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Abstract of the Dissertation

Impacts of European biofuel policies on global biofuel and agricultural markets

Arno Becker

The strong increase of global biofuel markets within the last years has led to a continuous increase of biofuel feedstock demand. Due to the current state of biofuel production technologies primarily traditional agricultural commodities, like cereals, sugar or vegetable oils are used for biofuel production. Thus, biofuel markets are closely connected to agricultural markets.

Future policy targets indicate that biofuel and thereby biofuel feedstock demand will further increase. The European Renewable Energy Directive of 2009, for example, sets the target to achieve 10% energy from renewable sources in total European transport energy consumption until 2020.

This thesis intends to assess and quantify impacts of European biofuel policies implemented to achieve the target of the European Renewable Energy Directive until 2020 on global biofuel and agricultural markets. A scenario analysis is done under different assumptions concerning global biofuel trade, the availability of 2nd generation biofuel production technologies, and price development of fossil fuel.

For the quantitative analysis, a behavioural market model for biofuels and biofuel feedstocks is developed extending the agricultural sector model CAPRI (Common Agricultural Policy Regional Impact). The extended version covers behavioural functions for biofuel supply, demand, trade and biofuel feedstock demand. Furthermore, functions approximating total fuel demand behaviour are introduced, differentiated into total diesel and gasoline demand. The model permits to simultaneously evaluate future biofuel and agricultural policies.

The results of the analysis show that by reaching the target of the Renewable Energy Directive about 20% of EU27 biofuel consumption in 2020 relies on imports. For European biodiesel production in 2020, it is shown that a notable share of the used feedstock (mainly rape oil) is imported. Furthermore, it is observed that biofuel by-products are used as substitutes for traditional feed crops in the livestock sector partially compensating the increase in biofuel feedstock demand. This is especially true for cereals. The compliance with the European Renewable Energy Directive in 2020 leads to increasing prices of agricultural products. Thereby, the observed shifts are more significant for biodiesel feedstocks (vegetable oils) compared to ethanol feedstocks (cereals, sugar).

Keywords*: European Renewable Energy Directive (RED), biofuel markets, agricultural markets, impact assessment, agricultural sector model, CAPRI*

Kurzfassung der Dissertation

Auswirkungen europäischer Biokraftstoffpolitiken auf globale Biokraftstoff- und Agrarmärkte

Arno Becker

Das starke Wachstum der globalen Biokraftstoffmärkte hat in den vergangenen Jahren zu einem kontinuierlichen Nachfrageanstieg nach Rohstoffen für die Biokraftstoffproduktion geführt. Aufgrund des aktuellen Entwicklungsstandes der Biokraftstoffproduktionstechnologien werden zu ihrer Herstellung zum überwiegenden Teil traditionelle Agrarprodukte, wie verschiedene Getreidesorten, Pflanzenöle oder Zuckerpflanzen, verwendet. Biokraftstoffmärkte sind daher eng mit landwirtschaftlichen Märkten verbunden.

Zukünftige Politikziele signalisieren, dass die Nachfrage nach Biokraftstoffen und entsprechenden Rohstoffen weiter steigen wird. So formuliert die europäische Erneuerbare Energien Richtlinie von 2009 das Ziel, 10% des Gesamtenergieverbrauchs im europäischen Verkehrssektor bis 2020 durch erneuerbare Quellen zu decken.

Die vorliegende Arbeit beabsichtigt Einflüsse europäischer Biokraftstoffpolitiken, welche in den europäischen Mitgliedsländern implementiert wurden um das Ziel der Erneuerbaren Energien Richtlinie bis 2020 zu erreichen, auf globale Biokraftstoff- und Agrarmärkte zu quantifizieren. Unter Berücksichtigung verschiedener Annahmen für den Biokraftstoffhandel, die Verfügbarkeit von Biokraftstoffproduktionstechnologien der 2. Generation und Preisentwicklungen fossiler Kraftstoffe, wird dazu eine Szenarienanalyse durchgeführt.

Für die quantitative Analyse wird ein globales Marktmodell für Biokraftstoffe und Biokraftstoffrohstoffe entwickelt und in das Agrarsektormodell CAPRI (Common Agricultural Policy Regional Impact) integriert. Die erweiterte CAPRI Version beinhaltet Verhaltensfunktionen für Biokraftstoffangebot, -nachfrage, -handel und Rohstoffnachfrage. Zudem werden Funktionen implementiert, die das Gesamtnachfrageverhalten nach Kraftstoffen, differenziert für Benzin und Diesel, annähern. Das Modell ermöglicht es damit zukünftige Biokraftstoff- und Agrarpolitiken simultan zu analysieren.

Die Ergebnisse der Analyse zeigen, dass unter Einhaltung des Ziels der Erneuerbaren Energien Richtlinie in 2020 bis zu 20% der EU27 Biokraftstoffnachfrage auf Importen basiert. Für die europäische Biodieselproduktion kann gezeigt werden, dass in 2020 ein bedeutender Teil der verwendeten Rohstoffe (vorwiegend Rapsöls) ebenfalls importiert wird. Zudem wird beobachtet, dass Nebenprodukte der Biokraftstoffproduktion als Substitute für traditionelle Futterpflanzen im Tierhaltungssektor verwendet werden, was den Anstieg der Rohstoffnachfrage für die Biokraftstoffproduktion teilweise kompensiert. Dies trifft vor allem für Getreide zu. Die Erfüllung der europäischen Erneuerbaren Energien Richtlinie in 2020 führt zu steigenden Preisen von

Agrarprodukten. Dabei sind die beobachteten Steigerungen deutlicher für Biodieselrohstoffe (Pflanzenöle) als für Ethanolrohstoffe (Getreide, Zucker).

***Schlüsselworte**: Europäische Erneuerbare Energien Richtlinie, Biokraftstoffmärkte, Agrarmärkte, Folgenabschätzung, Agrarsektormodel, CAPRI*

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List of Abbreviations

ACP	African, Caribbean and Pacific Group of States
Agg.	Aggregated
AgLink-COSIMO	Agricultural sector model of the OECD / FAO
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regionalized Impact model
CAPTRD	Trend projection tool of CAPRI
CARD	Center for Agricultural and Rural Development
CES	Constant elasticity of substitution
CGF	Corn Gluten Feed
CNFAP	Center for National Food and Agricultural Policy
COCO	Complete and consistent regional database of CAPRI
COMEXT	External trade statistic division of EUROSTAT
DDGS	Distillers Dried Grains with Solubles
Diff.	Difference
EBA initiative	Everything But Arms initiative
EBB	European Biodiesel Board
EBIO	European Bioethanol Fuel Association
EPURE	European Renewable Ethanol Association (former EBIO)
EU MS	European Member States
EUROSTAT	Statistical Office of the European Communities
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute
FT	Fischer - Tropsch synthesis
GDP	Gross domestic product
GHG	Greenhouse gas
GTAP	Purdue University, Center for Global Trade Analysis
HTU	Hydro thermal upgrading
HS code	Harmonized System Codes, commodity classification
ha	Hectare
IFPRI	International Food Policy Research Institute
IfW	Kiel Institute for World Economy
IIASA	International Institute for Applied Systems Analysis
IPTS	Institute for Prospective Technological Studies

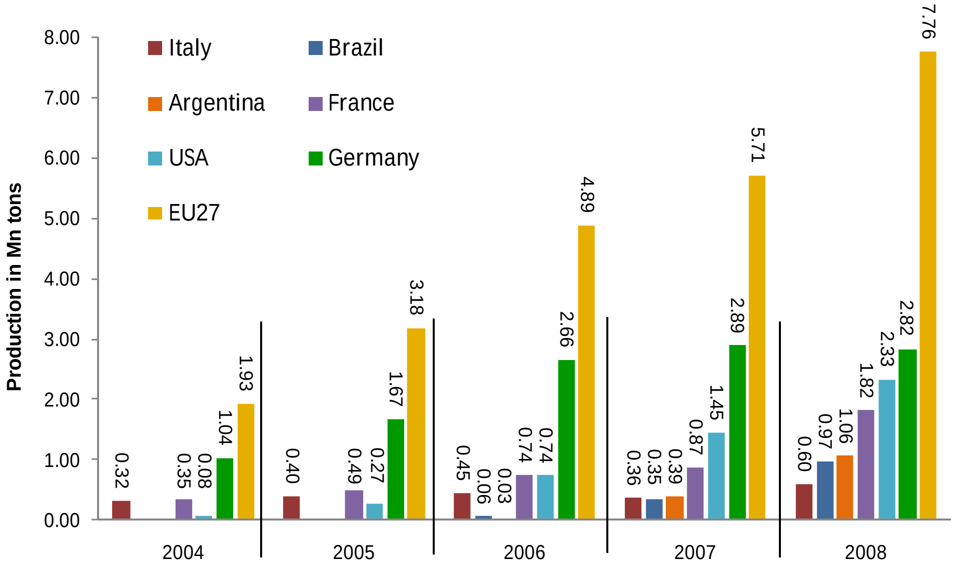
k	Kilo
LEI	Agricultural Economics Research Institute
Log	Logarithmic
Mn	Million
NUTS	Nomenclature of Statistical Territorial Units
NQ	Normalized quadratic
N_2O	Nitrous Oxide
OECD	Organisation for Economic Co-Operation and Development
OPEC	Organization of Petroleum Exporting Countries
POLES	Prospective Outlook on Long-Term Energy Systems model
PRIMES	European energy sector model PRIMES
PRODCOM	Production statistic division of EUROSTAT
RED	European Renewable Energy Directive (2009/28/EC)
Sel.	Selected
Sig	Sigmoid
t	Metric ton
toe	Ton Oil Equivalent
TRQ	Tariff rate quota
WTO	World Trade Organization

1. Introduction

1.1. Motivation and research objective

Through growing global biofuel markets driven by market forces and a strong policy support, biofuels play an increasingly significant role in global energy and agricultural markets. In comparison to 1990, where world fuel-ethanol production amounted to about 12Mn tons and biodiesel production was marginal, in 2008 world fuel-ethanol production amounted already up to 52Mn tons and biodiesel up to 13Mn tons (ENERS Energy Concept, 2010). Ambitious future biofuel targets as stated for example by the European Renewable Energy Directive of 2009 (European Commission, 2009) which set the target to achieve 10% energy from renewable sources in total European transport energy consumption in 2020, indicate that this trend will continue. While Europe is currently the most important biodiesel producer (Figure 1.1), the production of ethanol mainly takes place outside Europe (Figure 1.2), especially in the U.S. and Brazil. In 2008 EU27 biofuel facilities produced to about 7.8Mn tons of biodiesel (EBB, 2010).

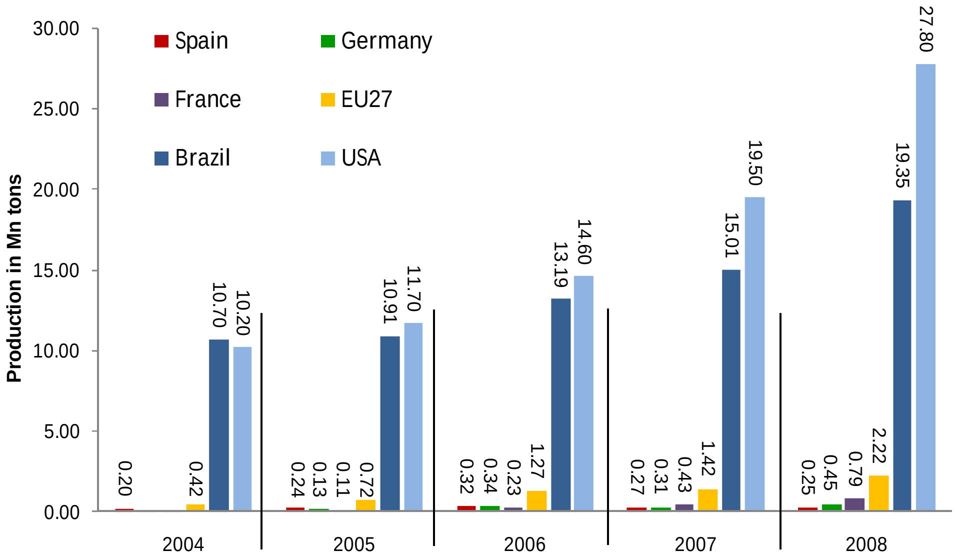
Figure 1.1: Biodiesel production in important global production regions



Source: Own compilation based on EBB (2010)

Besides positive economic and environmental effects which should be supported by an increasing substitution of fossil fuels by biofuels, the discussion on probable negative or at least uncertain indirect effects of growing biofuel markets is deepening, particular in the context of rising food prices.

Figure 1.2: Fuel-ethanol production in important global production regions



Note: This figure exclusively covers fuel-ethanol production. Total ethanol production, including ethanol produced for the chemical industry or beverages is not covered here.
Source: Own compilation based on EBIO (2010), F.O.Licht (2008, 2009) and UEPA (2008)

Up to now, almost all biofuels produced globally are based on so called 1st generation processing technologies, which predominately rely on traditional agricultural commodities like various cereals, vegetable oils or sugar crops. Hence, the production of biofuels is closely connected to agricultural product markets by inducing demand, supply and price shifts. Furthermore, an increasing supply of biofuel by-products (like DDGS) on global feed markets can be observed as a result of the growing biofuel production. Regarding feed markets the long-term impact of biofuel production is ambiguous. On the one hand, increasing prices of agricultural products used as feed components can lead to increasing feed prices and thus, to shifts in meat supply. On the other hand, growing supply of biofuel by-products which can be used as feed substitutes may cause opposite effects.

An uncertain aspect is the progress which can be realised in the development of so called advanced or 2nd generation biofuel production technologies. An increasing share of biofuels produced by 2nd generation technologies might reduce the linkage between energy and traditional agricultural product markets as feedstocks other than agricultural food crops, such as cellulosic biomass like agricultural residues or new energy crops can be processed. As long as a marketable production of 2nd generation biofuels is only marginal due to an insufficient technological progress, large-scale biofuel production will continue to impact agricultural product and food markets.

Within the evaluation of biofuel policies, the consideration of biofuel trade is crucial. As biofuels can be transported at relative low costs per unit and production costs vary strongly between countries, it is probable that the relevance of biofuel trade will further increase. Especially in the case of ethanol it is likely that a significant but unknown share of future EU27 demand will be met by imports from outside the EU, where ethanol can be produced very efficiently based on sugar cane (Henniges, 2006).

Apart from economic impacts of biofuel production further discussion takes place which relates to environmental impacts. It is largely undisputed that the reduction of greenhouse gas (GHG) emissions by reducing the use of fossil fuels is advantageous in terms of climate protection. However, the emission of additional GHG within the production process of biofuels and in particular biofuel feedstocks could even lead to a negative GHG balance and therefore question the substitution of fossil fuels by biofuels.

This thesis has the objective to assess and quantify impacts of European biofuel policies implemented to reach the target of the European Renewable Energy Directive (RED) in 2020 on global biofuel and agricultural markets. Thereby, the impact assessment is done under different assumptions concerning global bilateral biofuel trade, the availability of 2nd generation biofuel production technologies and price development of fossil fuel.

Three central questions will be investigated specifically:

(1) What are the impacts of biofuel support policies implemented by European Member States to reach the RED target of 10% biofuels in 2020 on European and global biofuel as well as agricultural markets?

(2) How do these impacts change if uncertain assumptions are varied (availability of 2nd generation technologies, existence of biofuel support and trade policies, changes of fossil fuel prices)?

(3) What are the impacts of shifts in agricultural production caused by an increasing biofuel production on the environment?

The results of this analysis will supplement already existing biofuel impact assessments referring to the agricultural sector as given e.g. by Lampe (2006 and 2008), Banse et al. (2008a), Banse and Grethe (2008), Havlik et al. (2010), Mantzos and Capros (2006) and Kretschmer et al. (2009c).

1.2. Methodological approach

Within this thesis a behavioural biofuel market model is developed extending the comparative static, spatial, agricultural sector model CAPRI (Common Agricultural Policy Regional Impact). This modified CAPRI version, the CAPRI biofuel model, permits to simulate simultaneously impacts of different biofuel and agricultural policies on global biofuel and agricultural markets. Thereby, it benefits from the already existent and well developed representation of agricultural supply behaviour in the core CAPRI system (Solberg et al., 2007). The estimation and specification of the behavioural biofuel model relies on microeconomic theory and information derived from already existing modelling approaches. The OECD-FAO agricultural sector model AgLink-COSIMO which already covers a detailed biofuel representation (Lampe, 2006 and 2008) is used to derive biofuel demand functions. Simulation results of the European energy sector model PRIMES (E3Mlab, 2011) are used to derive functions which approximate total fuel demand behaviour based on a response surface approach. For the quantitative analysis different biofuel scenarios are simulated each defined to address one of the above mentioned questions. The development of a reference scenario, the biofuel baseline, which assumes the continuation of the current European biofuel policy up to 2020 is done based on statistical trend estimations and external expert knowledge.

1.3. Structure of the thesis

The thesis comprises eight chapters. After this introduction, **Chapter 2** gives an overview of most important global biofuel markets and support policies (*Section 2.1*), while focussing in detail on the EU27 and the single Member States (*Section 2.2*). **Chapter 3** provides a survey of selected economic models which already capture a biofuel market representation and which are most applied in scientific literature. This survey should allow for integrating the methodological concept and the individual features of the CAPRI biofuel model in the framework of existing economic biofuel modelling approaches. **Chapter 4** starts with a description of the general concept of the CAPRI model (*Section 4.1*). Subsequently, the development of the CAPRI biofuel model is described in detail. After the envisaged general setting of the CAPRI biofuel model is described (*Section 4.2*) the conceptual design of the individual biofuel markets covered in the model is explained (*Section 4.3*). *Section 4.4* then develops the biofuel ex-post database which is required for the construction of the biofuel baseline. In *Section 4.5 to 4.7* the methodological derivation and statistical estimation of the behavioural biofuel market model is described. The calibration of the model is then done in *Section 4.8.* In the last section of Chapter 4 (*Section 4.9*) the applied indicators used to investigate selected environmental impacts are described. After the CARPI biofuel model has been developed, **Chapter 5** describes the reference scenario, the biofuel baseline. Before all baseline assumptions are explained (*Section 5.2*), *Section 5.1* describes the general baseline generation process applied in CAPRI. *Section 5.3* then summarises all baseline results. **Chapter 6** covers the quantitative analysis of biofuel and agricultural market behaviour by defining and simulating five different counterfactual scenarios (*Section 6.1*). The individual results are interpreted and discussed in detail in *Section 6.2*. A supplemental discussion on the projection results is given in **Chapter 7** where the CAPRI results presented in Chapter 6 are compared to existing projections form selected models whose general features have been described in Chapter 3. Differences which are observed are explained and justified. In **Chapter 8** the key findings of the thesis are summarised. A discussion on the limitations of the applied modelling approach is carried out and further research needs are highlighted.

2. Global biofuel markets and policies

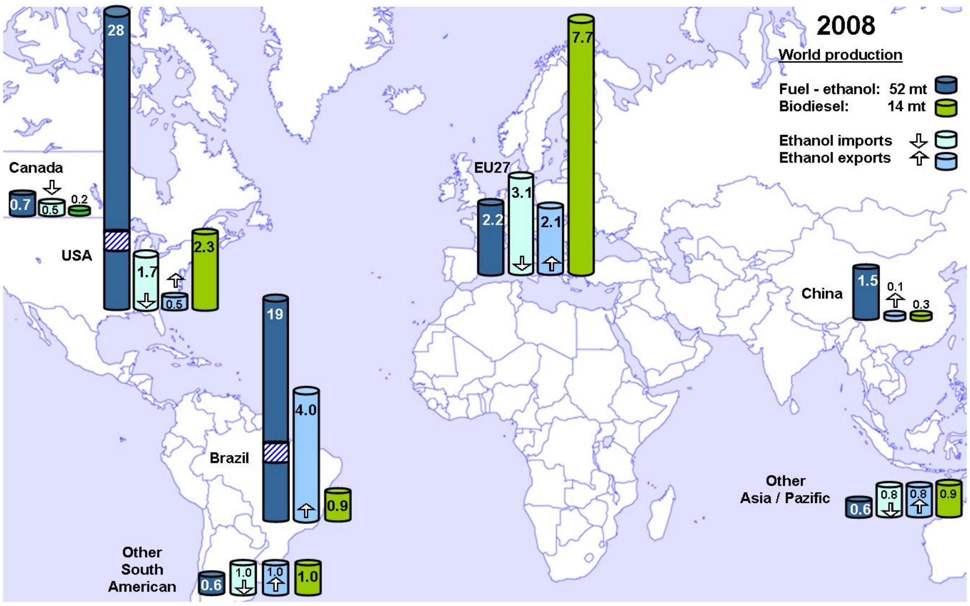
Biofuels can be distinguished between 1st and 2nd generation biofuels. This definition is often used in scientific literature, in economic as well as in natural engineering. Thereby, another synonym for 2nd generation biofuels is “advanced” biofuels. Following Eisentraut (2010, p.22), “[…] *1st generation biofuels are biofuels which are on the market in considerable amounts today. Typical 1st generation biofuels are sugar cane ethanol, starch or corn based ethanol, biodiesel and pure plant oil. The feedstocks for producing 1st generation biofuels either consists of sugar, starch and oil bearing crops or animal fats that in most cases can also be used as food and feed or consists of food residues.*” 1st generation biofuels are produced by traditional biofuel production technologies like fermentation in the case of ethanol and esterification in the case of biodiesel. “*2nd generation biofuels are those biofuels produced from cellulose, hemi-cellulose or lignin*” (Eisentraut, 2010, p.22). They are produced by advanced production technologies like Fisher-Tropsch-Synthesis (Capros, 2010) and are based on non-food biomass. Such alternative biofuel feedstocks are for example new energy crops like fast growing tree species or agricultural and forestry residues like straw or waste wood. The advantage of 2nd generation production technologies is on the one hand that food markets are not affected directly and, on the other hand, whole plants can be used for biofuel production instead of using only plant fractions (like oil seeds or cereals grains). This is much more effective in terms of energy efficiency. Biodiesel and ethanol, the most important biofuels worldwide, can be produced based on both technologies, 1st and 2nd generation. The resulting fuels do not differ significantly regarding their chemical characteristics. Thus, the differentiation between 1st and 2nd generation biofuels is only relevant for the supply side and does not affect the demand side. Up to now almost all biofuels worldwide are produced by 1st generation production technologies relying on traditional agricultural commodities like cereals, vegetable oils or sugar crops (IEA, 2009). At present only pilot or at most small scale facilities for 2nd generation biofuel production exist which are predominately not yet operating commercially. Thereby, “[…] *the main obstacle for 2nd generation biofuels are high initial investment costs as well as higher costs for the end-product compared to fossil fuels or many first-generation biofuels*” (Eisentraut, 2010, p.21). However, the future prospects of these technologies are immense. Bacovsky et al. (2010) gives an overview on important planned and existing 2nd generation biofuel facilities in Europe and further countries worldwide indicating that from 2010 onwards an increase in 2nd generation biofuels might occur. At which time 2nd generation biofuels will become commercially competitive and in which quantities is very uncertain.

The strong increase in 1st generation biofuel markets today is mainly induced by an intensified policy support in Europe and North-America. Whereas diesel and therefore biodiesel have traditionally a strong position in Europe, ethanol is the most dominant biofuel on global level.

2.1. Brazil, USA and Argentina

Traditionally, Brazil is an important producer and exporter of ethanol which is predominately based on sugar cane. Brazilian ethanol production in 2008 reached nearly 19Mn tons and 4Mn tons were exported (Figure 2.1). However, by strong policy support the U.S. has become the largest fuel-ethanol producer in the world since 2005. In 2008 the U.S. produced 27Mn tons of fuel-ethanol (Figure 1.2). U.S. exports are significantly smaller than the Brazilian ones as U.S. domestic consumption has also drastically increased within the last ten years. The EU27, the U.S. and Brazil together produced 78% of world biodiesel and 94% of world fuel-ethanol supply in 2008 (Figure 2.1).

Figure 2.1: World biofuel production 2008

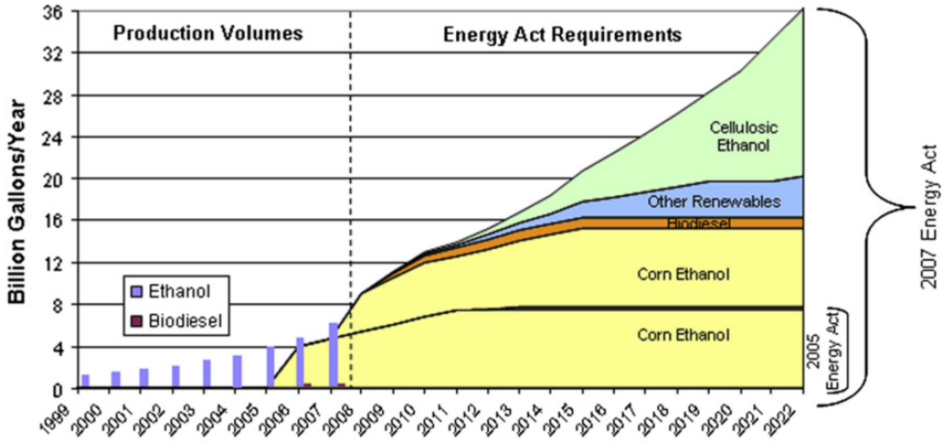


Source: Own illustration based on F.O.Licht (2008-2009) and ENERS Energy Concept (2010)

Whereas the European support policy framework will be addressed explicitly in Section 2.2, the main “milestones” in most important non-European biofuel markets (Brazil, USA and Argentina) will be shortly described here.

Fuel-ethanol has been produced in the U.S. since the late 1970s. The market launch was initiated by the Energy Tax Act of 1978 (U.S. Congress, 1978) which provided a tax exemption for fuel-ethanol of 40 U.S. cents per gallon. Until today this tax exemption has been varied several times. A further important step was the Energy Policy Act of 2005 (U.S. Congress, 2005) which contained many provisions to support biofuel markets. One of the most effective instruments included was the Renewable Fuels Standard (RFS) which required 4 billion gallons (12Mn tons) per year of ethanol to be blended into gasoline by 2006, extending up to 7.5 billion gallons (22.4Mn tons) per year by 2012. Furthermore, beyond 2012, at least 0.25 billion gallons (0.75Mn tons) of this ethanol must come from cellulosic sources. In 2007, President Bush announced the so called “20 in 10 Plan” (Bush, 2007) which calls for a 20% reduction in the consumption of conventional fuels by 2017. This reduction should result from a combination of increased fuel efficiency and increased use of biofuels. This 20 in 10 Plan also set an Alternative Fuels Standard (AFS) of 35 billion gallons of biofuels per year by 2017 which is much more than the requirement set by the Energy Policy Act of 2005. Following this policy strategy the U.S. Congress enacted the Energy Independence and Security Act of 2007 (U.S. Congress, 2007). In this act a RFS of 36 billion gallons per year of biofuels by 2022 was introduced (Figure 2.2).

Figure 2.2: U.S. renewable fuel production and requirements

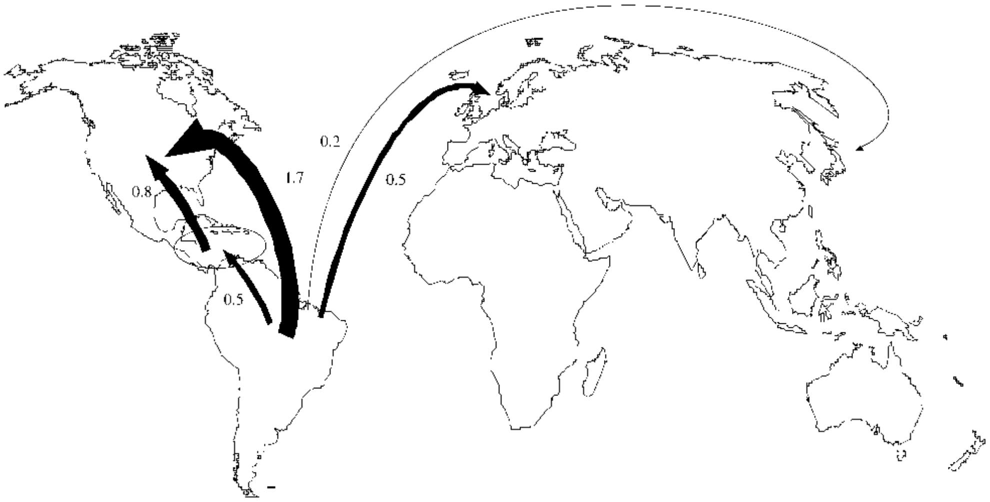


Source: Hoekman (2009)

In addition, 21 billion gallons per year must come from ‘advanced biofuels’ (for example cellulosic ethanol). For the first time, biodiesel was explicitly mentioned in the RFS, with a requirement of 1 billion gallons (3.3Mn tons) per year until 2012 (Hoekman, 2009). U.S. ethanol production has increased from 1.5 billion gallons (4.5Mn tons) in 1999 to 6.4 billion gallons (19Mn tons) in 2007 and 9 billion gallons (28Mn tons) in 2008, which is nearly equal to domestic consumption in 2008. However, this large volume of produced ethanol represents only about 4% (on energy basis) of total gasoline consumed in the U.S. (Hoekman, 2009). U.S. biodiesel production in 2008 only amounted to about 0.7

billion gallons (2.3Mn tons), but is also growing rapidly. The U.S. biofuel market is dominated by maize based ethanol. In 2006, 97% of U.S. ethanol was produced based on maize (Heinimö and Junginger, 2009). U.S. biodiesel is mainly based on soy oil. Even though the U.S. is the largest ethanol producer, the U.S. was net-importer of ethanol in 2008 which results from the also strong increasing domestic ethanol consumption. The only significant global ethanol exporter is Brazil with the U.S. and the EU27 being the largest importers as displayed in Figure 2.3.

Figure 2.3: Major ethanol trade streams in 2006, in Giga-Joule



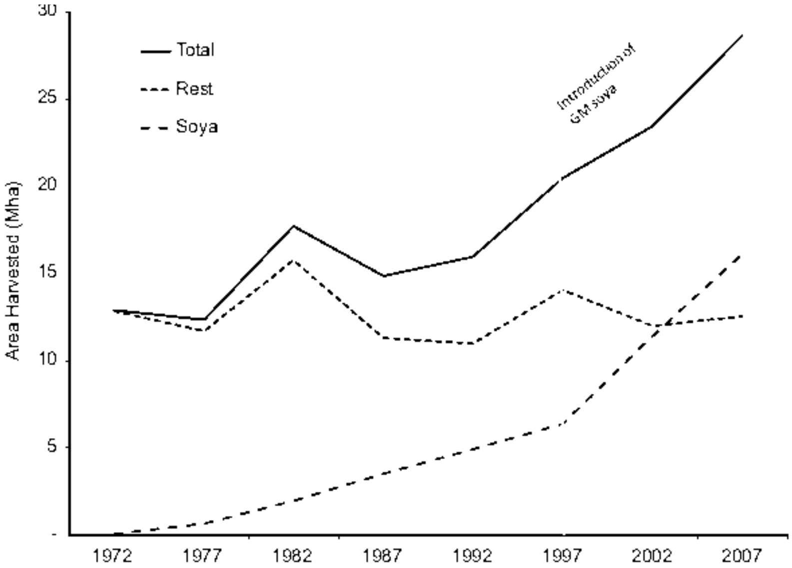
Source: Heinimö and Juninger (2009)

Brazil started with strong policy promotion for the use of fuel-ethanol already in the beginning 1970s. The Brazilian National Alcohol Programme - PROALCOOL (Brazilian Government, 1975) was established in 1975 with the main target to increase ethanol production for substituting gasoline consumption and thereby become independent from OPEC price policies. Following Da Costa et al. (2010) five phases of the PROALCOOL programme can be distinguished. In the 1st phase strong effort was set to increase ethanol production, using sugar cane based molasses, for blending with gasoline (1975–1979). The 2nd phase (1980–1986) was stimulated by a significant increase of the world crude oil price which reached U.S. $ 36/barrel. This led to an increase of ethanol production up to 12 billion litres (9.5Mn tons) in 1986. Furthermore, the share of ethanol cars increased from 0.46% in 1979 to 76.1% in 1986 (Da Costa et al., 2010). In the 3rd phase (1986 to 1995) Brazilian ethanol production stagnated as the world oil price decreased from U.S. $ 40 to U.S. $ 15/barrel. To secure the Brazilian biofuel market, the government reconsidered the PROALCOOL programme in 1995. This was the aim of the 4th phase which lasted until 2000 (Da Costa et al., 2010).

The government agreed to increase the alcohol blending share to gasoline from 22% to 24% to inhibit on the one hand a decreasing ethanol-car production and use and, on the other hand, a strategy change within the ethanol industry, which switch from ethanol to sugar production. The last phase which reaches to the present is characterised by an increasing global ethanol demand resulting from increasing crude oil prices and the renewable energy strategies of the EU27 and the U.S. (Da Costa et al., 2010). Combined with the availability of a very efficient biofuel feedstock, sugar cane, this early policy intervention has lead to a competitive biofuel industry today. Starting in 2008 the National Programme for Biodiesel - PNPB (Brazilian Government, 2004) the Brazil also begins to support biodiesel production with the objective to produce one billion litres of biodiesel per year. The programme also intends to increase biodiesel exports to the U.S. and Europe (Da Costa et al., 2010).

Against the background of an increasing biodiesel consumption in Europe and the U.S. several scientific sources (for example CAER, 2008; Tomei and Upham, 2009) signal that among others Argentina might become an important future producer and exporter of biodiesel, mainly based on soy oil. Excellent production conditions for soybeans caused by climatic conditions and relative low biodiesel production costs might encourage biodiesel production in the tropics. “*The key driver of biofuel markets in Argentina is not reducing emissions of greenhouse gases but rather economic development. Potential export markets, such as the EU, offer opportunities for increased trade and therefore economic development as poverty is a key concern for the Argentine government*” (Tomei and Upham, 2009, p.3892). Since 2006 Argentina has established a biofuel law which set a target of 5% (by volume) of biofuels in domestic fuel consumption which corresponds to approximately 0.6Mn tons of biodiesel and 0.2Mn tons of ethanol. However, as the domestic market has currently not the potential to demand large scale biofuel production quantities due to low domestic fossil fuel prices, biofuel producers are more interested in the growing export markets, especially into the EU27 and U.S. (Tomei and Upham, 2009). Another aspect is the fact that in order to promote domestic production of value added products, such as biodiesel, the Argentine government has installed reduced export taxes on such products. Exports of primary products like soy oil are faced to a much higher export tax. This situation leads to a strong support of the Argentine biofuel industry and let Argentina became the third largest biodiesel producer after the EU27 and the U.S. in 2008 (Figure 1.1). CAER (2008) estimates the biodiesel production capacity installed in Argentina in 2010 about 2.4Mn tons. As Argentine biodiesel production is mainly based on domestic produced soy oil and soybeans, respectively, soybean production in Argentina has also increased significantly within the last years as displayed in Figure 2.4.

Figure 2.4: Evolution of Argentine agricultural production



Source: Tomei and Upham (2009)

2.2. Europe

Since the early 1990s, the European Commission is discussing to amend the course of their long term energy strategy in a way that they will abate significant current and future problems such as the global warming effect, the regional concentration and limits of fossil energy resources and the rapidly increasing global demand for energy. Part of the current energy strategy is the introduction of biofuels, which are able to substitute fossil fuels in the transport sector and by doing so have the potential to reduce greenhouse gas emissions and the European energy dependency. Table 2.1 provides an overview of the main policy activities on European level regarding the promotion of biofuels until today.

Table 2.1: Chronological overview of EU biofuel policies

Reference	**Policy title**	**Year**	**Main aspects regarding biofuels**
CAP	Mc Sharry Reform	1992	Allowance to cultivate energy crops on set aside
COM (97) 599	White Paper: *Energy for the future - Renewable sources of energy*	1997	Articulation of overall targets (energy supply security, reduction of GHG emissions, etc.) which should be reached by using renewable energies

Cont. Table 2.1: Chronological overview of EU biofuel policies

Reference	**Policy title**	**Year**	**Main aspects regarding biofuels**
COM (2000) 769	Green Paper: *Towards a European strategy for the security of energy supply*	2000	"*Renewable sources of energy have considerable potential for increasing security of supply in Europe. Developing their use, however, will depend on extremely substantial political and economic efforts*"
Council meeting at Gothenburg	Communication on alternative fuels for road transport	2001	Agreement on a European strategy for sustainable development
Directive 2003/30/EC	Directive: *On the promotion of the use of biofuels or other renewable fuels for transport*	2003	Binding targets for biofuels (in % of energy in total EU27 fuel demand): 2005: 2.00% 2010: 5.75%
Directive 2003/96/EC	Directive: *On the taxation of energy products and electricity*	2003	Allows Member States to exempt or reduce excise duties for the promotion of biofuels
Directive 2003/17/EC	Revision of the Fuel Quality Directive 98/70/EC	2003	Incorporation of biofuels and biofuel-blends in fuel quality specifications
EN 14214	Revision of diesel norm and biodiesel quality norm	2003	Definition of minimum standards for biodiesel quality.
CAP	2003 reform	2003	Continuing the set aside regulation and introduction of an energy crop premium (45€/ha)
COM (2005) 628	*Biomass Action Plan*	2005	Set out to foster activities in analysing support policies, environmental standards, and global trade issues regarding biofuels.
COM (2006) 34	*An EU Strategy for Biofuels*	2006	Introduction of seven strategic policy areas for the development of the production and use of biofuels: "[…] *stimulate demand for biofuels, ensuring environmental benefits, developing the production and distribution of biofuels, expand feedstock supply, enhance the trade opportunities of biofuels, support developing countries and support research and innovation*."
EUR 22066	*Final report of the Biofuels Research Advisory Council*	2006	Advise for an indicative target for 2030 of 25% biofuels in EU27
COM (2006) 848	*Renewable energy road map - Renewable energies in the 21st century: building a more sustainable future*	2007	Indicative target for biofuels in 2020 of 10%
Directive 2009/28/EC	Directive: *On the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*	2009	Binding target of 10% biofuels in 2020. Definition of sustainability criteria for biofuels.

Source: Own compilation based on the different references mentioned in the table

In particular Directive 2003/30/EC and the subsequent amendment of 2009 (Directive 2009/28/EC) are of high importance because they set binding biofuel targets which should be reached by each European Member State: 5.75% in 2010 and 10% in 2020[1] (Table 2.1), subject to compliance with sustainability criteria for biofuels and the promotion of 2nd generation biofuels. The Biofuels Research Advisory Council stated a strategic target of 25% biofuels in 2030 which is not yet enforced by the European legislation but for the sake of completeness also mentioned here. While all Member States are obliged to meet the binding targets, the policy instruments selected for this purpose are flexible. Therefore, European Member States can implement support policies like tax exemptions or blending obligations (quotas) on the demand side and for example investment incentives or production subsidies on the supply side. As stated in Directive 2003/30/EC and subsequently also in Directive 2009/28/EC all European Member States are additionally obliged to report annually about the market status of biofuels and the policy instruments they have implemented to support them[2]. By comparing the reports of 2004 to 2009 a tendency of changing from predominately consumer tax exemptions in the initial phase (2004 - 2006) to predominately blending obligations in recent years can be observed. This tendency might result from the fact that the progress in biofuels envisaged by the European Commission was not achieved by most Member States in 2005. Also the situation in 2008, reported in the progress report of 2009 (European Commission, 2009) signal that the effort undertaken by some Member States was still insufficient to reach the 2010 target of 5.75%. A classification of the applied support policies can be done (1) by the policy area which is responsible for their implementation and (2) by the type of instrument. Regarding (1) three policy areas can be distinguished. The first one is agricultural policy. Measures which are implemented here focus on the promotion of crops which are exclusively produced for energy purposes (energy crops). Agricultural policies are handled on European level within the framework of the CAP. The second policy area which has a significant influence on the production of bioenergies and biofuels is the regional or structural policy. Support measures which result from this area are also predominately handled on European level, covering mainly investment subsidies based on structural funds. The last and most important area is the energy policy. Important energy policy issues are still handled under national authority on European Member State level (Breuer and Becker, 2008). Here, many countries reorganise their biofuel support strategies in relative short time intervals or have not implemented such instruments so far but

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[1] Share of renewable energies in total transport energy consumption.

[2] Member State reports are published by the European Commission. Available at: ec.europa.eu/energy/renewables/biofuels/ms_reports_dir_2003_30_en. Access date: 22.10.2010.

are discussing their implementation. From this it follows that a survey of biofuel policies implemented by the different European Member States requires a continuous update and any given survey will only provide a snap-shot. Based on the type of instrument the applied policies can be differentiated by two main criteria (Table 2.2): They are either regulatory or voluntary and they are either price or quantity-driven (Ragwitz et al., 2005).

Table 2.2: Classification of bioenergy / biofuel promotion instruments

		Price-driven	**Quantity-driven**
Regulatory	**Investment focussed**	• ***Investment incentives*** • Tax incentives	• Tendering system
	Production based	• Feed-in tariffs • ***Tax exemptions***	• Tendering system • ***Quota obligation*** • Environmental taxes
Voluntary	**Investment focussed**	• Shareholder programmes • Contribution programmes	• Voluntary agreements
	Production based	• Green tariffs	

Note: The bold and italicised instruments are the most used for the promotion of biofuels in the EU27.
Source: Ragwitz et al. (2005)

Regarding biofuels, the most applied instruments are investment incentives, consumer or producer tax exemptions and quota obligations. Tendering systems are also used but only rarely. Investment incentives support the development of renewable energy or fuel plants as a percentage subsidy over total costs, or as a defined amount of funds per installed unit of output (Ragwitz et al., 2005). The level of incentive is usually technology specific and often capped for large-scale plants. Quotas based on regulatory, not tradable obligations are often used in the case of biofuels to achieve a fast increase of market shares. Suppliers of fossil energies or fuels are forced to enclose a minimum of renewable energies or fuels in their supply. The quota could be formulated as a share (%) in total domestic supply or demand or as a fix amount over a specific time period. Production tax exemptions are production based, price driven mechanisms which work through payment exemption from the electricity or fuel taxes applied (Ragwitz et al., 2005). Tendering systems are quantity driven mechanisms. The financial support can either be focused on investment or on production. In the first case, a defined amount of capacity to be installed is announced and contracts are given following a predefined bidding process which offers winners favourable investment conditions (Ragwitz et al., 2005). The production based tendering systems work in a similar way. However, instead of providing up front support, they offer support in the size of the bid price per output unit for a guaranteed duration (Ragwitz et al., 2005). As well as the regulatory instruments, more and more voluntary approaches have appeared with ongoing market liberalisation. They are based on the willingness of consumers to pay premium rates for renewable energy or biofuels. However, in terms of effectiveness, their impact on total renewable energy or fuel deployments is negligible (Ragwitz et al., 2005). The current biofuel policies applied, summarised from the 2009 Member State reports (European Commission, 2009) are displayed in Table 2.3.

