European countries. The resulting compiled consumption data set differentiated in fuel-consumption (BIOF) and non-fuel consumption (INDM) and final consumption was proofed on consistency and completeness and was integrated into the biofuel-database. Fuel demand is displayed in Table 5.

Table 5: Fuel demand quantities of biofuels in European Member States (2002-2010)

		2002	2003	2004	2005	2006	2007	2008	2009	2010
BL000000	***BIOE***	0.55	1.1	4.25	2.8	7.71	17.19	24.81	100.28	111.71
BL000000	***BIOD***	0.88	0.27	0.37	0.49	0.68	0.68	84.89	93.83	189.99
DK000000	***BIOE***	0.53	2.51	4.17	6.56	8.86	11.67	25.19	27.61	63.2
DK000000	***BIOD***	1.13	2.5	10.26	15.85	17.77	35.08	69.84	95.23	93.77
DE000000	***BIOE***	110.52	52.48	68.02	260.96	511.56	479.58	609.94	1006.71	919.5
DE000000	***BIOD***	498.29	810.75	1142.93	1481.63	1837.27	3210.37	3315.42	2735.29	2890.19
EL000000	***BIOE***	0.01	0.34	1.12	2.1	3.31	6.58	8.61	10.55	7.81
EL000000	***BIOD***	15.88	14.01	13.92	11.74	1.88	78.7	128.72	104.08	77.39
ES000000	***BIOE***	20.64	32.74	66.39	169.4	180.64	187.87	157.6	158.04	127.6
ES000000	***BIOD***	71.8	93.86	118.42	139.17	144.69	62.19	270.63	580.46	1212.33
FR000000	***BIOE***	21.39	62.95	106.54	123.1	237.73	413.64	689.42	776.14	627.36
FR000000	***BIOD***	362.11	365.07	376.99	359.81	387.83	669.52	1379.36	2114.81	2050.25
IR000000	***BIOE***	4.96	5.5	5.84	5.84	0.01	5	15.96	13.08	0.87
IR000000	***BIOD***	0.17	0.35	0.47	0.69	0.78	0.87	19.08	30.6	28.09
IT000000	***BIOE***	7.83	22.44	41.53	63.03	85.67	93.32	101.34	124.56	148.36
IT000000	***BIOD***	36.06	72.13	108.19	143.91	163.15	146.83	142.45	613.12	1138.84
NL000000	***BIOE***	27.26	16.6	20.19	69.18	70.99	293.25	408.51	109.69	44.6
NL000000	***BIOD***	22.29	30.37	38.63	46.65	53.86	59.64	107.91	170.41	237.46
AT000000	***BIOE***	4.09	4.86	8.31	16.97	26.32	43.77	78.62	92.95	48.36
AT000000	***BIOD***	10.85	15.42	20.96	25.64	30.69	206.62	224.96	241.68	318.57
PT000000	***BIOE***	0	3.01	6.4	7.23	2.6	1.56	17.05	10.28	14.52
PT000000	***BIOD***	0.24	0.45	0.74	0.9	1.24	151.88	271.95	262.88	248.9
SE000000	***BIOE***	64	118.98	154.86	216.82	201.71	281.58	327.94	230.5	197.19
SE000000	***BIOD***	1.06	2.24	3.51	4.24	5.86	35.13	83.45	112.72	150.88
FI000000	***BIOE***	0.99	2.13	8.74	16.33	27.07	16.12	98.03	96.5	60.8
FI000000	***BIOD***	3.94	4.41	5.23	6.65	11.97	29.73	53.79	89.18	208.99
UK000000	***BIOE***	10.93	15.97	39.76	64.76	78.82	120.68	154.79	140.16	301.92
UK000000	***BIOD***	3.91	7.82	11.72	15.63	19.54	90.83	205.51	486.79	518.19
CY000000	***BIOE***	0.05	0.06	0.1	0.2	0.11	0.19	0.12	0.16	0.2
CY000000	***BIOD***	2.35	2.04	1.33	0.67	0.07	0.29	0.59	8.55	8.68
CZ000000	***BIOE***	0	0.03	0.09	2.7	2.42	3.8	26.25	50.39	43.51
CZ000000	***BIOD***	0.12	0.21	0.36	1.59	3.9	23.55	48.16	100.09	136.21
EE000000	***BIOE***	0.07	0.5	0.66	0.44	0.12	1	1.02	2.78	109.8
EE000000	***BIOD***	0.96	0.69	0.38	0.02	0.09	0.25	0.5	0.82	4.93
HU000000	***BIOE***	1.51	4.49	8.95	15.17	29.12	46.11	73.66	77.35	9.44
HU000000	***BIOD***	19.4	15.48	11.01	8.01	2.76	0.71	1.43	89.07	108.2
LT000000	***BIOE***	0.1	0.09	0.07	8.72	9.85	16.94	20.74	22.03	44.68
LT000000	***BIOD***	0.76	1.37	2.05	2.73	3.78	20.15	57.93	59.24	38.06
LV000000	***BIOE***	0	0.19	2.86	3.99	6.05	9.99	5.88	2.33	7.26
LV000000	***BIOD***	0.37	0.67	1.01	1.34	1.86	5.53	9.97	12.68	5.92
MT000000	***BIOE***	0.01	0.01	0.02	0.06	0.05	0.05	0.07	0.06	0.06
MT000000	***BIOD***	1.01	1.1	1.21	1.39	1.44	1.37	0.76	0.95	0.97
PL000000	***BIOE***	69.58	57.19	40.23	46.66	78.51	108.79	149.17	155.62	660.79
PL000000	***BIOD***	4.8	9.93	13.47	19.86	24.82	52.84	36.5	485.48	505.7
SI000000	***BIOE***	0.1	0.72	0.88	1.35	2.15	2.71	2.86	2.7	2.51
SI000000	***BIOD***	0.07	0.06	0	0.19	0.33	2.32	15.74	27.83	33.54
SK000000	***BIOE***	0.12	0.85	1.34	1.54	3.32	21.01	31.35	37.27	41.34
SK000000	***BIOD***	2.78	5.55	8.33	11.01	13.89	51.55	97.28	119.92	101.33
BG000000	***BIOE***	0	0.51	0.83	0.78	0.06	0.01	0.01	0.01	0.01
BG000000	***BIOD***	2.22	2.67	3.11	3.51	3.88	4.18	8.37	11.35	6.62
RO000000	***BIOE***	0	0	0	0	0	0.07	2.68	8.15	1.39
RO000000	***BIOD***	13.93	16.06	18.22	20.3	22.33	23.83	47.66	114.36	108.49

4.1.3 Trade flows

Ex post data on trade quantities are partly covered by the EUROSTAT foreign trade division COMEXT, the AgLink-Cosimo database and F.O. Licht. The PRIMES model does not include ex post trade quantities as they are calculated within the projections (up to 2015) as an endogenous variable. CAPRI needs aggregated import and export quantities for European Member States and import and export quantities described in a bilateral way for the EU aggregates (EU15, EU27) and non-European countries. Features of the different available data sources concerning their coverage of trade data are listed in Table 6. In addition to these disposed data sources, data information provided by the private data sources OILWORLD[3] was also used. Regarding OILWORLD data, no sufficient information on biodiesel trade flows but only on trade flows of vegetable oils could be identified which are already included in the CAPRI database. In the case of Glycerine it was decided to implement this product in a simplified manner with no trade consideration. Thus the information on Glycerine provided by OILWORLD was not taken into account.

Table 6: Overview on consulted data sources for the acquisition of biofuel trade data

Source	Variables covered	Time coverage	Regional coverage
EUROSTAT (COMEXT)	**Imports, Exports (bilateral)** **Unden. Ethanol (HS 20147400)** **Denat. Ethanol (HS 201474500)** **Biodiesel (HS 3824 9091)**	 **2000 - 2008** **2000 - 2008** **2008**	 **EU agg. + EU MS** **EU agg. + EU MS** **EU agg. + EU MS**
Aglink-Cosimo	**Net-trade** **Ethanol (not differentiated)** **Biodiesel**	 **2000 - 2008** **2005 - 2008**	 **EU27 agg. + OECD Members** **EU27 agg. + OECD Members**
F.O.Licht	**Imports, Exports (bilateral)** **Unden. Ethanol** **Denat. Ethanol** **Biodiesel**	 **2003 - 2008** **2003 - 2008** **2006 - 2008**	 **Sel. EU MS + non-EU countries** **Sel. EU MS + non-EU countries** **Sel. EU MS + non-EU countries**

Source: Own compilation

The AgLink-Cosimo model describes trade only by a net position, meaning that import and export flows are not described explicitly and an allocation of exported or imported quantities to individual trade partners does not take place. From this it follows that only the net trade information provided by the AgLink-Cosimo model was used. The trade division of EUROSTAT (COMEXT) describes European external trade in a bilateral way for the European aggregates and the individual Member States. This dataset only covers the products which are listed in the HS code scheme. This is an advantage in the case of ethanol as undenatured as well as denatured ethanol is explicitly covered lists. However, the dataset has a limitation on biodiesel as it is only covered explicitly from 2008. The other limitation of the dataset is it only reports trade flows which include the European Union or single Member States as reporters. Trade flows between non-European countries are not covered. For this reason it was decided to use the COMEXT data for ethanol and biodiesel to display European foreign trade in a bilateral way and aggregated import and export flows for the single European Member States. In the case of ethanol the data at hand was used by aggregating of denatured and undenatured ethanol. In the case of biodiesel the available explicit data for 2008 (HS 3824 9091) was used to estimate the share of biodiesel within the foregoing aggregates in which biodiesel was covered (HS 3824 9098 and HS 3824 9099). Thereby the absolute value in 2008 was used to calculate the percentage share of biodiesel within the 2007 value of the aggregate HS 3824 9098. This share was assumed to be constant over time which allows for a back calculation of absolute values for biodiesel trade in the relevant time period 2002-2005. Data on

[3] OIL WORLD : *http://www.oilworld.biz/app.php?ista=e6ec36decadfb6adc3c04f1f3bed072d*

ethanol trade between non-European countries were taken from F.O. Licht. However these flows are scaled such that the Aglink-Cosimo net trade position was met. In the case of biodiesel this data was very limited and mainly restricted to the production position. As in the covered ex post period only the USA and Argentina exported biodiesel and only the EU27 imported biodiesel the problem of the limited net trade information provided by AgLink could be neglected by assuming that all import quantities of biodiesel into the EU were exported from the USA and Argentina.

The compiled trade flows for European and non-European countries were proved on completeness and consistency by closing the market balances within the COCO and global database. If no information on trade flows but production and consumption quantities were available for a respective country and year it is assumed that the difference between production and consumption is equal to total imports if negative and equal to exports if positive. Naturally, all the national market balances are not closed on global level and do not match the bilateral trade flows. The standard CAPRI procedure to make them consistent with each other is to allow for adjustments in market balance positions of the non EU countries. The same procedure is applied here. The final market balances for all CAPRI regions are displayed in Annex 1 and Annex 2 for the base year as well as for the baseline. Exemplary bilateral trade flows of ethanol and biodiesel are shown in Annex 3 and Annex 4 for the baseline only, since trade flows in the base year appeared to be only marginal.

4.1.4 Prices

For the estimation of price elasticities which are needed for the specification of processing-, biofuel supply- and demand-functions and the base year calibration, ex post prices are required[4]. Furthermore, for the application of the Armington approach within the CAPRI market module (described in section 1.5), a differentiation of producer, consumer and import price is essential. These differentiated prices are not covered in any statistical database for biofuels but they can be derived indirectly by given information on taxes, tariffs and subsidies from the world market price which is available. Thus beside ex post prices information on consumer (excise) taxes, import tariffs and further subsidies are required. The AgLink-Cosimo database includes ex post world market prices for ethanol and biodiesel. This price was taken as the base value to calculate the differentiated prices in the respective countries. The import tariffs for ethanol and biodiesel were also taken from the AgLink-Cosimo database. As the consumer taxes for ethanol and biodiesel in most instances correspond to a reduced excise tax on fossil fuels the consumer taxes for gasoline and diesel were taken as a base value. This tax information was acquired from EurActiv[5] where levels of diesel and petrol taxation in 2002 are published for European Member States. For the required time period (2002-2005) taxation levels were calculated with respect to COM(2002)410[6] which set minimum excise tax rates for non-commercial diesel and petrol since 2006. To identify the excise tax exemptions and producer subsidies, if existent, for the single Member States the obligatory ‘Member States reports on the implementation of Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport’ were consulted which are published by the Commission[7]. Three different types of tax regulations for

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[4] For the baseline construction these price information is not essential as the supply, demand and trade quantities in the projection year will be statistically estimated and aligned with the PRIMES model projections within the CAPRI trend estimation procedure. However, as the most data needs are required in this first part of the project it was decided to develop the complete biofuel database already at this point in time even if this is not essential for the baseline construction.