Table 2.3: Biofuel policy instruments in European Member States

		Ethanol	Bio-diesel	Diesel	Gasoline	*in force*		Ethanol	Bio-diesel	Diesel	Gasoline	*in force*
Austria	CTAX.B	442	347	~	~	*2007*	Irland	510	370	~	~	*2010*
	CTAX.P	0	0	375	475	*2007*		510	370	370	510	*2010*
	OBLI	5.75%	5.75%	~	~	*2008*		6.00%	6.00%	~	~	*2012*
Bulgaria	CTAX.B	▨	▨	~	~	*2009*	Italy	▨	▨	~	~	~
	CTAX.P	0	0	270	320	*2009*		▨	▨	420	560	*2009*
	OBLI	~	~	~	~	~		5.75%	5.75%	~	~	*2010*
Belgium	CTAX.B	▨	▨	~	~	~	Lithuania	0	0	~	~	*2008*
	CTAX.P	▨	▨	350	620	*2009*		0	0	190	280	*2008*
	OBLI	~	~	~	~	~		5.75%	5.75%	~	~	*2010*
Luxemb.	CTAX.B	▨	▨	~	~	~	Latvia	306	191	~	~	*2008*
	CTAX.P	▨	▨	290	460	*2009*		0	0	240	290	*2008*
	OBLI	~	~	~	~	~		~	~	~	~	~
Cyprus	CTAX.B	470	360	~	~	*2009*	Malta	0	0	~	~	*2008*
	CTAX.P	470	360	360	470	*2009*		0	0	360	474	*2008*
	OBLI	2.00%	2.00%	~	~	*2010*		~	~	~	~	~
Czech Republic	CTAX.B	470	268	~	~	*2008*	The Netherl.	▨	▨	~	~	~
	CTAX.P	0	0	389	470	*2008*		▨	▨	370	670	*2009*
	OBLI	4.00%	4.00%	~	~	*2009*		5.75%	5.75%	~	~	*2010*
Germany	CTAX.B	650	480	~	~	*2009*	Poland	▨	▨	~	~	~
	CTAX.P	0	450	480	650	*2014*		▨	▨	330	440	*2009*
	OBLI	8.00%	8.00%	~	~	*2015*		~	~	~	~	~
Denmark	CTAX.B	0	0	~	~	*2005*	Portugal	▨	▨	~	~	~
	CTAX.P	0	0	400	515	*2005*		3	3	280	520	*2007*
	OBLI	~	~	~	~	~		▨	▨	~	~	~
Estonia	CTAX.B	0	0	~	~	*2005*	Romania	0	0	~	~	*2008*
	CTAX.P	0	0	250	290	*2005*		0	0	260	310	*2009*
	OBLI	~	~	~	~	~		4.00%	4.00%	~	~	*2009*
Greece	CTAX.B	360	290	~	~	~	Sweden	▨	▨	~	~	~
	CTAX.P	360	290	290	360	*2009*		▨	▨	450	550	*2009*
	OBLI	~	~	~	~	~		▨	▨	~	~	~
Spain	CTAX.B	0	0	~	~	*2008*	Slovenia	▨	▨	~	~	~
	CTAX.P	0	0	300	430	*2008*		▨	▨	320	400	*2009*
	OBLI	5.83%	5.83%	~	~	*2010*		7.50%	7.50%	~	~	*2015*
Finland	CTAX.B	650	350	~	~	~	Slovak Republic	0	0	~	~	*2008*
	CTAX.P	650	350	350	650	*2009*		0	0	460	523	*2008*
	OBLI	5.75%	5.75%	~	~	*2011*		5.75%	5.75%	~	~	*2010*
France	CTAX.B	460	350	~	~	*2011*	United Kingdom	620	680	~	~	*2010*
	CTAX.P	0	0	430	600	*2011*		620	680	680	620	*2010*
	OBLI	7.00%	7.00%	~	~	*2010*		5.00%	5.00%	~	~	*2010*
Hungary	CTAX.B	▨	▨	~	~	~	*CTAX.B= Consumer tax for blended fuel (€/1000l)*					
	CTAX.P	▨	▨	360	430	*2009*	*CTAX.P= Consumer tax for pure fuel (€/1000l)*					
	OBLI	~	~	~	~	~	*OBLI= Quota (energy share in fuel supply)*					

Note: in force=Year in which the instrument becomes legally binding; ~ = No policy in place (status 2009)
Source: Own compilation based on European Commission (2009)

The shaded cells signalise that the applied instrument could not be clearly identified which results either from the fact that they are still under discussion or no sufficient information was available. Furthermore, this survey only covers the most important instruments for the promotion of biofuels in Europe which are consumer tax exemptions and quota obligations. As most policies are defined for a time period (for example a quota obligation sets 2% in 2005, 4% in 2009, 6% in 2010 and 8% in 2015) only the latest available definition next to 2020 is selected and displayed in Table 2.3. The column ‘in force’ indicates the respective year in which the instrument has became or will become legally binding. In addition, the consumer taxes for fossil fuels (gasoline and diesel) are displayed to give a reference value for the amount of reduction applied for biofuels. As one can observe, about half of the Member States have implemented quota obligations until 2008, partially in combination with a consumer tax reduction, for example for pure biofuels, partially as a stand-alone instrument.

3. Biofuel representation in existing economic models

In order to relate the methodological concept and the specific features of the CAPRI biofuel model to existing biofuel modelling approaches, selected models are presented and shortly described here. Most of them cover an endogenous biofuel market representation and are already applied in scientific literature for the evaluation of future biofuel markets.[3] In general, two different model types can be distinguished for the evaluation of biofuel impacts: economic and non-economic modelling approaches. "*Economic models build on behavioural reactions - producers and consumers responding to price signals - which are supposed to be the dominant adaptive mechanism in market economies*" (De Vries, 2009, p.7). Here, the equilibrating interplay between supply and demand determines prices and quantities of biofuels as well as prices and quantities of connected markets. "*Non-economic models* […] *primarily lean upon forecasting techniques like linear programming, trend extrapolation, input-output matrices and system dynamics*" (De Vries, 2009, p.7). Non-economic models are often used in natural science for example to evaluate environmental impacts of certain market activities. The linkage of both model types is often applied in the literature to analyse the detailed physical impacts of economically derived market behaviour, as done for example in Leip et al. (2008) where the CAPRI model was linked to the biophysical model DNDC[4] to assess nitrogen and carbon losses from arable soils in Europe which are affected by agricultural cropping activities under a specific CAP setting. In the following, only economic modelling approaches are described which have a similar focus and a comparable structure like CAPRI.

The focus of the CAPRI biofuel model is to forecast and quantify primarily economic impacts of global and in particular European biofuel policies on global biofuel and agricultural markets with a detailed representation of the EU27 and its Member States. This covers supply, demand, trade and price shifts of biofuels and agricultural products. Beside these economic impacts also some environmental impacts are addressed, but exclusively those which are caused by changes in the production of agricultural products (for example greenhouse gas emission from agricultural production activities or losses of biodiversity by changes in agricultural landscape). Economic models which also address this kind of focus and which include a representation of biofuel and biofuel feedstock markets as

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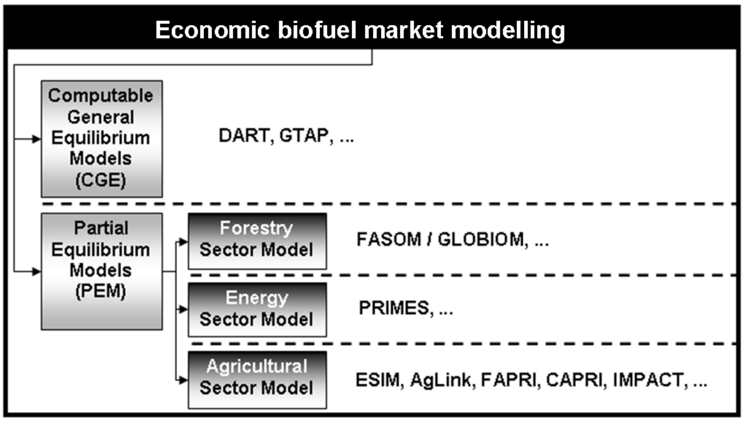
[3] A summary of model results will not be presented here. This is done in Chapter 7 to allow for a simultaneous comparison of results from the CAPRI biofuel model with these existing projections.

[4] DeNitrification - DeComposition model (DNDC). More information available at: www.dndc.sr.unh.edu. Access date: 26.10.2010.

well are first and foremost other partial equilibrium models (PEM) of the agricultural sector, like the European Simulation Model (ESIM), the model of the Food and Agricultural Policy Research Institute (FAPRI), the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), or the agricultural sector model of the OECD and FAO (AgLink-COSIMO). As the biofuel sector is strongly connected to the energy sector, some energy sector models like the European energy sector model PRIMES of the Economic-Energy-Environment Modelling Laboratory (E^3M-Lab) also incorporate biofuel markets and furthermore a more or less rough representation of biofuel feedstock markets. The same is true for partial equilibrium models which are primarily focussing on the forestry sector, like the European Forest and Agricultural Sector Optimization Model (EU-FASOM) or the Global Biomass Optimization Model (GLOBIOM). By contrast to partial also whole economy models (Computable General Equilibrium Models - CGE) have introduced biofuel market representations in their modelling systems. One of the well known CGE's is the Global Trade Analysis Project (GTAP) model of which some versions were extended to cover biofuels like the GTAP Energy model (GTAP-E) or the GTAP Biofuel model (GTAP-BIO). Also well developed for biofuel markets in a general equilibrium framework is the Dynamic Applied Regional Trade model (DART). Figure 3.1 gives an overview on some economic models stemming from different fields of economic research which all incorporate a biofuel market representation. These models will be described explicitly in this chapter as they are currently the most developed economic models with respect to biofuels and the most applied and discussed ones in the scientific literature.

Figure 3.1: Overview of selected economic market models covering biofuels



Source: Own compilation

The general question if PEM or CGE models are better suited to assess biofuel market developments and impacts is often discussed in the literature. The pros and cons are obvious. Partial equilibrium models have a rather detailed representation of the market they focus on, meaning that each covered product is represented by its own supply and demand function, whereas the covered product list is very detailed. Furthermore, the spatial differentiation is often also very detailed. Thus, "[…] *the strengths of PE-models lie in their relatively high level of sectoral, regional and institutional detail*" (De Vries, 2009, p.8). However, this high detail level equivalently triggers the main obstacle of partial equilibrium models with regard to the biofuel market: they neglect or at most consider a simplified treatment of interactions with the rest of the economy. General equilibrium models, on the other hand, allow simulating "[…] *potential impacts of prospective economic policies taking into account inter sectoral and international interactions*" (Beckman and Hertel, 2009, p.5). In the case of biofuel markets in particular this capability seems to be important as one has to take into account both, agricultural and energy markets and their interactions, respectively. However, the detailed level and thereby the disaggregation level of products and spatial regions covered in general equilibrium models is very limited. "*E.g. the number of primary agricultural products seldom exceeds ten. As a result, the design of GE-models may be too big-boned to enable recognition of the impacts from a single production chain like bioenergy*" (De Vries, 2009, p.9). It depends on the respective focus of the envisaged analysis which approach is more appropriate. If impacts on the agricultural sector should be investigated in detail, a partial equilibrium approach surely allows for highlighting agricultural market impacts in more detail. If the linkages between the energy, agricultural and further sectors should be analysed in detail, a general equilibrium approach seems to be more suitable. However, the possibility to link these modelling approaches and thereby using the strengths of both types can help to overcome the individual limits as done for example in Britz and Hertel, 2009. An alternative solution to overcome the missing feedback from other sectors from a partial equilibrium point of view is the incorporation of approximating functions which mimic market behaviour of external sectors where relevant interactions are observed.

Within the following survey, which is done in table form to allow for a better comparison (Table 3.1), the following crucial model features are described:

- General type: Partial equilibrium -PEM or general equilibrium -CGE model?

- Detail level of biofuel markets: Which biofuels are differentiated? Which production technologies are considered (1st and 2nd generation)? What agricultural products are considered as biofuel feedstocks? Are agricultural residues or new energy crops considered as 2nd generation biofuel feedstocks? How are biofuel by-products covered in the model? Are by-products linked to the feed market? How is biofuel demand modelled? Is biofuel trade considered (if yes, as a net-trade or bilateral trade model)?

- Simulation horizon: Which projection horizon is applied? Are intermediate projections possible (comparative static or recursive dynamic model)?
- Regional disaggregation: On which spatial level are projections possible?
- Presence of inter-sectoral interactions: Is an inter-sectoral linkage possible (for example between the energy and agricultural sector, or even whole economy)?

As one can observe in Table 3.1 all mentioned modelling systems include a behavioural model of the biodiesel and ethanol market, meaning that explicit supply and demand functions for the main biofuels are incorporated. The only exception is the IMPACT model where biofuel scenarios are modelled as a demand shock for agricultural commodities based on exogenously given biofuel production quantities and fixed conversion coefficients (Rosegrant et al., 2008 and Witzke et al., 2010). This treatment has the advantage that the modelling effort is very limited and rough biofuel market assessments can be done very fast. However, the main obstacle is the missing feedback from feedstock markets to biofuel supply and from biofuel supply to biofuel demand, meaning that price shifts of agricultural products do not affect biofuel supply and price shifts of biofuel products do not affect biofuel demand. The price responsiveness is only one example, other supply and demand drivers like various policy measures cannot be considered as a result of the exogenous treatment, too. Table 3.1 shows that biofuel supply and biofuel feedstock demand are covered in differed detail regarding the coverage and aggregation level of usable agricultural products (biofuel feedstocks) and the production technology applied (1st and 2nd generation). Starting from the considered production technologies the AgLink-COSIMO and PRIMES model include the most detailed biofuel supply differentiation. Here, biofuel supply, differentiated into ethanol and biodiesel, can be produced from 1st generation feedstocks, 2nd generation feedstocks and non-agricultural sources. The FAPRI model also considers a differentiation in 1st and 2nd generation biofuels. However, production based on non-agricultural feedstocks is not included. The GLOBIOM model differentiates only ethanol production in 1st and 2nd generation, whereas biodiesel is only represented by 1st generation technologies. The two CGE models DART and GTAP-BIO as well as the ESIM model do not distinguish 1st and 2nd generation biofuel production.

Table 3.1: Overview of selected economic models covering biofuel markets

Model	Applied by	Sector	Spatial differentiation	Product differentiation	Projection horizon	Further characteristics	References regarding biofuels
ESIM (European Simulation Model)	LEI[5] Uni. Hohenheim IPTS[6]	PEM: Agriculture	EU27 NUTS1[7] Turkey USA Rest of world	• 18 agricultural products • 12 feeding products • Ethanol, biodiesel (1st gen.) • 3 biofuel feedstock groups (plant oils, wheat, maize, sugar) • 4 biofuel by-products (gluten feed and meals from 3 different oils)	2020	• Comparative static • Net-trade • Explicit supply and demand functions for 1st gen. biofuels • Total fuel demand exogenous (based on PRIMES)	Banse and Grethe 2008 Blanco Fonseca et al. 2010
AgLink - COSIMO	OECD[8] FAO[9]	PEM: Agriculture	20 world regions (not al considered for biofuels) EU aggregates: EU12, EU15 (only EU27 for biofuels)	• 10 agricultural products • Ethanol and biodiesel (1st and 2nd gen.) • 6 biofuel feedstocks: agg. veg. oils, sugar beets, sugar cane, wheat, coarse grains and non-agricultural • 4 biofuel by-products (oil meals, DDGS, CGF, protein rich feed)	2020	• Recursive dynamic • Net-trade • Explicit supply and demand functions for 1st gen. biofuels • Exogenous representation of 2nd gen. biofuels • Total fuel demand exogenous	Lampe 2006 Lampe 2008 Blanco Fonseca et al. 2010
IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade)	IFPRI[10]	PEM: Agriculture	115 regions (focus on developing countries) EU aggregated	• 30 crop and livestock commodities • 5 biofuel feedstocks (maize, wheat, cassava, sugar cane, oilseeds) • No biofuel by-products considered	2010 2015	• Net-trade (not for biofuels) • No explicit supply / demand functions for biofuels	Rosegrant, et al. 2008 Witzke, et al. 2010

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[5] Agricultural Economics Research Institute - LEI, The Hague (Netherlands). Available at: www.lei.wur.nl. Access date: 18.04.2011

[6] Institute for Prospective Technological Studies - IPTS, Seville (Spain). Available at: www.ipts.jrc.ec.europa.eu. Access date: 18.04.2011

[7] Nomenclature of Statistical Territorial Units - NUTS. Available at: epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction. Access date: 18.04.2011

[8] Organisation for Economic Co-Operation and Development - OECD, Paris (France). Available at: www.oecd.org. Access date: 26.10.2010.

[9] Food and Agriculture Organization of the United Nations - FAO, Rome (Italy). Available at: www.fao.org. Access date: 26.10.2010.

[10] International Food Policy Research Institute - IFPRI, Washington DC (USA). Available at: www.ifpri.org. Access date: 26.10.2010.

Cont. Table 3.1: Overview of selected economic models covering biofuel markets

Model	Applied by	Sector	Spatial differentiation	Product differentiation	Projection horizon	Further characteristics	References regarding biofuels
FAPRI model (Food and Agricultural Policy Research Institute Model)	CARD[11] CNFAP[12]	PAM: Agriculture	EU25 agg. 31 countries and rest of world (for ethanol 8, for biodiesel 4 regions considered)	• 20 agricultural products • Ethanol and biodiesel (1st+2nd gen.) • 3 ethanol feedstocks: maize, non-maize products, cellulosic biomass • 3 biodiesel feedstocks: rape, palm and soy oil • 2 by-products (DDGS, corn oil)	2023	• Non-Spatial • Recursive dynamic • Net-trade • Explicit supply and demand functions for 1st gen. biofuels	Binfield, et al. 2008 Fabiosa, et al. 2009 Carriquiry, et al. 2010
GLOBIOM (Global Biomass Optimization Model)	IAASA[13]	PEM: Forestry Agriculture	2 settings: Either 11 regions (IIASA GCI[14]) or 27 regions for the linkage to the POLES[15] model	• 30 crops (17 crops detailed) • Ethanol (1st and 2nd gen.) based on 3 feedstocks: sugar cane, maize and fast growing trees. • Biodiesel (1st gen.) based on rape and soy oil. • Biofuel by-products not considered • Alternative feedstock considered	2030	• Recursive dynamic • Explicit supply and demand functions for 1st gen. biofuels • Total fuel demand exogenous (POLES)	Havlik et al. 2010 Witzke et al. 2010
PRIMES (Biomass-model)	Uni. Athens[16]	PEM: Energy	EU27 NUTS 1 Rest of world	• Ethanol and biodiesel (1st and 2nd generation) • By-products considered, no feed market • 8 biofuel feedstocks: 4 crops and 4 biomass waste aggregates	2030	• Recursive dynamic,net-trade • Explicit demand functions for biofuels in the core model • Explicit supply functions for biofuels and biofuel feedstocks	Mantzos and Capros 2006 Capros 2010

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[11] Iowa State University, Center for Agricultural and Rural Development-CARD, Ames (USA). Available at: www.card.iastate.edu. Access date: 26.10.2010.

[12] University of Missouri-Columbia, Center for National Food and Agricultural Policy-CNFAP, Columbia (USA). Available at:www.fapri.missouri.edu. Access date:26.10.2010.

[13] International Institute for Applied Systems Analysis - IIASA, Laxenburg (Austria). Available at: www.iiasa.ac.at. Access date: 26.10.2010.

[14] Regions definition by the Greenhouse Gas Initiative (GGI) at the IIASA

[15] POLES: Prospective Outlook on Long-Term Energy Systems model. Applied at the IPTS, Seville (Spain).

[16] National Technical University of Athens, Institute of Communication and Computer Systems, Athens (Greece). Available at: www.e3mlab.ntua.gr. Access date: 26.10.2010.

Cont. Table 3.1: Overview of selected economic models covering biofuel markets

Model	Applied by	Sector	Spatial differentiation	Product differentiation	Projection horizon	Further characteristics	References regarding biofuels
GTAP-BIO (Global Trade Analysis Project)	Uni. Purdue[17]	CGE: Overall Economy	19 regions, each divided into several agro-ecological-zones EU27 aggregate	• 6 crops • Ethanol and biodiesel (1st gen.) • 4 feedstock aggregates: cereal grains, sugar cane / beets, veg. oils • No palm oil or new energy crops • 4 by-products (veg. oil by- products, distillers solubles, wet distillers grains, DDGS)		• Static • Bilateral trade (Armington) • Explicit supply and demand functions for 1st gen. biofuels	Britz and Hertel 2009 Taheripour, et al. 2010 Birur, et al. 2008 Witzke, et al. 2010 Banse, et al. 2008a
DART (Dynamic Applied Regional Trade Model)	IfW[18]	CGE: Overall Economy	Biofuel version: 12 regions	• 27 products: 13 energy, 11 agri. • Ethanol and biodiesel (1st gen.) • 5 biofuel feedstocks: wheat, corn, agg. veg. oils, agg. sugar crops • No by-products, no energy crops	2020	• Recursive dynamic • Bilateral trade • Explicit supply and demand functions for 1st gen. biofuels	Kretschmer et al. 2008 Kretschmer et al. 2009a Kretschmer et al. 2009b Kretschmer et al. 2009c

Source: Own compilation based on the references mentioned in the table

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[17] Purdue University, Center for Global Trade Analysis, West Lafayette (USA). Available at: www.gtap.agecon.purdue.edu. Access date: 26.10.2010.

[18] Kiel Institute for World Economy-IfW, Department for Environment and Natural Resources, Kiel (Germany). Available at: www.ifw-kiel.de. Access date: 26.10.2010.

With respect to agricultural market impacts the detailed level of the considered biofuel feedstocks plays an important role. The ESIM model considers six feedstocks, vegetable oils (differentiated in sunflower, rape and soy oil), wheat, maize and sugar. In addition the AgLink model considers also 2nd generation feedstocks (new energy crops). Here, sugar crops are further differentiated into sugar beets and cane, whereas vegetable oils are only covered by an aggregate which does not allow for a differentiation of rape, soy, sunflower or palm oil. Cereals are differentiated in wheat and coarse grains (including maize). The FARPI model allows also for a differentiation of different vegetable oils, including palm oil, but distinguishes only ethanol from maize, non-maize products and cellulosic biomass. A similar feedstock differentiation is covered by the GLOBIOM model, which also does not cover cereals apart from maize for ethanol production. However, sugar cane, rape and soy oil are covered explicitly. The IMPACT model which has a strong focus on developing countries covers also cassava as a biofuel feedstock. Here, maize, wheat and sugar cane are explicitly covered, while vegetable oils are not differentiated. The two CGE models as well as the PRIMES model have a very aggregated feedstock coverage. GTAP-BIO only differentiates cereals, sugar crops and vegetable oils. Equivalently, PRIMES differentiates only starchy crops, vegetable oils and sugar crops. However, PRIMES considers four alternative biomass forms consisting of different agricultural and non-agricultural residues and waste. The DART model distinguishes wheat, maize, aggregated vegetable oils and sugar crops. Equivalently to the GTAP-BIO model new energy crops or agricultural residues are not considered. From this it follows that at the current setting no model exists which provides a detailed coverage of 1st and of 2nd generation biofuel feedstocks at the same time.

Also of high importance from an agricultural market perspective is the capability of the models to cover the linkage between the production of biofuel by-products (e.g. gluten feed and DDGS) and the feed market. Total demand for traditional agricultural feed might be reduced as biofuel by-products can be used as substitutes on the feed market. If this substitution effect is not considered, the demand growth for agricultural products caused by biofuel production might be overestimated. Within the selected biofuel models the ESIM, AgLink, GTAP-BIO and FAPRI model cover biofuel by-products and their linkage to the feed market. ESIM incorporates four by-products, gluten feed from ethanol processing and oil meals from three different oil seeds (soy, sunflower and rape seed). AgLink covers a more differentiated spectrum of by-products: DDGS and corn gluten feed from ethanol production and oil meals (as an aggregate with respect to the aggregation of vegetable oils) as well as protein rich feed from biodiesel processing. The GTAP-BIO model coverage is similar but here, beside DDGS, also wet distillers grains are differentiated which is an important by-product especially in the U.S. ethanol industry. FAPRI only distinguishes between DDGS and corn oil. A special case is the PRIMES model which covers also some biofuel by-products which can not be used in the feed sector like for example glycerine, stemming from the conversion of vegetable oils to biodiesel. However, feed markets are not incorporated in the PRIMES model. All other models (DART, GLOBIOM, IMPACT) do not consider biofuel by-products at all.

The spatial differentiation is a further distinctive feature of the above mentioned models. Only ESIM and PRIMES allow for a differentiation in individual EU27 Member States. However, these models are limited in the non-European country differentiation. PRIMES aggregates all non-European countries to one rest of world block (ROW). The same is true for ESIM with the exception that the U.S. and Turkey are covered explicitly. All other models aggregate the EU to a EU27 or EU25 block. However, the non-European country coverage varies. AgLink covers twenty regions (which themselves include fifty-two countries). GLOBIOM has two model settings which distinguish either eleven or twenty-seven global regions. The IMPACT model is much more differentiated in non-European countries. Here, one-hundred-and-fifteen market regions are distinguished which include most of the developing countries explicitly. In general, the FAPRI model is differentiated on non-European level, but the biofuel version distinguishes only eight regions for ethanol and four regions for biodiesel. GTAP-BIO and DART provide the most aggregated spatial coverage. GTAP-BIO distinguishes nineteen global regions, DART only twelve in its biofuel version.

One additional feature which should be highlighted at this point is the capability of the different models to represent biofuel trade. In general, all considered models represent biofuel trade with the exception of IMPACT. However, only the two CGE models (GTAP-BIO and DART) allow for a bilateral trade treatment, meaning that trade flows between two trade partners can be quantified explicitly and can be differentiated into import and export flows simultaneously. All other models include a net-trade representation for biofuels.

The last model characteristic resulting from the partial or general equilibrium characteristic of the individual model is the capability to cover linkages between different economic sectors. In the case of the biofuel market which is first and foremost linked through (bio-) fuel demand with the energy sector and through biofuel feedstock demand with the agricultural/forestry sector, the model should ideally be able to display responses of (bio-) fuel and biofuel feedstock demand to shifts in (bio-) fuel and biofuel feedstock prices. The general equilibrium models are per definition able to represent this linkage, as they cover the whole economy, including various economic sectors. In general all partial equilibrium models have to handle this problem through exogenous assumptions.

4. The CAPRI biofuel model

A description of the general concept and structure of the CAPRI modelling system is given as an introduction to the following chapter[19]. In addition, the initial representation of biofuel markets in the model will be discussed to indentify the capabilities and limitations of the previous model setting (Section 4.1). In Sections 4.2 to 4.8 the development of the CAPRI biofuel model is then described in detail. This chapter closes with a discussion on indicators usable to evaluate environmental impacts of shifts in agricultural production caused by an increasing biofuel production (Section 4.9).

4.1. General concept of CAPRI

In technical terms the CAPRI model can be described as an economic, comparative static[20], spatial[21], partial equilibrium model focussing exclusively on the agricultural sector. The system of behavioural functions within CAPRI is differentiated in two interlinked modules, a regional *supply module* and a global *market module*. The overall model structure of CAPRI and the linkage between the supply and the market module are displayed in Figure 4.1.

The supply module of CAPRI consists of independent non-linear programming models determining agricultural supply of crops and animal outputs individually for all EU27 countries and each of the respective administrative sub-units (NUTS2 regions). The programming models combine a Leontief-technology for variable costs covering a low and high yield variant for the different production activities with a non-linear cost function which captures the effects of labour and capital on the supply decisions. The module covers about fifty crop and animal activities for each of the around two-hundred-eighty EU27 NUTS2 regions. It capture in detail the premiums paid under the CAP, include nutrient balances and

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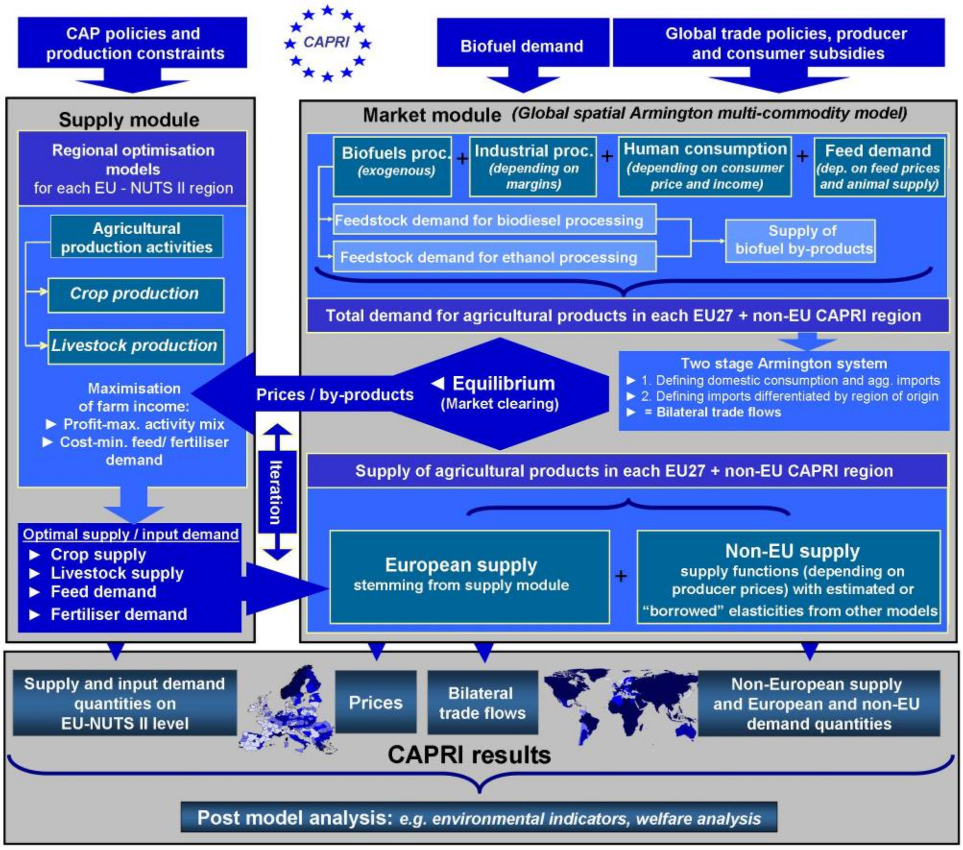
[19] For more detailed information about single CAPRI model components, their technical realization, related scientific publications and current or past research projects where the CAPRI model was or is involved, the CAPRI web page (www.capri-model.org, access date: 18.04.2011) provides a detailed source. In addition, a detailed model documentation is available (Britz and Witzke, 2009).

[20] Comparative static means that the model is able to estimate and compare shifts of a market equilibrium which has been initially estimated *for a particular point in time* (baseline), when external forces (exogenous variables of the model) are varied. In general this is done by comparing the baseline with different scenarios (sets of exogenous drivers), or scenario results among each other.

[21] Spatial stands for the capability of the model to represent bilateral trade of agricultural products. This is done by applying an Armington approach which drives the composition of demand from domestic sales and different import origins depending on price ratios (Britz and Witzke, 2009).

a module with feeding activities. Prices are exogenous in the supply module. They are provided by the market module which also covers non-European supply (Britz and Witzke, 2009).

Figure 4.1: General structure of the CAPRI model (initial setting)



Source: Own illustration based on Becker (2008) and Britz and Witzke (2009)

The market module of CAPRI is a global, spatial, multi-commodity model. It covers about fifty primary and secondary agricultural products and about sixty countries or country-aggregates. The market module includes behavioural function for non-European supply, European and non-European demand and bilateral trade. The supply functions depend basically on producer prices. Total demand is defined as the sum of demand for industrial processing (depending on processing margins), feed demand (depending on feed prices and animal supply), human consumption (depending on per capita income and consumer prices) and biofuel processing demand, which is handled exogenously in the initial CAPRI version. The used and implemented function parameters and elasticities are predominately derived from other global agricultural models.

Bilateral trade flows and prices are modelled based on the Armington assumptions (Armington, 1969). A two level Armington system is applied where at the top level domestic sales and overall imports of agricultural products are defined as a function of the internal market price and the average price for imports. The second stage then determines the import shares from different origins. Policy instruments which are considered cover producer support equivalents (*PSE*) and consumer support equivalents (*CSE*), tariffs, tariff rate quotas (*TRQ*) and for the EU27 intervention purchases and subsidised exports (Britz and Witzke, 2009).

Within the general concept of a scenario analysis done by applying the CAPRI model a reference scenario (baseline) for the projection year has to be developed. The baseline is estimated statistically (based on ex-post market observations and under consideration of external expert knowledge) to which the behavioural model is then calibrated. After the calibration procedure the behavioural model permits to run counterfactual scenarios which estimate new market equilibriums depending on the set of explanatory variables assumed. For the statistical estimation of a baseline and for the specification and calibration of the behavioural model a sufficient ex-post database is required which has to include time series for all relevant model variables, first and foremost market balance positions of agricultural commodities, prices, and technological parameters. When possible, well-documented, official and harmonised data sources are used to develop this database, like EUROSTAT[22], FAOSTAT[23] or OECDStatExtracts[24]. Explicit model components ensure that the CAPRI database is complete and consistent (Britz and Witzke, 2009).

To allow for rough estimates regarding the impacts of an increasing production of biofuels on the agricultural sector the CAPRI model was extended for the first time in 2007 by Wolfgang Britz[25]. He implemented a simplified treatment of 1st generation biofuel production into the model by introducing the new demand component *biofuel processing demand* (*BIOF*) in the framework of the CAPRI demand system. At that time, it was decided to refrain from implementing a behavioural model of the biofuel industry. Rather, an exogenous construction was implemented by using biofuel conversion coefficients (which define the

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[22] Statistical Office of the European Commission. Available at: epp.eurostat.ec.europa.eu. Access date: 18.04.2011.

[23] FAO statistics. Available at: http://faostat.fao.org. Access date: 18.04.2011.

[24] OECD statistics. Available at: http://stats.oecd.org . Access date: 18.04.2011.

[25] Dr. Wolfgang Britz is an agricultural economist and researcher at the Institute for Food and Resource Economics (ILR) at Bonn University specialised in economic modelling. He is one of the core developer of the CAPRI model and coordinator of the CAPRI developer network.

conversion rates within the processing of different agricultural products to biofuels and biofuel by-products) to calculate biofuel processing demand resulting from exogenously given biofuel production quantities. The required conversion coefficients were adopted from the AgLink model (Lampe, 2006) and the processing demand shares for the single agricultural products which were assumed to be usable as biofuel feedstock were fixed. Global biofuel trade was neglected. This simple biofuel representation enabled the model to simulate shocks in total demand for agricultural products with respect to exogenously defined biofuel production scenarios. The interaction of the supply and market modules in CAPRI then simulated changes in production, demand, imports, exports and prices for agricultural products resulting from those shocks, as well as allowing for the derivation of economic, social and environmental indicators covered in the post model analysis. Thus, the model was able to determine endogenously if the calculated processing demand quantities were provided by changes in production, trade or changes in other demand positions as for example feed demand. The main model extensions which were required in preparation for these simulation experiments are summarised in the following:

- The products biodiesel (*BIOD*) and ethanol (*BIOE*) were introduced.
- Palm oil (*PLMO*) was introduced in the demand system, but the use of palm oil for biodiesel production was not considered.
- To consider by-products from ethanol production the product gluten feed from ethanol production (*GLUE*) was added for the processing of cereals to ethanol and a product with similar characteristics was added to cover by-products from processing sugar beets to ethanol.
- The CAPRI ex-post database was enlarged to cover biofuel production quantities in European Member States. Data of biodiesel production were taken from EBB[26] statistics and ethanol quantities were taken from EBIO[27].
- For the transformation of exogenously given biofuel production quantities into processing demand, conversion coefficients were adopted from the OECD agricultural sector model AgLink (Lampe, 2006).
- In order to estimate biofuel processing demand for agricultural products, data of industrial use (*INDM*) from the CAPRI ex-post data base were used. From those quantities, expected shares for biofuel processing demand (*BIOF*) were derived and assumed as fixed parameters for the projection.

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[26] European Biodiesel Board. Available at: www.ebb-eu.org. Access date: 18.04.2011

[27] European Bioethanol Fuel Association. Available at: www.ebio.org. Access date: 18.04.2011

Simulations which can be realized with such a model setting mainly rely on two major exogenous assumptions: (1) total production quantities of ethanol and biodiesel differentiated by each covered region and (2) the composition of biofuel processing demand (feedstock shares) at those output quantities. The exogenous character of biofuel supply, demand and biofuel processing demand limits the executed simulations in two regards: On the one hand, biofuel supply and demand does not react on changes of biofuel prices and, on the other hand, biofuel processing demand for individual agricultural products does not react on changes of agricultural product prices. Furthermore, a substitution between the different agricultural products usable as biofuel feedstock does not take place. Whereas biofuel supply and demand were left exogenous, an upgrade of the simplified feedstock demand handling was introduced by Torbjörn Jansson[28] in 2008 to overcome the problem of fixed feedstock demand shares as described in Blanco Fonseca et al. (2010). In order to develop a first behavioural system for biofuel feedstock demand, a simplified processing sector for biofuels was introduced. Therefore, the processing firms were assumed to choose the cost minimizing mixture of inputs to produce an exogenously given amount of biodiesel or ethanol under given feedstock prices and technical conversion coefficients. As an appropriate functional form for the processing industry a simple constant elasticity of substitution (CES) function was assumed, derived from Banse et al. (2008a). The biofuel feedstocks could be supplied domestically or imported as it was already handled. As this implementation needed more data input and most of this information was not available from statistical sources, the remaining gaps were filled by a set of heuristics. Biofuel trade was still neglected.

In contrast to this approach Britz and Hertel (2009) assessed impacts of the European biofuels directive on global agricultural markets and environmental quality by linking the CAPRI model with the GTAP-BIO model. Here, the capability of the GTAP-BIO model to assess future biofuel market developments was used, whereas the detailed regional agricultural and selected environmental impacts in Europe were assessed by using the features of the CAPRI supply module. Such a model linkage is a sufficient solution to overcome individual model limits by using the capabilities of models which have a different focus and thus, are able to complement each other.

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[28] Dr. Torbjörn Jansson is an agricultural economist focused on statistical methods and economic modelling. He is policy analyst and researcher at the AgriFood Economics Centre in Sweden. He is developer in the CAPRI modelling network.

4.2. Setting of the CAPRI biofuel model

All extensions in CAPRI which are executed in this analysis are aimed to incorporate a behavioural market model for biofuels which allow for simulating and evaluating various biofuel scenarios including - among others - the following biofuel specific scenario variables which are defined for each model region:

- Tax rates for biodiesel, ethanol, gasoline and diesel
- Quota obligations for biodiesel and ethanol
- Availability of 2nd generation biofuel production quantities
- Consumer prices of fossil gasoline and diesel
- Import tariffs for biodiesel and bioethanol
- Technical progress in 1st and 2nd generation biofuel production technologies

Thereby, the CAPRI biofuel model cannot operate as a sub-module for the biofuel sector with an explicit link to the core CAPRI model. In fact, it is a completely independent CAPRI version which consists of a multitude of amendments to existing model parts but also includes various extensions like the introduction of behavioural functions for biofuel supply and demand. Having in mind the individual features of existing biofuel models described in Chapter 3, the CAPRI biofuel model is constructed with the intention to combine the existing advantageous features of the core CAPRI system (especially the detailed spatial and agricultural product differentiation of an agricultural sector model) with a detailed representation of global biofuel markets, covering 1st and 2nd generation production technologies, biofuel by-products, bilateral biofuel trade, new energy crops, and a linkage to the total fuel market. The envisaged setting of the CAPRI biofuel model is displayed in Table 4.1.

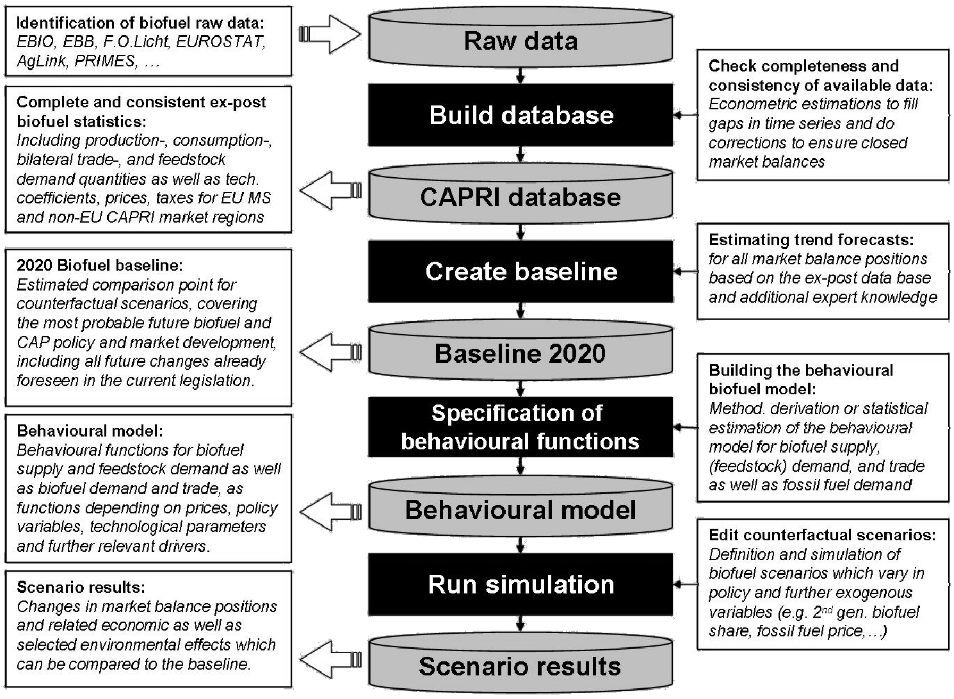
Table 4.1: Envisaged setting of the CAPRI biofuel model

Spatial differentiation	**Product differentiation**	**Further characteristics**	**References regarding biofuels**
<u>Supply module</u>: EU27 NUTS 2 Norway Turkey <u>Market module</u>: 60 countries or country aggregates	• 47 agricultural primary and secondary products (feed included) • Ethanol and biodiesel (1st, 2nd generation and non-agricultural production) • 15 biofuel feedstocks: 4 veg. oils, 6 cereals, sugar, table wine, new energy crops and agricultural residues • Various biofuel by-products (e.g. DDGS, glycerine, diff. oil cakes)	• Comparative static (projection to 2020) • Bilateral trade (Armington) • Explicit supply and demand functions for 1st gen. biofuels • Exogenous representation of 2nd gen. biofuels • Response surface for total fuel demand derived from PRIMES	Becker (2008) Becker et al. (2010) Blanco Fonseca et al. (2010)

Source: Own compilation

The whole workflow of the biofuel market simulation done in this thesis, including the development of a biofuel database, the construction of a biofuel baseline, the development of the CAPRI biofuel model and the definition and evaluation of biofuel scenarios is visualized in Figure 4.2.

Figure 4.2: Workflow of the executed CAPRI simulation

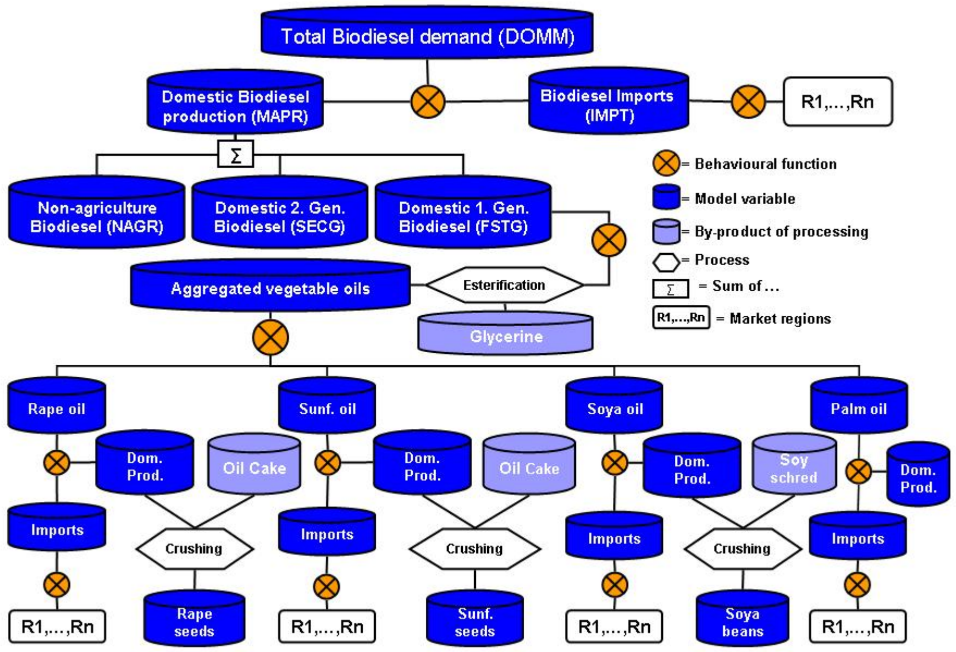


Source: Own illustration

4.3. Biofuel market construction in the model

In general two biofuels are considered explicitly in the CAPRI biofuel model: biodiesel (*BIOD*) and ethanol (*BIOE*). For consumption it is not relevant if these products are produced relying on 1st or 2nd generation technologies as the chemical features of biofuels stemming from both production paths are assumed to be equal. However, on the production side this differentiation is essential as different feedstocks are demanded. While biofuel supply of 1st generation biodiesel ($FSTG_{BIOD}$) and ethanol ($FSTG_{BIOE}$) is handled endogenously in the model, 2nd generation biofuel supply ($SECG_{BIOE,\ BIOD}$) and non-agricultural biofuel supply ($NAGR_{BIOE,\ BIOD}$) are defined by exogenous assumptions. The structure of the biodiesel and ethanol market including the related feedstocks and biofuel by-products is illustrated in Figure 4.3 for biodiesel and Figure 4.4 for ethanol. The crossed circles stand for a behavioural function implemented in the model, meaning that a decision problem in the respective place is solved endogenously within the simulation. Every cylinder stands for a model variable.

Figure 4.3: Biodiesel market construction in the CAPRI biofuel model



Source: Own illustration

Biodiesel can be produced domestically or can be imported. If biodiesel is produced domestically it can be produced by 1st generation technologies (*FSTG*), based on different vegetable oils (explicitly rape oil, sunflower oil, soy oil or palm oil), 2ndgeneration technologies (*SECG*) based on new energy crops or agricultural residues, and by technologies which do not rely on agricultural feedstocks (*NAGR*) but on by-products from the chemical industry like for example black liquor[29] or various waste oils. According to the production technology one by-product accrues within the processing of vegetable oils to biodiesel: glycerine. The ratio of biodiesel and glycerine production within the production process is constant. Glycerine is neither used in the livestock sector nor recycled by any agricultural activity. Thus, demand for glycerine and consequently prices are exogenous in the CAPRI biofuel model. It is assumed that an average producer price can be gained by the processing firm and that all produced quantities can be sold. The average price assumption is taken from the PRIMES model and is set to

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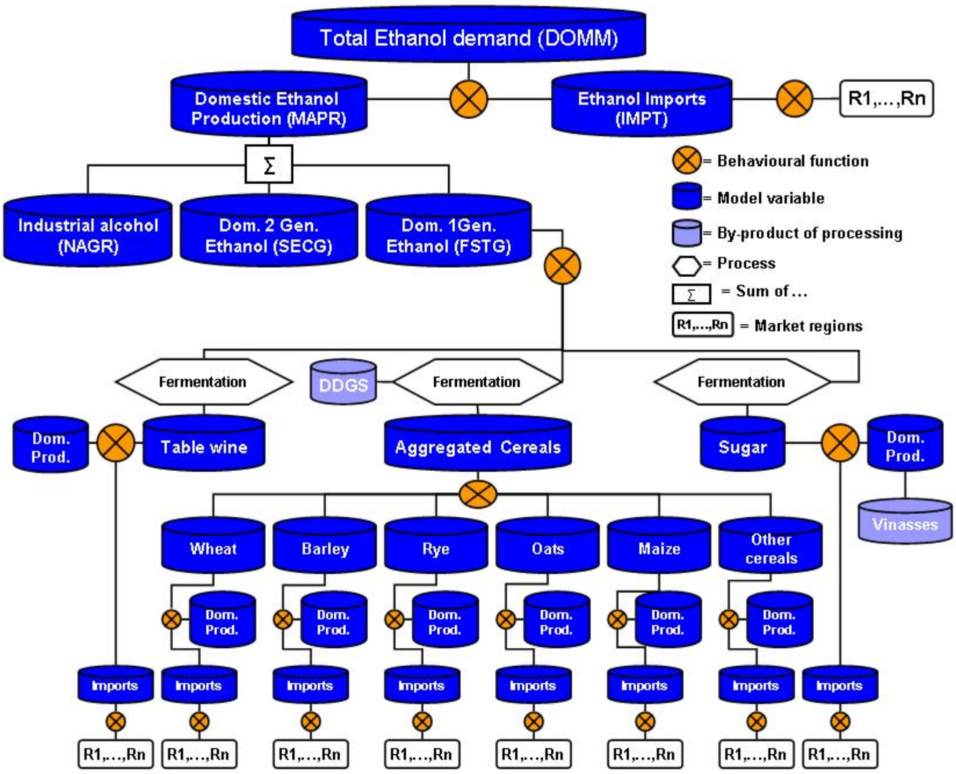
[29] Black liquor is a by-product of the processing of wood into paper.

300 €/t[30]. The different biodiesel feedstocks (rape oil, sunflower oil, soy oil and palm oil) are substitutes and are characterized by specific conversion coefficients. Feedstocks can also be produced domestically or imported to meet the final biodiesel processing demand. Rape seeds, sunflower seeds and soybeans, the feedstocks for these vegetable oils, can also be produced domestically or imported, not illustrated in Figure 4.3 but already included in the standard CAPRI model. The accruing by-products of oil seeds and soybeans when being processed to vegetable oils (rape cake, sunflower cake, soy shred) can be used as feed components in the livestock sector, which is also covered in the model.

Figure 4.4: Ethanol market construction in the CAPRI biofuel model



Source: Own illustration

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[30] Delivered by the PRIMES modelling team within the IPTS project 151250-2008 A08-DE. More information available at: www.ilr1.uni-bonn.de/agpo/rsrch/projects/ipts_biofuel_e.htm. Access date: 18.04.2011

Ethanol can also be produced domestically or be imported. If ethanol is produced domestically it can be produced by 1st generation technologies based on cereals (which are further differentiated in wheat, barley, rye and meslin, oats, maize and other cereals), sugar or table wine, or by 2nd generation technologies based on new energy crops or agricultural residues and by technologies which do not rely on agricultural feedstocks, like alcoholic by-products of the chemical industry (Figure 4.4). Within the ethanol production process different by-products accrue depending on the feedstock used. In Europe the traditional technology for the processing of cereals (wheat, barley, rye, meslin and oats) to ethanol is based on dry milling and a subsequent fermentation process. Here, one by-product (distillers' grain) is produced which has a water content more than 90%. This product is dried and compressed to pellets (Distillers Dried Grains with Solubles - DDGS) and offered as feed component to the livestock sector. An alternative processing technology for cereals is based on wet milling. This technology is mainly used in the U.S., especially if maize is used as feedstock. From this process gluten feed accrues which is, like DDGS, a protein-rich feeding component. For simplification it is assumed in the CAPRI biofuel model that cereals processing to ethanol is exclusively based on dry milling. As both by-products (DDGS and gluten feed) accrue in a similar processing ration to ethanol and furthermore have also similar nutritional values, this simplification does not lead to divergent impacts on feed and thereby agricultural markets. In the model DDGS enters the feed market as part of the feed aggregate 'Protein-rich feed' (*FPRI*) which also includes fish meal and by-products from milling and brewing. Also of high relevance for ethanol processing are sugar crops. Whereas in Brazil sugar cane is used, the processing of sugar beets for ethanol production takes place in Europe with an increasing importance during the last years. For the production of ethanol the sugar beets have to be chipped and boiled and the resulting sugar-containing syrup is then fermented. Within the fermentation one by-product occurs: vinasses. The production process of sugar and ethanol is linked as ethanol production based on sugar beets is often coupled with sugar production in one production plant. According to requirements the plant can decide if the high sugar-containing sugar beet syrup should be fermented to produce ethanol or should be crystallized to produce sugar. If sugar is produced, the resulting by-product molasses (a viscous liquid with remaining sugar content) can be subsequently fermented to gain ethanol. This principle is also true for ethanol processing based on sugar cane. However, as no sufficient information is available for this procedure the representation of sugar beet processing in the CAPRI biofuel model is simplified to either produce ethanol or sugar. If ethanol is produced vinasses occurs as by-product, if sugar is produced molasses occurs. Both products can be used as energy rich feed components in the livestock sector. As molasses and vinasses have comparable ingredients and molasses is already implemented in the model the implementation of vinasses is simplified by considering vinasses as a molasses-equivalent[31]. Like DDGS also molasses enter the feed market as part of a feed aggregate, Energy-rich-feed (*FENI*). Further simplification is done as sugar beets production is only covered in CAPRI for European countries and sugar cane production is not covered at all. However, to cover also the effects of an increasing ethanol production on sugar crop production in regions outside the EU the calculation is done on the level of the secondary product sugar which is considered for all model regions in CAPRI. Apart from sugar and starchy crops also table wine is used for ethanol production in some European countries which is also considered in the CAPRI biofuel model.

2nd generation ethanol or biodiesel supply is not covered by behavioural functions within the model but rather in a simplified treatment which allows for an exogenous consideration of those technologies. Therefore, technology parameters as well as data on usable feedstocks are collected. As a results of discussion between the CAPRI and PRIMES modelling teams, promising 2nd generation technologies are identified which might be relevant in a future renewable energy supply and thus, are considered in the biofuel model. Those technologies are lignocellulosic pre-treatment and fermentation to produce lignocellulosic based ethanol and Fisher-Tropsch synthesis and pyrolysis to produce biodiesel. A more detailed description of these technologies is given by Capros (2010). Figure 4.5 displays the structure of the 2nd generation biofuel production as implemented in the model. 2nd generation biofuel feedstocks are distinguished in two different product aggregates: (1) Agricultural residues (*ARES*) which cover for example straw from cereals or oil seed production and leaves from sugar beet production. (2) New energy crops (*NECR*) which cover cellulosic crops or fast growing tree species like miscanthus, poplars or willows[32]. Demand for 2nd generation biofuel feedstocks is also handled exogenously in the model, meaning that the feedstock demand shares for *ARES* and *NECR* which are required to produce the assumed 2nd generation biofuel quantities are also given by assumptions. This decision primarily rely on the observation that the potential of agricultural residues resulting from the respective activity levels of cereals, oilseeds and sugar beet production in the base and projection-year have such a high amount that even in a high 2nd generation scenario only a marginal share of

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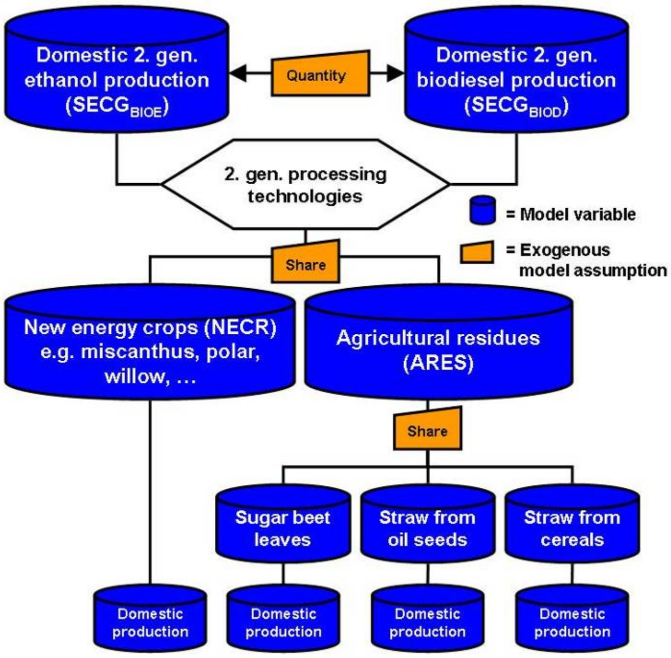
[31] Molasses is a viscous liquid with a remaining sugar content of 60%. Vinasses has a remaining sugar content of 6% which is equal to 10% of the sugar content of molasses. Thus, it is assumed that one-tenth of molasses is produced from sugar beet processing to ethanol.

[32] Initially, it was envisaged to consider also residues from livestock production (manure and cadavers). However, as information on this feedstock group is limited and the communication with the PRIMES team indicated that this group is only of marginal importance for biofuel processing, an implementation did not take place.

the production potential of agricultural residues is demanded.[33] Thus, only marginal price effects for agricultural residues might occur which do not affect biofuel feedstock demand and thus, do not require installing a price-response of 2nd generation feedstock demand. In the case of new energy crops the construction is different as their production requires agricultural land. This fact is considered by reducing the available agricultural land for the production of other agricultural products in accordance with the yield information collected for new energy crops.

Figure 4.5: 2nd generation biofuel production in the CAPRI biofuel model



Source: Own illustration

Whereas the feedstock markets of 1st generation biofuels are already part of the standard CAPRI version, the variables for biofuel processing, most by-products and 2nd generation feedstocks are newly introduced.

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[33] Even under consideration of a particular share of agricultural residues which have to be left on the acre to preserve sufficient humus content and under consideration of certain losses.

4.4. Building the biofuel database[34]

The establishment of a sufficient ex-post biofuel database is an ambitious exercise. The main difficulty results from the fact that notable biofuel market expansions have not started more than ten years ago. Even if the European discussion to promote biofuels already started in the 1990s and first support measures in European Member States were implemented between 2001 and 2003, a significant increase in biofuel production, consumption and trade did not materialize before 2005, with a market boost in 2007 and 2008. Hence, official statistical sources like EUROSTAT have not collected production or consumption data for long ex-post time series. Furthermore, biodiesel, in contrast to ethanol, was not shown explicitly in most official trade statistics until 2008. Whereas ethanol (differentiated in "undenatured" and "denatured" ethanol) is explicitly classified in the official HS code scheme[35], biodiesel was included in different aggregates of chemical products until 2008 which do not allow for a precise identification of biodiesel quantities. The consequence of these difficulties is that a variety of official statistics and privately offered data sources has to be consulted to develop the required database. The main problem with such a compiled database is to hold consistency as different data sources often vary in their variable definitions. In particular this is true for ethanol that may be defined as "fuel-ethanol" or "(all) ethanol" on the production and consumption side and "undenatured" or "denatured" ethanol within trade statistics. It is not always evident which definition is used by a particular data source and thus, the compilation requires a lot of care to reduce such uncertainties.

As the CAPRI trend estimation procedure, which is an important component of the baseline generation process, relies on a statistical analysis of ex-post time series, biofuel data should ideally be available for the full time horizon of the standard CAPRI database (COCO[36]). The COCO module (Britz and Witzke, 2009) includes statistical estimation procedures to fill gaps or to correct inconsistencies in the original statistical datasets. The time horizon covered in the COCO module (in its status of 2009) is 1985 to 2005. Thus, ex-post time series for biofuels should ideally cover the same time period or at least a certain section of this horizon. Subsequent biofuel data beyond 2005 are also useful, for example for cross checking with results from the trend estimation and for future database updates. Because production and consumption quantities of biofuels became notable in Europe not before 2002 and data for years beyond 2005 are very

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[34] This section is based on Becker, et al. (2010a)

[35] Harmonized Commodity Description and Coding System (HS)

[36] Complete and Consistent Data Base (COCO) of the CAPRI model

incomplete, it was decided to establish complete biofuel time series exclusively from 2002 to 2005 in COCO[37].

The specific data needs for the CAPRI biofuel representation result from the set of behavioural functions which should be implemented. As a complete market representation of 1st generation biofuels is envisaged, closed market balances for ethanol and biodiesel in European and non-European countries or country aggregates[38] are required for each ex-post year. In general, the market balance consists of four positions: domestic production, domestic consumption, imports and exports (all measured in 1000 metric tons). In addition ex-post biofuel prices (differentiated in producer, consumer, import, and export price) as well as some technical parameters are required to estimate price elasticities and parameter values within the calibration procedure. Furthermore, feedstock demand resulting from biofuel production has to be identified which should be consistent with the market balances for the agricultural products already covered in COCO. As CAPRI features bilateral trade only for the EU aggregates (EU10, EU15, and EU27) and for non-European countries or country aggregates, bilateral trade statistics for biofuels are not required for the individual European Member States. In this case only aggregated import or export positions have to be collected.

Market balances of ethanol and biodiesel

In the following the data sources used are described for each market balance position. The position production ($MAPR_{BIOE}$) covers both, fuel- and non-fuel ethanol. The positions import ($IMPT_{BIOE}$) and export ($EXPT_{BIOE}$) cover undenatured as well as denatured ethanol. By contrast, total domestic consumption ($DOMM_{BIOE}$) is split into fuel consumption ($HCOM_{BIOE}$) and non-fuel consumption ($INDM_{BIOE}$). In the case of biodiesel this differentiation is not required as biodiesel is only produced for fuel purposes and no additional demand beside fuel use exists. Thus, total biodiesel consumption is fully covered by fuel consumption ($HCOM_{BIOD}$), which is equal to total consumption ($DOMM_{BIOD}$). The resulting final biofuel market balances of European countries are displayed for the

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[37] Technically, biofuel market balances for European countries, prices and processing parameters are stored in the COCO module. Market balances for non-European countries or country aggregates are stored separately in the CAPRI world database called GLOBAL.

[38] The CAPRI biofuel model distinguishes European Member States and non-European countries or country aggregates in accordance with the standard CAPRI regional coverage as described in Britz and Witzke (2009).

calculated BaseYear[39] in Annex 10.1. The market balances for EU10, EU15 and important non-European production countries are shown for the BaseYear in Annex 10.2 for ethanol and in Annex 10.3 for biodiesel.

For ex-post biofuel production quantities in European and non-European countries the data sources listed in Table 4.2 are consulted. Whereas EBIO[40], EBB[41] and EUROSTAT[42] are official public available data sources, F.O.Licht[43] is a privately offered data source specialised on international sugar and biofuel markets. Within the development of this database several volumes of 2008 and 2009 of the “F.O.Lichts World Ethanol & Biofuels Report” are used. In addition, also data from the PRIMES[44] and AgLink-COSIMO[45] model (in the following called AgLink) are used. In the case of ethanol EBIO and PRIMES production data covers only fuel-ethanol quantities, whereas F.O.Licht and EUROSTAT differentiate between undenatured and denatured ethanol. The AgLink database does not differentiate into these sub-products but introduced a new differentiation into ethanol produced from agricultural sources and ethanol produced from non-agricultural sources. To achieve consistency among the different sources, the collected data are cross-checked. It becomes obvious that the PRIMES production data (fuel-ethanol production) is largely consistent with the EBIO data. Furthermore, the AgLink 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 permit to define the production activity variable for ethanol ($MAPR_{BIOE}$) which covers the whole ethanol production (undenatured and denatured, regardless of the feedstock used) in a certain country and year. The F.O.Licht production data for ethanol is taken as the basic dataset as it covers explicitly European as well as non-European countries. In the case of biodiesel PRIMES provides the basic data, whereas the F.O.Licht data is taken into consideration to amend non-European production. If production data from both, PRIMES and F.O.Licht are available for a respective region, the higher value is taken to define *MAPR*.

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[39] The BaseYear is a three years average of the ex-post years 2003, 2004, and 2005. It can be used as a comparison point for the projection-year (2020). An average is used instead of a single ex-post year to avoid the presence of single outliers in market balance positions.

[40] European Bioethanol Fuel Association. Available at: www.ebio.org. Access date: 24.06.2009.

[41] European Biodiesel Board. Available at: www.ebb-eu.org. Access date: 24.06.2009.

[42] EUROSTAT. Available at: epp.eurostat.ec.europa.eu. Access date: 24.06.2009.

[43] F.O.Lichts World Ethanol & Biofuels Report, monthly magazine (selected volumes 2008-2009).

[44] Baseline and ex-post data used in this analysis are extracted from a PRIMES version of December 2009. More information on PRIMES is available at: www.e3mlab.ntua.gr. Access date: 24.06.2009.

[45] Baseline and ex-post data used in this analysis are extracted from a AgLink version of October 2009. More information on AgLink is available at: www.oecd.org. Access date: 24.06.2009.

Table 4.2: Overview on data sources consulted to define biofuel production

Source	**Variables covered**	**Time period**	**Regions covered**
EBIO	Fuel ethanol production	2004 - 2008	Sel. EU MS
EBB	Biodiesel production	2003 - 2007	EU MS (EU27)
EUROSTAT-PRODCOM	Sold volume: biodiesel (code: 20595990),	2007 - 2008	Sel. EU MS
	undenatured ethanol (code: 20147400),	1995 - 2008	Sel. EU MS
	denatured ethanol (code: 201474500)	1995 - 2008	Sel. EU MS
PRIMES	Fuel ethanol production	2000 - 2007	Sel. EU MS
	Biodiesel production	2000 - 2007	EU MS (EU27)
AgLink	Ethanol production from agr.	2000 - 2008	EU27 + OECD Members
	Ethanol production from non-agr. inputs	2000 - 2008	EU27 + OECD Members
	Biodiesel production	2000 - 2008	EU27 + OECD Members
F.O.Licht	Undenatured ethanol production	2000 - 2008	Sel. EU MS + non-EU
	Denatured ethanol production	2000 - 2008	Sel. EU MS + non-EU
	Biodiesel production	2003 - 2008	Sel. EU MS + non-EU

Source: Own compilation

It is refrained from considering exclusively fuel-ethanol production, as a significant share of non-fuel ethanol is also produced from agricultural products. Thus, the differentiation into fuel- or non-fuel is not relevant for the production side. However, the differentiation into non-agricultural or agricultural ethanol is of course important, as it signals that not the whole ethanol production is based on agricultural sources. To consider this fact the AgLink data on non-agricultural ethanol are used to derive the supply share of non-agricultural ethanol which is used to calculate $NAGR_{BIOE}$. As AgLink only features EU27 aggregated data, this share is assumed to be equal for all European countries. For some non-European countries the AgLink data also indicate that non-agricultural based biodiesel quantities are produced. These quantities ($NAGR_{BIOD}$) are adopted. For biodiesel produced in Europe no indications for $NAGR_{BIOD}$ is given by AgLink.

For the definition of ex-post biofuel consumption the sources listed in Table 4.3 are consulted. Information on consumption quantities of ethanol and biodiesel in European and non-European countries are more limited than information on biofuel production. In addition, demand for ethanol can be described as fuel-ethanol consumption or total ethanol consumption which covers non-fuel ethanol demand quantities as well, for example ethanol used for beverage. Furthermore, a spatial mapping has to be developed, as PRIMES covers only European Member States, AgLink covers only the EU27 aggregated and OECD member countries and F.O.Licht includes information for European Member States as well as OECD and non-OECD countries, but only for selected ones. Consequently, the required consumption information is utterly incomplete. As it is necessary to split demand into fuel- and non-fuel ethanol demand further gaps occur.

Table 4.3: Overview on data sources consulted to define biofuel consumption

Source	Variables covered	Time period	Regions covered
EUROSTAT[46]	Consumption: Fuel-ethanol, biodiesel	2005 - 2007 2005 - 2007	EU MS EU MS
PRIMES	Consumption: Fuel-ethanol, biodiesel	2000, 2005 2000, 2005	EU MS EU MS
AgLink	Consumption: Fuel-ethanol, non-fuel ethanol, biodiesel consumption	2000 - 2008 2000 - 2008 2000 - 2008	EU27 + OECD Members EU27 + OECD Members EU27 + OECD Members
F.O.Licht	Consumption: Fuel-ethanol, non-fuel ethanol, biodiesel consumption	2000 - 2008 2000 - 2008 2003 - 2008	Sel. EU MS + non-EU Sel. EU MS + non-EU Sel. EU MS + non-EU

Source: Own compilation

Data for European and non-European (total) ethanol and fuel-ethanol consumption are taken from F.O.Licht, as this data source provides the most complete country and time coverage. Furthermore, it is predominately consistent with fuel-ethanol consumption quantities offered by PRIMES, EUROSTAT and AgLink. To fill remaining gaps the following assumptions are applied: If information on production and trade flows are available in a respective year and country, total consumption of ethanol ($DOMM_{BIOE}$) is equal to the production of ethanol ($MAPR_{BIOE}$) minus exports ($EXPT_{BIOE}$) plus imports ($IMPT_{BIOE}$). If no information on fuel-ethanol consumption ($HCOM_{BIOE}$) is available but total ethanol consumption exist, the EU27 share of non-fuel ethanol consumption (provided by AgLink) is used to calculate industrial ethanol demand ($INDM_{BIOE}$) and consequently fuel-ethanol demand in CAPRI.

Biodiesel consumption quantities for European countries are taken from the PRIMES model because the F.O.Licht data at hand are incomplete for the required ex-post time period. The PRIMES biodiesel consumption data is broadly consistent with F.O.Licht where overlaps exist. Furthermore, the PRIMES data is useful as it contains ex-post data for 2000 and 2005 and thus allows for an interpolation of the intermediate years. Biodiesel consumption for non-European countries is taken from F.O.Licht as PRIMES is limited to the EU27.

Ex-post data on trade flows are partly covered by the EUROSTAT foreign trade division COMEXT, the AgLink-COSIMO database and F.O.Licht. The PRIMES database does not include ex-post trade quantities. CAPRI needs

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[46] EUROSTAT. Available at: epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database. Access date:24.06.2009

aggregated import and export quantities for European Member States and import and export quantities described in a bilateral way for the aggregates EU10 and EU15 and for non-European countries. The data sources consulted for the definition of biofuel trade are listed in Table 4.4. The AgLink model describes trade by a net-trade position, meaning that import and export flows are not given explicitly and an allocation of exported or imported quantities to individual trade partners does not take place. Therefore, trade information provided by the AgLink model is mainly used for cross checking and comparison.

Table 4.4: Overview on data sources consulted for biofuel trade

Source	Variables covered	Time period	Regions covered
EUROSTAT (COMEXT)	Imports and exports (bilateral): undenatured ethanol (HS 20147400), denatured 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	Net-trade: ethanol (not differentiated), biodiesel	2000 - 2008 2005 - 2008	EU27 + OECD Members EU27 + OECD Members
F.O.Licht	Imports and exports (bilateral): undenatured ethanol, denatured ethanol, biodiesel	2003 - 2008 2003 - 2008 2006 - 2008	Sel. EU MS + non-EU Sel. EU MS + non-EU Sel. EU MS + non-EU

Source: Own compilation

The trade division of EUROSTAT (COMEXT) provides European external trade data in a bilateral way for the European aggregates and the individual Member States, usually in a high quality. However, there are two obstacles from a CAPRI perspective. On the one hand, COMEXT covers only products which are covered by the HS (or CN8) code scheme. This is perfect in the case of ethanol as undenatured as well as denatured ethanol is explicitly covered. However, as mentioned above, biodiesel was not covered explicitly before 2008. Thus, only biodiesel trade quantities for 2008 are described explicitly by COMEXT. On the other hand, COMEXT only reports from a European perspective, meaning that only trade flows are covered which include the European Union or single Member States as reporters. Trade flows between non-European countries are not covered. The only available source which covers European and non-European countries in such detail that allows for describing trade flows bilaterally is F.O.Licht. Furthermore, it includes some information about biodiesel trade. However, the data is only published for selected countries and in the case of biodiesel not before 2006. For this reason it is decided to use the COMEXT data for ethanol and biodiesel to define European foreign trade in a bilateral way and for aggregated import and export flows of single European Member States. In the case of ethanol the data at hand could be directly used. Only the aggregation of denatured and undenatured ethanol is required. In the case of biodiesel the available explicit data for 2008 (HS 3824 9091) given by EUROSTAT is used to estimate the share of biodiesel in the former aggregates including biodiesel (HS 3824 9098 and HS 3824 9099). Therefore, the absolute value in 2008 is used to calculate the percentage share of biodiesel within the 2007 value of the aggregate HS 3824 9098. This share is assumed to be constant over time which permits a backward calculation of absolute quantities for biodiesel trade in the relevant time period 2002-2005. Data on ethanol trade between non-European countries is taken from F.O.Licht, while this data source is very limited for biodiesel. Hence, the AgLink data is used which covers the main biodiesel production countries. As in the ex-post period basically only the U.S. exported biodiesel and only the EU27 imported biodiesel the problem of the limited net-trade information provided by AgLink could be resolved assuming that all import quantities of biodiesel into the EU27 are exported from the U.S.. If no information on trade flows but production (*MAPR*) and consumption (*DOMM*) quantities are available for a respective country and year, it is assumed that the difference between production and consumption is equal to an import flow (*IMPT*) if its value is negative and equal to an export flow (*EXPT*) if its value is positive. The resulting total import and export quantities of biodiesel and ethanol for European Member States and non-European countries are also covered in Annex 10.1, Annex 10.2 and Annex 10.3. Bilateral trade flows of biofuels between the EU10, EU15 and non-European countries are displayed for the BaseYear in Annex 10.4 and Annex 10.5.

Biofuel prices

For various purposes ex-post biofuel prices are required as well.[47] Furthermore, for the application of the Armington approach a differentiation into producer, consumer and import price is essential (Britz and Witzke, 2009). These differentiated prices are currently 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 database includes ex-post world market prices for ethanol and biodiesel. This price is taken as the base value to calculate the differentiated prices in the respective countries. The import tariffs for ethanol and biodiesel are adopted from the AgLink database. As consumer taxes for ethanol and biodiesel in most instances correspond to a reduced excise tax on fossil fuels,

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[47] For the baseline construction prices are not essential as supply, demand and trade are statistically estimated. However, they are required for the calibration of the behavioural model.

consumer taxes for gasoline and diesel are also collected. This tax information is taken from EurActiv[48] where levels of diesel and petrol taxation in 2002 are published for European Member States. For the desired years (2002-2005) taxation levels are calculated in line with COM (2002)410 (European Commission, 2002) which set minimum excise tax rates for non-commercial diesel and petrol since 2006. To identify the national excise tax exemptions and producer subsidies for biofuels, if existent, 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"[49] are consulted which are published by the European Commission, Directorate General for Energy. Three different types of tax regulations for biofuels are identified which are applied among the different Member States: (1) an absolute tax for biofuels, (2) an absolute reduced excise tax for fossil fuels applied for biofuels and (3) a relative reduced excise tax for fossil fuels applied for biofuels. These regulations have already been displayed in Table 2.3. Based on this information the different ex-post prices for the period 2002-2005 are calculated.

As the behavioural biofuel model will cover functions depending on the consumer price ration of biofuels to fossil fuels, fossil fuel prices are also required in the database. To ensure consistency between the collected biofuel and fossil fuel prices, the price information for fossil fuels is also adopted from the AgLink database which provides European market prices for diesel and petrol. For the re-calculation of consumer prices in individual European Member States the above mentioned taxation levels for fossil fuels are applied. Because there exists a significant difference between the physical energy contents and densities of biodiesel, ethanol, petrol and diesel a direct comparison of prices (in €/t) is not possible. For this reason fuel prices as well as the fuel taxation levels are converted into Euro (€) per *Ton Oil Equivalent* (toe) as displayed in Table 4.5.

Table 4.5: Coefficients for the transformation of ton in toe

	ton	**toe**
Petrol	1	1.05
Diesel	1	1.01
Biodiesel	1	0.86
Ethanol	1	0.64

Note: ton = metric ton; toe = ton oil equivalent
Source: PRIMES model

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[48] Available at: www.euractiv.com/en/taxation/fuel-taxation/article-117495. Access date: 20.07.2009.

[49] Available at: ec.europa.eu/energy/renewables/biofuels. Access date: 20.07.2009.

Biofuel feedstock demand

Official statistic sources which explicitly cover detailed information on the single feedstocks used for biofuel production over all European Member States and non-European regions could not be identified so far.[50] Therefore, the available data sources are screened to find indirect information on biofuel feedstock demand.

In several European countries and for some feedstocks, a positive correlation can be observed between the increase in ethanol and biodiesel production since 2002 and the evolution of industrial use (*INDM*) of agricultural crops (mainly cereals and oilseeds) as collected by EUROSTAT and already stored in the CAPRI database. This correlation is more significant in the case of ethanol than biodiesel and not obvious for all European countries. However, lacking other statistical information, it is assumed that the increase in industrial use of agricultural crops entirely results from the increasing demand for agricultural crops used by the biofuel industry. As this information is available for every European Member State and for each agricultural product within the time period 2002 - 2005, it is possible to estimate feedstock demand allocations for every Member State. Apart from some bounds and security mechanisms this requires first to calculate the increase in the *INDM* quantities of possible biofuel feedstocks before and after the biofuel boom. The share of these increases in the aggregate increase of *INDM* of potential feedstocks is used to initialise the feedstock shares. This approach can be applied to all feedstocks, but some pre-calculations have to be made in the case of palm oil as EUROSTAT does not cover this product. Hence, palm oil market balance positions are taken from FAO data and are rendered consistent with EUROSTAT-COMEXT data on import and export quantities of crude palm oil (HS 151110) for European Member States. In order to get a consistent dataset where the production of biofuels is equal to the sum of feedstocks multiplied with the respective conversion coefficient and to ensure closed market balances, a Highest Posterior Density estimator is applied (Heckelei et al., 2005), which includes the following constraints: (1) The sum of industrial use (*INDM*) and human consumption (*HCOM*) as given by EUROSTAT should not deviate strongly from the corrected estimates for industrial use (*INDM*) and human consumption (*HCOM*) plus the newly introduced position biofuel feedstock demand (*BIOF*). (2) The production of biofuels (*MAPR*) has to be equal to the sum of demanded feedstocks (*BIOF*) times their conversion coefficients. (3) The feedstock shares should be as close as

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[50] Private data sources like F.O.Licht, which offer estimates on feedstock shares in biofuel production, have not been subscribed for the analysis. On the one hand, because of budgetary limitations, on the other hand, it was not clear if the required data is sufficiently covered.

possible to the initially calculated shares above. The resulting estimated ex-post quantities of agricultural products used for biofuel production in European Member States are depicted for the BaseYear in Annex 10.6.

Other than statistical information on biofuel feedstock demand which is provided by governmental or non-governmental institutions or by biofuel enterprises is also collected and screened but the ex-post information included is too limited for providing an alternative for the estimation procedure as described above. However, even though this information is not used for the development of the database it delivers useful indications of trends in future biofuel feedstock demand which will be incorporated into the baseline generation procedure (Chapter 5). Therefore, a summary of the main finding will be given. In general all sources agree on the most important feedstocks which are used for biofuel production in major global production regions. FAPRI (2010) states the basic biofuel feedstocks by region as displayed in Table 4.6.

Table 4.6: Most important feedstocks used for biofuel production

Region	**Ethanol**	**Biodiesel**
USA	corn	soy oil
Argentina	-	soy oil
Brazil	sugar cane	soy oil
Canada	corn, wheat	-
Europe	cereals, sugar beets	rape oil
Indonesia / Malaysia	-	palm oil

Source: FAPRI (2010)

As the U.S. is currently the greatest ethanol producer, followed by Brazil (Figure 1.2), it can be assumed that the predominant share of total world ethanol is produced based on corn and sugar cane. In the case of biodiesel, where the EU27 and the U.S. are currently the biggest producers (Figure 1.1), it is obvious that firstly rape and secondly soy oil are the most important feedstocks. Balat and Balat (2010, p.1819) also identify rapeseed and sunflower oils as the main biofuel feedstocks in Europe, whereas "[…] *palm oil predominately dominates in biodiesel production in tropical countries, and soy-bean oil is the major feedstock in the Unities States*." Furthermore, "[…] *rapeseed oil has 59% of total global biodiesel raw material source, followed by soybean (25%), palm oil (10%), sunflower oil (5%) and other (1%). Rapeseed used for biodiesel is the EU's dominant biofuel crop with a share of about 80% of the feedstock.* […] *Soybean oil accounts for approximately 90% of biodiesel produced in the United States*." (Balat and Balat, 2010, p.1819). As Argentina and other South American countries are significantly increasing their biodiesel production capacities it is probable that in the mid-term soy oil will become the most important biodiesel feedstock worldwide (CAER, 2008). The European Bioethanol Fuel Association

(EBIO) estimates feedstock shares, but only for the aggregated EU27 fuel-ethanol production in 2006, 2007 and 2008 as summarised in Table 4.7.

Table 4.7: Feedstock demand shares (%) in EU27 ethanol production

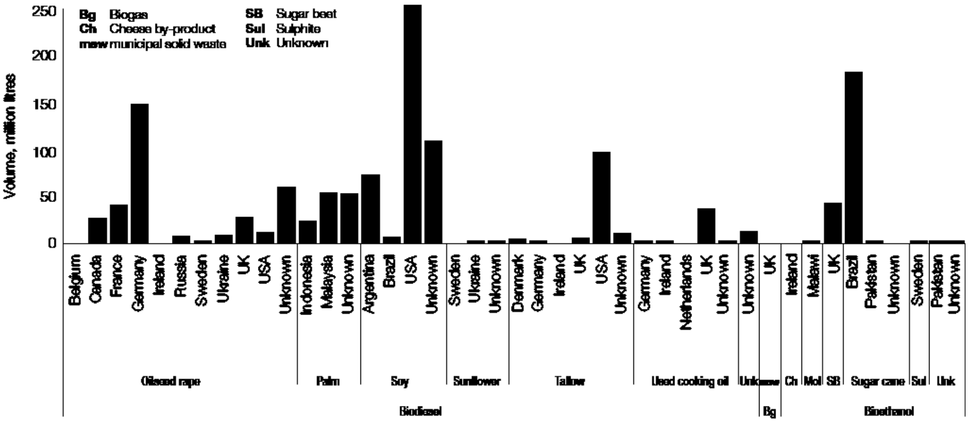
Feedstock	**2006**	**2007**	**2008**
Wheat	37	39	27
Rye	15	3	4
Molasses	16	24	27
Barley	7	12	3
Maize	2	13	26
Raw alcohol	23	9	8

Source: EBIO (2010)

This information is sufficient to differentiate the use of single cereals, as well as sugar (based on molasses) and industrial alcohol for ethanol production on European level. As one can observe the importance of sugar (molasses) and maize relative to wheat has increased over the past years. Given the ongoing European sugar market reform it can be expected, that the share of molasses, and thereby sugar beets, in ethanol processing will further increase. This trend is confirmed by the 2008 business report of the German ethanol enterprise *CropEnergies*, a subsidiary company of *Südzucker*, one of Germany’s major sugar producers. In the financial year 2007/2008 the ethanol facility in Zeitz, Germany (annual ethanol production output of 220 thousand tons) significantly increased the feedstock share of sugar beets (nearly 40%) in relation to the foregoing years. In this way demand for cereals could be decreased (CropEnergies, 2008). This trend is also described by AFC (2009). Here, it is mentioned that the share of cereals in total German ethanol production was 88%, for sugar beets 7.5%, respectively in 2007. In 2008 the share of cereals decreased to a level of 61%, while the share of sugar beets increased to a level of 36%.

The British Renewable Fuel Agency (RFA, 2010) gives further information on biofuel feedstocks use in individual European Member States and some non-European countries. As part of the reporting required by the British Renewable Transport Fuel Obligation they show the biofuel quantities consumed in the UK in year 2008/2009 differentiated into feedstock used and region of origin based on industry information. An overview of this compilation is given by Figure 4.6. It can be observed that in the case of biodiesel, Germany predominately processes rape oil. Waste oil (e.g. used cooking oil - UCO) or other feedstocks like tallow have only a marginal production share in European countries. The only exception is the UK and Ireland which predominately use such residues. However, the absolute quantities are moderate. The information and assumptions for non-European countries from above are confirmed by the British RFA. The U.S., Argentina and Brazil basically use soy oil and Indonesia / Malaysia basically use palm oil for biodiesel production. The information on ethanol feedstocks included in this source is limited as the fuel-ethanol quantities consumed in the UK are marginal relative to biodiesel. However, it becomes obvious that ethanol produced in the UK is predominately based on sugar beets and the Brazilian ethanol imports are predominately relying on sugar cane.

Figure 4.6: Volumes of biofuel consumed in UK differentiated by feedstock (2008/2009)



Source: Renewable Fuel Agency (2010)

Some information is also provided by the German Ministry for Environment, Nature conversation and Nuclear reactor security (BMU, 2010). The ministry gives estimates for feedstocks used in total domestic ethanol and biodiesel consumption in 2009 (Table 4.8).

Table 4.8: Feedstock shares (%) in German biofuel consumption in 2009

	Rape	Soy	Palm	Waste	Cereals	Sugar cane	Sugar beets	other
Biodiesel	79	10	5	6	-	-	-	-
Ethanol	-	-	-	-	42	35	21	2

Source: BMU (2010)

As Germany is the most important biodiesel producer in the EU27, it can be assumed that the predominant share of biodiesel quantities consumed in Germany is produced domestically. Thus, this information is very useful to identify the feedstock shares in German biodiesel production. The data confirms the dominant position of rape oil in Germany and thereby also in European biodiesel production. The relatively high share of soy oil (10%) might result from certain U.S. or Argentine biodiesel imports. However, it can be assumed that palm oil as well as waste oil have a non-negligible and probable increasing share in biodiesel production. Regarding ethanol the high share of sugar cane (35%) might result from significant ethanol imports from Brazil. Cereals (42%) and sugar beets

(21%) turn out as dominant ethanol feedstocks in domestically produced ethanol, as suggested above. Further national sources, for example from Spain or UK indicate that for biodiesel waste oil is a non-negligible feedstock[51]. However, until 2010 these quantities might be small if not marginal relative to total European biodiesel production. The Austrian Biomass Association[52] indicates that in addition to feedstocks stated by EBIO also table wine is used for ethanol production, in particular in Spain.

Information on alternative feedstocks

Data on alternative feedstocks is required to introduce 2nd generation biofuel production in the model. As already mentioned two alternative feedstock types are distinguished: (1) agricultural residues (*ARES)*, covering for example straw from cereals and oil seeds as well as leaves from sugar beets, and (2) new energy crops (*NECR)* covering for example fast growing tree or herbaceous species. While agricultural residues are by-products of crop production, meaning that no additional input factors like arable land or fertiliser are required for production (neglecting collection costs), new energy crops are produced on agricultural land and thus compete with other agricultural production activities within the production decision of a farm. Some considerations are made concerning the integration of these crops in the model. As production data and information on production costs and input requirements are very limited in literature, they have not been integrated as an explicit production activity in the CAPRI biofuel model. Instead they are handled exogenously, allowing to introduce a given share of these crops in future agricultural supply. The land requirements are estimated via assumed yields and lead to a decrease of available land for other agricultural production activities. Coefficients for the production of agricultural residues (Table 4.9) are taken from the PRIMES model, where the evaluation and estimation of alternative biomass potentials has been done in a former project, based on Fischer et al. (2007). Table 4.10 displays the initial yield information (also derived from Fischer et al., 2007) which is used for the calculation of land requirements. Average yields for new energy crops differentiated for selected European Member States are also shown in Table 4.10. The differentiation into four yield classes (depending on soil type) is provided by Fischer et al. (2007). Because the CAPRI model does not make such a distinction, the average yields

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[51] In spite of sketchy evidence that waste oil is non-negligible in some MS, it is ignored so far in the ex-post database establishment.

[52] Austrian Biomass Association. Available at: www.biomasseverband.at. Access date: 18.07.2009

(over all yield classes) are applied. Furthermore, as yields of herbaceous and woody energy crops differ only moderately simplification is done by using an average aggregated yield in CAPRI covering both, herbaceous as well as woody crops. This allows to handle woody and herbaceous crops as one product in the model: New energy crops (*NECR*).

Table 4.9: Production coefficients for agricultural residues

	Av. production coeff.	**Usability share**	**Water content**	**Av. prodcution coeff. for usable biomass**
Product	ratio	%	%	ratio
Wheat	1.23	50	15	0.52
Barley	1.70	50	15	0.72
Maize	1.50	50	15	0.64
Rye	2.00	50	15	0.85
Oats	2.00	50	15	0.85
Sugar beets	0.55	50	75	0.07
Sunflower seed	2.63	50	40	0.79
Rapeseed	2.75	50	40	0.83

Source: Own calculation based on Fischer et al. (2007)

Table 4.10: Average yields for new energy crops

Country		**Yields in t d.w./ha**				**Average yield**	**Average aggregated yield**
		Class 1	**Class 2**	**Class 3**	**Class 4**		
Germany	Herbaceous	16.60	12.90	9.00	5.20	10.93	9.83
	Woody	13.40	10.40	7.10	4.00	8.73	
France	Herbaceous	18.50	14.40	9.90	5.90	12.18	10.69
	Woody	15.40	10.80	7.10	3.50	9.20	
Italy	Herbaceous	19.50	14.70	10.20	6.30	12.68	10.90
	Woody	15.10	10.80	7.10	3.50	9.13	
UK	Herbaceous	14.00	11.60	8.40	4.50	9.63	9.00
	Woody	13.20	10.00	6.70	3.60	8.38	
Sweden	Herbaceous	10.90	9.60	6.90	4.10	7.88	7.27
	Woody		9.80	6.70	3.50	6.67	
Poland	Herbaceous	17.10	13.30	9.40	5.40	11.30	10.05
	Woody	13.30	10.60	7.20	4.10	8.80	
Bulgaria	Herbaceous	19.20	14.60	10.10	5.60	12.38	10.40
	Woody	13.80	9.60	6.80	3.50	8.43	

Source: Own calculation based on Fischer et al. (2007)

Technological parameters

Conversion coefficients for 1st generation biofuels are collected from different sources. The PRIMES database includes conversion coefficients but only for the feedstock aggregates which are covered in the PRIMES - Biomass model (Capros, 2010): vegetable oils, sugar crops, starchy crops and maize. As CAPRI needs coefficients for individual agricultural crops these parameter values are only used as a starting point. The AgLink model covers a set of conversion coefficients which are in line with the CAPRI product definition. These values are cross-checked against PRIMES and further information provided by Szulczyk (2007) and Fischer et al. (2007). Because the coefficient values differ only in a small range the average values over all sources are calculated (Table 4.11) and implemented in the CAPRI data base.

Table 4.11: Conversion coefficients for 1st generation biofuel production

		Ethanol	**By-products**	
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
	Maize (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	**By-products**	
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

*Note: *considered as molasses equivalent (1t vinasses = 0.1t molasses)*
Source: Own compilation base on the AgLink and PRIMES database (status October 2009) and Szulczyk (2007)

Conversion coefficients for 2nd generation technologies (Table 4.12) are taken from the PRIMES model and are also compared with other literature sources. As the processing of the considered agricultural residues and new energy crops to biofuels rely on the same ingredient (lingo- or herbaceous celluloses) which has nearly the same energy content per ton dry mass in both product groups, the conversion coefficients are assumed to be equal.

Table 4.12: Conversion coefficients for 2nd generation biofuel production

	FT Diesel	**FT By-product (tailgas)**	**Prolysis Diesel**	**HTU Diesel**	**LC Ethanol**	**LC By-product (lignin)**
Agricultural residues*	0.70	0.25	0.236	0.278	0.147	0.12
New energy crops**	0.70	0.25	0.236	0.278	0.147	0.12

*Note:*Grain or oil seed straw and sugar beet leaves **Cellulosic plant species as poplar, willow, miscanthus.*
FT=Fischer Tropsch, HTU=Hydro thermal upgrading, LC=Lignocellulosic
Source: Own compilation base on AgLink and PRIMES information and Szulczyk ((2007)

4.5. Behavioural model for biofuel supply and feedstock demand

In general total domestic biofuel supply (*MAPR*) is defined as the sum of domestic 1st generation (*FSTG*), 2nd generation (*SECG*) and non-agricultural (*NAGR*) biofuel production as already displayed in Figure 4.4 for ethanol and in

Figure 4.3 for biodiesel. While 2nd generation and non-agricultural biofuel production are exogenously determined and thus, depend on scenario assumptions, 1st generation biofuel supply represents the flexible part of the total supply function. Hence, the following methodological considerations are exclusively related to the specification of 1st generation biofuel supply (*FSTG*).

The analysis of firms' supply behaviour aims to improve the understanding of how producers combine inputs in the production process under the assumption of competition, to attain an optimal operating result. For the biofuel processing firm this means which combination of different biofuel feedstocks (agricultural crops) should be demanded and processed. For this decision problem, the *theory of the firm* provides a useful theoretical framework. Starting from a dual approach[53] of the production theory (Fuss and McFadden, 1987, or Krelle, 1980) optimal supply and feedstock demand can be derived either from a cost or profit function. The cost function represents the firms' economic behaviour as a cost minimization problem, subject to a given level of output quantities and input prices. The profit function represents the firms' profit as a function of input and output prices. Here, the firms' decision problem is to choose levels of output supply and input demand that maximize the firms' profit. If optimal feedstock demand and biofuel supply should rely on biofuel and biofuel feedstock prices a profit maximisation approach is suitable. If processing demand should rely on given biofuel supply quantities and feedstock prices a cost minimization approach is suitable. Because both approaches should lead to the same result the preference depends on the type of integration of the resulting behavioural functions in the respective model (Colman, 1983), in this case in the conceptual framework of the CAPRI biofuel model. As it is intended to implement a complete market representation of biofuels, biofuel as well as biofuel feedstock prices will be the main decision variables to determine supply and demand quantities under market equilibrium conditions. Hence, a profit maximisation approach is chosen.