[5] *http://www.euractiv.com/en/taxation/fuel-taxation/article-117495* , 20.07.2009

[6] Proposal for a Council Directive amending Directive 92/81/EEC and Directive 92/82/EEC to introduce special tax arrangements for diesel fuel used for commercial purposes and to align the excise duties on petrol and diesel fuel (COM(2002)410)

[7]

biofuels were identified which are applied among the different Member States: an absolute tax for biofuels, an absolute reduction of the excise tax on fossil fuels and a relative reduction of the excise tax on fossil fuels. All differentiated in taxation for blended biofuels or pure biofuels. Based on this information the different ex post prices for the period 2002-2005 were recalculated. As the envisaged biofuel demand function will be a function of (among other variables) the relation between fossil fuel consumer prices and biofuel consumer prices the acquisition of fossil fuel prices was required additionally. To hold consistency between the biofuel and fossil fuel prices the price information for fossil fuels were also taken from the AgLink-Cosimo database which provides EU market prices for diesel and petrol. For the recalculation of consumer prices in individual Member States the already collected taxation levels for fossil fuels were applied. Because there exists a significant difference between the physical energy content and the density of biodiesel, ethanol, petrol and diesel, a direct comparison of prices (in €/t) is not possible. For this reason the prices as well as the taxation levels were converted into Euro per ton oil equivalent (€/toe). The calculation procedure to derive the different price levels (import-, consumer-, and producer-price) will be explained in detail in later section.

4.1.5 Feedstock demand

There is a lack of official statistics that covers data on the use of feedstocks for biofuel processing. Thus ex post quantities of agricultural and other feedstock used for 1st generation biofuel processing in European Member States and non-European countries were derived from literature or indirectly using implicit information from existing agricultural statistics. In Figure 3 and Figure 4 the production possibility set for biodiesel and ethanol is described. Thus the products which can be used within the processing of ethanol and biodiesel are already identified. As a starting point to define feedstock demand quantities resulting from ethanol production information from EBIO was used where average feedstock demand shares on European level for 2006 and 2007 were published on the webpage[8]. The shares are summarized in Table 7. The EBIO aggregated EU27 values were used as a starting point to generate a distribution of feedstock demand on country level in CAPRI.

Table 7: Distribution of ethanol processing demand on different feedstock in EU27

Feedstock	2006 (in %)	2007 (in %)
Wheat	**37**	**39**
Rye	**15**	**3**
Molasses	**16**	**24**
Barley	**7**	**12**
Maize	**2**	**13**
Raw alcohol	**23**	**9**

Source: EBIO (http://www.ebio.org/product.php), 18.07.09

The same is true for feedstock demand information available from the AgLink-Cosimo model which only covers the EU as an aggregate. Thus national sources were drawn from accounts like the Austrian Biomass Association[9]. These sources provided data on an additional feedstock, table wine that is used for ethanol production especially in Spain and Sweden. However, after collecting different national data it was not

[8] *http://www.ebio.org/product.php*, extracted on 18.07.2009

[9] Österreichischer Biomasse-Verband (*http://www.biomasseverband.at/biomasse?cid=4*)

possible to merge a complete ex post feedstock demand dataset. This necessitates searching for further "implicit" information which might be included within existing official agricultural statistics. As mentioned above it was observed that a significant relation exists between the increase in ethanol and biodiesel production since 2002 and the position of industrial use (INDM) of agricultural crops (mainly cereals and oilseeds) collected by EUROSTAT and already implemented in the COCO database. Based on this fact an assumption is made that the increase in industrial use of agricultural crops mainly results from an increasing demand for agricultural crops caused by the biofuel processing industry. As this information is available for every European Member State and for each agricultural product within the time period 2002-2005 feedstock demand allocations for every EU Member State were estimated. Therefore, the observed changes in industrial use (in absolute quantities with respect to the observed average before 2002) in industrial use for a single product, country and year were mapped to the biofuel processing demand quantity for this product in the respective country and year. In order to get a consistent data set where the production of biofuels is equal to the sum of the inputs multiplied with the respective conversion coefficient, and the market balances are closed, a very simple Highest Posterior Density estimator was applied, which includes the following constraints:

- The sum of industrial use and human consumption as found in the CAPRI data base must be equal to the corrected estimates for industrial use and human consumption plus the newly introduced position "use for bio-fuel production".
- The production of biofuels must be equal to the sum of the processing input for the different products times their conversion coefficients.

This procedure could be applied for most feedstocks. Only one exception had to be made in the case of palm oil as the CAPRI database (COCO) doesn't cover an industrial use position for this product. EUROSTAT-COMEXT delivers data on import and export quantities of crude palm oil (HS 151110) for EU Member States. Thereby an increase of palm oil imports was observed within the relevant ex post period (2002-2005). Thus the following assumptions were made to derive approximated values for palm oil processing to biodiesel.

- Import quantities - export quantities are equal to domestic consumption of palm oil as domestic production in European Member States can be neglected.
- The average aggregated consumption quantity of palm oil before 2002 was assumed to be completely used for human consumption as no significant biodiesel consumption took place. By subtracting this constant share of human consumption from the observed consumption quantities after 2002 the quantities used for industrial processing could be derived which was assumed to be equal to processing.

The estimated quantities then were proofed on consistency within the same procedure as described above. The calculated ex post quantities of agricultural products used for biodiesel and ethanol production in European Member States are displayed exemplary for 2007 in Annex 6 and Annex 7.

4.1.6 Technology parameters

Conversion coefficients for 1st generation biofuels were collected from different sources. The PRIMES database includes conversion coefficients but only for the feedstock aggregates which are covert in the PRIMES - Biomass module (vegetable oils, sugar crops, starchy crops and corn)[10]. As CAPRI needs coefficients for

[10] Compare ANNEX2: PRIMES questionnaire

individual agricultural crops or products these parameter values were used as a starting point but further sources had to be consulted. The AgLink-Cosimo model (version 2010 includes a set of conversion coefficients which are in line with the CAPRI product definition. To proof these values further publications were taken into account[11] and the different sources were consolidated. Because the parameter values differ only in a small range the average values were calculated and implemented in the CAPRI data base. Table 8: Conversion coefficients for 1st generation biofuel production

Table 8 displays the used set of conversion coefficients for 1st generation biofuels and corresponding by-products.

Table 8: Conversion coefficients for 1st generation biofuel production

Conversion coefficients (t/t)		Ethanol	Byproducts
Grains	Wheat	0.274	0.266 DDGS
	Barley	0.247	0.266 DDGS
	Oats	0.247	0.266 DDGS
	Rye	0.247	0.266 DDGS
	Corn (dry milling)	0.335	0.292 DDGS
Other	Table Wine	0.100	
Sugar crops	Sugar	0.517	- -
	Sugar beets	0.079	0.004 Vinasses*
		Biodiesel	**Byproducts**
Vegetable oils	Rape oil	0.922	0.100 Glycerine
	Soy oil	0.922	0.100 Glycerine
	Sunflower oil	0.922	0.100 Glycerine
	Palm oil	0.922	0.100 Glycerine

* considered as molasses (1t vinasses=0,1 t molasses equivalent) depending on the reduced sugar content

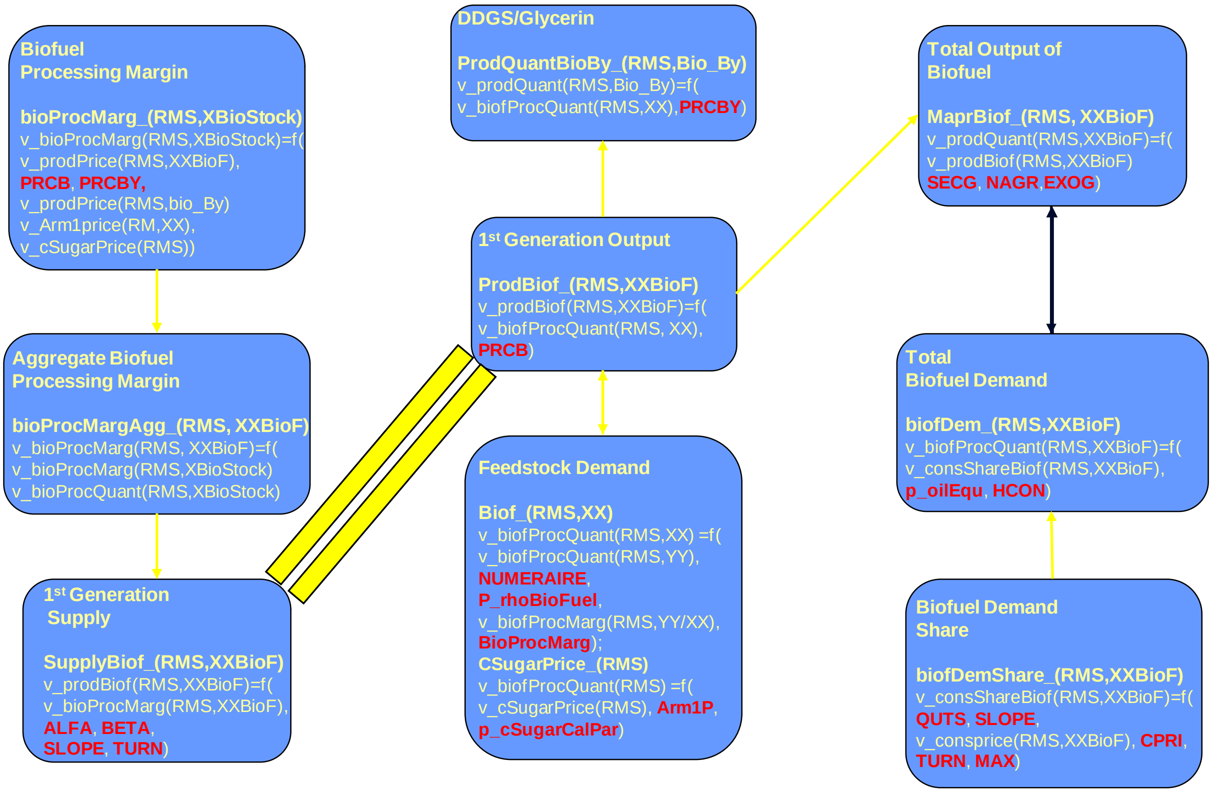
Source: Own compilation base on AgLink database, PRIMES questionnaire and Szulczyk, K. (2007)

4.2 Behavioural biofuel module

The biofuel module extended in CAPRI is represented in Figure 8. The actual variable names that were used in CAPRI are displayed in the figure. The module is described briefly in the following section.

11 i.e. “Market penetration of biodiesel and ethanol“ Szulczyk, K. (2007). Available at *http://agecon.tamu.edu/graduate/pdf/Szulczyk07a.pdf* (18.07.2009)

Figure 8: Flowchart, behavioural biofuel model implemented in CAPRI



4.2.1 Biofuel supply and feedstock demand

Biofuel supply and feedstock demand are driven by processing margins (μ). These are defined per ton of input used and are calculated for each feedstock used in a country by the relation of output revenues to input costs:

$$(1) \qquad \mu_{r,xf} = \frac{p_{r.xb}\alpha_{r,xf,xb} + p_{r.xbp}\alpha_{r,xf,xbp}}{p_{xf}}$$

The index r contains all regions in the market module that have biofuel production. All feedstocks that can be used to produce first generation biofuels are stored contained in the index xf, the two biofuel types ethanol and biodiesel in xb and the by-products Glycerine, DDGs and Vinasses in xbp. Prices are denoted by p. One speciality exists in the case of sugar prices in the EU, where a specific ethanol sugar price is assumed in case of the existence of production quotas. This is due to the fact that ethanol beet in the EU purchased at a lower price than beets processed to sugar.