For the specification of the underlying profit function the following methodological considerations regarding the biofuel specific production technology are made: In general the biofuel production firm produces two outputs (y_j): a biofuel product (y_1) which is the primary product, valued at producer price ($ppri_1$) and a respective by-product (y_2) valued at a producer price ($ppri_2$) which is simultaneously produced in a constant ratio to the biofuel product. Following this sort of production structure the firms' production technology can be defined as a

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[53] Duality between production-, cost and profit functions implies that there exists a correspondence between the cost- and profit function and their underlying production function. The correspondence is such that one or both (profit or cost-function) can be used to derive the properties of the production function (Fuss and McFadden, 1987).

multiple-output technology (Lau, 1972). The constant ratio between the production of output y_1 and y_2 characterises the output side of production technology as joint production under fixed proportions. Furthermore, the firm can process quantities of different inputs ($BIOF_i$) valued at a consumer price $cpri_i$ which are substitutable to produce a certain output level in the fixed relation between y_1 and y_2. The conversion coefficients α_{ij} which define the input-output ratio are fixed, meaning that every unit of input produces a specific quantity of output. Thus, the input side of the production function is characterised by a multi-input technology without any jointness, meaning that theoretically separate production functions for each input can be defined (Baumgärtner, 2001). Taking into account these specific features of the production technology some simplifications can be done. As the production technology is joint in outputs under fixed proportions and non-joint in inputs the outputs can be aggregated in one composite good which allows for simplifying the multiple output transformation function into a multiple input single output production function (Baumgärtner, 2001). Following this approach a composite good (yc) can be defined

$$\sum_j a_{ij} BIOF_i = yc_i = \textit{composite good} \tag{1.1}$$

which includes both: quantities of y_1 and y_2. The price of the composite good (pc_i) is defined as the sum over the respective conversion coefficients α_{ij} (depending on the inputs i and the outputs j) times the respective output prices $ppri_j$:

$$pc_i = \sum_j a_{ij}\, ppri_j \ . \tag{1.2}$$

The profit function depending on input and output prices can be formulated depending on processing margins (mar)

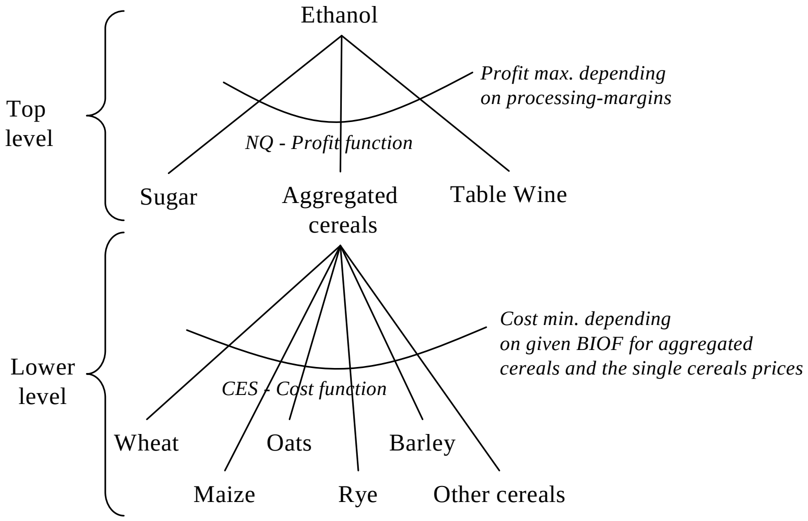
$$\begin{aligned} \max_{BIOF} \pi &= \sum_i pc_i \cdot yc_i - \sum_i cpri_i \cdot BIOF_i \\ &= \sum_i pc_i \left(a_{1i} BIOF_i + a_{2i} BIOF_i \right) - \sum_i cpri_i \cdot BIOF_i \\ &= \sum_i \left(pc_i a_{1i} + pc_i a_{2i} - cpri_i \right) BIOF_i \\ &= \sum_i mar_i BIOF_i \end{aligned} \tag{1.3}$$

because the respective conversion coefficient for every input i is constant. For both biofuels, ethanol and biodiesel, these general theoretical considerations are true. As the specification of the margin term (mar) and the derivation of the optimal biofuel feedstock demand function (*BIOF*) based on this profit function covers specific features their specification will be described separately.

Ethanol supply and feedstock demand

The calculation of profit maximising ethanol feedstock demand for individual feedstocks is split into two levels as displayed in Figure 4.7.

Figure 4.7: Two level ethanol feedstock demand system



Source: Own illustration

The top level is solved by the mentioned profit maximisation approach and defines profit maximising ethanol supply ($FSTG_{BIOE}$)

$$(1.4) \qquad FSTG_{BIOE} = \sum_{itop} \left(BIOF_{itop}(mar_{itop}) \cdot \alpha_{itop} \right),$$

where *itop* is a set of sugar, table wine and aggregated cereals. The margin term (*mar*) for sugar

$$(1.5) \qquad mar_{SUGA} = \frac{p_{BIOE} + \frac{(p_{MOLA} \cdot \beta_{SUGA})}{\alpha_{SUGA}}}{\frac{p_{SUGA}}{\alpha_{SUGA}}}$$

depends on the prices of ethanol (p_{BIOE}), sugar (p_{SUGA}), molasses (p_{MOLA}) and the conversion coefficients α, β. The margin for table wine (*TWIN*) is given by

$$(1.6)\qquad mar_{TWIN} = \frac{p_{BIOE}}{\frac{p_{TWIN}}{\alpha_{TWIN}}}$$

and depends on the prices of ethanol, table wine (p_{TWIN}) and the respective conversion coefficient α. All margins are defined as the relation of output revenues to input costs. Cereals' margins are covered in the top level by using an aggregated average margin (mar_{CERE})

$$(1.7)\qquad mar_{CERE} = \frac{\sum_{ilow}\left(mar_{ilow} \cdot BIOF_{ilow}\right)}{\sum_{ilow} BIOF_{ilow}}$$

depending on weighted individual margins for all usable cereals *ilow* (set of barley, wheat, rye, oats, maize and other cereals)

$$(1.8)\qquad mar_{ilow} = \frac{p_{BIOE} + \frac{\left(p_{DDGS} \cdot \beta_{ilow}\right)}{\alpha_{ilow}}}{\frac{p_{ilow}}{\alpha_{ilow}}}.$$

The decision of the distribution among the different cereals is done at the lower level. Here, demand quantities for individual cereals ($BIOF_{ilow}$), which can be processed in the same plant, are solved by using a cost minimization approach as it was already realised in the previous CAPRI version (Blanco Fonseca et al., 2009). It depends on single cereal prices (p_{ilow}) and the overall profit maximal demand quantity for cereals used for ethanol ($BIOF_{CERE}$) given by Equation (1.12) . Using a constant elasticity of substitution (CES) function the resulting feedstock demand quantities for single cereals ($BIOF_{ilow}$) can be described by the following cost minimization problem

$$(1.9)\qquad \begin{aligned} &\textit{Minimize} \sum_{ilow} BIOF_{ilow}\left(p_{ilow} - \beta_{ilow} \cdot p_{DDG}\right) \\ &\textit{subject to}\quad BIOF_{CERE} = \gamma\left[\sum_{ilow}\left(\delta_{ilow} \cdot \alpha_{ilow} \cdot BIOF_{ilow}\right)^{\rho}\right]^{\frac{1}{\rho}}. \end{aligned}$$

where $\rho = (\sigma\text{-}1)/\sigma$ is a parameter related to the elasticity of substitution σ which are adopted from the previous CAPRI version as described in Blanco Fonseca et al. (2009). γ,δ are calibration parameters, α,β the respective conversion coefficients. Taking the first order conditions for an optimal solution of this optimization problem gives

$$\begin{aligned}(1.10)\qquad & BIOF_{ilow}\left(p_{ilow} - \beta_{ilow} \cdot p_{DDG}\right)^{\frac{1}{1-\rho}}\left(\delta_{ilow} \cdot \alpha_{ilow}\right)^{\frac{\rho}{\rho-1}} \\ & = BIOF_{jlow}\left(p_{jlow} - \beta_{jlow} \cdot p_{DDG}\right)^{\frac{1}{1-\rho}}\left(\delta_{jlow} \cdot a_{jlow}\right)^{\frac{\rho}{\rho-1}}\end{aligned}$$

where *jlow* is an alias for *ilow*. Since the CES function exhibits constant returns to scale (Blanco Fonseca et al., 2009), the first order conditions come in pairs and are not sufficient in order to find a unique solution. Thus, Equation (1.10) is dropped for one input, called the numeraire, and the constraint covered by Equation (1.9) is used to determine the level of production. Equation (1.10) is implemented for all *ilow* ≠ 'numeraire' and *jlow* = 'numeraire' (Blanco Fonseca et al., 2009).

On the top level, profit maximal feedstock demand for aggregated cereals, sugar and table wine is derived from the above mentioned profit maximisation assumption. Different functional forms for the profit function are conceivable, like also a CES type, or more flexible ones like normalized quadratic or translog, due to their flexibility and wide use in economic research. The normalized quadratic (NQ) profit function has the advantages of linearity in parameters and simple expressions for the elasticities. Using a normalized quadratic functional form, the profit function (depending on margins) can be formulated as

$$(1.11)\qquad \frac{\pi}{p_{index}} = \lambda + \sum_{itop} \tau_{itop} \frac{mar_{itop}}{p_{index}} + \frac{1}{2} \sum_{itop} \sum_{ktop} \tau_{itop,ktop} \frac{mar_{itop}}{p_{index}} \cdot \frac{mar_{ktop}}{p_{index}}$$

where λ, τ_{itop} and $\tau_{itop,ktop}$ are calibration parameters, p_{index} is a price index and *ktop* is an alias for *itop*. The equation for estimating profit maximising input demand on the top level ($BIOF_{itop}$) can be derived form this profit function via Hotellings Lemma[54]. The resulting derivative with respect to normalised margins displays the input demand function

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[54] $$\text{Hotellings Lemma}: \frac{\partial \pi(p,w)}{\partial p} = y^*(p,w) = \text{profit max. supply quantity};$$

$$-\frac{\partial \pi(p,w)}{\partial w_i} = x_i^*(p,w) = \text{profit max. input demand quantity}$$

$$(1.12) \qquad BIOF_{itop} = \tau_{itop} + \sum_{ktop} \tau_{itop,ktop} \cdot \frac{mar_{ktop}}{p_{index}} .$$

Primarily it was envisaged to have the substitution between sugar, table wine and the different cereals in the same function but there are several advantages of having it separately as described:

- Being able to easily fix certain technology pathways (e.g. sugar)
- Being able to switch of the top level and run the model with exogenous feedstock demand
- Comparability with PRIMES/AgLink which work on higher aggregated levels (e.g. starchy crops and sugar crops in PRIMES)
- One could include production capacities as variables in the supply function.

Furthermore, it is assumed that in general different ethanol processing plants exist which are characterised by the usable feedstock group (for example sugar beets or cereals). A plant which is specialised on sugar beets might not be able to use cereals as feedstocks and the other way around. However, a biofuel plant which is specialised on starchy crops is able to substitute different types of cereals (like wheat, barely, oats, maize, etc.). This decision depends on individual feedstock costs. Exactly this is covered by the cost minimisation approach mentioned above.

Biodiesel supply and feedstock demand

Similar to total ethanol supply total domestic supply of biodiesel ($MAPR_{BIOD}$) is the sum of 1st generation production ($FSTG_{BIOD}$), depending on the average margin of vegetable oils (mar_{OILP}) and the exogenous parts ($SECG_{BIOD}$ and $NAGR_{BIOD}$):

$$(1.13) \qquad MAPR_{BIOD} = FSTG_{BIOD} + SECG_{BIOD} + NAGR_{BIOD}$$

where

$$(1.14) \qquad FSTG_{BIOD} = \sum_{OILP} \left(BIOF_{OILP}(mar_{OILP}) \cdot \alpha_{OILP} \right)$$

Thereby, α_{OILP} is the average conversion coefficient for processing of vegetable oils to biodiesel. The margins for individual vegetable oils are covered in the top level by using an average aggregated margin (mar_{OILP})

$$(1.15) \qquad mar_{OILP} = \frac{\sum_{ilow}\left(mar_{ilow}\cdot BIOF_{ilow}\right)}{\sum_{ilow} BIOF_{ilow}}$$

depending on weighted individual margins for all usable vegetable oils *ilow* (set of rape oil, sunflower oil, soy oil, palm oil) where

$$(1.16) \qquad mar_{ilow} = \frac{p_{BIOD} + \dfrac{\left(p_{GLY}\cdot\beta_{ilow}\right)}{\alpha_{ilow}}}{\dfrac{p_{ilow}}{\alpha_{ilow}}} .$$

p_{BIOD} is the price of biodiesel, p_{GLY} is the price of the by-product glycerine and β is the respective conversion coefficient for the by-product. The distribution among the different vegetable oils (rape, sunflower, soy, and palm) is then driven by a cost minimisation approach, equivalently to Equation (1.9)

$$(1.17) \qquad \begin{aligned} &\mathit{Minimize} \sum_{ilow} BIOF_{ilow}\left(p_{ilow} - \beta_{ilow}\cdot p_{GLY}\right) \\ &\mathit{subject\ to} \quad BIOF_{OILP} = \gamma\left[\sum_{ilow}\left(\delta_{ilow}\cdot\alpha_{ilow}\cdot BIOF_{ilow}\right)^{\rho}\right]^{\frac{1}{\rho}} \end{aligned}$$

where $\rho = (\sigma-1)/\sigma$ is a parameter related to the elasticity of substitution σ which are also adopted from Blanco Fonseca et al. (2009). Following Hotellings Lemma, profit maximizing feedstock demand ($BIOF_{OILP}$)

$$(1.18) \qquad BIOF_{OILP} = \tau + \mu\cdot\frac{mar_{OILP}}{p_{index}}$$

is the derivative with respect to normalised margins of the profit function

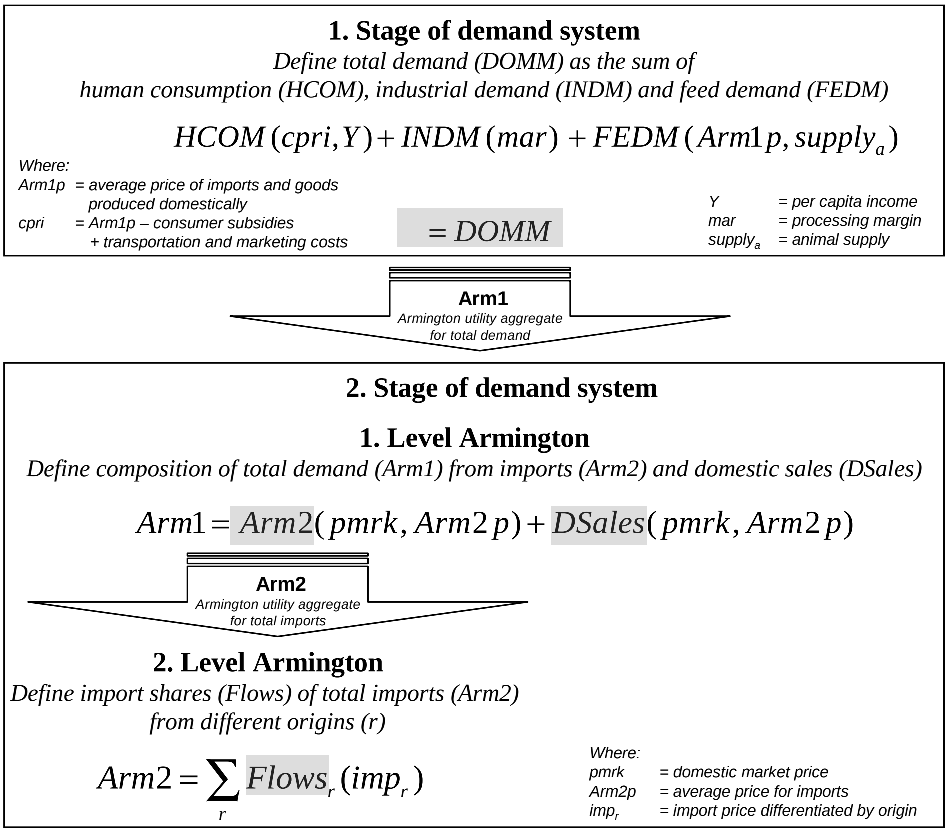
$$(1.19) \qquad \frac{\pi}{p_{index}} = \lambda + \tau\frac{mar_{OILP}}{p_{index}} + \frac{1}{2}\cdot\mu\left(\frac{mar_{OILP}}{p_{index}}\right)^{2} .$$

Behavioural functions for biofuel supply, feedstock demand and the functions for biofuel as well as total fuel demand which will be described in the next sections are specified for European and non-European regions.

4.6. Behavioural model for biofuel demand and trade

The general methodological concept for representing biofuel demand and trade in the CAPRI biofuel model is that of a two stage demand system as already applied for other agricultural commodities (Figure 4.8) in the standard CAPRI version (Britz and Witzke, 2009).

Figure 4.8: Two stage demand system in core CAPRI model



1. Stage of demand system

Define total demand (DOMM) as the sum of human consumption (HCOM), industrial demand (INDM) and feed demand (FEDM)

$$HCOM(cpri, Y) + INDM(mar) + FEDM(Arm1p, supply_a)$$

$$= DOMM$$

Where:

Arm1p = average price of imports and goods produced domestically

cpri = Arm1p – consumer subsidies + transportation and marketing costs

Y = per capita income

mar = processing margin

$supply_a$ = animal supply

2. Stage of demand system

1. Level Armington

Define composition of total demand (Arm1) from imports (Arm2) and domestic sales (DSales)

$$Arm1 = Arm2(pmrk, Arm2p) + DSales(pmrk, Arm2p)$$

2. Level Armington

Define import shares (Flows) of total imports (Arm2) from different origins (r)

$$Arm2 = \sum_r Flows_r(imp_r)$$

Where:

pmrk = domestic market price

Arm2p = average price for imports

imp_r = import price differentiated by origin

Source: Own illustration based on Britz and Witzke (2009)

Within the standard concept, the first stage defines total domestic demand as the sum of human consumption (depending on consumer prices and per capita income), processing demand (depending on processing margins) and feed demand (depending on the average price of imports and goods produced domestically and animal supply). For agricultural products which can be used as biofuel feedstock total domestic demand is extended to cover also the position *biofuel feedstock demand* (*BIOF*) which depends on processing margins as already described.

The second stage of the demand system then applies a two level Armington system: On the top level the composition of total demand (*Arm1*) into total imports (*Arm2*) and domestic sales (*DSales*) is determined as a function of the internal market price and the average price for imports. The lower level determines the import shares from different origins (*FLOWS)* as a function of import prices. Both functions are derived from CES utility functions, where *Arm1* defines the utility aggregate of the top level function which corresponds to the utility value of total demand (*DOMM*). *Arm2* defines the utility aggregate of the lower level function which corresponds to total imports. The substitution elasticities on the top level are smaller than for the second one, i.e. it is assumed that consumer will be less responsive regarding substitution between domestic and imported goods compared to changes between imported goods from different origins (Britz and Witzke, 2009).

Within the CAPRI biofuel model biofuel demand for fuel use is set on human consumption (*HCOM*) due to the fact that these biofuel quantities are consumed by households. Non-fuel demand for biofuels (for example by the chemical or beverage industry in the case of ethanol) is consequently set on industrial demand (*INDM*) which is defined by exogenous assumptions. Feed demand (*FEDM*) is neglected for biofuels, as no feed use exists. While the Armington system can be used directly to estimate biofuel imports and bilateral trade flows, the estimation of total fuel demand and total demand for biofuels in the first stage differs from the already applied demand system in the model (Figure 4.9). A modification becomes necessary as demand for fuels and biofuels respectively are functions of explanatory variables which are largely not covered explicitly in an agricultural sector model but more in an energy sector or general economic model. Macroeconomic variables like population growth and GDP, further variables like fossil fuel demand, supply and prices as well as energy policy variables are influencing factors. As the CAPRI database does not allow for the estimation of total fuel and biofuel demand functions by taking into account the unknown variables, it is decided to estimate the required functions based on existing specifications in other specialised models.

For the derivation of biofuel demand functions the existing specification in the OECD-FAO agricultural sector model AgLink (described in detail in Lampe 2006 and 2008) is taken as a starting point.[55] The biofuel demand representation in AgLink is already well developed and very detailed as it distinguishes biofuel demand into three demand components: biofuel use and an additive to fossil fuels, biofuel use as low-level blend in fossil fuels and biofuel use as high-level blend in fossil fuels. By several publications (for example Lampe 2006 and 2008) it is also

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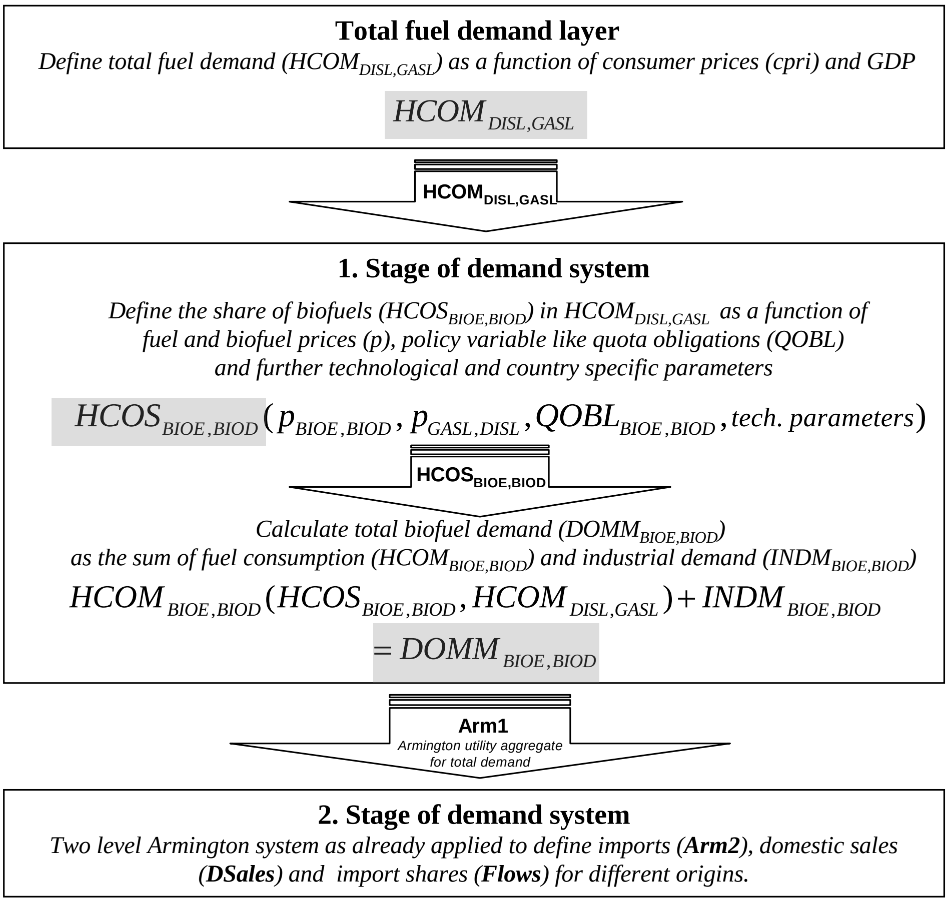
[55] The full dataset of the AgLink baseline (status October 2009) and the detailed AgLink model code was available within the preparation of this analysis.

well documented and currently used by the OECD and FAO within the biofuel market projections for the annual OECD FAO Agricultural Outlook[56].

Figure 4.9: Two stage demand system for biofuels in the CAPRI biofuel model



Total fuel demand layer

Define total fuel demand (HCOM$_{DISL,GASL}$) as a function of consumer prices (cpri) and GDP

$$HCOM_{DISL,GASL}$$

1. Stage of demand system

Define the share of biofuels (HCOS$_{BIOE,BIOD}$) in HCOM$_{DISL,GASL}$ as a function of fuel and biofuel prices (p), policy variable like quota obligations (QOBL) and further technological and country specific parameters

$$HCOS_{BIOE,BIOD}(p_{BIOE,BIOD}, p_{GASL,DISL}, QOBL_{BIOE,BIOD}, tech.\ parameters)$$

Calculate total biofuel demand (DOMM$_{BIOE,BIOD}$) as the sum of fuel consumption (HCOM$_{BIOE,BIOD}$) and industrial demand (INDM$_{BIOE,BIOD}$)

$$HCOM_{BIOE,BIOD}(HCOS_{BIOE,BIOD}, HCOM_{DISL,GASL}) + INDM_{BIOE,BIOD} = DOMM_{BIOE,BIOD}$$

2. Stage of demand system

*Two level Armington system as already applied to define imports (**Arm2**), domestic sales (**DSales**) and import shares (**Flows**) for different origins.*

Source: Own illustration

As biofuel quota obligations (generally defined as a percentage share in total domestic fuel consumption) are an important driver for biofuel demand, in particular in the EU27, biofuel demand strongly depends on total fuel demand. Instead of an exogenous handling of total fuel demand in the model, differentiated into diesel and gasoline, available information from the European energy sector model PRIMES are used to estimate functions approximating total diesel and

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[56] The Agricultural Outlook is an annual publication of the OECD and FAO which provides agricultural market projections for important agricultural commodities. More information available at: www.agri-outlook.org. Access date: 28.05.2011

gasoline demand behaviour. The estimation is done by applying a response surface approach based on various scenario simulations from the PRIMES model which include information on fuel demand and some corresponding key drivers, like fuel prices and GDP, for every European Member State. This allows for adding an additional layer on the top of the first stage (Figure 4.9) which covers functions approximating fuel demand for gasoline ($GASL$) and diesel ($DISL$), depending on fuel prices and economic growth for each covered model region. These functions further improve the CAPRI biofuel model as they permit to simulate fuel price or GDP scenarios. Within the biofuel demand system the estimated total fuel demand quantities then enter the biofuel demand functions ($HCOM_{BIOE,BIOD}$) which rely on the estimated shares of biofuels in total fuel consumption ($HCOS_{BIOE,BIOD}$). By adding the exogenously given industrial demand quantities for biofuels ($INDM_{BIOE,BIOD}$) total domestic biofuel demand ($DOMM_{BIOE,BIOD}$) can be defined.

Derivation of ethanol demand functions based on the AgLink specification

Demand for ethanol in AgLink is modelled as a tripartite demand function where the share of ethanol in total gasoline consumption reacts basically to the price ratio of ethanol to fossil gasoline, with quotas included. Box 4.1 displays the specification of these ethanol demand functions. Following this approach the resulting aggregated ethanol demand function (QC_{ET}) depends in addition to the price ratio between ethanol and gasoline on some technological parameters, some country specific coefficients and on the total consumption of gasoline which is handled exogenously in AgLink. Depending on the price ratio of biofuels to fossil fuels each of the functions for the three demand components can be differentiated in three ranges (defined by if else conditions): A range where the maximum blending share is realised, a range where the blending is equal to zero and a range between the maximum blending share and zero. Here, the function follows a sinus-shape. The composed demand functions (QCS^{LBLD}_{ET}, QCS^{LBLD}_{ET}, QCS^{LBLD}_{ET}) then follow an s-shape between 1, where the maximum blending share is realised and 0, where it is completely kicked out of the market, depending on the price ratio of biofuels to fossil fuels.

For approximating these functions in the CAPRI biofuel model sigmoid (sig) functions are selected which are suitable to reproduce this s-shape. These sigmoid functions are calibrated in a way that they approximate the AgLink functions for the given price-quantity ratios, differentiated for each covered region.

Box 4.1: The tripartite ethanol demand function in AgLink

The share (%) of ethanol in total gasoline consumption (QCS_{ET}), is given by

$$QCS_{ET} = QCS_{ET}^{ADD} + QCS_{ET}^{LBLD} + QCS_{ET}^{FFV} \text{.} \tag{1.20}$$

$QCS^{ADD}{}_{ET}$ represents demand for ethanol used as gasoline additive, $QCS^{LBLD}{}_{ET}$ represents demand for ethanol used in low-level blends, and $QCS^{FFV}{}_{ET}$ represents demand for ethanol used in high-level blends. As this demand function delivers a relative share, the absolute ethanol quantity (QC_{ET}) is calculated based on the total use of gasoline (QC_{Gas}), the relative energy content of ethanol ($ERAT_{ET,GAS}$) and certain additional ethanol quantities demanded e.g. by the chemical industry ($QC^{other}{}_{ET}$)

$$QC_{ET} = \frac{QCS_{ET} \cdot QC_{Gas}}{ERAT_{ET,Gas}} + QC_{ET}^{other} \text{.} \tag{1.21}$$

The three components of the total demand function (QCS_{ET}) are specified as follows.

(1) Demand for ethanol as a gasoline additive ($QCS^{ADD}{}_{ET}$) is given by

$$QCS_{ET}^{ADD} = \left\{ \begin{array}{l} if \ \textit{no alternative}: BLD_{ET,GAS}^{ADD,GE} \\ else\,if \ PR_{ET,GAS} > MP_{ADD}^{spl} + MP_{ADD}^{spr} : 0 \\ else\,if \ PR_{ET,GAS} < MP_{ADD}^{spl} - MP_{ADD}^{spr} : BLD_{ET,GAS}^{ADD,GE} \\ else: \left(\dfrac{\sin\left(\dfrac{\left(PR_{ET,GAS} - MP_{ADD}^{spl} + 2 \cdot MP_{ADD}^{spr} \right) \cdot \pi}{2 \cdot MP_{ADD}^{spr}} \right)}{2 + 0.5} \right) \cdot BLD_{ET,GAS}^{ADD,GE} \end{array} \right\} \tag{1.22}$$

where

QCS_{ET}^{ADD} = *Ethanol share in gasoline as an additive, energy equivalent*

$BLD_{ET,GAS}^{ADD,GE}$ = *Additive share in gasoline*

$PR_{ET,GAS}$ = *Price ratio between ethanol and gasoline market price*

MP_{ADD}^{spl} = *Price of additive relative to gasoline*

MP_{ADD}^{spr} = *Price spread in which substitution for additives occurs*

Cont. Box 4.1: The tripartite ethanol demand function in AgLink

(2) Demand for ethanol in low-level blends (QCS^{LBLD}_{ET}) is given by

$$
QCS^{LBLD}_{ET} =
$$

$$
\left\{ \begin{array}{l}
QCS^{OBL}_{ET} - QCS^{ADD}_{ET}, \\
\left[\begin{array}{l}
if\ PR_{ET,GAS} > MP^{PREM}_{ET} : 0 \\
else\,if\ PR_{ET,GAS} < ERAT_{ET,GAS} : QCS^{LIMIT}_{ET} - QCS^{ADD}_{ET} \\
else: \dfrac{\sin\left(\dfrac{\left(2 \cdot PR_{ET,GAS} + MP^{PREM}_{ET} - 3 \cdot ERAT_{ET,GAS} \right) \cdot \pi}{2 \cdot \left(MP^{PREM}_{ET} - ERAT_{ET,GAS} \right)} \right) + 1}{2} \\
\cdot \left(QCS^{LIMIT}_{ET} - QCS^{ADD}_{ET} \right)
\end{array} \right]
\end{array} \right\} \qquad (1.23)
$$

where
QCS^{LBLD}_{ET} = Ethanol share in gasoline as low level blend, energy equivalent
QCS^{OBL}_{ET} = Blending obligation, share, energy equivalent
MP^{PREM}_{ET} = Maximum premium price of ethanol in low - level blends, relative to gasoline price, ratio
$ERAT_{ET,GAS}$ = Energy content ratio between ethanol and gasoline
QCS^{LIMIT}_{ET} = Upper limit for ethanol in low - level blends, share

(3) Demand for ethanol as a neat fuel (QCS^{FFV}_{ET}) is given by

$$
QCS^{FFV}_{ET} =
$$

$$
\left\{ \begin{array}{l}
if\ PR_{ET,GAS} > ERAT_{ET,GAS} + MP^{spr}_{FFV} : 0 \\
else\,if\ PR_{ET,GAS} < ERAT_{ET,GAS} - MP^{spr}_{FFV} : 1 \\
else: \left(\sin\left(\dfrac{\left(PR_{ET,GAS} - ERAT_{ET,GAS} + 2 \cdot MP^{spr}_{FFV} \right) \cdot \pi}{2 \cdot MP^{spr}_{FFV}} \right) \Big/ 2 + 0.5 \right)
\end{array} \right\} \qquad (1.24)
$$

$$
\cdot FFV \cdot QCS^{HBLD}_{ET} \cdot \left(1 - QCS^{ADD}_{ET} - QCS^{LBLD}_{ET} \right)
$$

where
QCS^{FFV}_{ET} = Ethanol used as neat fuel by FFV vehicles, share, energy equivalent
MP^{spr}_{FFV} = Price spread in which substitution for FFVs occurs
FFV = Maximum share of FFVs in total vehicle fleet - changing exogenously over time
QCS^{HBLD}_{ET} = Ethanol share in high - level blends used in FFVs, energy equivalent

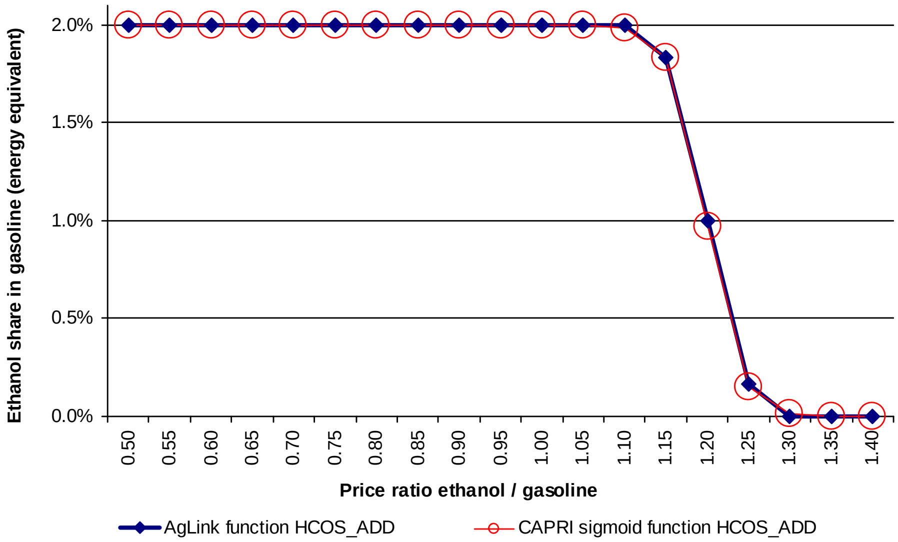
Source: Lampe, M. v. (2008)

In the case of the first demand component ($HCOS^{ADD}{}_{BIOE}$ = share of ethanol as an additive in gasoline) Equation (1.25) displays the approximating sigmoid function as implemented in the CAPRI biofuel model.

$$HCOS_{BIOE}^{ADD} = \left(1 - \frac{1}{1 + e^{-\left(\frac{p_{BIOE}}{p_{GASL}} \cdot \alpha - \beta \right)}} \right) \cdot BLD_{ET,GAS}^{ADD,GE} \tag{1.25}$$

$BLD^{ADD,GE}{}_{ET,GAS}$ is the maximum share of ethanol usable as additive in gasoline which results from technological restrictions. This share is assumed to be equal for all covered region and has a value of 2%. α, β are the calibration parameters. p_{BIOE} is the consumer price of ethanol and p_{GASL} the consumer price of gasoline. Figure 4.10 visualises the original AgLink function and the estimated sigmoid function, for different price ratios.

Figure 4.10: AgLink and *sig*-function for $HCOS^{ADD}{}_{BIOE}$



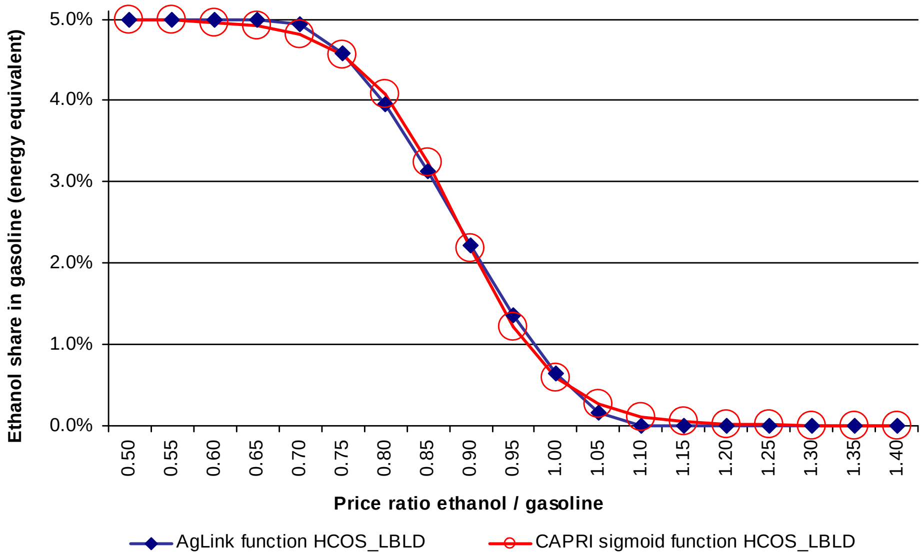
Source: Own illustration based on AgLink (status October 2009) and CAPRI biofuel model equations

An approximation for the second demand component in AgLink ($HCOS^{LBLD}{}_{BIOE}$ = share of ethanol as a low-level blend in gasoline) is given by

$$(1.26)\qquad HCOS_{BIOE}^{LBLE} = \left(1 - \frac{1}{1 + e^{-\left(\frac{p_{BIOE}}{p_{GASL}} \cdot \alpha - \beta \right)}} \right) \cdot \left(QCS_{ET}^{Limit} - \max\left(QOBL_{BIOE}, HCOS_{BIOE}^{ADD} \right) \right) .$$

The parameter $QCS^{Limit}{}_{ET}$ determines the maximum share of ethanol in low-level blends which results also from technological restrictions. This share is higher in Brazil compared to the EU and other countries due to the availability of vehicle engines which are able to tolerate a higher ethanol share than for example vehicles produced for the European market. $QOBL_{BIOE}$ represents a quota obligation which is unequal to zero if a quota is in place. It is assumed that only that part of the low-level demand function which is either above the additive demand share ($HCOS_{ADD}{}^{BIOE}$) or above a quota is a result of the price driven consumer decision for low-level blends. Thus, the maximum share of ethanol in low-level blends is reduced by the additive demand share or by the quota if its value is higher than the additive demand share. Figure 4.11 displays the original AgLink demand function and the estimated sigmoid function for different price ratios and for all countries expecting Brazil.

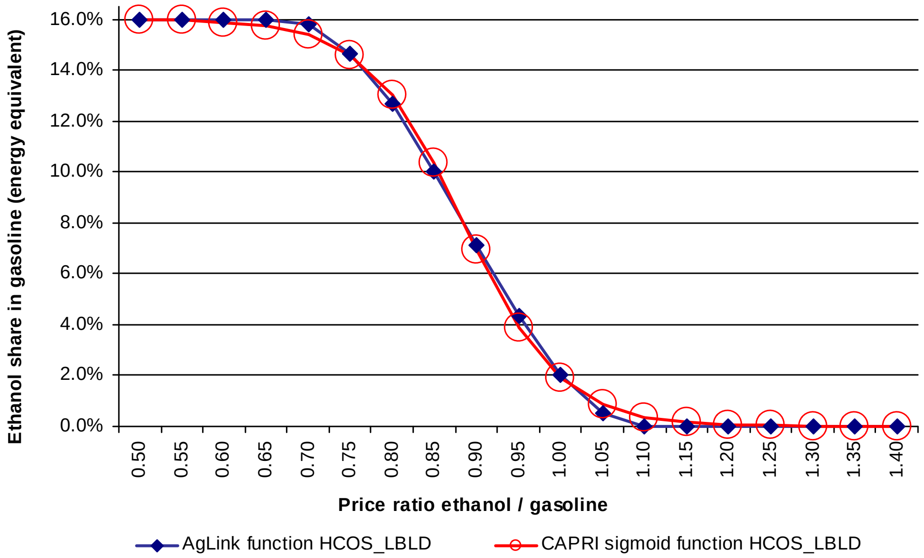
Figure 4.11: AgLink and *sig*-function for $HCOS^{LBLD}{}_{BIOE}$ (expecting Brazil)



Source: Own illustration based on AgLink (status October 2009) and CAPRI biofuel model equations

Figure 4.12 displays both curves for Brazil. In both cases it is assumed that no quota obligation is in place. Thus, the maximum share of ethanol as low-level blend in gasoline (EU 7%, Brazil 18%) is exclusively reduced by $HCOS_{ADD}{}^{BIOE}$ resulting from the respective price ratio.

Figure 4.12: AgLink and *sig*-function for $HCOS^{LBLD}{}_{BIOE}$ (Brazil)



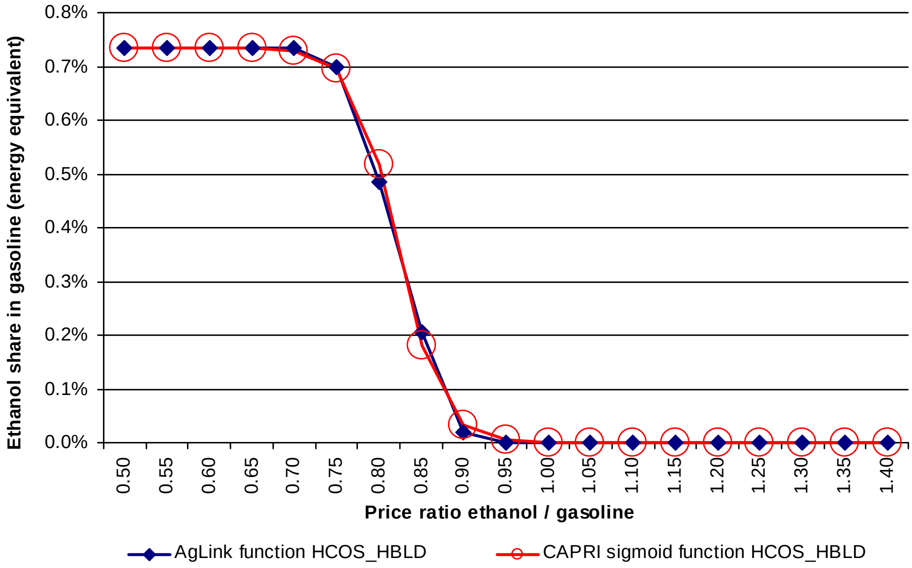
Source: Own illustration based on AgLink (status October 2009) and CAPRI biofuel model equations

The sigmoid function approximating the third demand component ($HCOS^{HBLD}{}_{BIOE}$ = share of ethanol as a high-level fuel in total gasoline consumption) is given by

$$HCOS^{HBLE}_{BIOE} = \left(1 - \frac{1}{1 + e^{-\left(\frac{\alpha - \left((PREM - 0.1) \cdot 20\right)}{MP^{spr}_{FFV} \cdot 10}\right) - \left(\frac{\beta + \left((PREM - 0.1) \cdot 20\right)}{MP^{spr}_{FFV} \cdot 10}\right)}}\right) \cdot FFV \cdot QCS^{HBLD}_{ET} \cdot \left(1 - HCOS^{ADD}_{BIOE} - HCOS^{LBLD}_{BIOE}\right) \tag{1.27}$$

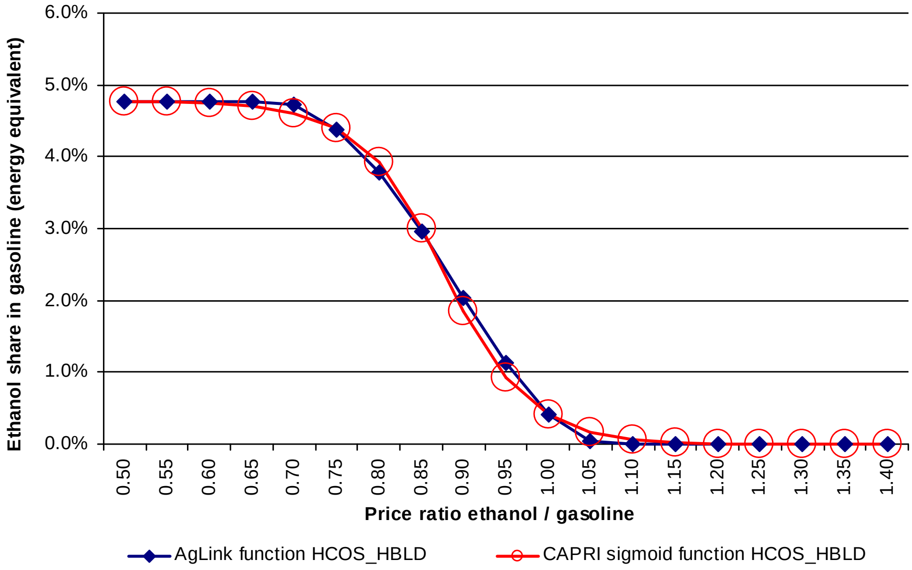
The parameter *FFV* determines the maximum share of Flexible Fuel Vehicles in total vehicle fleet which might be achieved if the use of high-level ethanol blends becomes profitable. The parameter $QCS^{HBLD}{}_{ET}$ defines the maximum share of ethanol in high-level gasoline blends. This share is again higher in Brazil (97%) than in other regions like the EU27 (79%) due to the long experience with ethanol containing fuel blends and the associated development of the automobile industry. The parameters $MP^{spr}{}_{FFV}$ (price spread in which substitution for *FFV* occurs) and *PREM* are country specific parameters which are adopted from AgLink. Figure 4.13 illustrates the original AgLink function and the estimated sigmoid function for the EU27, assuming a maximum share of 1% FFV cars. Figure 4.14 represents both curves for Brazil, assuming a maximum share of 6% FFV cars.