These margins are also aggregated to an average biofuel margin for ethanol and biodiesel:

$$(2) \qquad \mu_{r,xb} = \frac{\sum_{xf} \mu_{r,xf}\, fd_{xf}}{\sum_{xf} fd_{xf}}$$

The feedstock demand of each xf is denoted by fd.

The decision on the total biofuel production happens simultaneously with the decision on the optimal feedstock mix. The latter is based on a CES function for a given biofuel output:

(3)

$$fd_{r,xf} = fd^{B}_{r,xf}\left(fd^{B}_{r,num} \exp\left[-\frac{1}{1-\rho_{r,xb}} \ln\left(\frac{\mu_{r,num}\, fd^{B}_{r,xf}}{\mu_{r,xf}\, fd^{B}_{r,num}} \right)\right]\right) \quad \forall xf \neq num$$

$$s.t. \quad \rho_{r,xb} = \frac{1}{\sigma_{r,xb}} - 1$$

The superscript B denotes the baseline (or calibration point-) value of the respective variable. The substition elasticity of the CES function is given by σ.

First generation biofuel production (x^{1st}) is then derived by the product sum of feedstock demand and their biofuel processing coefficients:

(4)

$$x^{1st}_{r,xb} = \sum_{xf} fd_{r,xf}\, \alpha_{r,xf,xb}$$

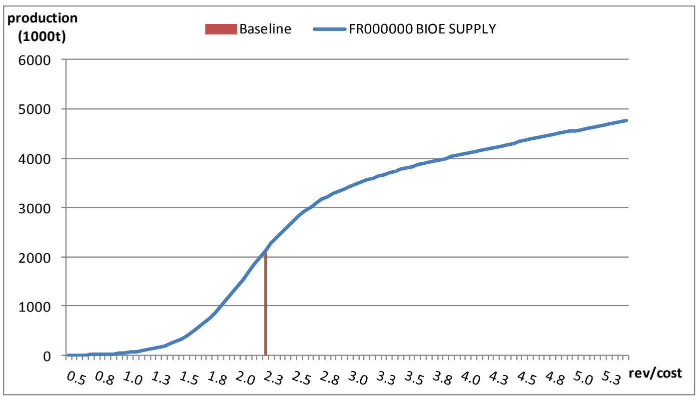
Simultaneously x^{1st} is a function of the aggregated processing margin. A synthetic supply function was chosen that satisfied some plausibility considerations, which were 1) that supply strongly decreases when the processing margin gets below a certain "trigger" margin and that this strong slope is not maintained throughout the whole function.

(5)

$$x^{1st}_{r,xb} = \left[\begin{array}{l} 0.1\mu_{r,xb} \\ +\exp\left(\beta^{1}_{r,xb} + \beta^{2}_{r,xb} \ln\left(\mu_{r,xb}\right)\right) \dfrac{1}{1+\exp\left(\left(\mu_{r,xb} - \delta^{1}_{r,xb}\right)\delta^{2}_{r,xb}\right)} \end{array} \right]$$

This function consists of three parts on the RHS: the first part is linear (10% of the processing margin, i.e. a relatively small number), the second part is semi-log and the third is sigmoid. The linear term guarantees a minimal slope, where the sigmoid function would return a slope of almost 0. The semi-log term is active at processing margins considerably higher than in the baseline point and the sigmoid function guarantees a steeper slope in a range where processing starts and production is close to zero when feedstock costs exceed output values. The coefficients β and δ are behavioural parameters in these functions. All biofuel supply equations are generally of the style presented below with an example of ethanol in France.

Figure 9: Biofuel supply function in France



The supply of by products is directly linked to the first generation biofuel output:

(6) $$x_{r,xbp} = fd_{r,xf}\alpha_{r,xf,xbp}$$

Total biofuel output is then defined as the sum over first generation, second generation (SECG), non-agricultural (NAGR) and some exogenous production (EXO) from products not mapped to the feedstocks in CAPRI (only relevant in extra EU countries):

(7) $$x_{r,xb}^{tot} = x_{r,xb}^{1st} + x_{r,xb}^{secg} + x_{r,xb}^{nagr} + x_{r,xb}^{exo}$$

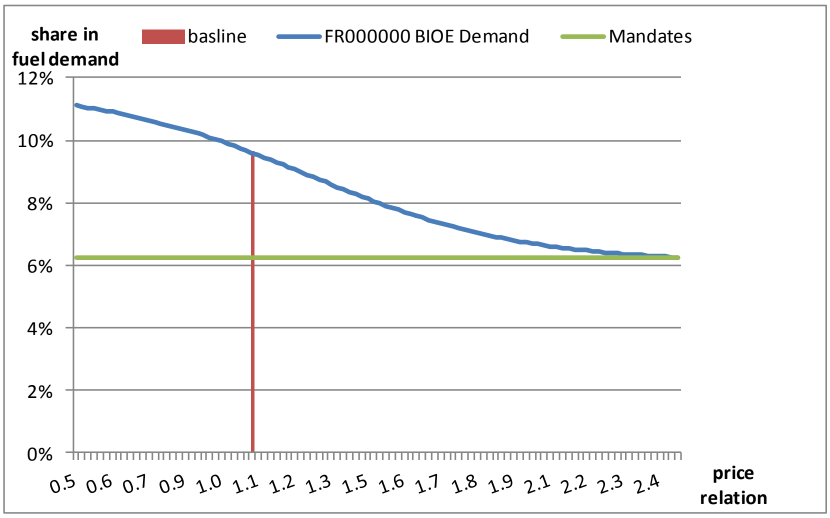
4.2.2 Biofuel demand

The representation of biofuel demand was simplified compared to the approach chosen first and applied in Becker (2011). There the Aglink demand system was more or less reproduced using a different functional form but keeping the three types of biofuel demand, the use as additive, as low blends and in flexible fuel vehicles. The actual biofuel demand equations consist of only one sigmoid function instead of stacking three of them. The share of biofuel in total fuel demand (*bsh*) is hereby defined as:

(8) $$bsh_{r,xb} = bsh_{r,xb}^{q} + \frac{bsh_{r,xb}^{\max}}{1+\exp\left(\left(\frac{p_{r,xb}}{p_{r,f}} - \chi_{r,xb}^{1}\right)\chi_{r,xb}^{2}\right)}$$

Again the coefficients χ are used to specify the exact slope of these functions. The first term (bsh^{q}) defines the part of the biofuel demand which is enforced by any kind of obligation quota or mandate, while the second part defines an "endogenous" part of the demand. This term has the upper limit *bsh* which represents the maximum biofuel share on top of the quota obligation that is deemed reachable in a certain country. The endogenous demand component is driven by the price relation of a biofuel ($p_{r,xb}$) to the respective fossil fuel substitute ($p_{r,f}$). These demand share functions are of the type represented by the example of France below:

Figure 10: Biofuel demand share function in France



Total biofuel demand ($d_{r,xb}$) is then derived by multiplying this share to the exogenous total fuel demand ($d_{r,f}$):

(9) $$d_{r,xb} = bsh_{r,xb} d_{r,f}$$

4.2.3 Total fuel demand

Total fuel demand is exogenous to the CAPRI model. However, an econometric estimation was undertaken to receive a demand reaction on exogenous drivers like the oil price and GDP. This function can then be used in the scenarios to adjust total fuel demand, if these drivers are altered. A response surface estimation on the basis of available PRIMES scenarios from 2008 was undertaken. The PRIMES output files at hand allow for estimating the relation between total fuel demand, GDP and fossil fuel prices. For the estimation an ordinary least square estimator is used. A double log demand function is chosen where the estimation coefficients can directly be interpreted as elasticities. The regression function and thereby the total fuel demand function is defined by:

(10)

$$\begin{aligned} &\log\left(\mathrm{y}_{\mathrm{i,j,s,t}}\right) \\ &= \delta_{\mathrm{i,j}} + \alpha_{\mathrm{i,j}} \cdot \log\left(\mathrm{p}_{\mathrm{i,j,s,t}}\right) + \beta_{\mathrm{i,j}} \cdot \log\left(\mathrm{gdp}_{\mathrm{j,s,t}}\right) \\ &\qquad + \gamma_{\mathrm{i,j}} \cdot \log\left(\mathrm{trend}_{\mathrm{t}}\right) + \varepsilon_{i,j,s,t} \end{aligned}$$

where:

i	= Fuel Type	trend	= Trend variable
j	= Region	ε	= Error term of the regression
s	= Scenario	δ	= Intercept
t	= Year	α	= Price elasticity of demand
y	= Fuel demand	β	= GDP elasticity of demand
p	= Fuel price including tax rates	γ	= Trend elasticity of demand
gdp	= Gross Domestic Product		

The results of the regression analysis (differentiated into biodiesel and ethanol for every EU MS) cover estimates for α, β, γ and the intercept (δ). The significant estimates are used directly in the respective fuel demand function. If no significance is observed for a coefficient in a respective country, the estimated value is replaced by an average value which is derived from the weighted average of significant coefficients over all EU MS. The resulting matrix of regression coefficients (elasticities) in the fossil fuel demand function is displayed in Table 9. The PRIMES data only covers values for European countries but as the estimates for the non-European CAPRI regions are also required it was assumed that the coefficient estimates for the aggregated EU27 are also applicable for those regions.

Table 9: Assumed elasticities for total fuel demand after filling with average values

		β (GDP)	α (price)
EU027000	GASL	0.515	-0.420
EU027000	DISL	0.538	-0.750
AT000000	GASL	0.515	-0.356
AT000000	DISL	0.538	-0.679
BE000000	GASL	0.515	-0.230
BE000000	DISL	0.538	-0.679
LU000000	GASL	0.515	-0.180
LU000000	DISL	0.538	-0.570
NL000000	GASL	0.290	-0.400
NL000000	DISL	0.538	-0.750
DE000000	GASL	0.515	-0.356
DE000000	DISL	0.538	-0.790
FR000000	GASL	0.515	-0.250
FR000000	DISL	0.538	-0.679
ES000000	GASL	0.360	-0.220
ES000000	DISL	0.538	-0.679
PT000000	GASL	0.515	-0.270
PT000000	DISL	0.538	-0.740
UK000000	GASL	0.460	-0.540
UK000000	DISL	0.538	-0.679
IR000000	GASL	0.260	-0.480
IR000000	DISL	0.530	-0.710
IT000000	GASL	0.500	-0.250
IT000000	DISL	0.538	-0.620
DK000000	GASL	0.515	-0.356
DK000000	DISL	0.538	-0.679
FI000000	GASL	0.515	-0.356
FI000000	DISL	0.538	-0.620
SE000000	GASL	0.515	-0.356
SE000000	DISL	0.538	-0.679
EL000000	GASL	0.515	-0.510
EL000000	DISL	0.538	-0.550
PL000000	GASL	0.450	-0.490
PL000000	DISL	0.538	-0.720
HU000000	GASL	0.470	-0.520
HU000000	DISL	0.310	-0.679
CZ000000	GASL	0.515	-0.356
CZ000000	DISL	0.538	-0.730
SK000000	GASL	0.515	-0.356
SK000000	DISL	0.538	-0.800
SI000000	GASL	0.515	-0.356
SI000000	DISL	0.538	-0.550
LT000000	GASL	0.680	-0.260
LT000000	DISL	0.460	-0.650
LV000000	GASL	0.790	-0.390
LV000000	DISL	0.690	-0.770
EE000000	GASL	0.730	-0.440
EE000000	DISL	0.710	-0.750
RO000000	GASL	0.680	-0.450
RO000000	DISL	0.530	-0.679
BG000000	GASL	0.510	-0.190
BG000000	DISL	0.538	-0.720
CY000000	GASL	0.515	-0.270
CY000000	DISL	0.538	-0.679
MT000000	GASL	0.515	-0.356
MT000000	DISL	0.538	-0.430

Source: Own calculation based on PRIMES 2009

4.2.4 Biofuel Trade

Behavioural functions for global bilateral trade of biodiesel and ethanol are intrinsically tied to the final biofuel demand functions. A two stage demand system relying on the Armington assumption is already applied for other agricultural commodities in a standard version of CAPRI[12]. In contrast to the common CAPRI variable notation within the demand system, biofuel demand for fuel use is set on BIOF (also used for feedstock demand) to ensure that biofuels do not enter the human consumption demand system. A non-fuel demand for biofuels (e.g. ethanol demand of the chemical industry) is consequently set on INDM or PROC (industrial use). The other demand components in the common CAPRI version feed demand and human consumption are neglected for biofuels.