Figure 4.13: AgLink and *sig*-function for $HCOS^{HBLD}_{BIOE}$ (EU27, 1% FFV)



Source: Own illustration based on AgLink (status October 2009) and CAPRI biofuel model equations

Figure 4.14: AgLink and *sig*-function for $HCOS^{HBLD}_{BIOE}$ (Brazil, 6% FFV)



Source: Own illustration based on AgLink (status October 2009) and CAPRI biofuel model equations

The estimated calibration parameters as well as all technological parameters which are adopted from the AgLink database are shown for the most important global biofuel consumption regions (EU27, USA, and Brazil) differentiated by each estimated sigmoid function in Table 4.13.

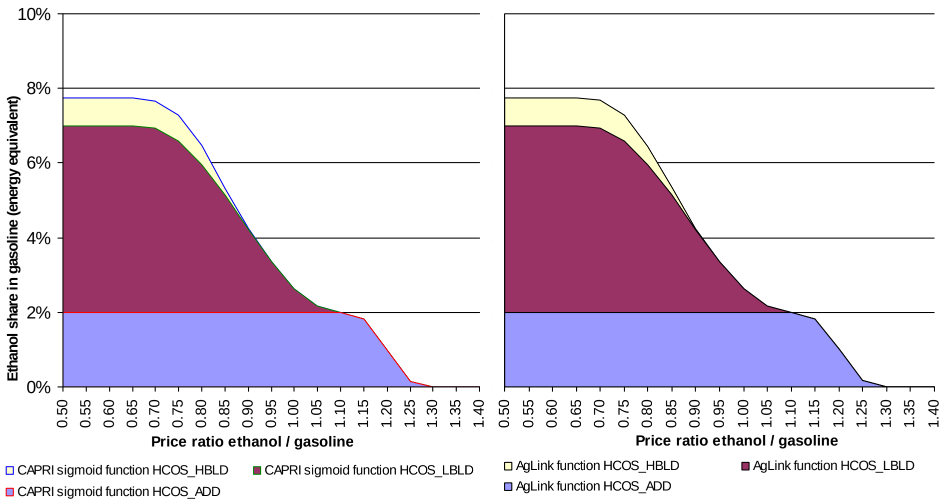
Table 4.13: Parameters of estimated sigmoid functions

Technical parameter	***EU27***	***USA***	***Brazil***
BLD_ADD_ET_GAS	0.02	0.02	0.02
QCS_LIMIT_ET	0.07	0.07	0.18
QCS_HBLD_ET	0.79	0.79	0.97
MP_SPR_FFV	0.10	0.20	0.20
PREM	0.15	0.10	0.20
ERAT_BIOE_GASL	0.67	0.67	0.67
ERAT_BIOD_DISL	0.80	0.80	0.80
Calibration parameter	***all regions***		
BIOE_ADD_α	48.8		
BIOE_ADD_β	58.8		
BIOE_LBLD_a	17.4		
BIOE_LBLD_β	15.4		
BIOE_HBLD_a	31.6		
BIOE_HBLD_β	40.7		
BIOD_a	6.4		
BIOD_β	3.6		

Source: AgLink (status October 2009) and CAPRI biofuel model equations

The function for the aggregated ethanol share in total gasoline consumption ($HCOS^{ET}$) resulting from the single demand components is depicted in Figure 4.15 for the EU27. The graph on the right hand side displays the original AgLink function the picture on the left hand side displays the estimated sigmoid function as implemented in the CAPRI biofuel model. As one can observe, the approximation in CAPRI is very close to the original one.

Figure 4.15: Agg. AgLink and CAPRI function for $HCOS^{ET}$ (EU27, 1% FFV)



Source: Own illustration based on AgLink (status October 2009) and CAPRI biofuel model equations

The final fuel ethanol demand function ($HCOM_{BIOE}$) which defines absolute fuel ethanol demand results from the estimated demand shares ($HCOS^{ADD}_{BIOE}$+ $HCOS^{LBLE}_{BIOE}$+ $HCOS^{HBLD}_{BIOE}$), the quota obligation ($QOBL_{BIOE}$) - if existent -, the overall gasoline consumption quantity ($HCOM_{GASL}$) and the energy ratio of ethanol compared to gasoline ($ERAT_{BIOE,GASL}$)

$$(1.28)\quad HCOM_{BIOE} = \frac{\left(\max\left(HCOS^{ADD}_{BIOE}, QOBL_{BIOE}\right) + HCOS^{LBLE}_{BIOE} + HCOS^{HBLE}_{BIOE}\right) \cdot HCOM_{GASL}}{ERAT_{BIOE,GASL}}.$$

Derivation of biodiesel demand functions based on the AgLink specification

Demand for biodiesel in AgLink is modelled in a simpler way as no comparable differentiation is assumed. The technological constraints for the use of biodiesel in comparison to ethanol are less, only the use of biodiesel beyond 50% blending share (like pure biodiesel - B100) necessitates some adaptations. Most new diesel cars are able to use biodiesel without any additional adaptations. However, because a potentially required adaptation might entail costs, this fact is considered within the consumer behaviour (price elasticity) of using biodiesel instead of diesel. Following these considerations the main drivers for biodiesel consumption are the price ratio of biodiesel compared to fossil diesel and quotas, if they exist. Box 4.2 gives an overview of the biodiesel demand specification in the AgLink model.

Box 4.2: The biodiesel demand function in AgLink

The energy share of biodiesel in total diesel consumption (QCS_{BD}) is given by

$$(1.29)\qquad \ln\left(QCS_{BD}\right) = \max\left\{\begin{matrix} QCS^{OBL}_{BD}, \\ const + \sum_{n=0}^{2} \alpha^{n} \cdot \ln\left(PR^{t-n}_{BD,Die}\right) + \beta \cdot \ln(t) \end{matrix}\right\}$$

where
QCS^{OBL}_{BD} = *Quota obligation*
$const$ = *Country specific constant*
$PR_{BD,Die}$ = *Price ratio biodiesel / diesel*
t = *Time period (year)*
α, β = *Calibration parameters*

Absolute biodiesel demand (QC_{BD}) is calculated based on total diesel consumption and the energy ratio of biodiesel compared to diesel ($ERAT_{BD,Die}$)

$$(1.30)\qquad QC_{BD} = \frac{QCS_{BD} \cdot QC_{Die}}{ERAT_{BD,Die}}.$$

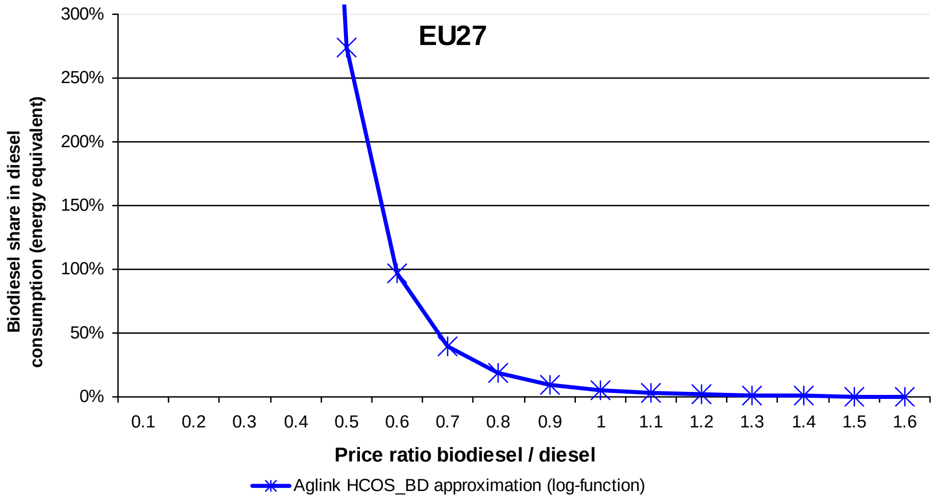
Source: Lampe, M. v. (2008)

Such logarithmic functions are typical for dynamic models like AgLink, where the demand decision in the current year depends also on variable values in the two foregoing years. As CAPRI is a static modelling system this functional construction cannot be transferred into CAPRI without modifications. Therefore, it is assumed that for the projection year (2020) the demand function derived from the original AgLink function is given by

$$(1.31)\qquad ln\left(QCS_{BD}\right) = constant_{new} + \alpha \cdot ln\left(PR_{BD,Die}\right),$$

where $constant_{new}$ is equal to *const* plus dynamic effect covered by $\alpha^{n} \cdot ln(PR^{t-n}_{BD,Die})$ and $\beta \cdot ln(t)$ for all $n \neq 0$. $PR_{BD,Die}$ is the price ratio of biodiesel and diesel in the projection year 2020. α is a calibration parameter. As the AgLink model projection provides values for $PR_{BD,Die}$ and the related biodiesel demand share (QCS_{BD}) for the year 2020 in each covered region, it is possible to take both values and calculate a new constant ($constant_{new}$), so that Equation (1.31) fits the respective value for QCS_{BD} under the given price ratio. Having this new constant the price ratio can be varied and the consumer demand behaviour, subject to different price ratios, can be observed. Figure 4.16 displays the resulting logarithmic demand function for the EU27 in 2020.

Figure 4.16: Estimated *log*-function for biodiesel demand (EU27, 2020)



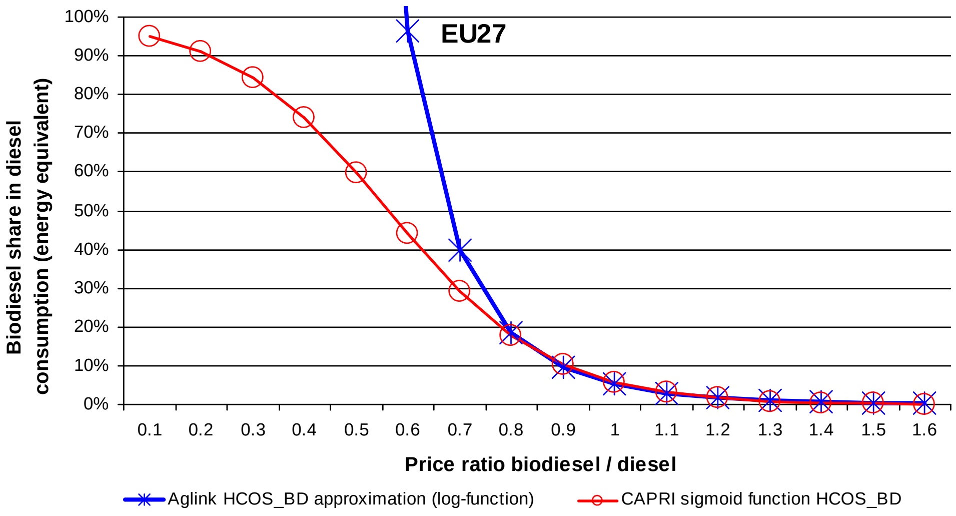
Source: Own illustration based on AgLink (status October 2009)

As one can observe, the function provides realistic values for QCS_{BD} in a range where the price ration is greater than 0.7. However, the significant demand increases resulting from price ratios which are smaller than 0.7 is not realistic and of course should not exceed 100%. For other regions like Brazil, USA or Canada the picture is similar, only the respective price ratio from where on the function overestimates consumer demand differs. Thus, this function is not suitable to display consumer demand behaviour for biodiesel for all values of $PR_{BD,Die}$. To overcome this problem it is assumed that the calculated logarithmic function gives a realistic picture for biodiesel demand in a defined range of price ratios which is for example for the EU27 given by all values which are equal or greater than 0.7. Taking into account the considerations for a sufficient functional form in the case of ethanol a sigmoid function is taken again and the functional parameters are calibrated in a way that they approximate the logarithmic function in the defined range of price ratios. The sigmoid function depends exclusively on the price ratio of biodiesel and diesel and on quota obligations, if existent.

$$(1.32) \qquad HCOS_{BIOD} = \left(1 - \frac{1}{1 + e^{-\left(\frac{p_{BIOF}}{p_{DISL}} \cdot \alpha - \beta\right)}} \right) \cdot \left(QCS_{BIOD}^{Limit} - QOBL_{BIOD} \right).$$

$HCOS_{BIOD}$ is the energy share of biodiesel in total diesel consumption, $QOBL_{BIOD}$ is the biodiesel quota obligation and p_{BIOD} / p_{DISL} is the price ratio of biodiesel and diesel. $QCS^{Limit}{}_{BIOD}$ is the maximum blending share of biodiesel in fossil diesel which is equal to 1, meaning that up to 100% biodiesel (B100) blends are technologically possible. α and β are calibration parameters. As the sigmoid function exclusively delivers values for $HCOS_{BIOD}$ between 0 and 1, the problem of demand shares which exceed 100% is automatically solved. The estimated calibration parameters are also displayed in Table 4.13. Figure 4.17 presents the estimated sigmoid function for biodiesel demand in the EU27 for 2020 which is aligned to the original logarithmic function in the mentioned range.

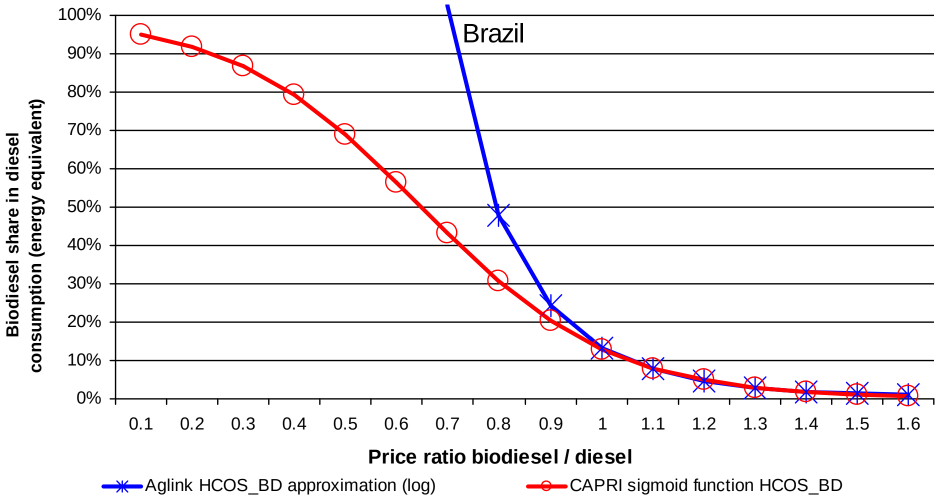
Figure 4.17: Estimated *sig*-function for biodiesel demand (EU27, 2020)



Source: Own illustration based on AgLink (status October 2009)

The sigmoid function for biodiesel demand in Brazil is displayed in Figure 4.18.

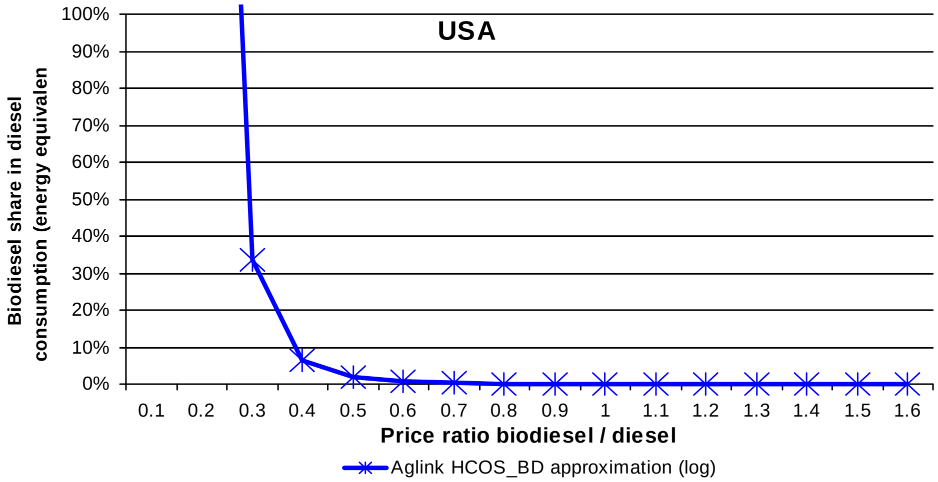
Figure 4.18: Estimated *sig*-function for biodiesel demand (Brazil, 2020)



Source: Own illustration based on AgLink (status October 2009)

Further regions which are covered by an explicit biodiesel demand function in AgLink are the USA and Canada. In both countries the estimated logarithmic functions derived from the original AgLink ones do not seem to be sufficient to display a realistic picture of biodiesel demand behaviour. These functions react very spontaneous for all price ratios of biodiesel to diesel. Figure 4.19 displays the logarithmic function for biodiesel demand in the USA for 2020 based on the original AgLink specification. For Canada the picture is similar.

Figure 4.19: Estimated *log*-function for biodiesel demand (USA, 2020)



Source: Own illustration based on AgLink (status October 2009)

To avoid such spontaneous biofuel demand behaviour in the model it is decided to refrain from estimating explicit demand functions for these countries and instead assume the EU27 demand function to be also representative.

Absolute biodiesel demand ($HCOM_{BIOD}$) resulting from the estimated biodiesel share in overall diesel consumption ($HCOS_{BIOD}$), a biodiesel quota obligation ($QOBL_{BIOD}$) - if existent -, the overall diesel consumption quantity ($HCOM_{DISL}$) and energy ratio of biodiesel compared to diesel ($ERAT_{BIOD,DISL}$) is given by

$$(1.33)\qquad HCOM_{BIOD} = \frac{\max\left(HCOS_{BIOD}, QOBL_{BIOE}\right)\cdot HCOM_{DISL}}{ERAT_{BIOD,DISL}}.$$

The above derived behavioural functions for biofuel demand (ethanol and biodiesel) are strongly affected by support policies. The most prominent ones are biofuel quota obligations and price support measures. The consideration of quotas within the biofuel demand system has already been explained. They can be reflected in the above described demand functions as horizontal lines, where the price ratio has no influence as long as the demand quantities lie below the quota. All kinds of price support (for example consumer tax exemptions) directly influence the price ratio of biofuels compared to fossil fuels which drives the biofuel demand functions.

4.7. Estimating total fuel demand functions

Functions approximating total fuel demand behaviour are derived in the CAPRI biofuel model by using a response surface approach which is based on simulation results from the PRIMES energy model. The PRIMES model (E3Mlab, 2011) was identified as an appropriate modelling system as it includes a very detailed representation of European energy markets and thus, permits good correspondence with CAPRI. The input which is provided by the PRIMES team for this analysis is a set of energy scenarios calculated in 2008 and 2009. These results which can be interpreted as simulated observations on total fuel demand behaviour (experimental data) include variations in the variables: *total energy demand*, *economic growth (GDP)*, *fuel price including tax rate* and *fuel price excluding tax rate*, all differentiated by fuel type (diesel, gasoline), European Member State and projection year (2010, 2015, 2020, 2025, 2030). For simplification, it is decided to limit the response surface to the responses of *GDP* and *fuel price including tax rate* to fossil fuel demand differentiated for diesel and gasoline. This is done, on the one hand, because it is assumed that these are the most important fuel demand drivers and, on the other hand, variations for further drivers are not clearly identified in the PRIMES scenario results at hand.[57]

The core assumption underlying this approach is that the experimental data deliver a realistic picture of the real world fuel demand behaviour. Basically, functions of the type

$$y_i = g_i\left(x_1,...,x_k,\overline{x_n}\right)+\varepsilon \tag{1.34}$$

are estimated. Thereby, *y* is the response variable (fuel demand), *n* is the number of influencing variables *X* and *k* is the number of variables which are investigated explicitly in the response surface. $\overline{X}$ denotes the variables which can not be considered as explanatory variables as they show no variance in the underlying dataset. Thus, they will become part of the constant response surface intercept and are assumed to be fixed within a subsequent scenario analysis. ε is an error term. The number of the variables *k* is restricted to (1) fuel price and (2) GDP. All other (policy) drivers are consequently covered in the constant response surface intercept or in the error term. The estimation of the response surface is done by a regression analysis. Following Brons (2006) a double log function is chosen to define the regression function (Equation (1.35)) as the estimated regression coefficients can directly be interpreted as elasticities in the demand function.

$$log\left(y_{i,j,s,t}\right)=\delta_{i,j}+\alpha_{i,j}log\left(p_{i,j,s,t}\right)+\beta_{i,j}log\left(GDP_{j,s,t}\right)+\gamma_{i,j}log\left(trend_t\right)+\varepsilon_{i,j,s,t} \tag{1.35}$$

where

$i =$ *fuel type (diesel, gasoline)*
$j =$ *region*
$s =$ *scenario*
$t =$ *year*
$y =$ *fuel demand*
$p =$ *fuel price (incl. tax)*

trend $=$ *trend variable*
$\varepsilon =$ *error term*
$\delta =$ *intercept*
$\alpha =$ *price elasticity of demand*
$\beta =$ *GDP elasticity of demand*
$\gamma =$ *trend elasticity of demand*

For the estimation of the regression coefficients an ordinary least squares criterion is applied. The cross price elasticities of diesel and gasoline are not considered in the regression analysis because simultaneity exist between both explanatory variables which is obvious as both are strongly connected to the crude oil price and thus are significantly correlated. The results of the regression analysis covering estimates for the regression coefficients α, β, and γ are shown in Annex

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[57] The response surface was limited to the existing PRIMES scenario results as sensitivity runs with additional key-drivers for fuel demand were not possible in the framework of this analysis.

10.16. The coefficient of determination (R^2) is used to evaluate the quality of the regression function and the *P-value* is used to evaluate the significance level of the single regression coefficients which are also displayed in Annex 10.16. As one can observe most of the significant β are predominantly positive which is understandable as an increasing GDP supposedly leads to increasing fuel consumption, due to the increase in prosperity. Most of the negative estimates for β are not significant. α is predominately negative which is also comprehensible as an increase in fuel price might lead to a decrease in fuel consumption. The negative estimates for γ indicate that apart from the impact of price and GDP a slight decrease of fuel demand might takes place per annum. This trend can be explained taking into account the European ambitions to increase energy efficiency in vehicle engines. δ is the constant term of the regression function covering further drivers which do not vary within the underlying dataset.

While most of the estimated regressions show a reasonable fit in terms of R^2 the *P-value* for β and in some cases α_{DISL} indicates less significance. In 50% of all regions these two coefficients turn out to be not significant. To find approximations for these coefficients which are urgently needed for the response surface, average coefficients are calculated based on the sum of existing significant observations as displayed in Table 4.14. If no significance is observed for a coefficient in a respective country the estimated value is exchanged by the corresponding average value.

Table 4.14: Average regression coefficients

β(GDP) for gasoline	0.52
α(price) for gasoline	-0.36
β(GDP) for diesel	0.54
α(price) for diesel	-0.68

Source: Own calculation based on Annex 10.16

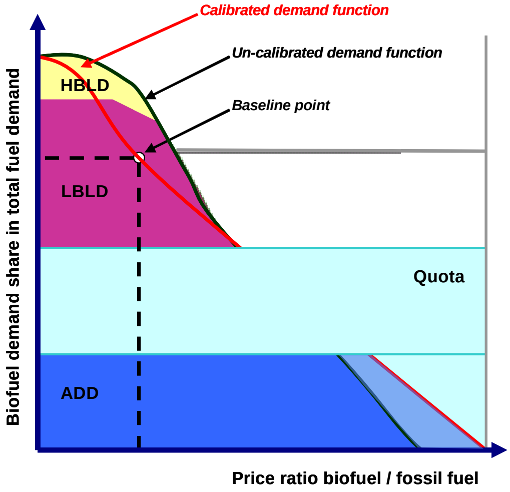
The resulting matrix of regression coefficients which are finally assumed in the response surface for total fuel demand is shown in Annex 10.17. As the PRIMES data only covers values for the EU27 and estimates for the non-European CAPRI regions are also required, it is assumed that the estimated coefficients for the aggregated EU27 are also applicable for non-European regions.

4.8. Calibration of the behavioural model

In Sections 4.5, 4.6 and 4.7 the general forms of the biofuel supply and demand functions are derived. All these behavioural functions have to be calibrated so that they exactly reproduce the price quantity framework of the biofuel baseline.

In a first step, the demand functions are calibrated to the observed combination of price ratio (biofuel to fossil fuel) and energy share of biofuels in total fuel consumption. Therefore, a calibration parameter is introduced and multiplied to the slope parameter of the respective demand function. This parameter is held constant during the simulations. In Figure 4.20 this procedure is visualized.

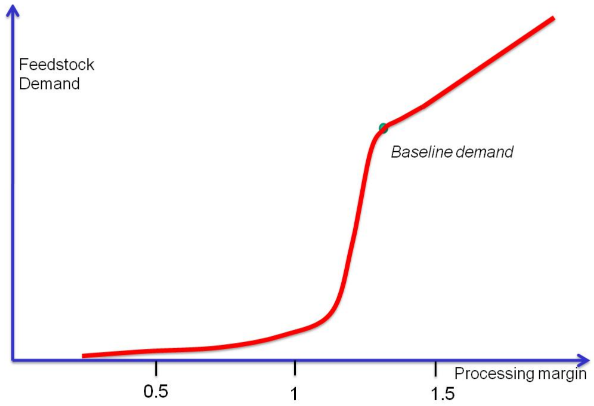
Figure 4.20: Calibration of the biofuel demand functions



Source: Own illustration

In a second step, the supply system is calibrated. As already mentioned, biofuel supply is basically driven by Equation (1.12) - for ethanol - and (1.18) - for biodiesel - which define profit maximising biofuel feedstock demand. Both feedstock demand functions are linear functions with respect to margins. Within the calibration it turns out that these linear functions are not sufficient for all price ratios to simulate a plausible feedstock demand and thereby biofuel supply response for biofuels. Plausibility in that case would imply that as soon as the feedstock costs exceed biofuel revenues, feedstock demand and thereby supply should almost disappear. This consequently implies a high supply elasticity in the range where the processing margin is close to one. On the other hand, one would not expect such a high elasticity for extending biofuel supply, if the margin is already at a high level (for example 1.3). The feedstock demand functions are linear with a constant slope parameter. To find an appropriate solution for that problem, the initial normalized quadratic function is used for the range of extending biofuel production and calibrated such that in the baseline point an elasticity of one would apply. For the range below the baseline margin and a margin of one a sigmoid function (depending on processing margins) is introduced. This function is specified such that the baseline point is reproduced and at the same time it runs through the point at a margin of one and 1% of the baseline supply. The resulting feedstock demand (and thereby biofuel supply) functions have the shape as displayed in Figure 4.21.

Figure 4.21: Calibrated feedstock demand function depending on margins



Source: Own illustration

4.9. *Environmental indicators*

For the assessment of environmental impacts resulting from shifts in European agricultural production, caused by an increasing biofuel production, indicators are used which are already part of the standard CAPRI model[58]. These indicators cover exclusively environmental impacts which are induced by agricultural production activities and farm management (Pérez Dominiguez, 2005). Environmental effects like the carbon dioxide reduction resulting from the substitution of fossil fuels by biofuels are not part of this analysis. For such a purpose detailed biofuel live cycle assessments as summarised for example by Larson (2006) or done by Kaltschmitt (1997) are more suitable instruments. Furthermore, the environmental indicators covered in the model exclusively account for environmental effects which accrue within the EU27. Thus, environmental impacts resulting from shifts in non-European agricultural production or changes in farm management can not be evaluated.

Two different environmental indicators are investigated. The first indicator, *N_2O emissions* per land use unit (kg/ha), accounts for all nitrous oxide emitting

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[58] 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 at: www.ilr1.uni-bonn.de/agpo/rsrch/dynaspat/dynaspat_e.htm. Access date: 29.10.2010.

agricultural activities as listed in Table 4.15, differentiated for all European regions. Shifts in this indicator refer to potential intensification processes in farming activities which might result from an increasing production of agricultural products and thereby, biofuel feedstocks.

Table 4.15: Different sources of N_2O emissions from agriculture

N_2O source	**Model acronym**
Manure management	N2Oman
Manure excretion on grazing	N2OGra
Emissions from synthetic fertiliser	N2OSyn
Emissions from organic animal waste	N2OWas
Emissions from fertiliser application	N2OApp
Emissions from crop residues	N2OCro
Emissions from nitrogen-fixing crops	N2OFix
Indirect emissions from ammonia losses	N2OAmm
Emissions from atmospheric deposition	N2ODep

Source: Britz and Witzke (2009)

The second indicator, the *crop share* (%) displays the share of land used by a particular cropping activity in total arable land used in a defined administrative region. This indicator refers to potential losses in crop-diversity of agricultural landscape and thereby, to potential losses of biodiversity. It has to be mentioned, that the indicator *crop share* is only useful to give a rough hint to the issue of biodiversity as it provides no information on the detailed spatial allocation of the arable land used for the cultivation of a particular crop species in a respective region.

Even though, the information and results provided by the described indicators are rather limited, they might be useful for further research specialised on issue of evaluating environmental impacts.

5. The reference scenario: CAPRI biofuel baseline

To quantify impacts of current biofuel policy strategies on the agricultural sector, different scenarios will be simulated and evaluated by using the new CAPRI biofuel model. For the analysis of scenario specific impacts a biofuel reference scenario (following biofuel baseline) has to be defined. The biofuel baseline represents a projection for the year 2020 covering probable future developments of the European agricultural and biofuel sector under the status quo policy setting and all future policy changes which are already foreseen in the current legislation. As baselines have to capture the complex interrelations between technological, structural, preference and policy changes they "[…] *are in most cases not a straight outcome from a model but developed in conjunction of trend analysis, model runs and expert consultations*" Britz and Witzke (2009, p.63).

5.1. Baseline construction

For the baseline generation process the CAPRI trend projection tool CAPTRD is used (Britz and Witzke, 2009). The trend estimation process consists of a three-stage procedure as described in detail in Britz and Witzke (2009). Basically, the first stage estimated unrestricted trend curves based on the ex-post database, the second step adds consistency conditions, for example related to consumer behaviour, agricultural production conditions or to ensure close market balances. The last step then adds results of market projections from other models (so called expert supports) to which the trend estimates are moved. Thereby, the weighting of these expert supports can be defined individually for each baseline.

Considering this general estimation procedure the biofuel baseline relies on the established biofuel database (Section 4.4) and on the expert supports provided by the recent AgLink and PRIMES baselines. When defining these supports it was decided to use primarily the results of the AgLink baseline (status October 2009) for two reasons: Firstly, this baseline was already checked by the European Commission Joint Research Centre, Institute for Prospective Technological Studies (IPTS) in 2009 and secondly, the PRIMES baseline (status October 2009) projected some implausible estimates for absolute 2nd generation biofuel quantities in Europe. However, as each baseline has a different regional coverage (AgLink EU27 and OECD member countries, PRIMES European Member States and rest of world aggregate) information from the PRIMES baseline is also used, in particular to derive distributions for aggregated EU27 values of AgLink to single European Member States. In the following the core assumptions underlying the biofuel baseline are described.

5.2. *Baseline assumptions*

Biofuel policies

The CAPRI biofuel baseline assumes that the EU27 biofuel target as stated by the European Renewable Energy Directive (European Parliament and Council, 2009) is fully reached. Equal to the AgLink baseline an energy share of 8.5% biofuels in total EU27 transport fuel consumption in 2020 is applied of which 7% consists of 1st and 1.5% consists 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.[59] Following this article, the 2020 target of 10%[60] biofuels in the EU27 is realized. The distribution of the 8.5% EU27 average across the single Member States (Table 5.1) is derived from the respective biofuel demand shares of the PRIMES baseline. The same procedure is applied to distribute the 1.5% 2nd generation share across the Member States.

To define the probably applied biofuel quotas obligations in 2020, the information on implemented quotas until 2009, mentioned in the annual biofuel progress reports by Member States (Table 2.3) is used as the base information. To consider a probable future biofuel policy setting it is assumed that all existing quota obligations which are defined in this table for a year before 2015 will be increased in the respective Member State in 2020 by 1.5%. All existing quotas which are already defined for a year beyond 2015 will only exceed the existing level by 1.1%. To avoid that the resulting quota obligation in 2020 exceed the absolute value of biofuel demand resulting from the trend estimation procedure in CAPTRD, the absolute value of biofuel demand acts automatically as the maximum quota value. For all European Member States where no quota exist until 2009 (Table 2.3), it is assumed that a minimum quota of 6.0% will be introduced by 2020. The calculated quota obligations which are assumed to be implemented in 2020 in the single European Member States are also displayed in Table 5.1. The differences between the assumed shares of biofuels in total fuel consumption and the assumed quotas in 2020 can be interpreted as additional price driven biofuel demand caused for example by existing tax exemptions for biofuels which are assumed to stay at the level as displayed in Table 2.3.

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[59] "*For the purposes of demonstrating compliance with national renewable energy obligations placed on operators and the target for the use of energy from renewable sources in all forms of transport referred to in Article 3(4), the contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels*". European Parliament and Council (2009, p. L140/41)

[60] Referring to the share of renewable energies in total transport energy consumption

Table 5.1: Share of biofuels in EU Member States: Baseline

Energy share (in%) of …	…ethanol in total gasoline	…biodiesel in total diesel	…biofuels in total fuel	...2nd gen. biodiesel in diesel	...2nd gen. ethanol in gasoline	...2nd gen. biofuels in total fuel	Quota for biodiesel	Quota for ethanol
EU27	8.5	8.5	8.5	1.5	1.5	1.5	0.0	0.0
Austria	9.4	8.5	8.8	0.7	0.0	0.5	7.5	6.4
Belgium / Luxemb.	9.3	7.9	8.2	0.6	0.0	0.5	6.9	6.0
Bulgaria	3.4	3.4	3.4	0.6	0.0	0.4	2.4	1.7
Cyprus	1.5	3.9	2.8	5.9	2.8	4.8	2.9	0.8
Czech Republic	7.1	8.4	8.0	1.8	2.8	2.0	6.0	4.1
Denmark	9.2	10.3	9.9	0.8	0.0	0.6	6.0	6.0
Estonia	5.6	5.1	5.3	0.5	0.0	0.4	4.1	2.8
Finland	7.5	6.9	7.1	0.0	2.1	0.9	5.9	4.5
France	8.2	9.1	8.9	0.0	0.0	0.0	8.1	5.2
Germany	11.7	11.0	11.2	0.9	0.0	0.6	10.0	8.7
Greece	6.5	6.2	6.3	0.7	0.0	0.5	5.2	3.5
Hungary	4.9	8.1	7.0	0.0	0.0	0.0	6.0	2.4
Ireland	5.9	7.0	6.6	0.6	5.6	2.9	6.0	2.9
Italy	7.1	9.2	8.4	0.0	0.0	0.0	8.2	4.1
Latvia	4.0	6.7	5.9	0.5	1.4	0.8	5.7	2.0
Lithuania	7.2	6.1	6.4	0.0	1.7	0.6	5.1	4.2
Malta	1.3	2.1	1.9	0.6	2.4	1.2	1.1	0.6
Netherlands	5.9	7.7	7.2	0.5	2.0	1.0	6.7	2.9
Poland	6.4	7.1	6.9	0.0	0.0	0.0	6.1	3.4
Portugal	5.6	6.5	6.3	0.0	2.5	0.6	5.5	2.8
Romania	3.2	3.3	3.3	0.0	1.4	0.4	2.3	1.6
Slovakia	6.0	6.8	6.6	0.0	1.9	0.6	5.9	3.0
Slovenia	5.2	9.0	7.9	0.2	0.4	0.3	8.0	2.6
Spain	10.5	8.6	8.9	0.3	1.2	0.5	7.6	7.5
Sweden	9.4	8.1	8.7	0.0	0.0	0.0	6.0	6.0
United Kingdom	9.4	7.4	8.2	0.0	0.0	0.0	6.4	6.4

Source: CAPRI biofuel model (2010), calculated based on AgLink and PRIMES 2009

The applied biofuel tariffs (Table 5.2) in the baseline are differentiated in ad valorem and specific tariffs for biodiesel and ethanol. They are obtained from the AgLink 2009 baseline. In the case of ethanol the tariffs for undenatured ethanol are assumed which is used for fuel purpose.

Table 5.2: Applied biofuel tariffs: Baseline

Applied tariffs	**Fuel ethanol**		**Biodiesel**	
	Specific €/toe	Ad valorem (%)	Specific €/toe	Ad valorem (%)
Norway	300	~	~	6.5
Turkey	~	3.0	~	16.3
EU15	300	~	~	6.5
EU10	300	~	~	6.5
Bulgaria and Romania	300	~	~	6.5
Rest of Europe	300	~	~	6.5
Russia, Belarus, Ukraine	~	15.2	~	13.7
USA	152	2.5	~	4.6
Canada	47	~	~	0.0
Brazil	48	20.0	~	4.6
India	~	34.2	~	99.8
Japan	~	15.2	~	13.7
LDC countries	~	23.8	~	16.3
ACP countries	~	~	~	10.0

Source: CAPRI biofuel model (2010), based on AgLink (2009)

Biofuel production, consumption and trade

As already mentioned, biofuel markets in the CAPRI baseline are predominately aligned with the forecasts given by the AgLink baseline (status October 2009). The AgLink forecasts enter the baseline generation procedure as expert supports from which the trend estimations are not allowed to deviate notably.

Since the collected ex-post numbers of the CAPRI biofuel database do not match the AgLink ex-post numbers on EU27 level exactly, it is assumed in the baseline that biofuel demand as well as biofuel production from the most recent ex-post year (2005) is increased in 2020 by the absolute difference of the respective AgLink data for the projection year (2020) minus the AgLink data of 2005. Industrial demand for ethanol ($INDM_{BIOE}$) is assumed to be constant on the average 2004/2005 level. The share of biofuels from domestic 1st generation production as well as 2nd generation production on EU27 level is adopted from the AgLink baseline. Ethanol made out of non-agricultural sources ($NAGR_{BIOE}$) is assumed to stay at 2005 level. For $NAGR_{BIOD}$, where no significant biofuel quantities are observed in Europe ex-post, the information provided by the PRIMES baseline (status October 2009) is used which estimates significant non-agricultural biodiesel quantities in 2020 for European countries. The consideration of non-agricultural biodiesel production is done following national sources (described in Section 4.4) which signalize that for example waste oil or used cooking oil will become notable biodiesel feedstocks in Europe. However, the absolute quantities delivered by the PRIMES baseline show very high $NAGR_{BIOD}$ quantities for biodiesel, which amount up to 50% of total EU27 biodiesel production in 2020. For this reason a maximum share for $NAGR_{BIOD}$ is introduced in the CAPRI biofuel baseline which is set on 30% of the initial PRIMES projection. In European countries where $NAGR_{BIOD}$ is present, the initial share of 1st and 2nd generation production in total biodiesel production is applied to the absolute difference of total biodiesel production minus non-agricultural biodiesel production. $NAGR_{BIOD}$ in non-European countries is assumed to be in line with the AgLink baseline which indicates that for example in the U.S., Brazil and Canada a notable production will take place. Exports and imports are shifted with the observed changes in net-trade given by the AgLink baseline. If net-trade is increasing from 2005 to 2020, the absolute difference is added to the export quantities of 2005 and if it is decreasing, it is added to the 2005 imports. The biofuel market balances for non-European countries are shifted in a first step also with the supports from the AgLink baseline. Here, the international market balances for ethanol are available until 2008. These last available positions are multiplied by the AgLink 2020 numbers 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. In a second step it is checked if the international market balances are consistent with the EU numbers. If necessary, some adjustments are done following consistency algorithms already covered in the standard CAPRI version (Britz and Witzke, 2009).

Biofuel feedstock demand

The projection of biofuel feedstock demand quantities shows two major challenges: (1) How to define their distribution in countries where biofuels are not produced ex-post and (2) how to introduce feedstocks that were not used ex-post for biofuel production. Since it is essential for later simulations to have already a number of feedstocks used in the baseline to get any substitution effect, a matrix including minimum shares for biofuel feedstocks used in 2020 - differentiated for each covered region - is defined (Table 5.3). The definition is based on information provided by governmental or non-governmental institutions or by annual reports of biofuel enterprises as already described in Section 4.4 and by Becker, A. et al (2010a).

Table 5.3: Matrix of minimum shares for biofuel feedstocks in 2020 (%)

	Ethanol						**Biodiesel**			
	Wheat	***Rye, Meslin***	***Barley***	***Oats***	***Maize***	***Other cereals***	***Rape oil***	***Sunfl. oil***	***Soy oil***	***Palm oil***
Belgium / Lux.	10	0	10	0	10	0	15	5	3	10
Denmark	10	10	10	0	0	0	0	0	0	10
Germany	10	10	10	10	10	5	10	0	5	10
Greece	0	0	10	0	10	0	0	30	0	10
Spain	5	10	10	10	10	5	10	10	5	10
France	10	0	10	0	10	5	10	10	5	10
Ireland	10	0	10	10	0	0	30	0	0	10
Italy	10	0	10	0	10	0	10	10	5	10
Netherlands	10	15	20	5	5	0	20	1	10	10
Austria	10	10	10	10	10	0	30	10	5	10
Portugal	0	0	10	0	10	0	0	20	5	10
Finland	10	20	10	10	0	0	10	0	5	10
Sweden	10	10	10	0	0	0	10	0	1	10
United Kingdom	10	0	10	10	10	0	10	0	5	10
Czech Republic	10	10	10	10	20	5	10	5	10	10
Estonia	10	10	10	0	0	0	20	0	0	10
Hungary	10	0	10	0	10	5	5	10	5	10
Lithuania	10	10	10	0	0	5	80	0	0	10
Latvia	10	10	10	0	10	5	30	10	5	10
Poland	10	10	10	0	10	0	30	0	5	10
Slovenia	0	0	10	0	10	0	10	20	5	10
Slovakia	10	10	10	0	10	5	10	20	5	10
Romania	10	0	10	0	10	0	10	20	5	10
Bulgaria	10	0	10	0	10	0	10	20	5	10
Cyprus	10	0	10	0	10	0	0	20	5	10
Malta	0	15	20	10	10	0	0	20	5	10

Source: CAPRI biofuel model (2010) based on Becker, A. et al (2010a)

Biofuel and fuel prices

Prices for biofuels are shifted with the respective increase described in the OECD Agricultural Outlook of 2009 (OECD-FAO, 2009). Prices for fossil diesel and gasoline in 2020 for the EU27 and non-European regions are adopted from the AgLink baseline. Thereby, the EU27 market price of AgLink is taken as the base value to calculate the consumer price for each European Member State as the sum of the market price plus the individual consumer tax. The consumer taxes for fossil fuels in European Member States are derived from European Commission (2002), for non-European regions they are adopted from the AgLink baseline which is also true for consumer taxes of ethanol and biodiesel in non-European regions. The taxes for ethanol and biodiesel in European countries are collected from the 2009 biofuel progress report (European Commission, 2009). As one can observe in Table 5.4 the biofuel baseline estimates a significant increase in diesel and gasoline market prices (70% to 110%). However, the changes in the resulting consumer price are somewhat less as it is assumed that the taxation of fuels and biofuels will only change marginally until 2020. Fuel and biofuel prices are measured in €/toe to make them comparable across the different fuels which are characterised by a specific energy content and physical density. The baseline consumer price for diesel and gasoline in the EU27 (which is an average over all European Member States) is assumed to reach 1,090 €/toe and 1,347 €/toe, respectively, which is equal to about 1.30 €/l for diesel and 1.73 €/l for gasoline.

Table 5.4: Assumed consumer taxes and prices for (bio) fuels: Baseline

	€/toe in 2020	**Market price**	**Consumer tax**	**Consumer price**
EU27	Biodiesel	1,250	126	1,377
	Ethanol	1,082	292	1,374
	Diesel	661	429	1,090
	Diff. to BaseYear	*74%*	*10%*	*42%*
	Gasoline	746	601	1,347
	Diff. to BaseYear	*93%*	*2%*	*38%*
USA	Biodiesel	1,189	24	1,213
	Ethanol	1,091	281	1,372
	Diesel	795	52	847
	Diff. to BaseYear	*84%*	*-18%*	*71%*
	Gasoline	1,087	44	1,131
	Diff. to BaseYear	*117%*	*-18%*	*104%*
Brazil	Biodiesel	1,194	202	1,396
	Ethanol	749	521	1,270
	Diesel	856	56	912
	Diff. to BaseYear	*95%*	*-19%*	*80%*
	Gasoline	987	299	1,286
	Diff. to BaseYear	*83%*	*-27%*	*36%*

Note: Prices for the EU27 are average prices and taxes over all EU27 Member States.
Source: CAPRI biofuel model (2010), based on AgLink (2009) and European Commission (2009).

Total fuel demand and GDP growth rate

Total fuel demand is estimated in line with the assumptions of the AgLink baseline. According to that gasoline and diesel demand for EU27 in 2020 is defined as displayed in Table 5.5 (values in bold). To derive estimates for total fuel demand in single European Member States the respective demand shares in total EU27 demand resulting from the PRIMES baseline are calculated for each Member State and multiplied by the absolute EU27 fuel demand quantity given by AgLink (Table 5.5).

Table 5.5: Total fuel demand by European Member State: Baseline

	Gasoline		**Diesel**	
	%	*kton*	*%*	*kton*
EU27	100.0	**106,256**	100.0	**248,558**
Austria	1.9	1,972	2.4	5,972
Belgium / Lux.	1.9	2,064	4.0	10,025
Netherlands	3.2	3,380	3.2	8,042
Germany	18.2	19,376	15.0	37,259
France	9.0	9,587	14.5	36,091
Spain	6.7	7,144	15.7	39,044
Portugal	1.6	1,700	2.2	5,551
United Kingdom	16.3	17,295	10.4	25,884
Ireland	1.8	1,952	1.3	3,131
Italy	13.7	14,600	11.0	27,446
Denmark	1.5	1,642	1.1	2,750
Finland	1.6	1,725	1.0	2,567
Sweden	3.5	3,748	1.8	4,473
Greece	3.9	4,101	1.3	3,216
Poland	5.2	5,551	5.3	13,090
Hungary	1.8	1,941	1.6	4,008
Czech Republic	2.3	2,417	2.2	5,458
Slovakia	0.8	856	0.8	2,016
Slovenia	0.7	775	0.9	2,143
Lithuania	0.4	410	0.5	1,365
Latvia	0.4	437	0.4	1,090
Estonia	0.3	291	0.2	598
Romania	2.2	2,308	1.9	4,681
Bulgaria	0.5	568	0.8	1,991
Cyprus	0.3	372	0.2	472
Malta	0.0	48	0.1	195

Source: CAPRI biofuel model (2010), calculated based on AgLink and PRIMES 2009

The assumed GDP growth rates of the PRIMES and AgLink baselines are predominately consistent for the aggregates EU12, EU15 and EU27. Thus, the GDP assumptions for the European aggregates and the single Member States are adopted from PRIMES and for non-EU countries from AgLink.

Agricultural market assumptions

All other than biofuel specific assumptions are adopted from the standard CAPRI baseline (status January 2010) which are first and foremost all assumptions regarding the European Common Agricultural Policy (CAP). The standard CAPRI baseline (status January 2010) is harmonized with the OECD FAO Agricultural Outlook of 2009 (OECD-FAO, 2009). As the outlook provides projections exclusively for the OECD Member countries and selected developing countries, FAO's projection for 2030 (Bruinsma, 2003) and results from the FAPRI model (FAPRI, 2010) are used as expert supports for the rest of the world.

As the CAP policy specification as considered in the biofuel baseline will stay unchanged over all scenarios only the central elements are shortly described in the following. A core issue in the CAP is the decoupling. In the 2003 reform the decoupling was completed for a large part of agricultural products and animals, including dairy. 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 were included in the common system of direct payments. European Member States had the possibility to maintain certain maximum shares of certain payments in the old coupled form, following a scheme published in Regulation 1782/2003 (European Commission, 2003). Furthermore, Article 69 of that regulation permit to retain up to 10% of the national ceilings for direct payments to provide support to specific types of farming and quality production. 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 5.6.

Table 5.6: Core assumptions regarding direct payments: Baseline

Instrument	**Baseline assumption**
Direct payments EU15	2003 reform fully implemented
Direct payments EU10	2003 reform fully implemented, special accession conditions recognised
Direct payments Bulgaria and Romania	Single Area Payment Scheme implemented
Set aside EU15, EU10, Bulgaria and Romania	Abolished
Article 69 of Council Regulation 1782/2003	Implemented
Modulation	EU25 5% minus franchise, Bulgaria and Romania none. Voluntary modulation for UK and Portugal

One of the greatest changes to the CAP next to the 2003 reform was the reform of the European sugar sector. Most of the expected developments here have already taken place in the past years, so that the national sugar quotas are fixed on their 2008 quantities. Subsidised exports of sugar beyond the WTO limits are not allowed, but a certain amount of ethanol beets is introduced. The reform of the European milk quota system is also considered in the baseline (Kempen et al. 2011). The reform was part of the 2008/2009 ‘Health Check’ of the CAP which includes the expiry of the milk quota system after 2014. Regarding tariffs, the main baseline assumptions are that the EU10, Bulgaria and Romania are part of the European single market and thus share the same tariff structure. The Everything But Arms initiative (EBA) provides duty-free and quota-free access for products from the Least Developed Countries (LDC) and the ACP sugar protocol is replaced by the Economic Partnership Agreement (EPA) which offers additional market access for the African, Caribbean and Pacific (ACP) countries.

Technological development

For the conversion coefficients (Table 5.7) technological progress (t.p.) is considered in line with the AgLink assumptions.

Table 5.7: Conversion coefficients for 1st generation biofuel production

Conversion coefficient (t/t) in 2020		**Ethanol**		**By-products**		
		t.p.(%)	*coeff.*	*t.p.(%)*	*coeff.*	
Grains	Wheat	7.29	0.294	0	0.266	DDGS
	Barley	7.64	0.266	0	0.266	DDGS
	Oats	7.64	0.266	0	0.266	DDGS
	Rye	7.64	0.266	0	0.266	DDGS
	Maize (dry milling)	7.64	0.361	0	0.292	DDGS
Other	Table wine	0.00	0.100	~	~	~
Sugar crops	Sugar	3.70	0.536	~	~	~
	Sugar beets	3.70	0.082	0	0.004	Vinasses*
		Biodiesel				
Vegetable oils	Rape oil	0.00	0.922	0	0.100	Glycerine
	Soy oil	0.00	0.922	0	0.100	Glycerine
	Sunflower oil	0.00	0.922	0	0.100	Glycerine
	Palm oil	0.00	0.922	0	0.100	Glycerine

*Note: *Considered as molasses equivalent ((1t vinasses=0,1 t molasses equivalent) Source: Own compilation base on AgLink database, PRIMES database and Szulczyk (2007)*

Here, ethanol processing coefficients are assumed to increase about 7.3% from 2005 to 2020 in the case of wheat and 7.6% in the case of coarse grains. Sugar processing coefficients increase slightly by 3.7% in 2020. For the processing of vegetable oil to biodiesel no shifts are expected as the processing technologies are assumed to be technically matured. Conversion coefficients for 2nd generation biofuels are assumed as already illustrated in Table 4.12. Also here, no technological progress is considered as the identified 2nd generation coefficients already describe future technologies.

The maximum share of Flexible Fuel Vehicles (FFV) in total vehicle fleet which might be realised if the consumption of high level ethanol blends becomes profitable is also adopted from the AgLink 2009 baseline. Here, a share 8.5% is expected for the EU27 in 2020 which is assumed to be equal across all European Member States in CAPRI. Following AgLink the maximum share is somewhat lower in the U.S. (6.5%) which is also assumed for non-EU countries which are not explicitly covered in AgLink. For Brazil, where FFV cars are widely-used since the 1970s (Section 2.1) a maximum FFV share of about 75% is assumed.

5.3. Results of the CAPRI biofuel baseline

The CAPRI biofuel baseline will be described in detail in the following section focusing on biofuel markets, biofuel feedstock demand and single feedstock markets. Thereby, most significant shifts in market balance positions in the projection year (2020) relative to the BaseYear are highlighted.

Biofuel market balances and global biofuel trade

As displayed in Table 5.8, EU27 production and consumption of biofuels increase significantly until 2020. This trend can be observed for both biofuels in all Member States. As quotas are the main support instrument (Table 5.1), biofuel demand is directly linked to total fuel demand. Due to the higher consumption of diesel in the EU27 (Table 5.5), biodiesel consumption (25Mn tons) is 1.7 times higher than the ethanol consumption (15Mn tons). Net-trade quantities of biofuels (Table 5.8) include intra-EU as well as extra-EU trade flows. For this reason extra-EU trade is considered separately (Table 5.9 and Table 5.10). The net-trade position in Table 5.8 signalises that most EU15 countries will be net-importer of biofuels in 2020 which is in most cases equivalent to the ex-post situation. Within the EU15 only two notable exceptions exist. This is in the case of biodiesel Germany (4.4Mn tons net-exports) and in the case of ethanol France (1.4Mn tons net-exports). In 2020, Germany is still the most important producer of biodiesel in the EU27 (9.3Mn tons) which corresponds to about 44% of total EU27 production. As these quantities exceed domestic demand significantly (4.8Mn tons), Germany gets in a strong net-export situation. The same is true for ethanol production and trade in France, which is traditionally the most important ethanol producer in the EU27. As ethanol production (3.2Mn tons) exceeds domestic demand (1.8Mn tons) significantly in 2020 France remains in a strong net-export situation for ethanol. By contrast to the situation in the EU15, most of the EU10 countries will become net-exporter of ethanol which results from the continuous increase in installed production capacities. In the case of biodiesel this tendency cannot be observed as the dominance of the EU15 in biodiesel production (mainly caused by Germany) is still existent.

Table 5.8: Biofuel market balance for EU Member States: Baseline

	Biodiesel 2020							Ethanol 2020							
1000 tons	**Net-trade**	**Total production**	**1st gen. production**	**2nd gen. production**	**Non-agri. production**	**Fuel demand**	**Total demand**	**Net-trade**	**Total production**	**1st gen. production**	**2nd gen. production**	**Non-agri. production**	**Fuel demand**	**Indust. demand**	**Total demand**
	NETT	*MAPR*	*FSTG*	*SECG*	*NAGR*	*HCOM*	*DOMM*	*NETT*	*MAPR*	*FSTG*	*SECG*	*NAGR*	*HCOM*	*INDM*	*DOMM*
Austria	-138	461	340	46	74	599	599	117	461	459	0	2	303	41	344
Bulgaria	192	271	215	6	51	80	80	81	114	104	11	0	32	1	33
Belgium / Lux.	-299	634	486	75	73	933	933	-48	355	355	0	0	316	86	403
Cyprus	1	23	21	0	2	22	22	-9	0	0	0	0	9	0	9
Czech Rep.	-318	221	146	39	36	540	540	360	644	546	96	2	281	2	284
Germany	4,442	9,250	5,327	2,561	1,362	4,808	4,808	-1,882	2,168	1,184	888	96	3,716	334	4,050
Denmark	-140	191	134	24	33	331	331	-247	35	29	0	6	248	35	283
Estonia	89	125	116	0	10	36	36	705	734	725	9	0	27	1	28
Greece	-137	97	77	0	20	234	234	-438	0	0	0	0	434	3	438
Spain	-2,714	1,206	681	354	171	3,921	3,921	-483	940	826	0	114	1,226	198	1,424
Finland	-46	160	127	0	34	207	207	-143	95	95	0	0	213	26	238
France	536	4,391	3,315	772	304	3,855	3,855	1,370	3,159	2,451	442	266	1,295	494	1,790
Hungary	-206	175	140	0	36	381	381	386	576	506	53	17	156	35	191
Ireland	-182	75	60	0	15	257	257	-197	0	0	0	0	189	9	197
Italy	-1,458	1,496	959	298	239	2,954	2,954	-1,466	415	368	0	47	1,700	181	1,881
Lithuania	37	136	106	0	29	99	99	503	554	535	17	2	49	3	51
Latvia	55	141	113	0	28	86	86	10	46	33	10	3	29	7	36
Malta	-5	0	0	0	0	5	5	-1	0	0	0	0	1	0	1
Netherlands	-186	545	390	58	97	730	730	-284	142	139	0	2	327	100	426
Poland	-659	430	277	83	69	1,089	1,089	-399	304	109	125	70	583	120	703
Portugal	-34	387	289	32	66	421	421	-165	0	0	0	0	156	9	165
Romania	91	272	206	13	53	181	181	-87	36	22	15	0	123	0	123
Sweden	-223	202	137	31	34	425	425	-135	448	60	344	44	577	6	583
Slovenia	-158	68	60	0	8	226	226	-71	0	0	0	0	66	5	71
Slovakia	34	196	150	12	35	163	163	103	193	165	29	0	85	5	90
United Kingdom	-2,152	99	79	0	20	2,251	2,251	-1,502	1,409	725	597	87	2,655	255	2,911
EU27		**21,253**	**13,948**	**4,403**	**2,901**	**24,834**	**24,834**		**12,831**	**9,436**	**2,636**	**759**	**14,795**	**1,958**	**16,753**
abs. diff. to baseyear		*19,375*	*12,071*	*4,403*	*2,901*	*22,829*	*22,829*		*11,060*	*8,342*	*2,636*	*82*	*14,341*	*163*	*14,504*

Source: CAPRI biofuel model: Biofuel baseline, 18.11.10

While industrial demand for ethanol in the EU27 shows only a slight change until 2020 (+0.16Mn tons), EU27 fuel ethanol consumption increases strongly from 0.5Mn tons up to about 15Mn tons in 2020. European biodiesel consumption actually increases from 2Mn tons to about 25Mn tons in 2020. Thereby, Germany, France, Italy, Spain and the UK demand together about 70% of the EU27 biofuel consumption which corresponds to the high overall fuel consumption quantities in those countries (65% of total fuel demand in EU27 as shown in Table 5.5). Biodiesel imports into the EU27 significantly increase up to 4Mn tons (Table 5.9), while European exports only change marginally compared to the BaseYear. Main biodiesel exporters become Argentina (1.7Mn tons), the U.S. (1.8Mn tons), India (0.5Mn tons), Indonesia and Malaysia where the latter two are covered among others in the CAPRI rest of world aggregate (*ROW*). In particular the U.S. and Argentina significantly increase their biodiesel exports into Europe (each by 1.6Mn tons). This can be explained by strong biofuel support measures given by the U.S. government and the privileged position of processed agricultural products (like biofuels) within the Argentine export strategy (Section 2.1).

Table 5.9: Bilateral trade flows of biodiesel (1000 tons): Baseline

			Exporter							
Importer	*abs. diff. to baseyear*	***Total imports***	EU15	EU10	Bulgaria, Romania	USA	Argentina	India	LDC	Rest of world
EU15	*2,891*	***3,120***	~	76	25	1,489	1,112	168	54	196
EU10	*1,295*	***1,317***	378	~	12	350	431	59	11	76
Bulgaria, Romania	*25*	***25***	0	0	~	0	20	2	1	2
USA	*790*	***798***	9	2	0	~	88	270	74	354
Argentina	*162*	***162***	0	1	101	0	~	0	0	61
Rest of world		***310***	0	108	170	1	0	32	0	~
		Total exports	***387***	***187***	***308***	***1,840***	***1,652***	***531***	***139***	***689***
		abs. diff. to baseyear	*369*	*81*	*308*	*1,653*	*1,652*	*528*	*139*	

Source: CAPRI biofuel model, Biofuel baseline, 18.11.10

In Table 5.10 which shows global ethanol trade, it can be observed that the main exporters in 2020 are Brazil (14Mn tons), the EU10 (2Mn tons), the U.S. (0.4Mn tons) and other South American countries. Brazil is still the dominant ethanol exporter whose exports go predominately to the U.S. (9Mn tons) and Europe (2.5Mn tons). Exports of the EU10 go mainly into EU15 countries. Main importers of ethanol in 2020 are the EU27 (about 4Mn tons from outside the EU) and the U.S. (9.5Mn tons).

Table 5.10: Bilateral trade flows of ethanol (1000 tons): Baseline

			Exporter									
Importer	*abs. diff. to baseyear*	***Total imports***	EU15	EU10	USA	Argentina	Brazil	Bolivia	Rest South-America	India	Japan	Rest of word
EU15	*5,017*	***5,541***	~	1,927	188	67	2,192	170	244	41	0	713
EU10	*427*	***433***	27	~	10	6	254	20	31	4	0	80
USA	*8,190*	***9,482***	10	2	~	63	8,710	0	299	0	0	398
Canada	*190*	***301***	0	0	76	0	200	0	0	0	0	26
Brazil	*-74*	***64***	0	0	63	0	~	0	0	0	0	2
India	*-283*	***87***	0	0	18	0	64	0	0	~	0	4
China	*1,429*	***1,436***	0	0	4	0	1,176	0	0	0	214	42
Japan	*301*	***671***	0	0	3	0	644	0	7	6	~	12
Rest of world		***893***	0	90	43	113	471	36	11	79	30	~
		Total exports	***37***	***2,020***	***412***	***249***	***13,711***	***226***	***598***	***129***	***243***	***1,276***
		abs. diff. to baseyear	*13*	*1,991*	*29*	*201*	*11,595*	*200*	*453*	*120*	*237*	

Source: CAPRI biofuel model, Biofuel baseline, 18.11.10

Production and consumption of biofuels in non-European countries also increase significantly until 2020 as displayed in Annex 10.8 for ethanol and in Annex 10.9 for biodiesel. The U.S. increases its ethanol production (primarily based on maize) up to 49Mn tons. However, considering the also drastically increasing domestic fuel ethanol demand (58Mn tons), U.S. exports only expand marginally. With about 9.5Mn tons of imports, the U.S. becomes a strong net-importer of ethanol, primarily supplied by Brazil (Table 5.10). Brazilian ethanol production grows up to 50Mn tons while consumption remains on a level of 36Mn tons (Annex 10.8). Thus, with about 14Mn tons Brazil defends its dominant global ethanol export position. The EU10 also exports notable ethanol quantities (2Mn tons) but predominately in other EU15 countries and not to the world market. Other important ethanol producers like India (3.0Mn tons), China (4Mn tons), Canada (1.8Mn tons) or Russia (2Mn tons) do not appear on the world market as they also demand notable ethanol quantities on their domestic markets (Annex 10.8). Depending on the assumptions underlying the baseline the only countries which are considered to produce notable 2nd generation ethanol quantities are the EU27 and the U.S. as these countries already have stated 2nd generation targets in their legislations (Chapter 2). Notable growth of 2nd generation ethanol production in Brazil is not assumed as low production costs of sugar cane based ethanol further hamper their market launch. Non-agricultural based ethanol production exists only in Europe (0.7Mn tons) and North-America (1.2Mn tons) and does only change marginally in the EU27 until 2020.

The growth in global biodiesel production is also significant (Annex 10.9) but on a much lower level than for ethanol. Beside the EU27 (Table 5.8) in particular India (8Mn tons), the U.S. (4.3Mn tons), Brazil (2.8Mn tons) and Argentina (1.8Mn tons) as well as Malaysia and Indonesia (covered in *ROW*), become most important global biodiesel producers. Whereas American and Argentine production predominately rely on soy oil, Malaysian and Indonesian production is based on palm oil. However, only the U.S. and Argentina significantly increase their world market exports (1.8Mn tons and 1.6Mn tons) as domestic biodiesel demand also growth rapidly in India, Brazil and Europe (Annex 10.9). 2nd generation production of biodiesel is only assumed to reach a notable production in the EU27 (4.3Mn tons). Non-agricultural biodiesel production (based e.g. on waste oil) in the U.S. (1.4Mn tons), Canada (0.25Mn tons) and Brazil (0.3Mn tons) will increase continuously until 2020. The relative high biodiesel quantities based on non-agricultural sources in 2020 for the EU27 (3Mn tons) in comparison to 14Mn tons 1st generation and 4.4Mn tons 2nd generation biodiesel (Table 5.8) are derived from the PRIMES baseline as described in Section 5.1 and rely on the assumption that non-agricultural feedstocks like waste oil or e.g. black liqueur will increase their relevance in European biodiesel production until 2020. In Germany, Europe’s biggest biodiesel producer, biodiesel production based on non-agricultural sources in 2020 (1.4Mn tons) has a share of 15% in total biodiesel production which amounts about 9Mn tons.

Feedstock demand

Biofuel feedstock demand *(BIOF)* for traditional agricultural crops displayed in Table 5.11 for the EU27 (by Member State) and the most relevant global biofuel production countries is exclusively calculated based on the absolute quantities of 1st generation biofuel production in 2020. No traditional agricultural crops are used for 2nd generation or non-agricultural biofuel production. Following the described growth in 1st generation biofuel production, it is obvious that European biofuel feedstock demand also increases significantly until 2020. The composition of biofuel feedstocks used in 2020 is estimated to be in-line with the trends observed in the BaseYear, taking into account the considerations described in Section 5.2 (Table 5.3).

In the case of ethanol feedstocks, wheat shows the highest absolute growth of biofuel feedstock demand in EU27 (6.7Mn tons) until 2020, followed by barley (6Mn tons), maize (4.5Mn tons) and sugar (3.5Mn tons) based on sugar beats. Biofuel feedstock demand for rape oil, Europe’s most important biodiesel feedstock, expands by 8Mn tons up to 9.5Mn tons, while biofuel feedstock demand for soy oil in Europe stagnates at a level of 1Mn tons. By looking at the relative shares of biofuel feedstock demand in total domestic demand for the respective crops it appears that in particular European rape oil consumption is boosted strongly by the additional biofuel demand quantities. Here, biofuel feedstock demand amounts up to 70% of total EU27 rape oil consumption. The same tendency can be observed for other vegetable oils where 36-44% of total European consumption is used for biofuel production. For cereals, including maize, the demand shares are more moderate. However, in the case of rye and meslin (25%) and sugar (17%) also a notable share of domestic consumption is used for biofuel production.

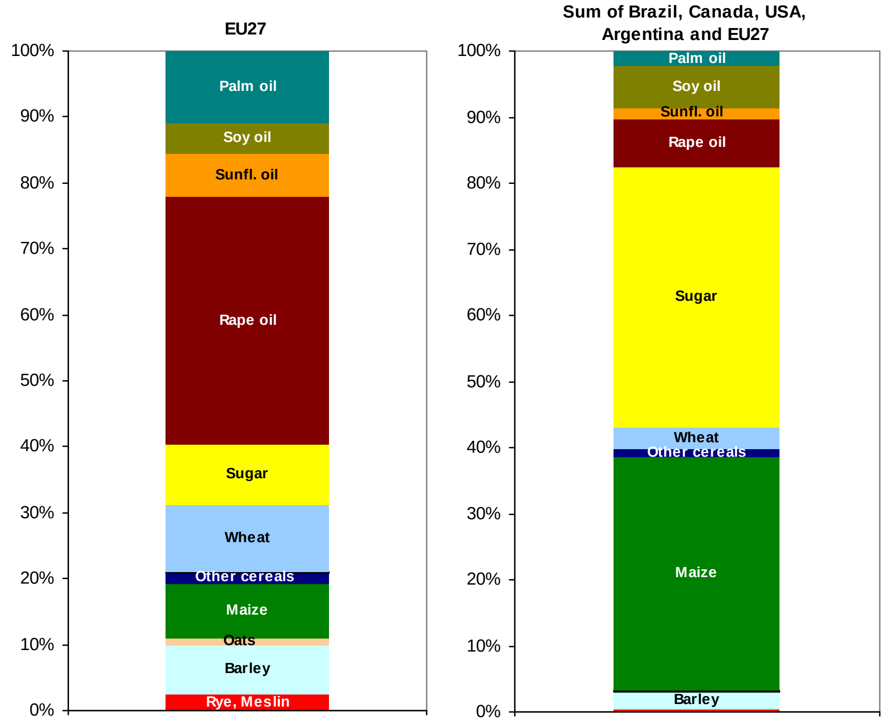
Table 5.11: Biofuel feedstock demand in EU Member States and most important biofuel production regions: Baseline

1000 tons	**Rye, Meslin**	**Barley**	**Oats**	**Maize**	**Other cereals**	**Table wine**	**Wheat**	**Sugar**	**Rape oil**	**Sunfl. oil**	**Soy oil**	**Palm oil**
Belgium / Lux.	0	399	0	295	0	0	362	63	447	22	13	45
Denmark	8	71	0	0	0	0	7	12	107	0	0	38
Germany	307	152	152	276	134	0	503	1,369	4,432	0	281	1,059
Greece	0	0	0	0	0	0	0	0	0	20	0	64
Spain	251	663	252	837	129	142	337	115	65	500	32	142
France	0	437	0	1,844	219	0	1,698	2,054	2,479	331	166	616
Ireland	0	0	0	0	0	0	0	0	15	0	0	50
Italy	0	131	0	542	0	0	462	0	676	114	49	201
Netherlands	62	82	21	39	0	0	255	10	206	10	103	103
Austria	113	572	113	590	0	0	104	0	222	31	88	29
Portugal	0	0	0	0	0	0	0	0	0	187	97	28
Sweden	6	6	0	0	0	0	57	74	134	0	1	13
Finland	141	71	71	0	0	0	64	0	59	0	29	49
UK	0	221	221	164	0	0	1,757	52	50	0	4	32
Cyprus	0	0	0	0	0	0	0	0	8	9	1	3
Czech Rep.	119	119	119	334	189	0	686	140	96	7	41	14
Estonia	761	945	0	0	0	0	905	0	62	9	45	9
Hungary	0	1,272	0	132	86	0	294	14	26	52	26	48
Lithuania	171	932	0	0	662	0	189	13	61	0	0	54
Latvia	11	44	0	14	21	0	24	0	92	12	9	10
Malta	0	0	0	0	0	0	0	0	0	0	0	0
Poland	22	98	0	93	0	0	20	70	201	25	18	57
Slovenia	0	0	0	0	0	0	0	0	16	27	13	9
Slovakia	130	139	0	102	69	0	126	0	15	71	61	16
Bulgaria	0	129	0	95	0	0	117	0	0	142	35	56
Romania	0	27	0	20	0	0	25	0	50	103	25	44
EU27	**2,102**	**6,511**	**950**	**5,377**	**1,507**	**142**	**7,994**	**3,985**	**9,520**	**1,673**	**1,137**	**2,789**
abs. diff. to baseyear	*2,026*	*6,037*	*799*	*4,515*	*1,459*	*3*	*6,712*	*3,492*	*8,011*	*1,576*	*1,095*	*2,399*
% of total demand	***25%***	***12%***	***8%***	***8%***	***14%***	***1%***	***6%***	***17%***	***69%***	***37%***	***36%***	***44%***
USA	0	3,312	0	115,993	4,968	0	2,581	532	175	175	3,145	0
Canada	0	2,278	0	1,120	0	0	2,809	0	183	0	51	0
Argentina	0	0	0	0	0	0	0	246	0	216	1,946	0
Brazil	0	0	0	0	0	0	0	87,659	0	0	2,477	275
Sum	**2,102**	**12,101**	**950**	**122,490**	**6,475**	**142**	**13,384**	**92,423**	**9,877**	**2,064**	**8,756**	**3,064**
abs. diff. to baseyear	*2,026*	*10,629*	*799*	*97,258*	*5,390*	*3*	*12,102*	*68,632*	*8,352*	*1,950*	*8,398*	*2,674*
% of total demand	***24%***	***17%***	***5%***	***24%***	***25%***	***1%***	***7%***	***73%***	***64%***	***34%***	***36%***	***46%***

Source: CAPRI biofuel model, Biofuel baseline 18.11.10

The situation in important non-European production regions differs. In Brazil 1st generation production of ethanol in 2020 is completely produced based on sugar cane which corresponds to about 88Mn tons of sugar. Here, similarly to the U.S. and Argentina, soy oil is the most processed biodiesel feedstock which amounts up to 2.5Mn tons (U.S. 3Mn tons and Argentina 2Mn tons). Whereas wheat is the most used ethanol feedstock in Canada (2.8Mn tons), maize is by far the dominant ethanol feedstock in the U.S. (115Mn tons). By accumulating these quantities for all regions covered in Table 5.11 it gets obvious that maize becomes the most important first generation biofuel feedstock on global level with about 122Mn tons, followed by sugar (92Mn tons), wheat (13Mn tons), barley (12Mn tons), rape oil (10Mn tons) and soy oil (9Mn tons). In relation to the total demand volume on global level the impacts of biofuel feedstock demand are significant in particular for sugar, rape oil and palm oil, where more than half of global consumption is used for biofuel production. However, for the identification of most relevant biofuel feedstocks referring to the total production volume of biofuels a direct comparison of biofuel feedstock demand is misleading as each feedstock is characterised by an individual conversion coefficient (Table 5.7). For this sort of comparison the produced biofuel quantities have to be compared differentiated by the feedstock used. Such a differentiation is given by Figure 5.1.

Figure 5.1: Share of feedstocks used in 1st generation biofuel production: Baseline



Source: CAPRI biofuel model, Biofuel baseline, 18.11.2010

Here, it can be observed that wheat, barley, maize and sugar are the main feedstocks for 1st generation ethanol production in Europe, while European biodiesel production is still dominated by rape oil. Sunflower oil and soy oil are less important in Europe. However, palm oil is of high relevance for European biodiesel production which corresponds to the BaseYear situation. Also displayed in Figure 5.1 is the situation for most important global biofuel production regions, considered as sum of Brazil, Canada, USA, Argentina and the EU27. Here, by contrast to the EU27, it can be observed that maize and sugar dominate in global 1st generation biofuel production.

Biofuel feedstock market balances

The observed shifts in biofuel feedstock demand for agricultural products (Table 5.11) subsequently cause changes in further market balance positions of single agricultural crops. These shifts are of high importance from an agricultural perspective as they provide indications for shifts in production and trade of directly affected and linked agricultural commodities. As (indirect) land use change resulting from an increasing biofuel feedstock production becomes currently a central topic within the evaluation of biofuel markets, an analysis of this sort of impacts provides useful information. Table 5.12 displays the aggregated EU27 market balance in 2020 for agricultural products which are used for 1st generation ethanol production.

Table 5.12: Market balance of 1st gen. ethanol feedstocks, EU27: Baseline

Quantities in Mn t and *absoltue changes compared to baseyear*	**Biofuel feedstock demand**	**Human demand**	**Indust. demand**	**Feed demand**	**Imports**	**Exports**	**Total production**	**Net-trade**	**Total demand**
	BIOF	*HCOM*	*INDM*	*FEDM*	*IMPT*	*EXPT*	*MAPR*	*NETT*	*DOMM*
Wheat	8.0	59.1	4.0	49.7	6.7	28.2	142.2	21.5	120.7
	6.7	*2.6*	*0.0*	*-1.3*	*4.8*	*11.1*	*12.9*	*6.2*	*6.7*
Rye, Meslin	2.1	2.1	0.6	3.1	1.7	1.3	7.6	-0.4	8.0
	2.0	*-1.1*	*0.0*	*-1.0*	*1.4*	*0.6*	*-0.5*	*-0.8*	*0.3*
Barley	6.5	0.8	9.6	36.6	1.0	10.6	63.0	9.6	53.5
	6.0	*0.0*	*-0.3*	*-2.6*	*0.0*	*2.7*	*6.2*	*2.7*	*3.4*
Oats	1.0	0.9	0.1	10.4	0.3	1.5	13.5	1.2	12.4
	0.8	*-0.1*	*0.0*	*-0.7*	*0.1*	*0.6*	*0.5*	*0.4*	*0.1*
Maize	5.4	5.6	4.7	52.7	2.3	9.3	75.4	7.0	68.4
	4.5	*0.1*	*0.0*	*3.2*	*-1.8*	*4.7*	*13.9*	*6.5*	*7.4*
Other cereals	1.5	0.2	1.0	8.1	4.5	3.4	9.8	-1.1	10.8
	1.5	*0.0*	*0.0*	*-1.5*	*3.3*	*2.8*	*-0.6*	*-0.6*	*0.0*
Sugar	4.0	18.0	0.3	0.0	8.2	2.9	17.5	-5.3	22.8
	3.5	*0.2*	*-0.6*	*0.0*	*7.4*	*0.1*	*-3.6*	*-7.3*	*3.5*
Protein feed	0.0	0.0	0.0	24.5	4.9	1.1	20.7	-3.8	24.5
	0.0	*0.0*	*0.0*	*0.6*	*-0.1*	*1.0*	*1.7*	*1.0*	*0.6*

Source: CAPRI biofuel model, Biofuel baseline, 18.11.2010

Total demand as displayed in Table 5.12 is the sum of feed demand, industrial demand, biofuel feedstock demand and human consumption. In addition to these demand components also intervention stock changes are considered which is not displayed explicitly in Table 5.12 but also considered in total demand. Changes are not exclusively caused by biofuel policies as the baseline also includes assumptions for the CAP and trade regimes (Section 5.2). It can be observed that total demand increases for all covered products (excepting other cereals) which is in most cases mainly caused by shifts in biofuel feedstock demand. Regarding the single crops, two general trends can be distinguished: (1) an increasing biofuel feedstock demand leads to a proportional increase in total demand or even to an over-proportional increase if simultaneously feed demand increases, too. This is true for wheat and maize where the increase in total demand (each by 7Mn tons) is equal to or even exceeds biofuel feedstock demand. In both cases the additional demand is mainly filled by a significant growth of domestic production (13Mn tons and 14Mn tons). (2) The increasing biofuel feedstock demand leads to an under proportional increase in total demand which is mainly caused by a declining feed demand. This effect can be explained by a substitution effect on the feed market as the by-product of cereals processing to biofuels (*DDGS*) can be used as substitute for traditional feed crops. In general this is true for rye and meslin, barley, oats and other cereals. Depending on the absolute quantity of this substitution effect still an increase of total demand or even a decrease of total demand can be observed in Table 5.12. Caused by these demand shifts domestic production is also affected significantly where beside the mentioned increase in European wheat and maize production also a production increase of barley (+6Mn tons) and oats (+0.5Mn tons) can be observed. The decrease in the case of rye and meslin (-0.5Mn tons) and other cereals (-0.6Mn tons) can be explained by the mentioned substitutions effect on the feed market. For a better understanding of this substitution effect the activity “Protein rich feed” *(FPRI)* which covers among others the cereals to ethanol by-product DDGS is also shown in Table 5.12. Here, an increase in production (1.6Mn tons) and feed demand (0.6Mn tons) for protein rich feed occurs. A special case is sugar. A substitution effect on the feed market does not take place as sugar is not used in the livestock sector. Thus, the strong increase in biofuel feedstock demand leads to a proportional increase in total demand. However, the absolute production quantities in Europe decrease by a significant amount (-3.6Mn tons) which is higher than the demand increase of 3.5Mn tons. Therefore, imports of sugar grow drastically by more than 7Mn tons which leads to a strong net-import situation of 5Mn tons in 2020. This trend can be explained by the CAP policy assumptions of the baseline (Section 5.2). Here, the sugar market reform implies a reduction of production quotas for European producers. The increase in total demand caused by biofuel production only partially compensates the trend of decreasing sugar production in Europe.

Market balances for main ethanol feedstocks in selected single European Member States are displayed in Table 5.13[61].

Table 5.13: Market balance of ethanol feedstocks in sel. EU Member States: Baseline

Quantities in Mn t and *absoltue changes compared to baseyear*		**Biofuel feedstock demand**	**Human demand**	**Industrial demand**	**Feed demand**	**Total demand**	**Imports**	**Exports**	**Total production**
		BIOF	*HCOM*	*INDM*	*FEDM*	*DOMM*	*IMPT*	*EXPT*	*MAPR*
Germany	Barley	0.15	0.15	2.21	7.43	9.82	0.69	4.03	13.16
		0.15	*0.00*	*-0.12*	*0.33*	*0.35*	*-0.31*	*1.02*	*1.68*
	Maize	0.28	1.69	0.51	4.53	6.99	3.54	2.58	6.03
		0.18	*0.44*	*-0.02*	*1.47*	*2.08*	*0.82*	*0.91*	*2.17*
	Wheat	0.50	7.21	0.63	10.02	18.70	11.52	21.00	28.18
		0.35	*0.39*	*-0.01*	*0.47*	*1.18*	*9.06*	*13.69*	*5.80*
	Sugar	1.37	2.88	0.04	0.00	4.47	3.07	2.82	4.23
		1.37	*-0.13*	*0.01*	*0.00*	*1.39*	*1.55*	*0.39*	*0.23*
Spain	Barley	0.66	0.04	0.83	7.66	8.90	0.97	0.00	7.93
		0.53	*0.01*	*0.01*	*-0.41*	*0.14*	*-0.24*	*-0.13*	*0.25*
	Maize	0.84	0.07	0.94	8.21	9.94	4.11	0.45	6.29
		0.68	*0.01*	*0.02*	*1.94*	*2.66*	*0.75*	*0.01*	*1.92*
	Wheat	0.34	4.63	0.09	4.95	9.94	7.63	3.29	5.60
		0.29	*0.02*	*0.00*	*1.40*	*1.71*	*3.12*	*1.77*	*0.36*
	Sugar	0.12	1.43	0.02	0.00	1.58	1.17	0.22	0.62
		0.03	*0.08*	*-0.05*	*0.00*	*0.08*	*0.64*	*0.03*	*-0.53*
France	Barley	0.44	0.12	0.28	3.60	4.18	0.11	8.75	12.81
		0.44	*0.01*	*0.00*	*0.00*	*0.43*	*-0.05*	*2.06*	*2.53*
	Maize	1.84	0.12	0.68	4.25	6.67	0.42	12.28	18.54
		1.55	*-0.11*	*0.03*	*-0.62*	*0.85*	*-0.29*	*3.42*	*4.56*
	Wheat	1.70	8.15	0.72	9.53	20.37	10.86	27.03	36.53
		1.37	*1.03*	*0.00*	*-0.28*	*2.09*	*9.55*	*8.73*	*1.27*
	Sugar	2.05	2.39	0.01	0.00	4.66	2.11	2.39	4.94
		1.65	*0.11*	*-0.50*	*0.00*	*1.42*	*0.91*	*-0.88*	*-0.37*
Italy	Barley	0.13	0.01	0.25	1.85	2.24	1.40	0.00	0.83
		0.13	*0.00*	*0.00*	*-0.10*	*0.03*	*0.28*	*-0.01*	*-0.26*
	Maize	0.54	0.33	0.49	11.73	13.34	0.12	1.47	14.69
		0.43	*-0.05*	*0.01*	*2.06*	*2.45*	*-1.41*	*0.67*	*4.53*
	Wheat	0.46	9.13	0.21	0.43	10.67	7.47	3.28	6.48
		0.37	*0.05*	*0.00*	*-0.70*	*-0.28*	*0.62*	*0.12*	*-0.78*
	Sugar	0.00	1.89	0.00	0.00	1.92	1.28	0.22	0.87
		0.00	*-0.01*	*0.00*	*0.00*	*0.02*	*0.34*	*-0.21*	*-0.54*

Source: CAPRI biofuel model, Biofuel baseline, 18.11.2010

It can be observed that in Germany only the total demand increase for sugar (1.4Mn tons) can be attributed to the increasing biofuel feedstock demand (1.4Mn tons) which amounts to about 30% of total sugar demand in Germany in 2020. By

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[61] Apart from *intervention stock changes*, also *stock change on market* is not explicitly displayed in Table 5.13 but considered within total demand (*DOMM*).

contrast, on EU27 level only 18% of total sugar demand goes to biofuel production. Such a strong increase in biofuel feedstock demand for sugar can be additionally observed only in France (1.6Mn tons) where biofuel feedstock demand has a share of 45% in total domestic sugar consumption in 2020. However, these additional quantities are mainly compensated by increasing imports or decreasing exports. Maize production shows a significant increase in all Member States but not in all cases caused by an increasing biofuel production. In Germany, Spain and Italy the drastically increasing total demand for maize is predominately caused by growing feed demand quantities (between 1.5 and 2Mn tons). In France the opposite is true. Here, the growth in biofuel feedstock demand (1.5Mn tons) is mainly responsible for the increase in total domestic demand (0.9Mn tons). By contrast to sugar, the additional demand quantities for maize are predominately met by an increasing domestic production which can also be observed in Table 5.12 for the EU27. Maize shows the largest domestic production shift over all affected agricultural crops in Europe (+14Mn tons) which is due to the combination of increasing biofuel and feed demand quantities.

Market balances for main biofuel feedstocks in important non-European biofuel production countries (USA, Canada, Brazil, and Argentina) are displayed in Table 5.14. As one can observe, maize demanded for biofuel production in the U.S. is immense (116Mn tons). The also high demand for human consumption and feed lead to a domestic maize production in 2020 of almost 400Mn tons which is more than five times higher than the EU27 production (75Mn tons). Beside maize, also barley and wheat for ethanol and soy oil for biodiesel production achieve notable quantities in the U.S. but on a much lower level than maize. In the case of barley this leads to a domestic production increase of 0.7Mn tons and for soy oil of 3.3Mn tons. For all cereals a significant decline in U.S. feed demand can be observed (-2.5Mn tons for barley, -2.8Mn tons for wheat and -51Mn tons for maize) which results from the mentioned substitution effect of traditional feed components by biofuel by-products on the feed market. Soy oil production in Argentina is also affected strongly, where biofuel feedstock demand grows to about 2Mn tons which leads to an equivalent increase in domestic production. Sugar is by far the most processed feedstock in Brazil whose domestic sugar production increases by 75Mn tons to about 104Mn tons in 2020. About 88Mn tons are processed to ethanol, which takes 85% of total domestic sugar production. Apart from domestic ethanol production, sugar exports also drastically increase by 20Mn tons to about 23Mn tons which results among others from increasing exports to the EU27. In Canada primarily cereals like wheat, barley and maize are most important biofuel feedstocks while the additional demand is predominately met by increasing imports. Furthermore, a significant increase in rape oil production and exportation (each 6Mn tons) can be observed which results from increasing rape oil exports to the EU27.

Table 5.14: Market balance of biofuel feedstocks in non-EU countries: Baseline

Quantities in Mn t and *absoltue changes compared to baseyear*		**Biofuel feedstock demand**	**Human demand**	**Industrial demand**	**Feed demand**	**Imports**	**Exports**	**Total production**
		BIOF	*HCOM*	*INDM*	*FEDM*	*IMPT*	*EXPT*	*MAPR*
USA	Barley	3.31	0.00	0.00	2.32	0.21	0.57	6.00
		2.62	*0.00*	*0.00*	*-2.50*	*-0.56*	*0.01*	*0.69*
	Maize	115.99	124.20	0.00	100.88	0.08	51.51	392.50
		91.77	*54.95*	*0.00*	*-51.27*	*-0.34*	*15.97*	*111.76*
	Wheat	2.58	26.92	0.00	2.93	0.01	1.73	34.15
		2.58	*-18.71*	*0.00*	*-2.81*	*-0.46*	*-4.30*	*-22.77*
	Sugar	0.53	10.59	0.00	0.00	2.55	0.04	8.61
		0.53	*0.25*	*0.00*	*0.00*	*1.45*	*-0.08*	*-0.75*
	Rape oil	0.17	0.37	0.20	0.00	0.40	0.47	0.81
		0.16	*-0.02*	*-0.04*	*0.00*	*-0.05*	*0.42*	*0.57*
	Soy oil	3.15	8.79	0.00	0.00	0.03	0.79	12.69
		2.83	*0.62*	*0.00*	*0.00*	*-0.04*	*-0.15*	*3.34*
Canada	Barley	2.28	0.00	0.00	8.80	0.03	0.85	11.90
		1.97	*0.00*	*0.00*	*-1.13*	*-0.04*	*-0.51*	*0.37*
	Maize	1.12	5.40	0.00	8.76	3.43	0.03	11.88
		0.97	*3.00*	*0.00*	*0.00*	*0.67*	*-0.28*	*3.01*
	Wheat	2.81	5.59	0.00	4.12	0.00	0.81	13.34
		2.81	*-2.28*	*0.00*	*-3.24*	*-0.01*	*-7.26*	*-9.97*
	Sugar	0.00	2.99	0.00	0.00	2.85	0.00	0.15
		0.00	*1.20*	*0.00*	*0.00*	*2.54*	*-0.02*	*-1.37*
	Rape oil	0.18	0.70	0.00	0.00	0.47	7.37	7.78
		0.18	*0.11*	*0.00*	*0.00*	*0.47*	*6.03*	*5.86*
	Soy oil	0.05	0.00	0.26	0.00	0.03	0.00	0.29
		0.05	*0.00*	*-0.05*	*0.00*	*-0.02*	*-0.02*	*0.00*
Argentina	Barley	0.00	0.00	0.00	0.85	0.00	0.35	1.20
		0.00	*0.00*	*0.00*	*0.32*	*-0.03*	*0.08*	*0.43*
	Maize	0.00	3.76	0.00	17.20	0.16	4.08	24.88
		0.00	*0.89*	*0.00*	*8.49*	*0.15*	*-0.60*	*8.64*
	Wheat	0.00	7.92	0.00	0.05	0.00	0.58	8.55
		0.00	*-1.04*	*0.00*	*-0.02*	*0.00*	*-4.64*	*-5.70*
	Sugar	0.25	1.77	0.00	0.00	0.00	0.95	2.97
		0.25	*0.38*	*0.00*	*0.00*	*0.00*	*0.78*	*1.41*
	Rape oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
	Soy oil	1.95	1.29	0.00	0.00	1.18	4.77	6.83
		1.95	*0.14*	*0.00*	*0.00*	*1.16*	*0.89*	*1.81*
Brazil	Barley	0.00	0.00	0.00	1.11	0.94	0.00	0.17
		0.00	*0.00*	*0.00*	*0.50*	*0.54*	*0.00*	*-0.04*
	Maize	0.00	7.86	0.00	52.77	0.06	10.03	70.59
		0.00	*1.62*	*0.00*	*20.81*	*-0.57*	*9.47*	*32.47*
	Wheat	0.00	4.75	0.00	0.27	0.26	0.00	4.76
		0.00	*-3.12*	*0.00*	*-0.03*	*-3.13*	*-0.14*	*-0.17*
	Sugar	87.66	0.71	0.00	0.00	7.35	23.39	104.41
		64.36	*-2.04*	*0.00*	*0.00*	*7.35*	*20.57*	*75.54*
	Rape oil	0.00	0.00	0.04	0.00	0.00	0.00	0.04
		0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
	Soy oil	2.48	2.95	0.00	0.00	0.02	2.76	8.17
		2.48	*-0.88*	*0.00*	*0.00*	*-0.03*	*1.17*	*2.80*

Source: CAPRI biofuel model, Biofuel baseline, 18.11.2010

In Table 5.15 the market balances of vegetable oils used for 1st generation biodiesel production are displayed for the aggregated EU27 in 2020.