4.3 Calibration of the biofuel system

So far, only the general forms of the biofuel supply and demand functions were derived. But without any adjustments, they did not reproduce the biofuel price-quantity framework of the baseline. Both behavioural functions (equation (1.5) and (1.8)) were therefore taken through a calibration process. Firstly, the demand system was calibrated. It is assumed that only the part of the observed biofuel demand share in total fuel demand that is above the quota obligations is the result of a consumer decision and thus a result of the flexible parts on the demand equations (Equation (1.5)). To calibrate the demand functions to the observed combination of the price ratio bio- to fossil fuel and demand share in total fuel consumption, two parameters χ^1 and χ^2 were chosen such that:

It recovers the baseline combination of price and quantity relations

It reaches 90% of the max share (bsh^{max}) at a certain price relation (currently 0.5 for ethanol and 0.3 for biodiesel).[13]

The maximum biofuel demand share of a region was chosen 2% above the observed baseline share. Biofuel supply is basically driven by equation (1.5). The parameters β^2, representing the supply elasticities of the double log part in this equation, were chosen at 0.5 [14]. For the two δ parameters, following rules were applied. The turning point of the sigmoid function, δ^1 was defined to be left to the calibration point at 90% of the processing margin of the baseline. The slope parameter, δ^2 was defined in a range where the sigmoid function increases from 0 to 1. A higher value corresponds then to a steeper slope. Assuming that countries with higher processing margin are more competitive, it is assumed that a higher slope for lower processing margins. Furthermore in non-EU countries, the functions were to be less steep. Finally the parameter β^1 is chosen such that the baseline was reproduced.

[12] Described in detail in: BRITZ, W., WITZKE, P.: CAPRI model documentation 2008: Version 2. Bonn, 2009

[13] These values were chosen by trial and error to achieve a reasonable demand response in certain scenarios. However a more empirically based representation of the demand response would greatly improve the system.

[14] An elasticity below 1 turned out to produce more reasonable supply responses as above 1. Again an empirical basis for this is still missing.

5 Definition of the baseline scenario

5.1 Construction of the CAPRI baseline scenario

In general the aim of the baseline is to create a point of comparison for counterfactual analysis. The baseline may be interpreted as a projection in time covering the most probable future development of the European agricultural sector under the status quo policy and including all future changes already foreseen in the current legislation. Conceptually, the baseline should capture the complex interrelations between technological, structural and preference changes for agricultural products worldwide in combination with changes in policies, population and non-agricultural markets. Given the complexity of these highly interrelated developments, baselines are in most cases not a straight outcome from a model but developed in conjunction of trend analysis, model runs and expert consultations. In this process, model parameters (such as elasticities) and exogenous assumptions (such as technological progress captured in yield growth) are adjusted in order to achieve plausible results (as foreseen by experts, e.g. European Commission projections). Therefore, the CAPRI projection tool (CAPTRD) is fed by trend forecasts using data from the COCO database as well as projections from different experts or modelling tools. The purpose of the trend estimates is, on the one hand, to compare expert forecasts with a purely technical prolongation of time series and on the other hand, to provide a safety net position in case no values from external projections are available. A more detailed description of the CAPRI projection tool can be found in Britz and Witzke (2012). The specific exogenous drivers and assumptions on policy changes underlying the baseline projection for 2020 are described in more detail below.

Considering this general estimation procedure, the biofuel baseline relies, as already mentioned, on the established biofuel database and on the forecast and expert knowledge provided by recent projections from the AgLink and PRIMES models. This expert knowledge is used in CAPRI by means of expert supports. Deviations from these supports are punished very strongly[15]. Since the ex-post time series resulting from the COCO step does not map the PRIMES ex-post data exactly, it is assumed that the biofuel use for the transport sector (stored on the CAPRI column BIOF) as well as biofuel production quantities from the most recent ex-post year (2005) is increasing by the difference of the respective PRIMES data for the projection year (2020) minus the PRIMES demand data of 2005. It is also assumed that the use of ethanol other than fuel use (stored on INDM) is constant on the average 2004/2005 value. The share of biofuels from domestic 1st generation (non-lignocellulosic) as well as 2nd generation biofuel production is taken over from PRIMES, allowing for some plausibility adjustments[16]. The ethanol quantities made out of raw alcohol (stored on NAGR) are assumed to stay at 2005 levels. For biodiesel non-agricultural sourced quantities are mapped to biodiesel made out of waste oil in the PRIMES model. Exports and imports are shifted with the resulting changes in net trade. If net trade is increasing from 2005 to 2020, the difference is added to the export quantities from 2005 and if it is decreasing, it is added to the 2005 imports.

Naturally PRIMES projections do not exactly match the Aglink projection for the EU27 aggregate. Therefore the Trend estimator offers a scaling option, where the national market balance positions can be exactly scaled such that the EU27 fits to the Aglink projections. This option is used in this baseline. The projection of biofuel feedstock quantities shows two major challenges; i. to define their distribution in countries where biofuels were not produced in the base period and ii. to introduce feed stocks which were not used in the base period.

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[15] CAPTRD calls a gams file called 'captrd\define_stats_and_supports.gms' in which the support points for the final estimation step are defined. This file itself calls a new file, where all the supports for the biofuel sector are defined: 'biofuel\bio_trends.gms'.

[16] The PRIMES model offers on the feedstock side quantities of lignocellulosic biomass used for bioethanol. These numbers are used to calculate the second generation share of bioethanol production. For biodiesel, 1st generation biodiesel is offered and second generation quantities are calculated as the difference of total biodiesel and these 1st generation quantities.

Since it is essential to have a mix of feedstocks used in the baseline to get any substitution effects for later simulations, a matrix with the feedstock we expect to be important in the future was defined for each country. If these feedstocks are not used in the base period, they are introduced with a certain minimum share. Furthermore, processing coefficients are shifted with the trend used in the AgLink baseline. Price projections for biofuels and fossil fuels as well as import tariffs were shifted with the respective increase of the OECD Agricultural outlook (2010), while holding consumer taxes on the 2005 levels or 2010 projections if available.

The market balances for non EU countries are not produced by trend estimations but are an outcome of the baseline calibration step. Thereby, the national market balance positions are shifted in a first step with projections of other models. In case of the biofuel market balance positions, the AgLink projections are used. The international market balances for bioethanol are available until 2008. These last available positions are shifted with the AgLink 2020 numbers (calculated as above) divided by their 2008 values. If exports and imports are not available, they are shifted with the net trade development. If it is increasing most of the difference goes to exports, if it is decreasing it goes to imports. International market balances are then made consistent with the EU numbers via the standard procedure in CAPRI.

5.2 Agricultural policy specification

The overall assumption underlying the biofuel baseline and every biofuel scenario is predominately the CAP (Common Agricultural Policy) policy specification. As the biofuel module is based on the recent CAPRI trunk version (status June 2012) all agricultural policy assumptions as well as macroeconomic assumptions are the same used in this extended CAPRI model. Major developments in the EU27 agricultural sector underlying the standard CAPRI baseline are in-line with the latest DG-AGRI baseline of 2010. The central element of CAP Reforms since the 1992 MacSharry reform was 'decoupling' that took place under the 'Mid Term Review' of CAP in 2003 which included a large part of agricultural crops and animals, including dairy (if EU MS did not opt for partial decoupling). The 2004 'Mediterranean' reform applied this principle basically also to tobacco, cotton, olives, and hops, with transition periods being completed before 2020. In 2007 the sugar sector and the fruits and vegetables sector have been included in the common system of direct payments. The MS had the possibility to maintain certain maximum shares of certain payments in the old coupled form, following a scheme published in Regulation 1782/2003[17], and furthermore the article 69 of that regulation allowed coupling of 10% of the total payment ceilings for sub-sectors. In CAPRI, the decoupled payments are modelled as payments per hectare of land, with the same amount per hectare applying regardless of production chosen. The core assumptions regarding the implementation of the direct payments are summarised in Table 10.

Table 10: Core assumptions regarding direct payments in the Baseline

Instrument	Baseline
Direct payments EU15	2003 reform fully implemented
Direct payments EU10	2003 reform fully implemented, special accession conditions recognised.
Direct payments BUR	SAPS
Set aside EU15	Abolished

[17] COUNCIL REGULATION (EC) No 1782/2003. Available at: http://faolex.fao.org/docs/pdf/eur40622.pdf

Set-aside EU10 and BUR	Abolished
Article 69 payments	Implemented
Modulation	EU25 5% minus franchise, BUR none. Voluntary modulation for UK and Portugal

Another significant change in the CAP in recent years is the reform of the sugar sector where the 2006 reform is implemented. Most of the expected developments especially the restructure issues of sugar quotas, where EU Member States had the possibility to sell quotas to a restructuring pond and others could buy parts from it, have already taken place in the past years, so that the national sugar quotas are fixed on their 2011 quantities. Subsidised exports of sugar beyond the WTO limits are not allowed, but a certain amount of ethanol beets is introduced using expert knowledge from industry specialists and the Aglink projections. The 'Health Check' of the CAP (2008/2009) under which the abolition of milk quota is also included in the baseline.

The AgLink model only provides results for EU15 and EU12 rather than individual Member States. This requires significant adjustment in the handling of this expert information because the information from the regional aggregates has to be linked to individual Member States for use in CAPRI. For the rest of the world, FAO's projection for 2030 (Bruinsma 2003) and results from the FAPRI model (FAPRI 2009) as well as from AgLink were used as a yardstick for the projection. The CAP policy specifications for the recent 2020 baseline of the core CAPRI version and thereby also of the biofuel baseline are described as follows.

5.3 Specific biofuel assumptions

As described in the previous section, the biofuel baseline projection relies mainly on the baseline projection from the AgLink and PRIMES model. Thereby the PRIMES baseline is exclusively used to derive a distribution of the aggregated EU27 values of the AgLink baseline to the single EU MS. Thus, the biofuel policy specifications of the CAPRI biofuel baseline are mostly equivalent to those used in the AgLink 2010 baseline.

5.3.1 Fossil fuel demand

In line with the AgLink baseline we assume fossil fuel demand for EU27 in 2020 as displayed in Table 11. To derive estimations for fossil fuel demand in the single EU MS we take the respective demand shares by MS resulting from the recent PRIMES baseline and apply them to the EU27 fuel demand assumption of AgLink displayed also in Table 11.

Table 11: Fossil fuel demand by EU Member State in 2020 (relative and absolute values)

	Diesel		Gasoline	
	%	**kton**	**%**	**kton**
EU027000	100%	202249	100%	87916
BL000000	4%	8698	2%	1744
DK000000	1%	2283	2%	1508
DE000000	16%	31806	20%	17716
EL000000	1%	2495	4%	3484
ES000000	14%	29291	6%	5461
FR000000	16%	32556	9%	8108
IR000000	1%	2273	2%	1480
IT000000	11%	23229	12%	10762
NL000000	3%	6903	3%	3075
AT000000	3%	5152	2%	1642
PT000000	2%	4609	2%	1445
FI000000	1%	2274	2%	1505
SE000000	2%	3408	4%	3285
UK000000	11%	22568	17%	15353
CZ000000	2%	3870	2%	1864
EE000000	0%	429	0%	245
HU000000	1%	2951	1%	1254
LT000000	0%	911	0%	290
LV000000	0%	756	0%	329
PL000000	4%	8514	5%	3962
SI000000	1%	1211	1%	577
SK000000	1%	1348	1%	625
CY000000	0%	350	0%	304
MT000000	0%	167	0%	44
RO000000	1%	2826	2%	1421
BG000000	1%	1370	0%	434

Source: CAPRI model calculated based on AgLink and PRIMES

5.3.2 Gross Domestic Product

The assumed GDP growth rates of the PRIMES and AgLink baselines are predominately consistent for the EU12, EU15 and EU27. Thus, we adopt the GDP assumptions for the EU aggregates and the single EU MS from the PRIMES baseline. For non-EU countries we take the assumptions of the recent AgLink baseline.

5.3.3 Biofuel policies

In line with the AgLink biofuel policy assumption in 2010, the CAPRI also assumes a biofuel energy share of about 8.5% in total transport fuel consumption for the EU27 average in 2020. This comes approximately with 7% consisting of 1st generation biofuels and 1.5% consisting of 2nd generation biofuels. In accordance with article 21 of the Renewable Energy Directive of 2009 the energy provided by 2nd generation fuels is considered twice[18]. Following this article, the 2020 target of 10% biofuels (referring to the energy content of biofuel in total energy consumption in the transport sector) in the EU27 is fully reached by this assumption. The distribution of the 8.5% EU27 average across the single EU MS, is thereby also derived from the biofuel demand shares of the recent PRIMES baseline and displayed in Table 12. Ethanol contributes in this Baseline stronger to the reaching of the RED target than biodiesel, by taking a higher share than 10% even without considering the double counting of second generation biofuels.

Table 12: Share of biofuels in EU Member States (2020): Baseline assumption

	Energy share of ethanol in gasoline consumption	Energy share of bio diesel in diesel consumption
European Union 27	10.1	8.0
Belgium	11.7	8.3
Germany	10.5	9.1
Denmark	8.6	9.6
Netherlands	7.5	8.1
Austria	9.7	6.9
Portugal	6.0	6.1
France	8.2	8.0
Greece	9.1	7.9
Spain	11.8	8.9
Ireland	10.5	9.5
Italy	9.7	8.8
Sweden	8.8	8.0
Finland	9.3	7.3
United Kingdom	11.1	7.6
Czech Republic	11.5	6.3
Malta	4.0	2.6
Lithuania	15.9	4.5
Latvia	7.0	4.5
Estonia	13.5	3.9
Hungary	9.1	6.3
Slovak Republic	14.7	5.5
Cyprus	4.1	3.5
Poland	13.2	6.6
Slovenia	11.7	9.9
Bulgaria	9.6	4.4
Romania	7.4	4.1

Source: CAPRI model calculated based on AgLink and PRIMES

It is also assumed that the share of this biofuel demand in 2020 is predominately resulting from the implementation of quota obligations. Therefore the information on implemented quotas covered in the MS biofuel progress reports is used as the base information. It is assumed that all existing quota obligations which are defined in this table for a year before 2015 will be increased by 1.5%. All existing quotas which are already defined for a year beyond 2015 will be increased by 1.1%. The absolute value of biofuel demand from the trend estimation procedure is set as the maximal quota value to avoid that the quota obligation in 2020 exceed the absolute value of biofuel demand. For the EU MS where no quota exists, it is assumed that a minimum quota of 6% will be introduced in 2020. The resulting calculated quota obligations which are assumed to be implemented in 2020 for every EU MS are displayed in Table 13. The respective differences between the assumed share of biofuels in total fuel consumption as displayed in Table 13 and the assumed

[18] European Parliament and Council: Directive 2009/28/EC, 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, 2009

quota obligation in 2020 can be interpreted as additional biofuel demand which relies on price driven demand components as i.e. the use of ethanol in FFV vehicles or the blending of biodiesel and bioethanol resulting from the price ratio between the biofuel and fossil fuel consumer price caused by existing tax exemptions.

Table 13: Assumed quota obligations in 2020 (Baseline)

	Energy share of ethanol quota obligation in gasoline consumption	Energy share of bio diesel quota obligation in diesel consumption
European Union 27	8.2	6.8
Belgium	8.5	7.5
Germany	9.5	8.1
Denmark	5.9	5.9
Netherlands	6.8	7.3
Austria	4.9	4.9
Portugal	5.4	5.5
France	6.1	6.1
Greece	8.2	7.1
Spain	8.9	8.0
Ireland	8.1	8.1
Italy	6.4	6.4
Sweden	7.9	7.2
Finland	8.4	6.6
United Kingdom	9.9	6.8
Czech Republic	9.5	5.7
Malta	3.6	2.4
Lithuania	9.2	4.1
Latvia	3.5	3.5
Estonia	9.3	3.5
Hungary	8.2	5.6
Slovak Republic	9.9	5.0
Cyprus	3.7	3.2
Poland	10.0	6.0
Slovenia	6.3	6.3
Bulgaria	5.9	4.0
Romania	6.0	3.7

Source: CAPRI model (Biofuel branch), calculated based on AgLink 2009 and EUROPEAN COMMISSION, COM(2009) 192 final. Brussels, 2009

5.3.4 Conversion technologies

Conversion coefficients for 1st generation biofuel processing are assumed as displayed in Table 14. Conversion factors for biofuel production from feedstocks as well as for associated by-products are in line with the AgLink database. Technological progress is considered in line with the AgLink assumptions: while ethanol processing coefficients are assumed to increase through time, for vegetable oil processing to biodiesel no change is assumed.

Table 14: Conversion coefficients for 1st generation biofuel production (t/t)

		2005		2020	
		Ethanol	By-product	Ethanol	By-product
Grains	Wheat	0.283	0.371 DDGS	0.305	0.369 DDGS
	Barley	0.283	0.371 DDGS	0.305	0.369 DDGS
	Oats	0.283	0.371 DDGS	0.305	0.369 DDGS
	Rye	0.283	0.371 DDGS	0.305	0.369 DDGS
	Maize	0.309	0.313 DDGS	0.335	0.310 DDGS
Sugar crops	Sugar	0.478	-	0.496	-
	Sugar beets	0.076	0.004 Vinasses	0.078	0.004 Vinasses
Other	Table wine	0.100	-	0.100	-
		Biodiesel	By-product	Biodiesel	By-product
Vegetable oils	Rape oil	0.959	0.100 Glycerine	0.959	0.100 Glycerine
	Soy oil	0.959	0.100 Glycerine	0.959	0.100 Glycerine
	Sunflower oil	0.959	0.100 Glycerine	0.959	0.100 Glycerine
	Palm oil	0.959	0.100 Glycerine	0.959	0.100 Glycerine

Source: Own compilation from the RED and the AgLink database.

The AgLink model does not cover second generation production and thereby conversion coefficients in detail. Therefore, conversion factors for 2nd generation technologies are derived from the JEC-WTW studies (http://iet.jrc.ec.europa.eu/about-jec/jec-well-wheels-analyses-wtw). We assume that the aggregates "Agricultural residues" (ARES) and "New energy crops" (NECR) can be used for the production of Fischer-Tropsch diesel and lignocellulosic ethanol. Conversion factors for 2nd generation biofuels are assumed as displayed in Table 15.

Table 15: Conversion coefficients for 2nd generation biofuel production

	Tons of biofuel per dry ton of biomass	
	FT diesel	Lignocellulosic ethanol
Agricultural residues*	0.195	0.147
New energy crops**	0.195	0.147

* Grain straw and sugar beet leaves ** Poplar, willow, miscanthus

Source: Own compilation from JEC-WTW studies

5.3.5 Biofuel tariffs

The biofuel tariffs, specific (measured in €/toe), as well as ad valorem are taken from the Aglink-COSIMO2010 baseline (Table 16). For ethanol, applied tariffs for undenatured ethanol (which is used for fuel purpose) is assumed. Unfortunately, this AGLINK-COSIMO baseline does only feature tariff information for OECD countries. Therefore only those tariffs are taken into account, currently.

Table 16: Assumed import tariffs: Baseline

	Ethanol		Biodiesel	
	specific	ad valorem	specific	ad valorem
European Union 27	300			6.50%
USA	150	2.4%		4.6%
Brazil				4.60%
Canada	50			

Source: CAPRI model, based on AgLink 2009

6 Working with the CAPRI biofuel module

6.1 Definition of policy scenarios

Once the behavioural functions for biofuel markets have been incorporated into CAPRI, the model allows for simulating a variety of biofuel scenarios including, among others, the definition of:

- Quota obligations for ethanol and biodiesel
- Tax rates for ethanol, biodiesel, gasoline and diesel
- Import tariffs for ethanol and biodiesel
- Availability of 2nd generation biofuels
- Technical progress in 1st and 2nd generation technologies for biofuels

Within the EU, policy instruments can be differentiated at the Member State level.

6.2 Post model analysis

6.2.1 Socioeconomic indicators

The CAPRI biofuel module extends the capabilities of the CAPRI model to jointly assess biofuel and agricultural policies. The set of socioeconomic indicators in CAPRI now includes:

- Biofuels production and consumption
- Biofuel prices
- Market balances for biofuels and biofuel by-products
- Bilateral trade flows
- Feedstocks used for biofuel production

To illustrate the outputs of the CAPRI model, we present some results corresponding to the CAPRI baseline (status June 2012). It should be noted, however, that the biofuel baseline is fully integrated into the CAPRI system and, therefore, it is updated yearly.

Table 17 illustrates the market balance of the biofuels for the EU 27. In the baseline scenario a total of 30.2 Mt of biofuels is produced. Biodiesel has a slightly larger share (51%) in total biofuel production than ethanol. First generation biofuels represent a large share of total production both for ethanol and biodiesel. The biofuel production through first generation covers around 84% of total ethanol production and 77% of total biodiesel production. This means that for biodiesel production, the use of second generation technology is relatively higher than that for the ethanol production.

Regarding consumption, biodiesel has a higher consumption share than ethanol in the EU. This follows the higher consumption of diesel in the EU compared to gasoline.

The EU is net importer of both biofuels, with more biodiesel imported. The consumer tax for biodiesel is substantially lower than ethanol in the baseline as firstly consumer tax on diesel is lower than petrol and secondly, under the biofuel policy, many Member States chose to reduce tax on biodiesel more than on ethanol.

Table 17: Biofuel market balance for EU 27

Biofuel markets [0]

Region: European Union 27 | Years: 2020 | View type: Table

	CAPRI_baseline	
	Bio diesel	Bio ethanol
Total Biofuel production [1000 t]	15426.0	14585.2
First Generation Biofuels (from Agriculture) [1000 t]	10865.5	11625.4
Second Generation Biofuels [1000 t]	3539.3	2335.9
Biofuels from non-agricultural sources [1000 t]	1021.3	624.0
Biofuel-use by transport sector [1000 t]	19061.8	15280.1
Biofuel-use by industry [1000 t]		1853.0
Energy share in total fuel use [%]	8.0	10.6
Energy share in total fuel use of Quota obligation [%]	6.8	8.4
Imports [1000 t]	4815.5	6688.9
Exports [1000 t]	1179.7	4006.2
consumer prices [Euro/ton]	1457.1	1500.5
consumer taxes [Euro/Ton]	50.2	474.3

Source: CAPRI results.

CAPRI provides market balances not only for the EU but also for the rest of the world. Table 18 shows global biofuel production.

Table 18: Global biofuel production

Biofuel markets [0]

Balance item: Total Biofuel production [1000 t] | Years: 2020 | View type: Table

	CAPRI_baseline	
	Bio diesel	Bio ethanol
European Union 27	15426.0	14585.2
Europe, Non-EU		6588.8
Russia		4066.9
Ukraine		2521.9
Africa	99.7	198.9
North America (USA, Canada, Mexico)	3415.8	55553.2
USA	3056.1	54640.3
Canada	359.8	840.5
Middle and South America	6381.7	58429.7
Brazil	2353.7	56791.7
Argentina	3030.5	458.5
Rest of Middle and South America	997.5	872.6
Asia	6289.7	11663.6
India	2938.6	2224.9
China		4340.3
Japan		561.5
Malaysia and Indonesia	1886.3	454.8
Asian Tigers		1090.5
Asian South East	1186.2	2178.3
Asian and Oceania Rest	278.6	756.3
Australia and New Zealand	560.8	274.3
Non-EU	16747.7	132708.3
World	32173.8	147293.6

Source: CAPRI results.

Within the EU, results are also available at the Member State level. As an example, table 19 displays biofuel consumption for EU27 countries.