Table 5.15: Market balance of 1st gen. biodiesel feedstocks in EU27: Baseline

Quantities in 1000 t and *absoltue changes compared to baseyear*	**Biofuel feedstock demand** *BIOF*	**Human demand** *HCOM*	**Industrial demand** *INDM*	**Feed demand** *FEDM*	**Imports** *IMPT*	**Exports** *EXPT*	**Total productio n** *MAPR*	**Net-trade** *NETT*	**Total demand** *DOMM*
Rape oil	9,520	3,003	1,099	278	7,136	820	7,584	-6,316	13,900
	8,012	*497*	*-56*	*88*	*7,046*	*558*	*2,054*	*-6,488*	*8,541*
Sunf. oil	1,673	2,479	265	85	1,188	176	3,489	-1,012	4,501
	1,577	*32*	*-12*	*18*	*561*	*-153*	*901*	*-714*	*1,615*
Soy oil	1,137	1,661	214	193	546	661	3,319	115	3,205
	1,095	*-13*	*4*	*55*	*260*	*-129*	*751*	*-389*	*1,141*
Palm oil	2,789	97	3,512	0	6,334	0	63	-6,334	6,397
	2,399	*-6*	*57*	*0*	*2,424*	*0*	*26*	*-2,424*	*2,450*
Rape cake	0	19	17	7,645	159	3,005	10,527	2,846	7,681
	0	*9*	*5*	*1,128*	*69*	*2,407*	*3,479*	*2,338*	*1,142*

Source: CAPRI biofuel model, Biofuel baseline, 18.11.2010

For rape oil it can be observed that the increasing biofuel feedstock demand (+8Mn tons) is mainly compensated by a significant increase in imports (7Mn tons), while production shows relatively slight changes (+2Mn tons). Whereas the EU27 was a net-exporter of rape oil in the BaseYear it gets in a strong net-import situation in 2020. By more than 6Mn tons Canada will become the most important importer of rape oil into Europe. For sunflower and soy oil the picture is somewhat different. Here, the demand increase (1.6Mn tons and 1Mn tons) is predominately met by increasing domestic production (0.9Mn tons and 0.7Mn tons). In the case of palm oil, which is only produced in the EU on a marginal level (0.06Mn tons), the demand increase (2.3Mn tons) is completely compensated by increasing imports which predominately come from ACP countries, Indonesia or Malaysia. Also covered in Table 5.15 is the market balance for rape cake which is a by-product of rape seed processing to rape oil. Even though the increase in domestic rape oil production is relatively moderate, rape cake production grows about 3.5Mn tons which is mainly exported as the domestic feed market only demand 1Mn tons of this surplus. More detailed information on biodiesel feedstock market balances for single Member States is given by Annex 10.7. Here, it is shown that in particular Germany, which processes the largest quantities of rape oil to biodiesel in Europe (4.4Mn tons) in 2020, mainly meet the increasing demand (about 4Mn tons) by increasing imports (+2.2Mn tons). Domestic production only grows by 0.9Mn tons. This trend can also be observed in Italy and France where 0.8Mn tons of the additional biofuel feedstock demand for rape oil (2Mn tons) is met by imports. Sunflower oil which is the most important biodiesel feedstock in Spain is predominately produced domestically (0.4Mn tons).

6. Scenario analysis

The different scenarios simulated in this analysis are defined to address the four central questions of this thesis (Section 1.1).

6.1. Scenario definition

Scenario 1 (*no EU biofuel support*) represents a situation where all support policy instruments for biofuels in Europe are abolished. Consequently, all existing quota obligations in the EU27 (Table 5.1) are taken out and the existing consumer taxes for fossil fuels in European Member States (Table 2.3) are also applied for biofuels. Non-European biofuel taxation and all other relevant biofuel variables are assumed to stay at the baseline level. Also the European import tariffs for biofuels are untouched. In particular this first scenario will indicate the impacts of the current European biofuel policy on global agricultural and biofuel markets.

Scenario 1-a (*high fuel price*) builds on Scenario 1. In addition it is assumed that the market price for fossil fuels (gasoline and diesel) exceed the 2020 level of the baseline (Table 5.4) by 40%. This assumption increases for example the EU27 consumer price of the baseline (European market price plus average consumer tax) from about 1.3 €/l for diesel and 1.9 €/l for gasoline up to 1.7 €/l and 2.3 €/l, respectively. This scenario is defined to indicate if such an increase in fuel prices leads to a situation where the European biofuel industry is able to compete against fossil fuels without any support measures.

Scenario 2 (*no EU biofuel tariffs*) represents the baseline situation except that the existing European import tariffs for biodiesel and fuel-ethanol (Table 5.2) are abolished in 2020. This scenario should indicate to which level European biofuel production might decrease and international imports into the EU might increase if the existing European import tariffs are abolished.

Scenario 3 (*high 2nd generation share*) differs from the baseline regarding the availability of 2nd generation technologies which is assumed to increase more rapidly until 2020. The European trade policy regime is untouched. To introduce a higher 2nd generation share in total biofuel production it is assumed that all European Member States are able to produce at least 50% of their biodiesel production and 50% of their ethanol production by 2nd generation technologies. Furthermore, it is assumed that 50% of total 2nd generation production is based on new energy crops and 50% on agricultural residues. Trade with agricultural residues or new energy crops is neglected as the transportability of these products seems to be rather restricted.

Scenario 4 (*lower fuel demand*) differs in two important assumptions compared to the baseline. (1) The minimum share of biofuels in total fuel consumption for the EU27 average is not aligned with the assumptions of the AgLink baseline (8.5%) but with the assumptions of the PRIMES baseline (status December 2009). This baseline estimates a rather tentative increase in European biofuel consumption (6.9% in 2020) as displayed in Table 6.1.

Table 6.1: Share of biofuels in EU27 fuel consumption: Scenario4

Energy share (in%) of …	**...ethanol in gasoline demand**	**...biodiesel in diesel demand**	**...biofuels in total fuel demand**	**Total diesel demand** (1000 t)	**Total gasoline demand** (1000 t)
Austria	6.4	7.5	7.2	5,093	1,935
Bulgaria	2.1	2.6	2.5	1,698	557
Belgium / Luxemb.	6.4	7.0	6.9	8,549	2,025
Cyprus	1.0	3.4	2.3	403	365
Czech Republic	4.9	7.4	6.6	4,654	2,371
Germany	8.0	9.6	9.0	31,775	19,011
Denmark	6.3	9.0	7.9	2,346	1,611
Estonia	3.9	4.5	4.3	510	285
Greece	4.4	5.5	4.9	2,743	4,023
Spain	7.2	7.5	7.5	33,297	7,009
Finland	5.2	6.0	5.7	2,189	1,692
France	5.7	8.0	7.5	30,778	9,406
Hungary	3.4	7.1	5.8	3,418	1,905
Ireland	4.0	6.2	5.3	2,670	1,915
Italy	4.8	8.0	6.8	23,406	14,324
Lithuania	5.0	5.2	5.2	1,164	402
Latvia	2.8	5.9	4.9	929	429
Malta	0.8	1.7	1.5	167	47
Netherlands	4.0	6.8	5.9	6,858	3,316
Poland	4.4	6.2	5.6	11,164	5,446
Portugal	3.8	5.7	5.2	4,734	1,668
Romania	2.2	2.9	2.7	3,992	2,264
Sweden	6.4	7.1	6.8	3,815	3,677
Slovenia	3.5	7.9	6.6	1,828	761
Slovakia	4.1	5.4	5.0	1,719	840
United Kingdom	6.4	6.5	6.5	22,074	16,969
EU27	**5.8**	**7.5**	**6.9**	**211,972**	**104,253**
% diff. to baseline	***-31.6%***	***-12.0%***	***-18.5%***	***-14.7%***	***-1.9%***
	EU27 *total fuel demand in 1000 toe*			***323,557***	
			% diff. to baseline	***-11%***	

Source: PRIMES baseline (status October 2009)

Thus, the EU27 does not meet the RED target of 10%. Since the biofuel demand share is an endogenous variable in the CAPRI biofuel model, the national biofuel quotas are adjusted so that the PRIMES demand shares are met. (2) The assumptions for EU27 total fuel demand is also adopted from the PRIMES baseline. Here, EU27 total fuel demand in 2020 is estimated to be about 11% less than in the CAPRI baseline (Table 6.1), while the assumptions on the GDP growth rates are almost equal. This difference might result from European ambitions to increase energy efficiency (also in the transport sector) which are considered in more detail in the PRIMES model and its baseline.

6.2. Scenario results

The simulation results of the different counterfactual scenarios are described in the following section focusing on changes in biofuel markets and corresponding shifts in single feedstock markets compared to the baseline. Environmental indicators as described in Section 4.9 are analysed in the end of this chapter.

Changes in biofuel market balances and global biofuel trade

An overview on EU27 biofuel market balances for each scenario is given by Table 6.2. A more detailed view on biofuel market balances for each scenario in single European Member States provides Annex 10.12.

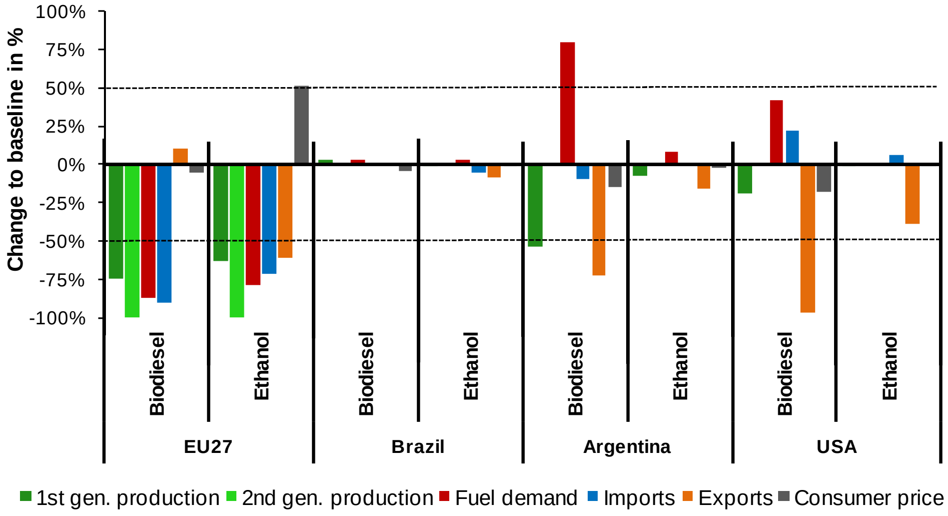
Table 6.2: Biofuel market balance for EU27: Scenarios

EU 27	**baseline**		**no EU support**		**high fuel price**		**no EU tariffs**		**high 2nd gen.**		**low fuel demand**	
	Biod.	*Eth.*	*Biod.*	*Eth.*	*Biod.*	*Eth.*	*Biod.*	*Eth.*	*Biod.*	*Eth.*	*Biod.*	*Eth.*
Total production (Mn t)	**21**	**13**	**4**	**4**	**5**	**6**	**21**	**10**	**25**	**14**	**18**	**10**
1st generation	14	9	4	3	5	5	14	7	11	7	11	7
2nd generation	4	3	0	0	0	0	4	3	11	6	4	3
Non-agricultural	3	1	0	1	0	1	3	1	3	1	3	1
Fuel demand (Mn t)	**25**	**15**	**3**	**3**	**5**	**5**	**25**	**18**	**27**	**16**	**21**	**11**
Biofuel-share* (%)	8.5	8.4	1.0	1.8	1.9	3.0	8.5	10.1	9.3	9.0	7.0	6.2
Net-trade (Mn t)	**-3.6**	**-3.9**	**0.5**	**-0.9**	**0.4**	**-1.0**	**-3.9**	**-9.9**	**-2.6**	**-3.7**	**-2.2**	**-2.7**
Imports	4.5	6.1	0.4	1.7	0.7	2.2	4.8	11.4	3.8	6.1	3.2	4.3
Exports	0.9	2.1	1.0	0.8	1.1	1.2	0.9	1.4	1.3	2.4	1.0	1.7
Consumer price (1000€/ toe)	**1.3**	**1.5**	**1.2**	**2.3**	**1.3**	**2.2**	**1.3**	**1.3**	**1.1**	**1.4**	**1.1**	**1.4**

*Note: *Energy share of biodiesel in total diesel consumption and ethanol in total gasoline consumption.*
Source: CAPRI biofuel model, 26.11.2010

Without biofuel support polices in **Scenario 1,** EU27 biofuel demand significantly decreases to about 3Mn tons for biodiesel as well as for ethanol (Table 6.2). This is caused on the one hand by the abolishment of the applied quota obligations in each Member State (Table 5.1) and, on the other hand, by a significantly higher consumer tax for biofuels which is assumed to be equal to the consumer tax on fossil fuels in 2020 (Table 5.4). Therefore, the share of biofuels in total European fuel consumption decreases to about 1.0% in the case of biodiesel and to about 1.8% in the case of ethanol. Subsequently, European production of biofuels is also strongly affected. 1^{st} generation production decreases to about 4Mn tons of biodiesel and 3Mn tons of ethanol. Thus, European biodiesel production declines nearly to the level of 2005 (Figure 1.1). 2^{nd} generation biofuel production which depends also on a strong financial support is reduced to a marginal level. At the same time biodiesel produced from non-agricultural sources also vanish which leads to a decline of total European biofuel production between 70 - 80% (Figure 6.1). Caused by the significant demand decrease in Europe, imports also decrease significantly by 90% in the case of biodiesel and 70% in the case of ethanol (Figure 6.1). By looking at global bilateral trade for biodiesel (Annex 10.10) the significant decrease of European imports results from an equivalent reduction of exports from all important biodiesel export countries, first and foremost the U.S. and Argentina which export flows into the EU27 decline by more than 1.7Mn tons and 1.4Mn tons, respectively. The same is true for ethanol (Annex 10.11) where the main global production regions decrease their exports into the EU27 by more than 70% from 3Mn tons to 0.7Mn tons. With about 1.9Mn tons the highest decrease in exports can be observed for Brazil. An overview on the relative changes in biofuel market balances for the EU27 and most important non-European production regions in Scenario 1 provides Figure 6.1.

Figure 6.1: Relative changes of biofuel markets compared to baseline: Scenario1

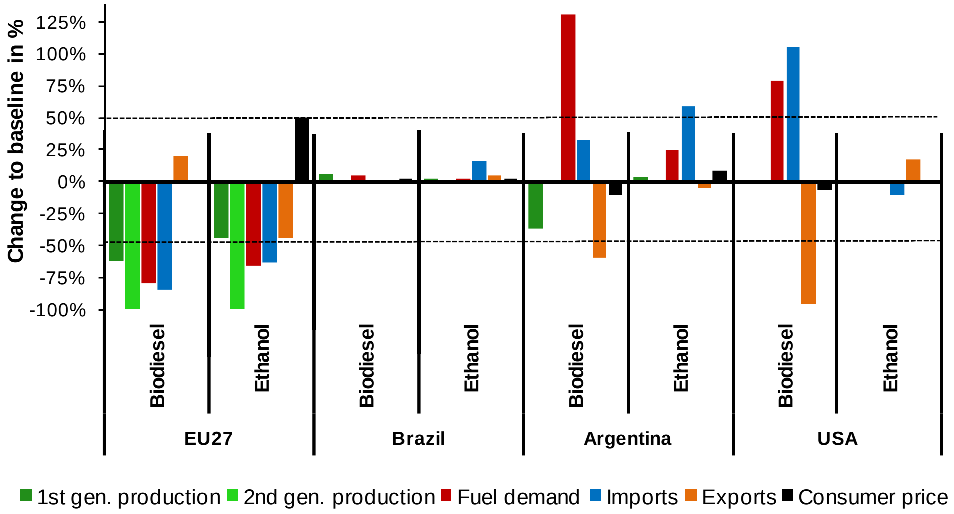


Source: CAPRI biofuel model, 26.11.2010

Considering the significant trade shifts, serious changes for biofuel production and demand also take place in non-European regions. This observation emphasizes the high relevance of the EU27 biofuel support regime for global biofuel markets. With about 7Mn tons of biofuels in 2020 the EU27 will be, beside the U.S. (10Mn tons), one of the most important biofuel importers worldwide. Consequently, a breakdown of the European biofuel market leads also to a production decrease in most relevant global regions. By contrast, domestic consumption outside the EU increases as a result of the decreasing biofuel consumer prices outside Europe (Figure 6.1) which compensates the decreasing exports to some extent on the demand side. Thereby, excepting the EU27, the consumer taxes in non-European regions remain on the baseline level. The slight decline of the biodiesel consumer price in the EU27 (-6%) which already includes the higher taxation level, results from the fact that a strong decrease of the biodiesel market price overcompensates the higher European taxation level in this scenario. As one can observe, this is not true for ethanol as the decline of the ethanol market price is significantly lesser. The different impact on the biodiesel and ethanol market price is obvious as Europe is the most dominant biodiesel consumer worldwide (70% of global biodiesel demand in 2020), whereas the U.S. and Brazil are the most important ethanol consumers (together about 85% of global ethanol demand). Thus, a significant decrease of European biofuel demand will have a much stronger impact on the biodiesel price. From this it follows that the decrease in biofuel production outside the EU is more significant for biodiesel (-1.4Mn tons) than for ethanol (-0.4Mn tons) as the increasing non-European ethanol consumption mostly compensates the missing European imports.

Basically, the same effects can be observed in **Scenario 1a** (Figure 6.2).

Figure 6.2: Relative changes of biofuel markets compared to baseline: Scenario1a

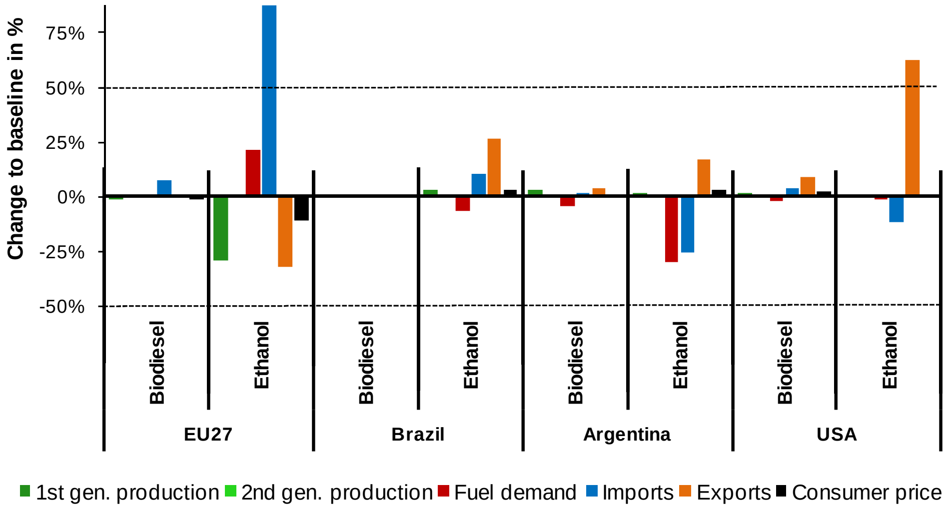


Source: CAPRI biofuel model, 29.11.2010

The differences which result from higher fossil fuel prices (+40% compared to Scenario 1) can be explained by two effects. On the one hand, an increasing fuel price leads to a decrease of total fuel demand. This demand decrease leads automatically to a decrease of biofuel demand as both markets are strongly connected by fuel blendings. On the other hand, the ratio of biofuel and fossil fuel consumer prices changes for the benefit of biofuels which increase their demand share in total fuel consumption. This effect leads to a higher substitution of fossil fuels by biofuels. As the first effect compensates the substitution effect to some extent and the high taxation level for biofuels as assumed in Scenario 1 and 1a is still in place, a significant decrease for biofuel demand, supply and imports can also be observed here (Figure 6.2). However, the decrease takes place on a lower level as in Scenario 1 because the changing price ratio attenuate the missing tax exemption for biofuels. The resulting share of biofuels in total European fuel consumption in this scenario only decreases to a level of 1.9% in the case of biodiesel and 3.0% in the case of ethanol (Table 6.2) which is in both cases about 1% higher as in Scenario 1. The same tendency can be observed in the detailed trade balances where the effects of Scenario 1a are not as high as in Scenario 1 but still on a significant level. These results show that even in a situation where fossil fuel prices significantly increase (+40% compared to the assumed increase of the baseline) European biofuel supply and demand will drastically decrease to a level which is far below the 10% target, if no support policies are in place.

Lower European import tariffs for biofuels in **Scenario 2** lead to a significant increase (+88%) of EU27 ethanol imports (Figure 6.3).

Figure 6.3: Relative changes of biofuel markets compared to baseline: Scenario2

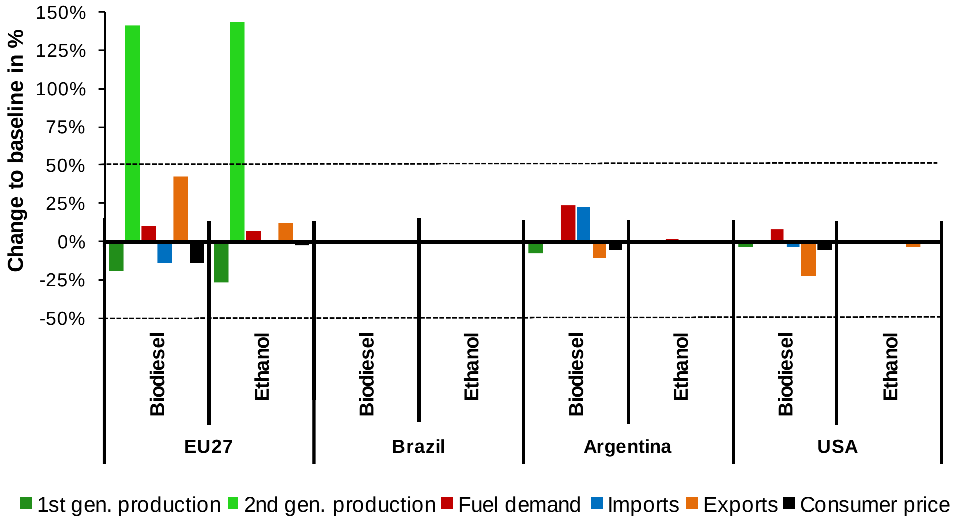


Source: CAPRI biofuel model, 29.11.2010

However, biodiesel imports are nearly unchanged. The bilateral trade table for biodiesel (Annex 10.10) shows that the absolute biodiesel import quantities, stemming mainly from the U.S., Argentina and India grow only by about 0.28Mn tons, while ethanol imports (Annex 10.11), mainly stemming from Brazil, other South American countries and the U.S., notably increase by about 5.1Mn tons up to 8Mn tons. This results first and foremost from a strong growth of Brazilian ethanol exports into the EU (+5.0Mn tons). Consequently, the European consumer price for biodiesel decreases moderately by -1% whereas the ethanol price significantly decreases by -11% as displayed in Figure 6.3. The stronger impact on the ethanol market results from the current and baseline relevant specific European import tariff applied for fuel ethanol (300 €/toe) which is more effective as the applied European ad valorem tariff for biodiesel of 6.5% (Table 5.2). Consequently, this scenario has a higher impact on the ethanol market compared to the biodiesel market. Due to the price decrease, European demand for ethanol increases about 22%, while biodiesel demand only increase about 1% and thus, remains nearly on the baseline level (Figure 6.3). Subsequently, European biodiesel production decreases only marginally, whereas European ethanol production declines strongly by more than 20%. In line with a reduced domestic production, European ethanol exports decrease also more significantly up to 32%, while biodiesel exports remain on baseline level (Figure 6.3). The price decrease in this scenario and the resulting demand increase in Europe, especially in the case of ethanol, lead consequently to a higher share of biofuels in total European fuel consumption. The share of ethanol in total gasoline consumption increases from 8.4% to 10%, whereas the biodiesel share only grows to 8.5% (Table 6.2). The impacts of this scenario on non-European biofuel markets are caused predominately by the increasing import quantities of ethanol. As more than 90% of the additional ethanol imports are stemming from Brazil, the most significant market shifts in absolute quantities can be observed here (Annex 10.13). Brazilian ethanol production increases up to 51.5Mn tons (+3%), whereas domestic demand declines to about 32.7Mn tons (-7%).

Under the assumptions of **Scenario 3** EU27 2nd generation biofuel production increases significantly by about 140% for both, biodiesel and ethanol (Figure 6.4).

Figure 6.4: Relative changes of biofuel markets compared to baseline: Scenario3

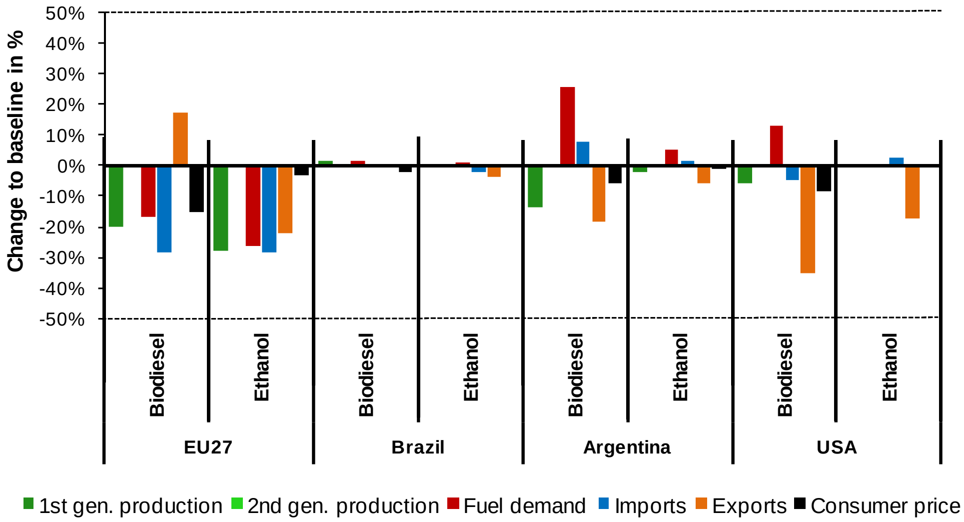


Source: CAPRI biofuel model, 29.11.2010

This supply shock leads to decreasing consumer prices of biodiesel (about 14%) and of ethanol (about 3%). European consumption of biodiesel increases by about 10% and ethanol consumption by about 7%. The more considerable effect on the European biodiesel consumer price compared to the ethanol price which leads subsequently to a stronger demand increase for biodiesel in Europe results from the fact that the absolute 2nd generation production quantities which are assumed to reach 50% of total EU27 biodiesel and ethanol production in Scenario 3 are considerably higher in the case of biodiesel (10.6Mn tons) than for ethanol (6.4Mn tons). Thus, the relative share of this increase in global biodiesel production is much higher than for ethanol which leads to stronger price effects. The increasing European demand consequently leads to a higher share of biofuels in total fuel consumption (9.3% for biodiesel and 9% for ethanol). On the supply side, total biofuel production increases about 10 - 15% as a result of the higher 2nd generation production quantities. 1st generation production declines by more than 20% in both cases as shown in Figure 6.4. Due to the higher domestic biofuel production European imports of biodiesel decrease by 15% whereas European biodiesel exports increase by 43%. However, most of the mentioned biodiesel exports are intra-EU flows between the EU15 and the EU10 as one can observe in the bilateral trade balance (Annex 10.10). The decrease of EU27 biodiesel imports results mainly from a decline in U.S. (-0.4Mn tons), Argentine (-0.2Mn tons) and Indian (-0.09Mn tons) exports into the EU27. Imports of ethanol from non-EU regions decrease only slightly (Figure 6.4). These observations indicate that an increase in European 2nd generation production predominately effects intra-European biofuel markets and first and foremost leads to a substitution of 1st by 2nd generation production quantities within the EU.

Due to the main variation in **Scenario 4** which introduces a lower total fuel demand in Europe and in addition a lower share of biofuels in total fuel consumption (6.9% instead of 8.5%) in 2020 (Table 6.1), European demand for biofuels is notably lower (Figure 6.5). For ethanol a demand reduction of 26% (from 14.8Mn tons to 10.9Mn tons) and for biodiesel a reduction of 17% (from 24.8Mn tons to 20.6Mn tons) can be observed in EU27 (Figure 6.5). Consequently, the share of ethanol in total European gasoline consumption decrease to a level of 6.2% and the share of biodiesel in total European diesel consumption decrease to a level of 7.0% (Table 6.2). The different shares for biodiesel and ethanol result from the PRIMES assumption, which projected that biodiesel has a higher share in European biofuel consumption than ethanol. Also this assumption is different to the baseline where on EU27 level both biofuels have the same demand share. Consequently, production of 1st generation ethanol decreases more significantly (-28%) than the production of 1st generation biodiesel (-20%).

Figure 6.5: Relative changes of biofuel markets compared to baseline: Scenario4



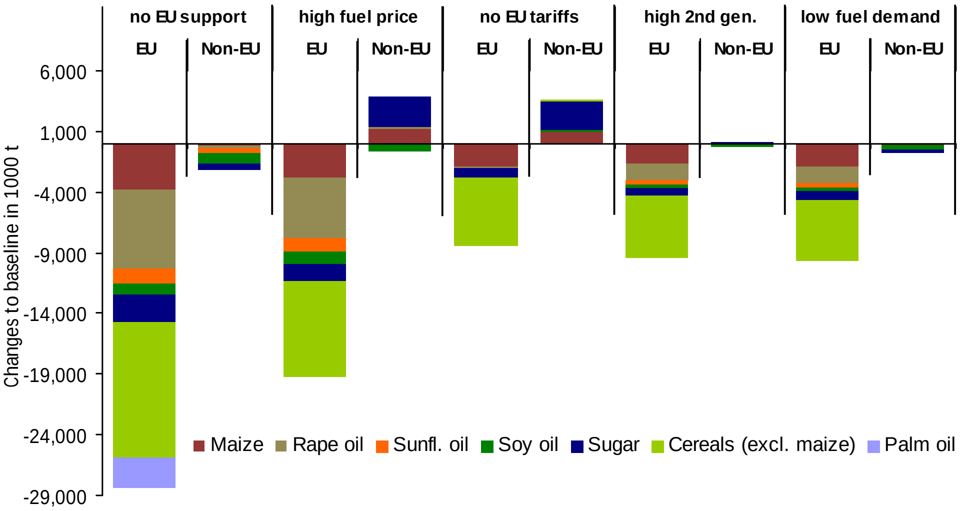
Source: CAPRI biofuel model, 29.11.2010

Non-agricultural and 2^{nd} generation biofuel production are equal to the baseline. Due to the lower European biofuel demand biofuel prices also decrease by 15% for biodiesel and 3% for ethanol (Figure 6.5). European biofuel imports are about 30% under the baseline level (-3Mn tons) and EU27 biofuel production decreases by approximately 5.5Mn tons. This scenario shows how sensitive biofuel market projections are to the assumptions concerning the future fuel and biofuel demand behaviour.

Changes in feedstock market balances

In general all calculated scenarios show a decrease in European 1^{st} generation biofuel production as described above, only the level is different. Consequently, in all scenarios a decrease in European feedstock demand for 1^{st} generation biofuel production takes place which is shown in Annex 10.14 for the aggregated EU27 and most demanded biofuel feedstocks. Biofuel feedstock demand quantities for most important non-European biofuel production regions (Brazil, USA and Argentina) are also displayed in Annex 10.14 for all scenarios. Here, by contrast to the EU27, shifts in biofuel feedstock demand vary across the different scenarios what is considerable as non-European biofuel production is affected differently. The absolute changes of biofuel feedstock demand compared to the baseline for each scenario differentiated into EU27 and aggregated non-European demand is depicted in Figure 6.6. Thereby, the non-European aggregate covers the most important global biofuel producers (Brazil, USA and Argentina).

Figure 6.6: Absolute changes of biofuel feedstock demand compared to baseline: Scenarios



Source: CAPRI biofuel model, 30.11.2010

The changes in biofuel feedstock demand confirm the conclusions which have already been drawn within the evaluation of the biofuel market balances. The substitution of 1st by 2nd generation biofuel production quantities in Scenario 3 (*high 2nd gen.*) affects to a large extent only the European biofuel market and thereby only leads to a decline of European 1st generation feedstock demand. The strong increase of biofuel imports into the EU27 in Scenario 2 (*no EU tariffs*), which is a result of the abolished European biofuel tariffs, leads to an increase in non-European biofuel feedstock demand which is due to the increasing non-European biofuel production. As this scenario predominately affect the ethanol market notable changes in biofuel feedstock demand take place only for ethanol feedstocks which are first and foremost maize and sugar. The strongest decrease of biofuel feedstock demand is displayed in the "*no EU support*" scenario (Scenario 1). The comparison of this scenario with the baseline is in particular suitable for evaluating the impacts of the current European biofuel policy (represented by the baseline) on global agricultural markets as it simulates a situation where all currently applied support measures to reach the target of the European Renewable Energy Directive are eliminated. By aggregating the changes in biofuel feedstock demand of this scenario in Figure 6.6 for European and non-European regions total biofuel feedstock demand for agricultural crops exclusively caused by the European biofuel support policies in 2020 can be derived: 11Mn tons of cereals (excluding maize), 4Mn tons of maize, 7Mn tons of rape oil, 2Mn tons of soy oil, 2Mn t of sunflower oil, 2Mn t of palm oil, and 3Mn tons of sugar. These absolute quantities are notable. However, to which extent they impact the respective feedstock markets depends on the relative share of biofuel feedstock demand in total demand which will be evaluated later.

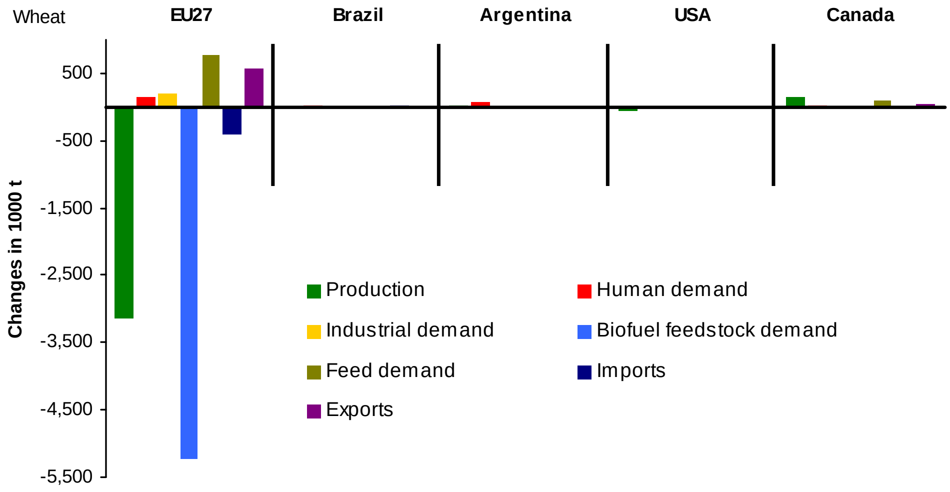
In the “*high-fuel price”* scenario EU27 feedstock demand declines as expected less pronounced compared to Scenario 1. The growth in feedstock demand in non-European regions indicates that, by contrast to the situation in the EU27, the substitution effect as described above overcompensates the quantity effect of a decreasing total fuel demand and thus, leads to an increasing biofuel demand and thereby also to an increasing feedstock demand. By looking into Annex 10.14 it gets obvious that this increase results first and foremost from an increasing maize processing in the U.S. and an increasing sugar processing in Brazil.

The lower feedstock demand level in Scenario 4 (*low fuel demand*) is due to the lower biofuel production level as described above.

To quantify the impacts of changing biofuel feedstock demand on individual agricultural markets shifts in production, consumption, trade and prices of most demanded 1st generation biofuel feedstocks are evaluated in the following. The focus is set on the effects of the “*no EU support”* scenario (Scenario 1). In Annex 10.15 the full market balances of Scenario 1 for wheat, maize, rape oil, soy oil and sugar, which are the most demanded biofuel feedstocks on global level, are displayed for the EU27, Brazil, USA, Argentina and Canada. To give an illustrative overview on the shifts which occur on global agricultural markets the following figures picture the absolute market balance changes (Scenario 1 compared to the baseline) separately for wheat, sugar, rape oil and soy oil for most affected global regions.

As one can observe in Figure 6.7 changes on the global wheat market notably occur only inside Europe.

Figure 6.7: Changes in global wheat markets compared to baseline: Scenario1



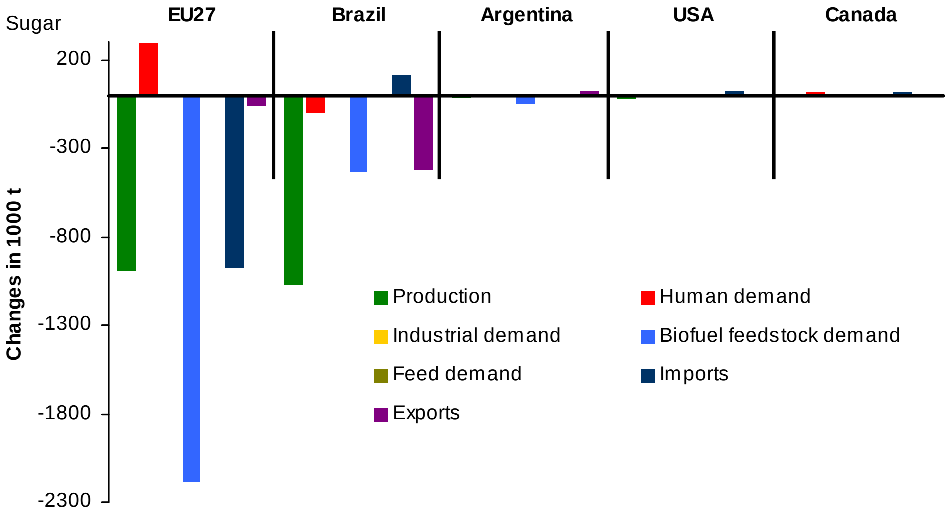
Source: CAPRI biofuel model, 30.11.2010

Without European biofuel support policies EU27 wheat production declines by about 3Mn tons which results from a decreasing biofuel feedstock demand of about 5Mn tons which is partially compensated by an increasing feed demand (0.7Mn tons) and increasing exports (0.6Mn tons). The substitution effect of traditional feed components by biofuel by-products has already been described in Section 5.3. Following this effect a reduction of biofuel production consequently leads to a reduced production of biofuel by-products (here DDGS) and thereby leads to an increasing demand of traditional feed components like wheat. As the total volume of the European wheat market is very high (140Mn tons production and to about 100Mn tons total demand in 2020 as displayed in Table 5.12) the relative market impacts are marginal inside the EU27 (-2% production, +2% feed demand, +2% exports as shown in Annex 10.15). Significant changes in regions outside the EU27 are not observed (Figure 6.7). In the case of wheat the moderate market impact of biofuel production can be basically explained by the relative low share of biofuel feedstock demand in total EU27 wheat demand, even in the baseline (6%) where the compliance with the European Renewable Energy Directive is assumed (Table 5.11).

A comparable situation as for wheat exists for maize. Also here, notable changes only occur inside Europe where the decline in biofuel feedstock demand (4Mn tons) leads to a reduced production by 3% and to an increasing feed demand by 2%. The effects on non-European regions are marginal. As European biofuel feedstock demand for maize is limited to 8% of total EU27 maize consumption in the baseline and U.S. ethanol production (which is predominately consumed domestically) accounts for more than 20% (Table 5.11), the decline of the EU biofuel market leads not to serious global maize market shifts.

In Figure 6.8 changes in global sugar markets are presented. As one can observe the European biofuel support does not only affect the EU27 market. An equivalent decrease of sugar production by 1Mn tons also occurs in Brazil which results from a reduced domestic ethanol production caused by decreasing exports into the EU27 (Annex 10.11). However, as shown in Annex 10.15 the absolute decrease in production amounts only to about 1% of total Brazilian sugar production due to the large market volume of sugar cane based sugar in Brazil in 2020 (100Mn tons production, 87Mn tons ethanol feedstock demand). The impact on the European sugar market in relative terms is much higher and is equal to a production decrease of 6%. As the impacts of decreasing European ethanol imports on Argentine, U.S. and Canadian ethanol production are more less and in addition sugar is not the dominant ethanol feedstock in these regions, the respective domestic sugar markets are not affected.

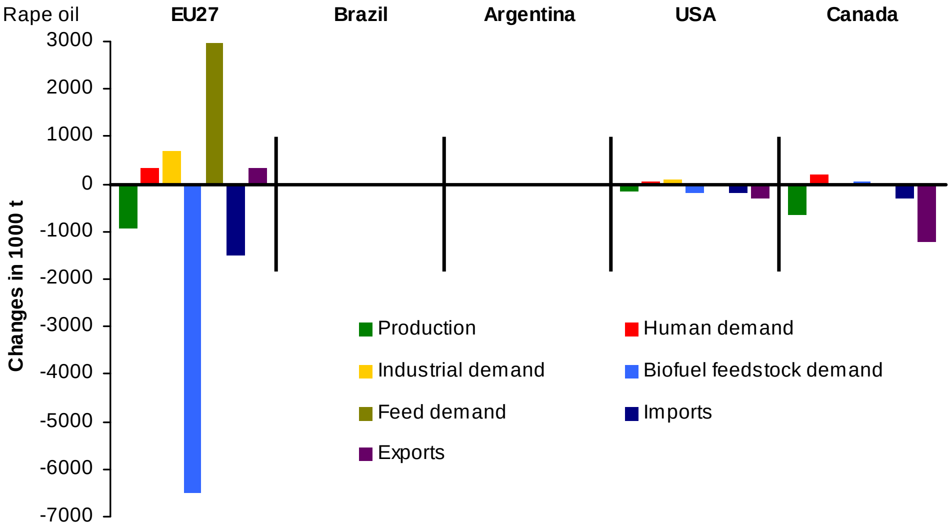
Figure 6.8: Changes in global sugar markets compared to baseline: Scenario1



Source: CAPRI biofuel model, 30.11.2010

Changes in global rape oil markets (Figure 6.9) occur notably also in non-European countries, first and foremost in Canada which is by about 7Mn tons the most important rape oil importer into the EU27 in the baseline (Table 5.14).

Figure 6.9: Changes in global rape oil markets compared to baseline: Scenario1

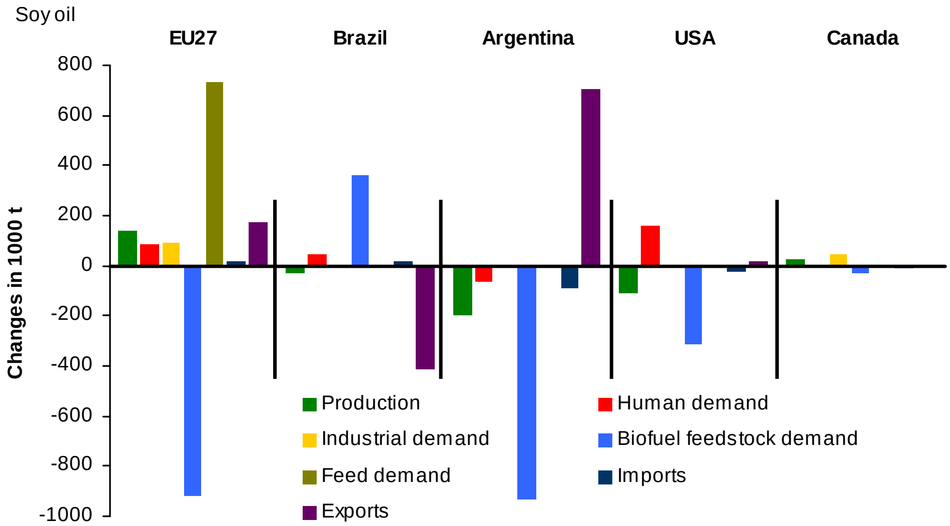


Source: CAPRI biofuel model, 30.11.2010

The reduced EU27 imports consequently lead to an equivalent decrease of Canadian rape oil exports. About half of the reduced biofuel feedstock demand in Europe is compensated by increasing feed and industrial demand as well as growing exports. However, in Europe as well as in Canada a production decrease up to 1Mn tons can be observed. Taking into account the relative low market volume of rape oil in comparison to wheat or maize (7.5Mn tons production in the EU27 as well as in Canada in the baseline) the abolished EU27 biofuel support leads to a relative production decrease of 9 - 12% in both regions Annex 10.15).

As biodiesel imports into the EU27 predominately rely on soy oil the reduced imports of biodiesel in Scenario 1 (-4Mn tons as displayed in Table 6.2) consequently lead to reduced feedstock demand for soy oil in main non-European biodiesel production regions, in particular in Argentina (Figure 6.10).