Table 19: Biofuel consumption at the Member State level

Biofuel markets [0]

Balance item: Biofuel-use by transport sector [1000 t] | Years: 2020 | View type: Table

	CAPRI_baseline	
	Bio diesel	Bio ethanol
European Union 27	19061.8	15280.1
Belgium	844.3	353.8
Denmark	256.4	223.4
Germany	3406.0	3213.8
Austria	415.9	275.9
Netherlands	606.5	409.0
France	3053.7	1127.8
Portugal	331.1	142.6
Spain	3044.5	1118.1
Greece	219.1	543.0
Italy	2384.3	1791.5
Ireland	253.3	259.1
Finland	187.1	240.7
Sweden	320.1	509.9
United Kingdom	2007.5	2924.0
Czech Republic	290.5	359.1
Estonia	19.7	56.2
Hungary	209.5	204.0
Lithuania	51.8	68.9
Latvia	42.3	38.9
Poland	675.7	883.9
Slovenia	141.0	112.3
Slovak Republic	98.9	153.7
Cyprus	13.7	20.6
Malta	3.8	3.0
Bulgaria	67.4	69.7
Romania	117.5	177.1

Source: CAPRI results.

We already mentioned that the EU is a net importer of biodiesel and ethanol. As shown in Table 20, the largest exporter of ethanol to the EU. In case of biodiesel, Argentina is the largest exporter to the EU, followed by Indonesia and Malaysia. Bilateral trade flows for biodiesel and ethanol are available for all trade blocks.

Table 20: EU imports for ethanol and biodiesel

Import flows, price and tariffs market model detailed [0]

Importer: European Union 27 | Activity: Quantities [1000 t] | Years: 2020 | View type: Table

	CAPRI_baseline	
	Bio diesel	Bio ethanol
from Ukraine		500.54
from Africa LDC nes	54.64	34.49
from USA	40.87	1100.90
from Middle and South Americs, ACP		146.19
from Brazil		765.94
from Argentina	2578.92	
from Rest of Middle and South America	357.13	872.55
from India		103.00
from Japan		55.60
from Malaysia and Indonesia	667.30	
from Asian Tigers		293.46
from Asian South East	78.04	507.29
from Asian and Oceania Rest		181.89

Source: CAPRI results.

Table 21 provides a closer look into main non-EU exporting regions.

Table 21: Biofuel exports of major Non-EU biofuels producers

Biofuel markets [0]

Balance item: Exports [1000 t] | Years: 2020 | View type: Table

	CAPRI_baseline	
	Bio diesel	Bio ethanol
Ukraine		1361.6
USA	100.3	1126.7
Canada		227.0
Brazil		26148.1
Argentina	2578.9	381.4
Rest of Middle and South America	357.1	872.6
India		206.8
China		287.1
Malaysia and Indonesia	669.1	245.2
Asian Tigers		968.4
Asian South East	78.0	510.2
Asian and Oceania Rest		184.2
Australia and New Zealand		274.3

Source: CAPRI results.

Feedstocks used for biofuel production are shown in Table 22. In the EU27, wheat is used the most as a feedstock for ethanol production followed by sugar, maize and barley. The Member States have different preferences of feedstock used for ethanol production (Annex 2). For instance, Germany produces ethanol mostly from sugar, wheat, rye and maize whereas majority of ethanol is produced from wheat in the UK. For biodiesel, rapeseed is the major oil crop that is used for biofuel production in the EU. Germany as the largest producer of biodiesel is the highest user of rapeseed oil (Annex 2).

Table 22: First generation biofuel production from the feedstock in EU 27

Biofuel production by feedstock [0]

Region: European Union 27 — Years: 2020 — View type: Table

	CAPRI_baseline	
	Bio diesel	Bio ethanol
First generation biofuels (from Agriculture) [1000 t]	10865.5	11625.4
- produced from wheat [1000 t]		4464.2
- produced from barley [1000 t]		1991.5
- produced from rye [1000 t]		1066.8
- produced from oats [1000 t]		455.6
- produced from maize [1000 t]		1793.0
- produced from other cereals [1000 t]		573.0
- produced from sugar [1000 t]		1211.3
- produced from rapeoil [1000 t]	7109.9	
- produced from sunfloweroil [1000 t]	1186.6	
- produced from soyoil [1000 t]	1116.2	
- produced from palmoil [1000 t]	1452.8	

Source: CAPRI results.

As illustrated in Table 23, demand balances indicate the share of cereals, sugar and vegetable oils used for biofuel production.

Table 23: Demand balance for biofuel feedstocks in EU 27

Demand Balances [0]

Region: European Union 27 — Years: 2020 — View type: Table

CAPRI_baseline

	Total Demand [1000 t]	Human Consumption [1000 t]	Feed [1000 t]	Internal Use and Seed [1000 t]	Processing [1000 t]	Biofuels processing [1000 t]	Losses and Stock Changes [1000 t]
Cereals	314516.3	63548.3	159349.5	10358.9	25508.8	50412.5	5338.3
Oils	26704.0	8616.3	699.3		5522.7	11693.5	172.1
Cereals	314516.3	63548.3	159349.5	10358.9	25508.8	50412.5	5338.3
Soft wheat	118779.3	47004.4	45583.6	4688.7	4164.9	15098.1	2239.7
Durum wheat	24748.9	7792.9	1061.9	619.8	6.1	15098.1	170.2
Rye and meslin	10831.8	2588.3	2853.4	458.3	659.4	3987.4	284.9
Barley	57737.4	393.7	38044.0	2391.1	8470.2	7443.3	995.1
Oats	12806.2	895.9	8634.2	842.3	374.7	1702.9	356.3
Grain maize	65498.4	4401.1	50842.8	434.1	3937.3	4941.2	941.8
Other cereals	21009.2	472.0	12329.6	734.1	4942.9	2141.4	389.1
Oils	26704.0	8616.3	699.3		5522.7	11693.5	172.1
Rape seed oil	11598.1	2830.1	406.7		669.0	7649.9	42.4
Sunflower seed	4030.5	2514.5	81.5		103.7	1278.0	52.8
Soya oil	2914.7	1234.5	211.0		218.9	1201.7	48.5
Palm oil	6129.0	122.4			4442.7	1563.9	
Sugar	21797.5	17993.9	81.1		1432.6	2257.2	32.8

6.2.2 Land use indicators

Effects of biofuel policies on land use can be assessed looking at changes on cropland allocation and crop production. Table 24 shows cropland allocation in the baseline for main biofuel feedstocks.

Table 24: EU cropland allocation

Supply details [0]

Region: European Union 27 | Years: 2020 | View type: Table

CAPRI_baseline

	Hectares or herd size [1000 ha or hds]	Yield [kg, Const EU or 1/1000 head/ha]	Supply [1000 t, 1000 ha or Mio Const EU]
Cereals	58389.8	745.7	43540.3
Soft wheat	23101.1	6267.6	144788.5
Durum wheat	3011.0	3336.2	10045.3
Rye and Meslin	3071.0	3517.9	10803.4
Barley	12831.8	4835.0	62041.4
Oats	4168.3	3393.2	14143.8
Grain Maize	8570.3	7582.3	64982.4
Other cereals	3214.2	4160.9	13374.1
Oilseeds	11497.7	881.4	10134.2
Rape	6866.7	3639.8	24993.4
Sunflower	3854.6	2072.4	7988.2
Soya	458.4	2635.4	1208.1
Sugar Beet	1370.4	73511.4	100737.7

Source: CAPRI results.

6.2.3 Environmental indicators

Besides economic impacts, also some environmental impacts linked to the development of biofuels are addressed, but only those linked to changes in agricultural activity levels (for example greenhouse gas emission from agricultural production activities or losses of biodiversity by changes in agricultural landscape).

Indicators used are already part of the standard CAPRI version[19]. In general, environmental indicators in CAPRI cover environmental impacts which are exclusively induced by agricultural production activities and farm management. Thus, environmental effects like the carbon dioxide reduction resulting from the usage of biofuels instead of fossil fuels are not part of this post model analysis. For this purpose detailed biofuel live cycle assessments are obviously a more adequate instrument. However, as e.g. carbon dioxide or nitrate emissions resulting from biofuel feedstock production are part of such assessments the indicator results which will be presented in the next chapter can be used as helpful information.

Two groups of environmental indicators will be investigated in this analysis: (1) Indicators derived from farming management and (2) Landscape indicators. Within the first group the focus is set on Green House Gas (GHG) emissions caused by agricultural production activities as displayed in Table 25. The indicators “Methane (CH4) Emissions”, “Nitrous Oxide (N20) Emissions” and “Global Warming Potential” are explicitly covered within the post model analysis for all European regions. In addition the results show every emission category per agricultural activity so that an allocation to the origin is possible.

[19] The already available indicators were mainly developed within the CAPRI DynaSpat project which was executed between 2004 and 2007 under the 6th EU Framework Programme. Further information available by http://www.ilr1.uni-bonn.de/agpo/rsrch/dynaspat/dynaspat_e.htm

Table 25: Environmental indicators covering GHG emissions from agriculture

Environmental indicators per activity, multiplied with activity levels [0]

Region: European Union 27 | Years: 2020 | View type: Table

CAPRI_baseline

	Global warming potential [1000 t]	Methane output [1000 t]	N2O output [1000 t]	Ammonia output [1000 t]	Water surplus/deficite [Mio m-3]
Cereals	48802.1		157.4	287.4	
Soft wheat	21580.6		69.6	129.5	
Durum wheat	1648.2		5.3	16.6	
Rye and Meslin	1736.2		5.6	8.7	
Barley	8764.4		28.3	48.7	
Oats	2700.2		8.7	12.8	
Grain Maize	9492.0		30.6	48.0	
Other cereals	2407.8		7.8	17.2	
Oilseeds	12459.2		40.2	55.9	
Rape	9399.5		30.3	42.6	
Sunflower	2297.8		7.4	11.5	
Soya	574.5		1.9	0.7	
Sugar Beet	3037.9		9.8	10.9	

Within the second category the focus is set on changes in agricultural land use caused by shifts in agricultural production. The “Activity level” (in ha) per agricultural product directly indicate changes in land use per activity. However, this indicator does not give information on the diversity of agricultural land use. Therefore, the “Crop share” (in % of arable land used by activity / total sum of used agricultural area) is a more suitable indicator.

7 Strengths and limitations of the methodology

This report presents the methodological extension of the CAPRI model to represent biofuel markets.

From the methodological point of view, the main enhancement of the CAPRI model compared to earlier versions is the endogenous representation of biofuel markets (ethanol and biodiesel). While keeping the focus on regional impacts in the EU, CAPRI now includes a global representation of biofuel markets, with endogenous supply, demand and trade flows for biofuels and biofuel feedstocks. The model is capable of simulating the impacts of EU biofuel policies on food production and prices, the potential use of by-products in the feed chain, the increasing pressure on marginal and idle land and the share of imported biofuels (self-sufficiency indicators). Thus, these model extensions allow for a detailed analysis of most relevant biofuel support instruments like consumer tax exemptions or quota obligations at European Member State and international level. Additionally, the consideration of advanced biofuels (2nd generation and non-agricultural sources for biofuel production) allows different technological development pathways to be represented.

The biofuel baseline is fully integrated into the CAPRI system. Thus, the baseline is updated yearly and the model is ready for the counterfactual analysis.

Compared to other modelling systems, the main advantage of the CAPRI biofuel module is its capability to simulate biofuel policy instruments defined at the Member State level. Besides, policy impacts are assessed both at the aggregate level (trade blocs) and at regional level within the EU (NUTS2 level).

This enhanced capability to represent EU biofuel markets is not without cost. Updating the biofuel database requires exploring a variety of international and national data sources to obtain detailed data at the Member State level.

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Annexes

Annex 1: Bio ethanol market balances in the base year (2004) and the baseline (2020)

	Base year (2004)					Baseline					
	Production	*first generation*	*non - Agri*	Demand	Net Trade	Production	*first generation*	*second generation*	*non - Agri*	Demand	Net Trade
EU015000	1622.6	*1014.8*	*607.8*	*1887*	*-264.4*	*9196.3*	*8494.8*	*233.4*	*468*	*13900*	*-4703.7*
BL000000	0	*0*	*0*	*11.2*	*-11.2*	*314.9*	*288.8*	*8.1*	*18*	*380.4*	*-65.5*
DK000000	15	*9.5*	*5.5*	*18*	*-3*	*18.5*	*15.8*	*0.5*	*2.2*	*240.7*	*-222.2*
DE000000	220.6	*138.8*	*81.7*	*381.2*	*-160.6*	*1137.5*	*1007*	*28.9*	*101.6*	*3622.5*	*-2485*
EL000000	0	*0*	*0*	*4.6*	*-4.6*	*487.9*	*475.3*	*12.6*	*0*	*523.4*	*-35.5*
ES000000	263.7	*168.6*	*95.1*	*261.5*	*2.2*	*1330.4*	*1247.3*	*30.7*	*52.4*	*1225.7*	*104.7*
FR000000	668.7	*412.4*	*256.3*	*480.8*	*187.9*	*2385.3*	*2141.6*	*61.6*	*182*	*1118.1*	*1267.2*
IR000000	0	*0*	*0*	*6.8*	*-6.8*	*0.2*	*0*	*0*	*0.1*	*254.1*	*-254*
IT000000	120.3	*75.1*	*45.2*	*167.7*	*-47.5*	*402.6*	*380.3*	*10.4*	*11.9*	*1780.2*	*-1377.6*
NL000000	2.1	*1.7*	*0.5*	*135.3*	*-133.2*	*35.5*	*34.5*	*0.9*	*0*	*399.6*	*-364.1*
AT000000	5.8	*3.7*	*2.1*	*39.5*	*-33.7*	*367.5*	*343.2*	*9.5*	*14.8*	*281.4*	*86.2*
PT000000	0	*0*	*0*	*7.7*	*-7.7*	*8.1*	*7.9*	*0.2*	*0*	*149.6*	*-141.5*
FI000000	0	*0*	*0*	*32.6*	*-32.6*	*202.8*	*197.2*	*5.2*	*0.3*	*254.7*	*-51.9*
SE000000	94.9	*62.4*	*32.5*	*175.5*	*-80.6*	*69.2*	*38.8*	*1.8*	*28.7*	*623.6*	*-554.4*
UK000000	231.5	*142.6*	*88.9*	*164.7*	*66.8*	*2436*	*2317.1*	*63*	*56*	*3046*	*-610*
EU010000	229	*148.1*	*80.9*	*239.5*	*-10.5*	*3575.5*	*3161.5*	*239*	*174.9*	*2049.8*	*1525.8*
CZ000000	4	*3.2*	*0.9*	*2.8*	*1.3*	*708.2*	*648.9*	*44.9*	*14.4*	*369.2*	*339*
EE000000	0	*0*	*0*	*2.5*	*-2.5*	*91.3*	*61.2*	*5.7*	*24.4*	*102.6*	*-11.3*
HU000000	41.8	*26.2*	*15.5*	*37.5*	*4.3*	*400.9*	*363.8*	*25.4*	*11.7*	*191*	*209.9*
LT000000	2.3	*1.8*	*0.5*	*4.9*	*-2.6*	*691.6*	*624.1*	*55.8*	*11.7*	*95.6*	*596.1*
LV000000	6.4	*4.5*	*1.9*	*8.4*	*-2*	*32*	*28.6*	*2.1*	*1.2*	*40.9*	*-8.9*
PL000000	174.5	*112.4*	*62.1*	*173.4*	*1.1*	*1305.2*	*1124.8*	*82.9*	*97.4*	*948.7*	*356.5*
SI000000	0	*0*	*0*	*4.1*	*-4.1*	*142.6*	*133.7*	*8.9*	*0*	*111.4*	*31.2*
SK000000	0	*0*	*0*	*5.4*	*-5.4*	*203.9*	*176.4*	*13.3*	*14.1*	*167.2*	*36.7*
CY000000	0	*0*	*0*	*0.4*	*-0.4*	*0*	*0*	*0*	*0*	*20.4*	*-20.4*
MT000000	0	*0*	*0*	*0.1*	*-0.1*	*0*	*0*	*0*	*0*	*2.9*	*-2.9*
BUR	0	*0*	*0*	*3.1*	*-3.1*	*1863.2*	*0*	*1863.2*	*0*	*241.9*	*1621.3*
RO000000	0	*0*	*0*	*0*	*0*	*1340.6*	*0*	*1340.6*	*0*	*173.8*	*1166.8*
BG000000	0	*0*	*0*	*3.1*	*-3.1*	*522.6*	*0*	*522.6*	*0*	*68.1*	*454.5*
USA	12308.5	*11919.2*	*389.3*	*12412.9*	*-104.4*	*54561.9*	*45684.5*	*7823.1*	*1054.4*	*73746.4*	*-19184.5*
CAN	273.4	*115.4*	*158*	*324.2*	*-50.8*	*840.1*	*677.4*	*0*	*162.8*	*2188.8*	*-1348.7*
MEX	36.4	*36.4*	*0*	*53.9*	*-17.5*	*72.4*	*72.4*	*0*	*0*	*239.7*	*-167.3*
ARG	126.7	*126.7*	*0*	*55.3*	*71.3*	*458.8*	*458.8*	*0*	*0*	*285.9*	*172.9*
BRA	5660	*5660*	*0*	*5729.3*	*-69.4*	*57388*	*57388*	*0*	*0*	*32491.6*	*24896.4*
MER_OTH	41.1	*41.1*	*0*	*41*	*0*	*160.8*	*160.8*	*0*	*0*	*160.8*	*0*
CHL	0	*0*	*0*	*21.7*	*-21.7*	*0*	*0*	*0*	*0*	*88.2*	*-88.2*
BOL	41.1	*41.1*	*0*	*19.3*	*21.7*	*160.8*	*160.8*	*0*	*0*	*72.6*	*88.2*
MSA_ACP	91.4	*91.4*	*0*	*6.3*	*85*	*146.7*	*146.7*	*0*	*0*	*337.6*	*-190.9*
RSA	29.3	*29.3*	*0*	*6.8*	*22.5*	*872*	*872*	*0*	*0*	*451.5*	*420.5*
RUS	614.7	*614.7*	*0*	*614.7*	*0*	*4066.9*	*4066.9*	*0*	*0*	*4066.9*	*0*
UKR	201.9	*201.9*	*0*	*42.9*	*158.9*	*2521.9*	*2521.9*	*0*	*0*	*1221.1*	*1300.8*
MED	27.1	*27.1*	*0*	*27.1*	*0*	*84.4*	*84.4*	*0*	*0*	*84.4*	*0*
EGY	27.1	*27.1*	*0*	*27.1*	*0*	*84.4*	*84.4*	*0*	*0*	*84.4*	*0*
MIDEAST	21	*21*	*0*	*21*	*0*	*56.9*	*56.9*	*0*	*0*	*56.9*	*0*
ZAF	12.7	*12.7*	*0*	*12.7*	*0*	*11.9*	*11.9*	*0*	*0*	*18.8*	*-6.9*
NGA	0	*0*	*0*	*5.9*	*-5.9*	*0*	*0*	*0*	*0*	*7.7*	*-7.7*
AFR_LDC	13.6	*13.6*	*0*	*0*	*13.6*	*102.7*	*102.7*	*0*	*0*	*28*	*74.7*
AFR_REST	0	*0*	*0*	*4*	*-4*	*0*	*0*	*0*	*0*	*4.9*	*-4.9*
IND	1051.5	*1051.5*	*0*	*1015.4*	*36.2*	*2224.9*	*2224.9*	*0*	*0*	*2685.7*	*-460.9*
PAK	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
CHN	2868.4	*2868.4*	*0*	*2550.8*	*317.6*	*4340.2*	*4340.2*	*0*	*0*	*6634.6*	*-2294.4*
JAP	88.2	*88.2*	*0*	*370.9*	*-282.8*	*561.3*	*561.3*	*0*	*0*	*1364.6*	*-803.4*
MALIND	84.3	*84.3*	*0*	*0*	*84.3*	*454.7*	*454.7*	*0*	*0*	*209.7*	*245*
TAW	0	*0*	*0*	*60.5*	*-60.5*	*0*	*0*	*0*	*0*	*65.2*	*-65.2*
ASI_TIG	125.9	*125.9*	*0*	*119.5*	*6.4*	*1090.5*	*1090.5*	*0*	*0*	*2041.5*	*-951*
ASI_SE	319.5	*319.5*	*0*	*158.1*	*161.4*	*2173.9*	*2173.9*	*0*	*0*	*2267.5*	*-93.6*
ASOCE_REST	18.2	*18.2*	*0*	*0*	*18.2*	*770.6*	*770.6*	*0*	*0*	*671.9*	*98.6*
ANZ	21.5	*21.5*	*0*	*7.7*	*13.8*	*273.6*	*273.6*	*0*	*0*	*346.5*	*-73*

Annex 2: Biodiesel market balances in the base year (2004) and the baseline (2020)

	Base year (2004)					Baseline					
	Production	*first generation*	*non - Agri*	Demand	Net Trade	Production	*first generation*	*second generation*	*non - Agri*	Demand	Net Trade
EU015000	2029.9	*1863.2*	*166.6*	*1843.5*	*186.4*	*13710*	*9991*	*2989.7*	*729.2*	*17383.6*	*-3673.6*
BL000000	0.3	*0.3*	*0*	*0.4*	*0*	*200.2*	*154.5*	*14.8*	*30.9*	*846.9*	*-646.7*
DK000000	60.1	*54.1*	*6*	*9.5*	*50.6*	*218.6*	*159.3*	*37.4*	*21.9*	*257.1*	*-38.5*
DE000000	1132.5	*1062.8*	*69.7*	*1146.2*	*-13.7*	*4322.4*	*3297*	*848.4*	*177*	*3379.8*	*942.6*
EL000000	1	*0.9*	*0.1*	*13.2*	*-12.2*	*263.2*	*171.4*	*72.8*	*19*	*232.3*	*30.9*
ES000000	31.3	*28.3*	*2.9*	*117.3*	*-86*	*1073.4*	*748.3*	*295.5*	*29.7*	*3046.8*	*-1973.4*
FR000000	395.8	*355.8*	*40*	*367.7*	*28.2*	*3613.6*	*2569.6*	*871.1*	*172.9*	*3047.7*	*566*
IR000000	1.6	*1.5*	*0.2*	*0.5*	*1.1*	*161.8*	*105.7*	*50.7*	*5.3*	*254.2*	*-92.4*
IT000000	326.4	*292.7*	*33.7*	*108.2*	*218.2*	*1105.1*	*865.2*	*167.1*	*72.8*	*2388.8*	*-1283.6*
NL000000	0	*0*	*0*	*38.6*	*-38.6*	*46.9*	*32.3*	*8.5*	*6.2*	*655*	*-608*
AT000000	56.8	*50.9*	*5.9*	*20.7*	*36.1*	*405*	*289.8*	*60.3*	*54.9*	*415.2*	*-10.2*
PT000000	0.3	*0.3*	*0*	*0.7*	*-0.4*	*117.1*	*84.1*	*22.6*	*10.4*	*332.1*	*-214.9*
FI000000	0	*0*	*0*	*5.4*	*-5.4*	*194.1*	*123.6*	*38.2*	*32.3*	*194.7*	*-0.6*
SE000000	1	*0.9*	*0.1*	*3.3*	*-2.4*	*375.9*	*269.1*	*82.3*	*24.6*	*320.7*	*55.3*
UK000000	22.7	*14.7*	*8*	*11.7*	*10.9*	*1612.4*	*1121.1*	*420*	*71.3*	*2012.5*	*-400.1*
EU010000	137.9	*123.4*	*14.5*	*125.9*	*12*	*1579.2*	*865.7*	*444*	*269.5*	*1521.8*	*57.4*
CZ000000	63.3	*56.7*	*6.6*	*5.7*	*57.5*	*315.3*	*222.8*	*7.9*	*84.7*	*287.3*	*28*
EE000000	2.3	*2*	*0.2*	*5.4*	*-3.1*	*0*	*0*	*0*	*0*	*19.7*	*-19.7*
HU000000	0	*0*	*0*	*28.6*	*-28.6*	*202*	*65.1*	*118.1*	*18.8*	*217.3*	*-15.3*
LT000000	3.9	*3.5*	*0.4*	*7.3*	*-3.4*	*51.1*	*24.6*	*21.5*	*4.9*	*48.6*	*2.4*
LV000000	1.6	*1.5*	*0.2*	*6*	*-4.4*	*49.5*	*25.9*	*15.6*	*8*	*39.8*	*9.7*
PL000000	32.7	*29.2*	*3.5*	*35.9*	*-3.2*	*686.9*	*357.2*	*228.4*	*101.4*	*661.4*	*25.5*
SI000000	2.6	*2.3*	*0.3*	*3.6*	*-1*	*73.8*	*36.5*	*27*	*10.3*	*141*	*-67.3*
SK000000	30.5	*27.3*	*3.2*	*20.7*	*9.9*	*189.2*	*128.1*	*20.2*	*40.9*	*87*	*102.2*
CY000000	0.3	*0.3*	*0*	*6.4*	*-6.1*	*8.9*	*3.2*	*5.3*	*0.4*	*14.4*	*-5.5*
MT000000	0.7	*0.6*	*0.1*	*6.3*	*-5.6*	*2.4*	*2.3*	*0*	*0.1*	*5.2*	*-2.7*
BUR	0	*0*	*0*	*21.3*	*-21.3*	*177.8*	*61.7*	*104*	*12*	*208.1*	*-30.3*
RO000000	0	*0*	*0*	*18.2*	*-18.2*	*112.9*	*40.3*	*66.1*	*6.5*	*137.3*	*-24.4*
BG000000	0	*0*	*0*	*3.1*	*-3.1*	*64.9*	*21.4*	*37.9*	*5.5*	*70.8*	*-6*
USA	152.3	*137.6*	*14.7*	*415.5*	*-263.2*	*3053.8*	*717.6*	*0*	*2336.2*	*2938.4*	*115.4*
CAN	3.8	*0*	*3.8*	*3.8*	*0*	*359.8*	*24.7*	*0*	*335*	*359.8*	*0*
ARG	0	*0*	*0*	*0*	*0*	*2854.1*	*2854.1*	*0*	*0*	*509.2*	*2344.9*
BRA	0	*0*	*0*	*0*	*0*	*2354.7*	*2065.8*	*0*	*288.9*	*2354.7*	*0*
RSA	0	*0*	*0*	*0*	*0*	*996.6*	*996.6*	*0*	*0*	*616.3*	*380.3*
ZAF	0	*0*	*0*	*0*	*0*	*5.3*	*5.3*	*0*	*0*	*5.3*	*0*
AFR_LDC	0	*0*	*0*	*0*	*0*	*94.4*	*94.4*	*0*	*0*	*39.6*	*54.8*
IND	27.1	*27.1*	*0*	*323.4*	*-296.3*	*2938.9*	*2938.9*	*0*	*0*	*3021*	*-82.1*
MALIND	514.7	*514.7*	*0*	*132.3*	*382.4*	*1848.6*	*1848.6*	*0*	*0*	*1093.4*	*755.2*
ASI_SE	113.2	*113.2*	*0*	*113.2*	*0*	*1173.8*	*1173.8*	*0*	*0*	*1095.7*	*78*
ASOCE_REST	0	*0*	*0*	*0*	*0*	*276.4*	*276.4*	*0*	*0*	*276.4*	*0*
ANZ	36	*24.7*	*11.3*	*36*	*0*	*560.5*	*33.3*	*0*	*527.2*	*560.5*	*0*

Annex 3: Bilateral bio ethanol trade flows in the Baseline (2020)

	EU015000	EU010000	BUR	USA	CAN	MEX	ARG	BRA	MSA_ACP	IND	ASI_TIG	ASI_SE	ASOCE_REST	OTHER
EU015000	0	*2262*	*32*	*811*	*0*	*0*	*0*	*450*	*108*	*66*	*177*	*339*	*120*	*473*
EU010000	25	*0*	*4*	*116*	*0*	*0*	*0*	*72*	*39*	*11*	*119*	*122*	*37*	*198*
BUR	0	*0*	*0*	*1*	*0*	*0*	*0*	*141*	*0*	*6*	*4*	*7*	*3*	*68*
USA	37	*4*	*1791*	*0*	*220*	*71*	*378*	*16780*	*0*	*0*	*0*	*0*	*0*	*891*
CAN	0	*0*	*0*	*1*	*0*	*0*	*0*	*1575*	*0*	*0*	*0*	*0*	*0*	*0*
MEX	0	*0*	*0*	*0*	*0*	*0*	*0*	*239*	*0*	*0*	*0*	*0*	*0*	*0*
ARG	0	*0*	*0*	*0*	*0*	*0*	*0*	*205*	*0*	*0*	*0*	*0*	*0*	*0*
BRA	0	*0*	*0*	*11*	*0*	*1*	*0*	*0*	*0*	*0*	*14*	*0*	*2*	*1190*
MSA_ACP	0	*0*	*0*	*0*	*0*	*0*	*0*	*338*	*0*	*0*	*0*	*0*	*0*	*0*
NGA	0	*0*	*0*	*0*	*0*	*0*	*0*	*8*	*0*	*0*	*0*	*0*	*0*	*0*
AFR_REST	0	*0*	*0*	*0*	*0*	*0*	*0*	*5*	*0*	*0*	*0*	*0*	*0*	*0*
IND	0	*0*	*0*	*30*	*0*	*0*	*0*	*514*	*0*	*0*	*0*	*0*	*0*	*0*
TAW	0	*0*	*0*	*0*	*0*	*0*	*0*	*65*	*0*	*0*	*0*	*0*	*0*	*0*
ASI_TIG	68	*0*	*0*	*0*	*0*	*0*	*0*	*1197*	*0*	*0*	*0*	*0*	*0*	*0*
ASI_SE	0	*0*	*0*	*0*	*0*	*0*	*0*	*562*	*0*	*0*	*0*	*0*	*0*	*0*
ASOCE_REST	0	*0*	*0*	*0*	*0*	*0*	*0*	*63*	*0*	*0*	*0*	*0*	*0*	*0*
OTHER	3	*2*	*24*	*18*	*7*	*0*	*0*	*3901*	*0*	*0*	*0*	*0*	*0*	*26*

Annex 4: Bilateral biodiesel trade flows in the Baseline (2020)

	EU015000	EU010000	BUR	USA	ARG	RSA	AFR_LDC	MALIND	ASI_SE
EU015000	0	*932*	*25*	*21*	*2072*	*140*	*43*	*524*	*52*
EU010000	121	*0*	*21*	*20*	*491*	*40*	*12*	*147*	*26*
BUR	5	*2*	*0*	*0*	*0*	*201*	*0*	*0*	*0*
USA	5	*0*	*54*	*0*	*0*	*0*	*0*	*84*	*0*
ARG	0	*0*	*0*	*218*	*0*	*0*	*0*	*0*	*0*
IND	4	*0*	*78*	*0*	*0*	*0*	*0*	*0*	*0*

Annex 6: Ethanol production from feedstocks in individual Member States

	Feedstock (1000t)						
Member States	wheat	barley	rye	oats	maize	other cereals	sugar
Belgium	89.6	89.7	0.0	0.0	89.6	0.0	26.0
Denmark	0.0	0.0	0.0	0.0	0.0	0.0	17.6
Germany	339.6	67.2	175.1	67.3	116.6	40.8	827.8
Austria	47.0	18.6	18.7	18.7	139.9	0.0	106.2
Netherlands	5.9	8.9	3.4	1.1	7.7	0.0	7.0
France	803.4	109.8	0.0	0.0	271.2	54.9	870.4
Portugal	0.0	4.0	0.0	0.0	4.0	0.0	0.0
Spain	426.3	478.4	91.8	91.6	91.4	45.7	5.8
Greece	0.0	237.1	0.0	0.0	247.7	0.0	0.0
Italy	84.9	32.9	0.0	0.0	244.1	0.0	0.0
Ireland	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	40.6	40.6	79.2	40.6	0.0	0.0	0.0
Sweden	96.0	9.6	9.6	0.0	0.0	0.0	19.5
United Kingdom	1529.1	190.1	0.0	190.7	280.7	0.0	118.0
Czech Republic	153.2	20.3	20.2	20.3	40.5	15.7	92.2
Estonia	7.7	7.7	7.7	0.0	0.0	0.0	0.0
Hungary	17.6	17.6	0.0	0.0	166.1	8.8	0.9
Lithuania	39.1	39.2	67.3	0.0	20.0	266.6	14.8
Latvia	10.0	1.6	2.4	0.0	1.6	2.3	0.0
Poland	104.0	165.8	217.0	0.0	116.7	12.5	26.1
Slovenia	0.0	36.9	0.0	0.0	37.1	0.0	0.0
Slovak Republic	18.1	18.1	18.2	0.0	18.1	9.1	15.2
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bulgaria and Romania	2.7	2.7	0.0	0.0	2.7	0.0	0.0
Bulgaria	0.8	0.8	0.0	0.0	0.8	0.0	0.0
Romania	2.0	2.0	0.0	0.0	2.0	0.0	0.0

Annex 7: Biodiesel production from feedstocks in individual Member States

	Feedstocks (1000t)			
Member States	rapeoil	sunfloweroil	soyoil	palmoil
Belgium	6.2	0.4	0.2	1.8
Denmark	22.0	0.0	0.0	8.0
Germany	1105.1	0.0	68.4	260.8
Austria	0.2	0.0	0.0	0.0
Netherlands	9.3	0.5	4.7	4.7
France	271.3	39.0	50.7	39.2
Portugal	0.0	7.9	32.0	4.6
Spain	6.6	49.1	10.6	6.6
Greece	0.0	17.0	9.6	5.5
Italy	167.3	93.4	110.5	98.2
Ireland	6.1	0.0	0.0	2.2
Finland	28.5	0.0	14.2	27.7
Sweden	10.0	0.0	0.1	2.2
United Kingdom	58.0	0.0	3.8	18.5
Czech Republic	105.9	6.6	13.2	13.2
Estonia	0.0	0.0	0.0	0.0
Hungary	2.9	5.8	2.9	5.8
Lithuania	6.7			0.9
Latvia	4.6	0.5	0.2	0.5
Poland	75.2	9.7	4.7	9.6
Slovenia	0.4	1.0	2.8	0.6
Slovak Republic	35.8	12.2	9.3	6.2
Cyprus		0.4	0.3	0.1
Malta	0.1	1.0	1.1	0.5
Bulgaria and Romania	3.5	6.9	1.7	3.5
Bulgaria	1.3	2.5	0.6	1.3
Romania	2.2	4.4	1.1	2.2

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Abstract

This report is based on the outcome of a study carried out by the European Commission's Joint Research Centre - Institute for Prospective Technological Studies (JRC-IPTS, Spain) in cooperation with EuroCARE (Bonn, Germany). The report provides a detailed description of the methodology developed to assess the implications of the European Renewable Energy Directive on the agricultural sector, with an explicit focus on regional effects of biofuel targets in the EU.

For the analysis, the spatial agricultural sector model CAPRI has been extended to include a global representation of biofuel markets (with endogenous supply, demand and trade flows for biofuels and biofuel feedstocks) while keeping the focus on regional impacts in the EU. The model is capable to simulate the impacts of EU biofuel policies on food production and prices, the potential use of by-products in the feed chain, the increasing pressure on marginal and idle land and the share of imported biofuels (self-sufficiency indicators).

CAPRI is now able to jointly assess biofuel and agricultural policies, including policy instruments defined at the Member State level. The CAPRI biofuel module allows for a detailed analysis of most relevant biofuel support instruments like consumer tax exemptions, quota obligations, import tariffs and other trade measures. Additionally, the model allows for analysing scenarios regarding technical progress in 2nd generation technologies for biofuels.

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As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new standards, methods and tools, and sharing and transferring its know-how to the Member States and international community.

Key policy areas include: environment and climate change; energy and transport; agriculture and food security; health and consumer protection; information society and digital agenda; safety and security including nuclear; all supported through a cross-cutting and multi-disciplinary approach.

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