Figure 6.10: Changes in global soy oil markets compared to baseline: Scenario1



Source: CAPRI biofuel model, 30.11.2010

From this it follows that beside the European reduction in biofuel feedstock demand as shown in Figure 6.10, which is mainly compensated by an increasing domestic feed demand, also Argentine biodiesel feedstock demand for soy oil declines drastically caused by the reduced domestic biodiesel production for the European import market. The surplus of Argentine soy oil production is than exported without any refining. The same is true for the U.S. which is the second important biodiesel exporter into Europe (2Mn tons in the baseline). However, the increase of human demand and the reduced production compensate the decrease of biodiesel feedstock demand in the U.S.. Another effect can be observed in Brazil where biodiesel is predominately produced for domestic consumption. As the reduced global demand for soy oil leads to decreasing soy oil prices it is more attractive for Brazil to use soy oil domestically for biodiesel production which is intended to increase until 2020.

Based on the described shifts in European and global market balances of agricultural commodities, Table 6.3 summarises the underlying price shift in Europe for most affected agricultural products used as biofuel feedstock for all simulated scenarios.

Table 6.3: EU27 market prices for most affected feedstocks in €/ton and relative change (%) to baseline: Scenarios

	no EU support	high fuel price	no EU tariffs	high 2nd gen.	low fuel demand
Average price for cereals	**98**	**99**	**100**	**100**	**100**
	-4%	***-2%***	***-2%***	***-1%***	***-1%***
Wheat	121	121	122	123	122
	-2%	*-2%*	*-1%*	*-1%*	*-1%*
Rye, Meslin	96	97	99	99	99
	-6%	*-4%*	*-3%*	*-2%*	*-2%*
Barley	95	96	97	97	97
	-3%	*-2%*	*-1%*	*-1%*	*-1%*
Oats	73	74	75	76	75
	-4%	*-3%*	*-2%*	*-1%*	*-1%*
Maize	92	93	94	94	94
	-3%	*-2%*	*-1%*	*-1%*	*-1%*
Other cereals	109	110	111	112	112
	-4%	*-3%*	*-2%*	*-1%*	*-1%*
Sugar	**399**	**399**	**400**	**402**	**402**
	-1%	***-1%***	***-1%***	***0%***	***0%***
Average price for vegetable oils	**450**	**466**	**587**	**543**	**542**
	-24%	***-21%***	***0%***	***-8%***	***-8%***
Rape oil	400	430	574	525	523
	-31%	*-25%*	*0%*	*-9%*	*-9%*
Sunfl. oil	515	533	620	582	585
	-17%	*-14%*	*0%*	*-6%*	*-6%*
Soy oil	434	434	566	521	520
	-24%	*-24%*	*0%*	*-8%*	*-8%*

Source: CAPRI biofuel model, 02.12.2010

In particular these price shifts are of high interest with respect to the recent discussion on rising food prices resulting from European biofuel support measures. Two general trends can be observed: (1) prices of biodiesel feedstocks (rape oil, soy oil and sunflower oil) are more affected than ethanol feedstocks (cereals and sugar) and (2), which is obvious, the strongest price effects occur in the "*no-EU support*" scenario. Both trends are in line with the observations made in the beginning of this section. Thereby, the first effect can be explained on the one hand, by the fact that Europe is the most important producer and consumer of biodiesel on global level (Annex 10.9) and thus, changes on this market strongly impact global biodiesel markets and, on the other hand, the share of EU27 biofuel feedstock demand for vegetable oils in total vegetable oil consumption (40-70%) is much higher than for cereals (Table 5.11). For ethanol the situation is different as the most important producers and consumers are non-European countries (Annex 10.8), first and foremost the U.S. and Brazil. Furthermore, the share of EU27 biofuel feedstock demand in global cereals consumption is much smaller (10-25%), even though the absolute quantities of biofuel feedstock demand are higher. Thus, a reduction of 1st generation biodiesel production in Europe, which takes place in all calculated scenarios, has a more significant impact on global vegetable oil markets and prices as a shift in European ethanol production might have on global cereals or sugar markets and prices.

The second trend is due to the fact that the strongest reduction of biofuel production in Europe and thereby also the strongest reduction of biofuel feedstock demand take place in the "*no-EU support*" scenario (Scenario 1). The price shifts observed are of high interest as they indicate which impact the sum of all already applied and envisaged European biofuel support policies might have on agricultural product prices and thereby also on food prices until 2020. If no European biofuel support policies are in place in 2020, cereals prices are 3-4% lower than in the baseline. Prices of sugar are 1% lower and prices for vegetable oils are reduced by 20-25% with the strongest decrease (30%) for rape oil prices compared to the baseline (Table 6.3).

Impacts on European environment

The environmental indicators as described in Section 4.9 are exclusively caused by shifts in European production of different cropping and animal activities. This is true for *Nitrous Oxide* (N_2O) *emissions*, as well as for the *Crop share* which indicates the share of arable land used by a specific cropping activity in total arable land. As described in the foregoing section absolute changes in EU27 crop production resulting from shifts in biofuel feedstock demand and thus, from shifts in 1st generation biofuel production, are moderate with the most significant changes in Scenario 1 (Annex 10.15). Here, it can be observed, that without European biofuel support policies EU27 production of wheat is about 2% lower (maize 3%) than in the baseline. Sugar production is 6% lower and the highest decrease is observed for rape oil, where EU27 production is 12% lower than in the baseline. These rather moderate shifts relative to the shifts on the biofuel market can be explained based on three effects: (1) a notable share of EU27 biofuel consumption in 2020 relies on imports and thus is produced outside Europe. This is in particular true for ethanol where the share of imports in domestic consumption lies above 25% (Table 5.8 and Table 5.10). Consequently, a notable share of the underlying feedstocks (mainly sugar and maize) are demanded and processed outside the EU27, particularly in the U.S. and Brazil. (2) A significant share of the required feedstocks for EU27 domestic biofuel production rely also on imports from non-European regions which is in particular true for biodiesel where almost 70% of the biofuel feedstock demand for rape oil is imported (Table 5.15), mainly from Canada (Table 5.14). (3) The increase in biofuel feedstock demand resulting from increasing domestic biofuel production is partially compensated by a reduced feed demand as a consequence of the substitution of traditional feed components by biofuel by-products which is in particular true for cereals (Table 5.12).

From this it follows, that also environmental impacts might only be observed on a rather moderate level within the EU27. Table 6.4 shows the use of arable land (*Land use*) differentiated by crop activities (in Mn ha) and the share (%) of arable land used for the cultivation of a particular crop in total land use (*Crop share)* for the EU27 and each scenario.

Table 6.4: EU27 land use by crop activity (Mn ha) and crop shares (%): Scenarios

EU27 absolute values and ***absolute diff. compared to baseline***	**no EU support**		**high fuel price**		**no EU tariffs**		**high 2nd gen.**		**low fuel demand**	
	Land use	**Crop share**	**Land use**	**Crop share**	**Land use**	**Crop share**	**Land use**	**Crop share**	**Land use**	**Crop share**
	Mn ha	%	Mn ha	%	Mn ha	%	Mn ha	%	Mn ha	%
Aggregated cereals	56	30.1	57	30.3	57	30.2	56	30.0	57	30.2
	-0.66	***-0.26***	***-0.39***	***-0.14***	***-0.40***	***-0.20***	***-0.63***	***-0.36***	***-0.38***	***-0.18***
Wheat	21	11.1	21	11.1	21	11.1	21	11.1	21	11.1
	-0.34	***-0.15***	***-0.22***	***-0.09***	***-0.19***	***-0.09***	***-0.26***	***-0.15***	***-0.19***	***-0.09***
Rye, Meslin	2	1.1	2	1.1	2	1.1	2	1.1	2	1.1
	-0.05	***-0.03***	***-0.03***	***-0.02***	***-0.04***	***-0.02***	***-0.05***	***-0.03***	***-0.03***	***-0.02***
Barley	13	7.1	13	7.1	13	7.1	13	7.0	13	7.1
	-0.15	***-0.06***	***-0.07***	***-0.02***	***-0.11***	***-0.05***	***-0.19***	***-0.11***	***-0.09***	***-0.04***
Oats	4	2.4	4	2.4	4	2.4	4	2.4	4	2.4
	0.07	***0.04***	***0.05***	***0.03***	***0.03***	***0.01***	***-0.01***	***-0.01***	***0.01***	***0.00***
Maize	9	5.0	9	5.0	9	5.0	9	5.0	9	5.0
	-0.17	***-0.07***	***-0.11***	***-0.05***	***-0.08***	***-0.04***	***-0.08***	***-0.04***	***-0.08***	***-0.03***
Other cereals	3	1.4	3	1.5	3	1.4	3	1.4	3	1.4
	-0.01	***-0.01***	***0.00***	***0.00***	***-0.01***	***-0.01***	***-0.04***	***-0.03***	***-0.01***	***-0.01***
Rape seed	6	3.2	6	3.2	6	3.3	6	3.3	6	3.3
	-0.29	***-0.14***	***-0.21***	***-0.10***	***0.00***	***0.00***	***-0.11***	***-0.06***	***-0.09***	***-0.04***
Sunfl. seed	4	1.9	4	1.9	4	1.9	4	1.9	4	1.9
	-0.03	***-0.02***	***-0.02***	***-0.01***	***0.00***	***0.00***	***-0.03***	***-0.02***	***-0.02***	***-0.01***
Soya bean	1	0.4	1	0.4	1	0.4	1	0.4	1	0.4
	0.03	***0.02***	***0.02***	***0.02***	***0.00***	***0.01***	***0.01***	***0.01***	***0.01***	***0.01***
Sugar beet	2	0.8	2	0.9	2	0.9	2	0.8	2	0.8
	-0.08	***-0.04***	***-0.01***	***0.00***	***0.02***	***0.01***	***-0.04***	***-0.02***	***-0.04***	***-0.02***

Source: CAPRI biofuel model, 03.12.2010

As one can observe, changes in crop shares do not exceed 0.4% over all scenarios and are in most cases below 0.1%. This corresponds to the marginal changes in land use by crop activity.

The same is true for the emissions caused by agricultural production as displayed in Table 6.5. The changes in *N_2O emissions* over all scenarios are smaller than 0.1 kg/ha on EU27 level which indicate that no significant increase in production intensity takes place as a consequence of the EU27 biofuel strategy.

Thus, the emissions and the crop shares caused by EU27 agricultural production in the baseline do not change notably through all scenarios. However, it is likely that environmental impacts caused by an increasing EU27 demand for biofuels and biofuel feedstocks notably occur outside the EU27, especially in those countries which increase their production, processing, or exportation of biofuels or biofuel feedstocks under the European biofuel support policy regime. This is among others true for Brazil, Argentina, U.S. and Canada (Annex 10.15).

Table 6.5: N_2O emissions from crop activities in EU27 (kg/ha): Scenario

EU27 absolute values and ***absolute diff. compared to baseline***	**no EU support**	**high fuel price**	**no EU tariffs**	**high 2nd gen.**	**low fuel demand**
Wheat	3.18	3.2	3.2	3.21	3.2
	-0.04	***-0.02***	***-0.02***	***-0.01***	***-0.02***
Rye, Meslin	1.3	1.32	1.31	1.31	1.31
	-0.03	***-0.01***	***-0.02***	***-0.02***	***-0.02***
Barley	2.09	2.1	2.1	2.11	2.1
	-0.02	***-0.01***	***-0.01***	***0***	***-0.01***
Oats	1.81	1.83	1.83	1.83	1.83
	-0.04	***-0.02***	***-0.02***	***-0.02***	***-0.02***
Maize	3.41	3.44	3.45	3.46	3.46
	-0.08	***-0.05***	***-0.04***	***-0.03***	***-0.03***
Other cereals	2.45	2.47	2.46	2.46	2.47
	-0.04	***-0.02***	***-0.03***	***-0.03***	***-0.02***
Rape seed	4.92	4.94	4.97	4.97	4.96
	-0.06	***-0.04***	***-0.01***	***-0.01***	***-0.02***
Sunfl. seed	1.44	1.45	1.46	1.45	1.45
	-0.02	***-0.01***	***0***	***-0.01***	***-0.01***
Soy bean	3.95	3.96	3.98	3.97	3.97
	-0.03	***-0.02***	***0***	***-0.01***	***-0.01***
Sugar beet	5.69	5.73	5.73	5.71	5.71
	-0.05	***-0.01***	***-0.01***	***-0.03***	***-0.03***

Source: CAPRI biofuel model, 03.12.2010

7. Comparison of biofuel market projections from different models

In Chapter 5 and 6 the CAPRI biofuel baseline and the simulation results of different counterfactual scenarios have been discussed. Following, as mentioned in Chapter 3 where general features of alternative economic biofuel models have been described, a comparison of results referring to the impacts of European biofuel policies on global biofuel and agricultural markets is done. The main challenge when preparing such a comparison is to make model results comprehensible. This is ambitious as the projection output strongly depends on the scenario definition, the specification of behavioural functions, the simulation horizon, the underlying database, the regional and commodity disaggregation and various additional assumptions and model specifications which vary across the different models. For this reason, some important model features have been described in Chapter 3 which should permit to interpret and explain the identified differences between the respective projections.

Basically, there are different ways to make model outcomes more comparable. One of them is the definition of basic scenarios which clearly define the bulk of exogenous variables and which are simulated by each of the compared models (Blanco Fonseca et al., 2010). This approach is very efficient but necessitates specific model runs which are in most cases not applicable because of budgetary or time limitations. Another approach permits to use already existing scenario results of different models directly by applying a decomposition methodology. Here, the individual model results which are based on different exogenous assumptions are decomposed and normalised to comparable key indicators or values (Witzke et al., 2010). This approach does not necessitate specific model runs and hence is more applicable. However, the disadvantage is that the comparison is limited to the number of calculated key indicators. Furthermore, the decomposition procedure requires nearly the full set of scenario results and detailed information of the underlying model parameters. In the majority of cases, this full set of information is not integrated in scientific publications as they are often focussing on a specific part of results.

The following comparison is based on model results which have already been published in scientific journals or research reports. The only exception is the AgLink biofuel baseline (status October 2009) whose detailed set of results was available within this analysis. Further model specific publications which are taken into account have been mentioned in Table 3.1. The comparison of results will be differentiated into projections referring to future biofuel and agricultural commodity markets. It is not possible to compare the projection results from each model mentioned Table 3.1. However, for each category (CGE or PEM) two examples will be picked. In the case of agricultural sector models a comparison of

CAPRI with ESIM and AgLink results is prepared and in the case of the general equilibrium models GTAP and DART results are taken into account. While the comparison with AgLink and ESIM projections builds on the previous work of Blanco Fonseca et al. (2010), the comparison with GTAP and DART results is more limited, building on the projection results published in Banse et al. (2008a) as well as on Kretschmer et al. (2009c) and Witzke et al. (2010).

In Blanco Fonseca et al. (2010) the impacts of the European 2020 biofuel target on agricultural markets and land use are described by a comparative modelling assessment. The models incorporated (AgLink, ESIM and CAPRI) are all applied at the *Integrated Agro-economic Modelling Platform* (iMAP)[62] installed at the Institute for Prospective Technological Studies (IPTS) in Seville. Two general scenarios are simulated in each of the models for the year 2020: A baseline which represents the current CAP policy setting and projects an optimistic biofuel share which tends to reach the 10% target of the RED. This baseline corresponds to the CAPRI biofuel baseline. The counterfactual scenario simulates a more pessimistic biofuel market share resulting form reduced policy support for biofuels in the EU27. This scenario corresponds to the "*no-EU support*" scenario in CAPRI. The CAPRI version used in Blanco Fonseca et al. (2010) is a previous one and does not include an endogenous biofuel market. Thus, biofuel feedstock demand is modelled as an exogenous demand shock for agricultural products. For this reason the following review only summarises the findings of the AgLink and ESIM projections and compare them with the recent projections from the CAPRI biofuel model. As the baseline and scenario assumptions of ESIM and AgLink described in Blanco Fonseca et al. (2010) differ slightly in some point, the differences should be highlighted.

The ESIM baseline projects a share of 7% biofuels in overall EU27 fuel consumption in 2020 which is assumed to be produced only by 1st generation technologies. The CAP is implemented as up to the state of 2008. Total fuel consumption is taken over from PRIMES projections. The counterfactual scenario assumes that Member State support policies in the EU27 for biofuels are not expanded and thus, are maintained on the 2009 level up to 2020. This leads to a EU27 biofuel share of only 3.7% in 2020 (Blanco Fonseca et al., 2010).

The AgLink baseline projects also a share of 7% 1st generation biofuels in total EU27 fuel consumption in 2020. However, in addition 1.5% of fuels consumed in the EU27 in 2020 are produced from 2nd generation biofuel technologies. Given the fact that in accordance with article 21 of the RED (European Parliament and Council, 2009) the energy provided by 2nd generation fuels is considered twice, the 10% biofuel target is fully reached by this assumption. Total fuel consumption

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[62] More information available in Pérez Dominguez et al. (2008)

is taken over also from PRIMES projections. The counterfactual scenario assumes that Member State support policies in the EU27 for biofuels are completely abolished which leads to a share of 2% ethanol and only 1.3% biodiesel in total EU27 gasoline and diesel consumption (Blanco Fonseca et al., 2010).

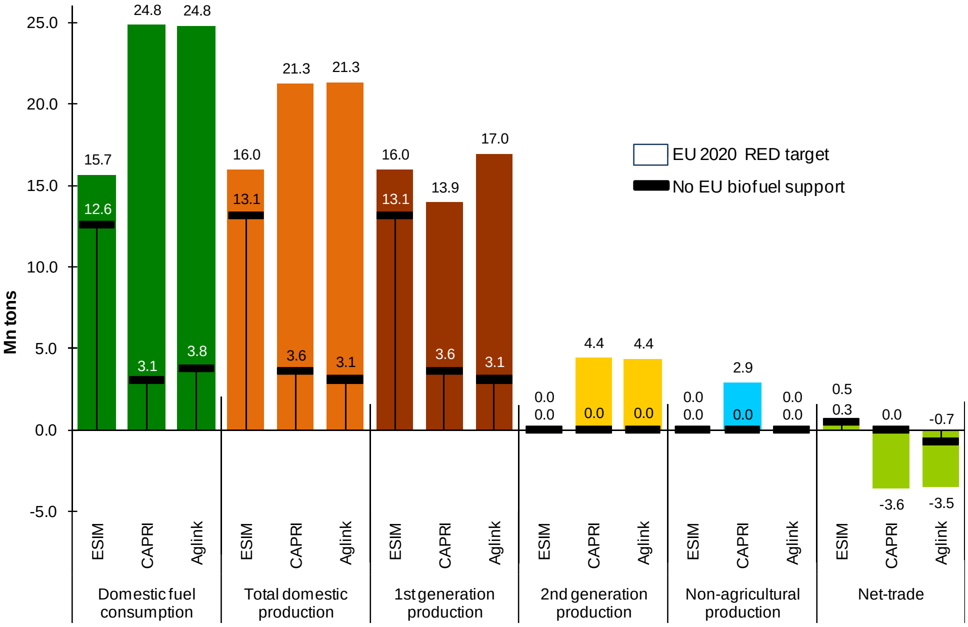
Banse et al. (2008a) describe an application of the GTAP-E model, an extended version of the GTAP model, introducing (among others) biofuel markets. Here, two scenarios are simulated: a "*global economy*" scenario, which represents the CAP as of 2003 (full decoupling) and assumes that no biofuel blending obligations are existent in the EU27. This scenario corresponds to the "*no-EU support*" scenario in CAPRI. The GTAP-E "*policy scenario*" assumes the compliance with the European RED by implementing blending obligations for biodiesel and ethanol of 10% in 2020 in each Member State. While ethanol is modelled explicitly which can be produced from cereals or sugar beets or cane, biodiesel is not considered explicitly but covered by a fuel aggregate relying on vegetable oils. This scenario corresponds to the biofuel baseline of CAPRI.

Kretschmer et al. (2009c) develop and apply an extended version of the DART model introducing biofuel and renewable electricity markets. They simulate various scenarios in their analysis; only two are picked here which focus on the effect of the EU RED target. Firstly, a "*business as usual*" scenario which does not include biofuel obligations in the EU27 and secondly a "*biofuel scenario*" which assumes the compliance with the RED target by implementing blending obligations for biodiesel and ethanol of 10% in 2020 in each Member State. Ethanol and biodiesel are modelled explicitly which can be produced from wheat, maize, vegetable oils and sugar crops. This scenario corresponds to the CAPRI biofuel baseline, whereas the "*business as usual*" scenario corresponds to the "*no-EU support*" scenario of CAPRI. In both CGE modelling approaches 2nd generation biofuel are not considered.

7.1. Impacts of European biofuel policies on biofuel markets

In Figure 7.1 the different projections from ESIM, AgLink and CAPRI for the EU27 biodiesel market in 2020 are displayed. Thereby, the coloured pillars represent the baseline situation assuming a high biofuel share in overall fuel consumption. The black cross beams (integrated in the pillars) represent the results of the counterfactual scenarios assuming a fully abolished or at least reduced European policy support for biofuels. As one can observe biodiesel demand in the ESIM baseline (16Mn tons) is significantly lower than CAPRI and AgLink EU27 biodiesel demand (25Mn tons). This results from two different assumptions. Firstly, the assumed overall EU27 biofuel share in the ESIM baseline is set on 7% whereas the CAPRI and AgLink baseline assume nearly 10%, resulting from 7% 1st generation and 1.5% 2nd generation biodiesel.

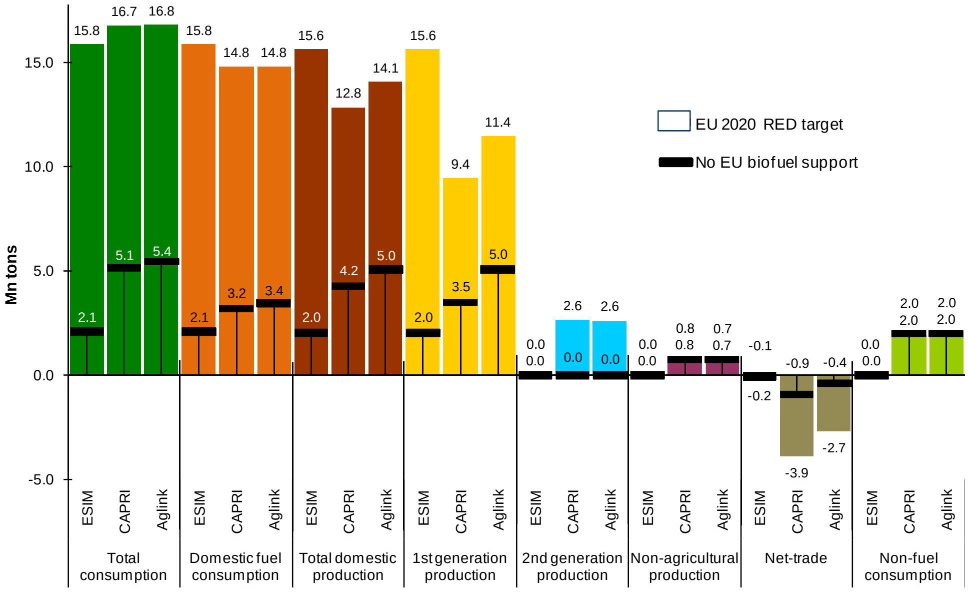
Figure 7.1: Comparison of EU27 biodiesel market projections



Source: Own compilation based on Blanco Fonseca et al. (2010), AgLink (2009) and CAPRI biofuel model, 06.12.2010

So, if one subtracts the 4.4Mn tons 2nd generation production quantities assumed in the CAPRI and AgLink baseline (covered in the yellow pillars) from this demand difference, the ESIM deviation is reduced to about 5Mn tons. The remaining difference can be explained by the assumption of ESIM that biodiesel and ethanol have nearly an equivalent absolute demand quantity in the EU27, meaning that the relative share of ethanol in total gasoline consumption is higher than the share of biodiesel in total diesel consumption, given the fact that absolute EU27 diesel consumption is higher than EU27 gasoline consumption. Contrary to this, the CAPRI and AgLink baseline assume that the relative share of biodiesel and ethanol in total diesel and gasoline consumption is nearly equivalent which leads by a higher absolute diesel consumption to a higher demand quantity for biodiesel in comparison to ethanol. This fact can be confirmed by looking at Figure 7.2 where fuel demand for ethanol in the ESIM baseline is slightly higher than in AgLink and CAPRI, even though the overall biofuel share in total fuel consumption is 3% less. However, total domestic consumption of ethanol in the AgLink and CAPRI baseline exceeds total consumption in the ESIM baseline as additional non-fuel demand quantities for ethanol (2Mn tons) are assumed which is not considered in ESIM. As this additional demand component does not exist for biodiesel, Figure 7.1 does not display such a differentiation.

Figure 7.2: Comparison of EU27 ethanol market projections



Source: Own compilation based on Blanco Fonseca et al. (2010), AgLink (2009) and CAPRI biofuel model, 06.12.2010

Within the counterfactual scenario the ratio between biodiesel and ethanol demand changes significantly. Whereas biodiesel demand in CAPRI and AgLink declines to a level of 3 - 4Mn tons, biodiesel demand quantities of ESIM remain at a level of 13Mn tons. An opposite shift occurs in the case of ethanol. Here, ESIM fuel demand decreases to a level of 2Mn tons whereas AgLink and CAPRI remain on a level of 3 - 3.5Mn tons. The higher overall biofuel demand in ESIM results from the fact that in the ESIM scenario reduces European biofuel support policies only to the level of 2009. Contrary to this, CAPRI and AgLink simulate a complete abolishment of all European biofuel support policies. From this it follows that the biofuel share in AgLink and CAPRI declines to a level of 1.5% whereas this share only decreases to a level of 3.7% in ESIM. Furthermore, by contrast to ESIM, the AgLink and CAPRI results indicate that without any support measures the competitiveness against fossil fuels is nearly equivalent for both biofuels (ethanol and biodiesel) with a slightly better situation for ethanol resulting from the low production costs in non-European regions like Brazil. In ESIM it is projected that in the EU27 biodiesel is much more competitive without strong support policies.

The fact that the AgLink and CAPRI baseline and scenario results for total biofuel demand are nearly equivalent is obvious remembering the construction of the CAPRI biofuel baseline (Chapter 5) for which the AgLink baseline is used as an anchor for the CAPRI trend estimation. Furthermore, the specification of the behavioural model for biofuel demand (Section 4.6) is derived from the AgLink specification (Lampe, 2006 and 2008).

On the production side, the ESIM baseline assumes that Eu27 production is more or less equal to EU27 demand with a slight surplus in the case of biodiesel which leads to a net-export situation (0.3Mn tons) and a slight difference in the case of ethanol which leads to a net-import situation (-0.2Mn tons) in 2020. The overall production level of biodiesel in the CAPRI and AgLink baseline is significantly higher as a result of the considered additional 2nd generation and non-agricultural production quantities. As the CAPRI baseline in contrast to ESIM and AgLink assumes in addition a certain level of non-agricultural biodiesel production (derived from the PRIMES baseline), 1st generation production of biodiesel in CAPRI is lower than in AgLink or ESIM. Furthermore, in contrast to ESIM, the CAPRI and AgLink baselines assume that in 2020 the EU27 will become a net-importer for both biofuels (nearly 3.5Mn tons for biodiesel and 3-4Mn tons for ethanol). The models behaviour in the counterfactual scenario is similar as on the demand side. Whereas total production of biodiesel in ESIM remains on a high level (13Mn tons) total production in AgLink and CAPRI drastically decreases to a level of 3 - 4Mn tons. The slightly higher production decrease in AgLink is thereby compensated by remaining net-import quantities of biodiesel (0.7Mn tons). As ESIM biodiesel production decreases almost equivalently to the demand decrease, net-trade for biodiesel does not change significantly.

The European production level of ethanol in the CAPRI and AgLink baseline is lower (about 1-2Mn tons) compared to ESIM as result of the lower ethanol demand and the assumption that the EU27 will become a net-importer of ethanol (3-4Mn tons) in 2020. Furthermore, 1st generation production of ethanol is significant lower in AgLink and CAPRI as both models assume a certain level of 2nd generation (2.6Mn tons) and non-agricultural (0.7Mn tons) ethanol production in their baselines. As ESIM does not consider 2nd generation and non-agricultural production and assumes that European ethanol production nearly meets ethanol demand (net-imports only about 0.01Mn tons) 1st generation production is considerably higher. Also here, the models supply behaviour in the counterfactual scenario is similar as on the demand side. Whereas total production of ethanol in ESIM declines significantly to a level of 2Mn tons total production in AgLink and CAPRI decreases only to a level of 4-5Mn tons. Contrary to biodiesel, the scenario assumptions of CAPRI and AgLink assume exclusively a decline for 2nd generation production, while non-agricultural ethanol production remains at the baseline level. The slightly higher production decrease in CAPRI is thereby compensated by a remaining net-import amount of ethanol of 0.9Mn tons whereas in AgLink the EU27 net-imports decrease to 0.4Mn tons. Ethanol net-trade in ESIM is marginal in the baseline as well as in the counterfactual scenario.

To summarise the comparison of biofuel market projections from ESIM, AgLink and CAPRI it should be highlighted that most differences can be explained by the different baseline or scenario assumptions and the fact that AgLink and CAPRI include 2nd generation and non-agricultural biofuel production components on the supply side. Furthermore, on the demand side AgLink and CAPRI consider in addition a non-fuel demand component for ethanol. Notable is also the observation that ESIM projects nearly similar absolute demand and production quantities for biodiesel and ethanol in the EU27 even though the EU27 consumption of diesel is much higher than total consumption of gasoline. Also the marginal EU27 biofuel trade quantities projected by ESIM are noticeable considering that countries like the U.S., Brazil or other South American countries have a very competitive ethanol industry and continuously increase their world market exports.

In both CGE models biofuel as well as biofuel feedstock markets are not covered in such detail as in the above described partial equilibrium models. Thus, the following explanations are on a more aggregated level. However, these general trends are also helpful to cross check the recent CAPRI results.

Banse et al. (2008a) show that the increase in EU27 biofuel consumption leads to rising biofuel prices and thereby to a decline of the biofuel consumption share in countries outside Europe (-1% in Brazil and -5% in the NAFTA[63] region). This trend can also be observed in CAPRI where the "*no-EU support*" scenario leads to an increase of the biofuel share in Argentina, USA, Canada and Brazil of about 1-2% (Annex 10.13). In GTAP-E the import shares in EU27 biofuel consumption are estimated about 30 - 35% in the "*policy scenario"* assuming that the availability of 2nd generation biofuels is rather limited in 2020. This share is higher as in the corresponding CAPRI baseline where the import share in EU27 consumption for ethanol is estimated to about 25% and about 16% for biodiesel. The different projection is caused in particular by the assumed availability of 2nd generation biofuels in CAPRI (1.5% of total EU27 fuel consumption in 2020) which are produced domestically and thus, increase the share of total domestic production in consumption.

The DART model (Kretschmer et al., 2009c) also shows a significant increase of EU27 biofuel production under the "*biofuel scenario"* which leads to a situation where EU27 biofuel production reaches the level of Brazilian biofuel production in 2020. In the "*business as usual"* scenario European biofuel production amounts only 20% of the Brazilian biofuel production. In spite of a significant increase in European biofuel production in the CAPRI biofuel baseline

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[63] NAFTA: North American Free Trade Agreement. The agreement came into force in 1994 and was signed by Canada, USA and Mexico.

(Table 5.4) total EU27 biofuel production in 2020 is about 10Mn toe less than the Brazilian production which results from a strong production increase also in Brazil (Annex 10.13) caused by the expansion of European ethanol imports. The *"biofuel scenario"* in DART shows in addition that European biofuel policies drives Brazilian ethanol exports away from the USA to the EU27 which can be confirmed by the CAPRI projections where the abolishment of the European support policies leads to an increase of U.S. imports and a decrease of European imports from Brazil about nearly the same quantity (Annex 10.11).

7.2. Impacts of European biofuel policies on agricultural markets

Basically, the impacts of expanding biofuel markets on agricultural markets depend (1) on the absolute quantities of 1st generation biofuel production assumed or simulated in the individual models and (2) on the agricultural products which are assumed to be usable for biofuel production. Therefore, the assumptions of the different models concerning 1st generation production are summarised shortly before the detailed market impacts are described.

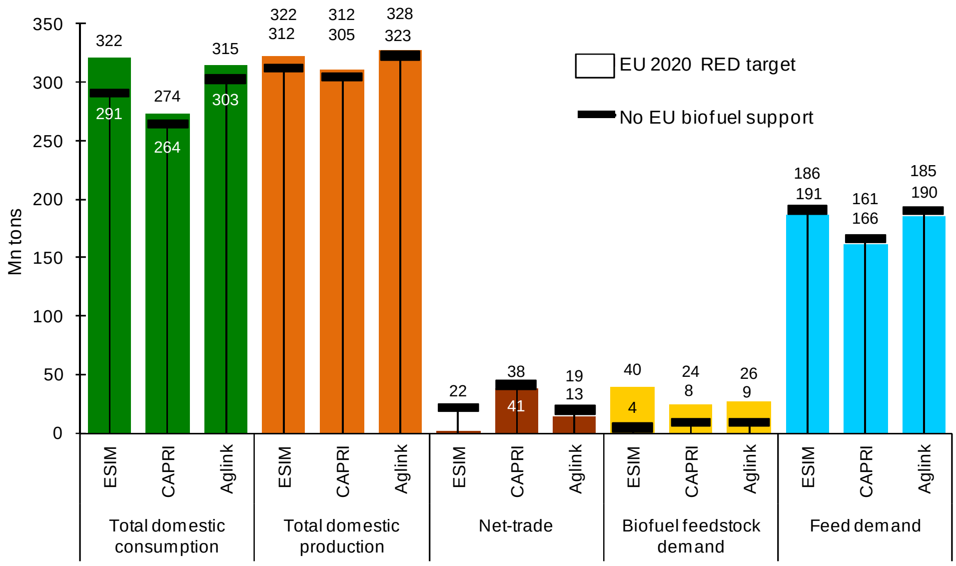
ESIM assumes oil seeds (differentiated into sun, soy, rape and palm oil) as feedstocks for biodiesel production and wheat, maize and sugar as feedstocks for ethanol production (Blanco Fonseca, et al., 2010). ESIM assumes in its baseline the highest 1st generation quantity for ethanol (15.6Mn tons) and a nearly similar 1st generation quantity for biodiesel (15.9Mn tons). In the counterfactual scenario this amount decreases drastically in the case of ethanol (to 2Mn tons) and only marginal in the case of biodiesel (to 13Mn tons).

AgLink assumes oil seeds (only aggregated including also palm oil) as feedstocks for biodiesel production and wheat, coarse grains (including maize) and sugar crops (including beats and cane) for ethanol production. AgLink estimates in its baseline the highest 1st generation quantity for biodiesel (17Mn tons) and a lower quantity (11Mn tons) for ethanol. In the counterfactual scenario this amount decreases significantly in the case of biodiesel (to about 3Mn tons) and more moderately in the case of ethanol (to about 5Mn tons).

CAPRI assumes oil seeds (differentiated in sun, soy, rape and palm oil) as feedstocks for biodiesel production and cereals (differentiated in wheat, maize, barley, oats, rye and other cereals), sugar, and table wine for ethanol production. CAPRI estimates in its baseline the lowest 1st generation quantities for biodiesel (14Mn tons) and ethanol (9.5Mn tons) of all models resulting from the consideration of 2nd generation and non-agricultural biofuel production quantities. In the *"no-EU support"* scenario this amount decreases to 3.5Mn tons in the case of ethanol and to 3.6Mn tons in the case of biodiesel (Figure 7.1 and Figure 7.2).

Mostly affected by the global biofuel market expansion (in absolute quantities) is the cereals market, including maize (Figure 7.3). As the AgLink model does not explicitly cover maize, the comparison is done on the level of aggregated cereals which is covered by all models.

Figure 7.3: Comparison of EU27 cereals market projections

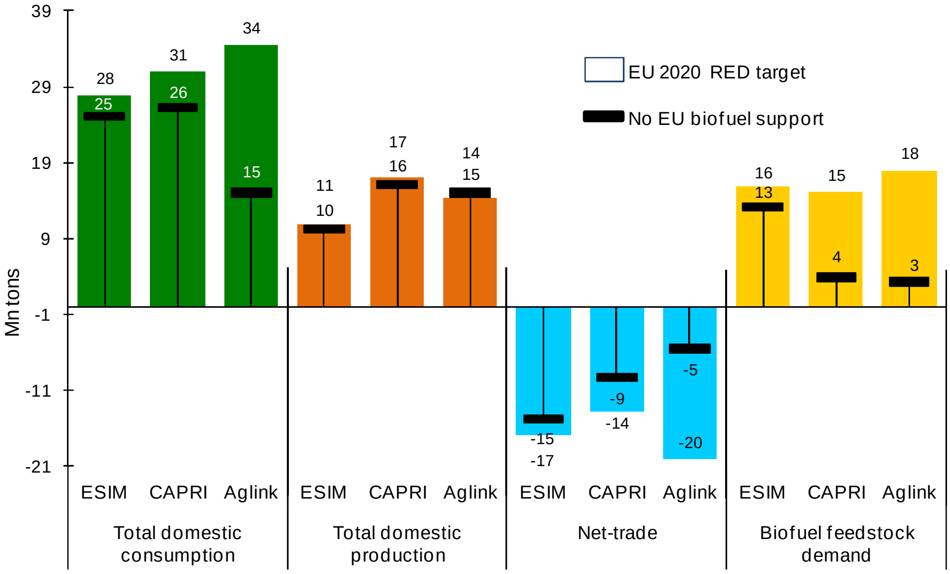


Source: Own compilation based on Blanco Fonseca et al. (2010), AgLink (2009) and CAPRI biofuel model, 06.12.2010

By looking at biofuel feedstock demand (yellow pillars in Figure 7.3) it can be observed that the highest quantity in the baseline (39Mn tons) is assumed by ESIM, the lowest by CAPRI (24Mn tons). The situation changes in the counterfactual scenario. In accordance with the lowest 1st generation ethanol production simulated by ESIM (Figure 7.2), feedstock demand for cereals significantly decreases to 4.2Mn tons, while cereals demand for biofuel production remains at a level of 8-9Mn tons in AgLink and CAPRI. In spite of a significant lower 1st generation ethanol production simulated in the CAPRI "*no-EU support*" scenario compared to AgLink (Figure 7.2), feedstock demand for cereals is nearly equal. This results from the fact that CAPRI simulates a more significant reduction in feedstock demand for sugar than AgLink. Apart from the significant net-export decrease for cereals in the counterfactual scenario projected by ESIM, the general effects of an increasing biofuel feedstock demand combined with a simultaneously increasing by-product supply can be observed in all models for cereals. On the on hand, biofuel feedstock demand goes up which leads to an increasing total demand and to increasing cereals prices. On the other hand, the increasing supply and demand of biofuel by-products on the feed market leads to a reduced feed demand for cereals and thus, to decreasing cereals prices. Both effects partially compensate each other. In the case of CAPRI the aggregated cereal price is simulated to increase by 3.7% if the European RED target in 2020 is reached. This is similar in AgLink. ESIM simulates a price increase of 8.3% (Blanco Fonseca et al., 2010) which is significantly higher and results first and foremost from the significantly higher European 1st generation production projected in the case of ethanol (Figure 7.2).

The impacts on the vegetable oils market differ also throughout the three models (Figure 7.4).

Figure 7.4: Comparison of EU27 vegetable oils market projections

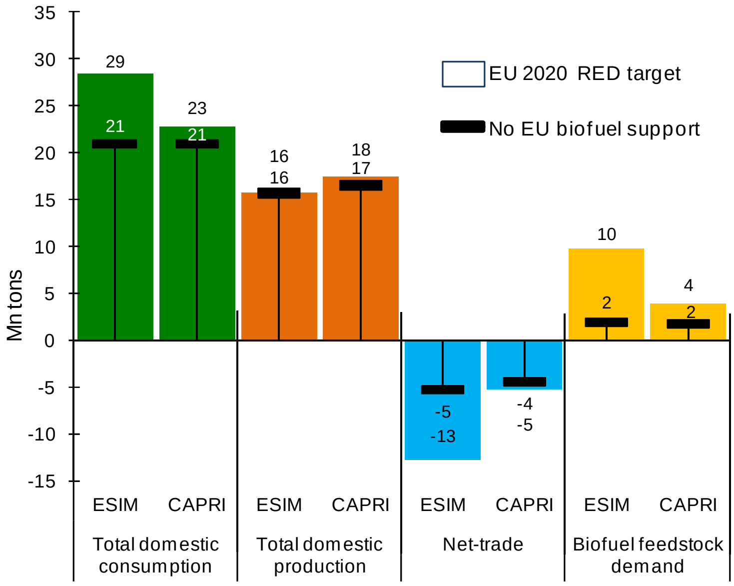


Source Own compilation based on Blanco Fonseca et al. (2010), AgLink (2009) and CAPRI biofuel model, 06.12.2010

Feedstock demand for vegetable oils in CAPRI and ESIM baselines is rather equal (15Mn tons) while the AgLink assumption exceed this quantity by 2-3Mn tons. Correspondingly, AgLink assumes the highest total demand (34Mn tons) and also the highest quantities for net-imports (20Mn tons). As the CAPRI baseline assumes a higher domestic production quantity of vegetable oils in the EU27 (17Mn tons) compared to ESIM (11Mn tons) the net-import quantity assumed by ESIM (17Mn tons) is higher than in CAPRI (14Mn tons). The counterfactual scenarios indicate the price shifts for vegetable oils resulting from a situation where the RED target in 2020 is reached. ESIM simulates a moderate price increase for palm oil (1.3%) but a significant increase in the case of soy oil (17%), rape and sunflower oil (35%) as described in Blanco Fonseca et al. (2010). AgLink simulates an increase of 15% for aggregated oil seeds and CAPRI estimates an increase of 17% in the case of sunflower oil, 23% for soy oil and more than 30% in the case of rape oil (Table 6.3). The significantly higher feedstock demand quantity in ESIM under the counterfactual scenario is due to the higher 1st generation production quantities of biodiesel in ESIM (Figure 7.1).

As AgLink calculates ethanol production not on the level of the secondary product sugar (like it is done in ESIM and CAPRI) but on the individual primary products sugar beets and sugar cane a comparison of projections results can not be done directly in Figure 7.5. Thus, the comparison of model projections referring to the sugar market is done on the level of sugar and thereby restricted to ESIM and CAPRI. By comparing the baseline results it becomes obvious that the ESIM model assumes a higher EU27 feedstock demand quantity for sugar (10Mn tons) than CAPRI (4Mn tons) which is once again a result of the higher projection for 1st generation ethanol production in the EU27 (Figure 7.5). Taking into account the results of the counterfactual scenario it can be observed that the additional demand quantities in ESIM are fully compensated by a significant increase of net-imports. Domestic sugar production in ESIM remains nearly unchanged at the baseline level. By comparing the simulated price effects of ESIM and CAPRI the higher demand in the ESIM baseline causes a higher sugar price increase of 20% (Blanco Fonseca, et al, 2010) while CAPRI simulates only an increase of less than 1% (Table 6.3) under the assumption that the RED target is fully reached in 2020.

Figure 7.5: Comparison of EU27 sugar market projections



Source: Own compilation based on Blanco Fonseca et al. (2010), AgLink (2009) and CAPRI biofuel model, 06.12.2010

By reflecting the different model projections referring to the impacts of European biofuel policies up to 2020 on agricultural markets, it can also be concluded that the differences basically result from the different assumptions concerning overall biofuel consumption and the fact that the AgLink and CAPRI model consider 2nd generation and non-agricultural production components on the biofuel supply side. Furthermore, it can be observed that simulated changes in domestic production depend strongly on shifts in the projected trade flows. Here, all models present different projections. In particular these trade projections are important as they indicate to which amount environmental impacts caused by shifts in agricultural production take place inside or outside Europe. The simulated effects on agricultural product prices are always higher in ESIM which results from a higher 1st generation biofuel production than projected by AgLink or CAPRI.

The results of the DART model (Kretschmer et al., 2009c) show that prices for biofuel feedstocks under the European RED target rise between 4 and 7.4%. EU27 production of biofuel feedstocks expand considerably whereas production of non biofuel feedstock crops decrease. The GTAP-E projection (Banse et al., 2008a) also shows that real prices for biofuel feedstocks rise under the EU RED target. However, for most crops the overall trend of decreasing prices projected in the "*global economy*" scenario is only lowered. The oilseed sector shows the highest price shift. Here, the effects of the EU RED target compensate the long-term trend of decreasing agricultural product prices so that a slight increase of the real price in 2020 is observed.

Taking into account the model specific assumptions described in this section the simulated impacts of European biofuel support policies implemented to reach the target of the European RED until 2020 on agricultural markets are rather similar. Basically, in all models vegetable oil and corresponding oil seed markets are more affected than cereal markets.

8. Summary

Growing global biofuel markets have led to a continuous increase of biofuel feedstock demand. Due to the current state of biofuel processing technologies, predominately traditional agricultural commodities, like different cereals, sugar or vegetable oils are used for biofuel production. Thus, biofuel markets are closely connected to agricultural markets. The aim of this thesis is to quantify impacts of European biofuel policies implemented to reach the target of the European Renewable Energy Directive (RED) in 2020 on firstly biofuel and secondly agricultural markets. Three central questions are investigated specifically:

(1) *What are the impacts of biofuel support policies implemented by European Member States to reach the RED target of 10% biofuels in 2020 on European and global biofuel as well as agricultural markets?*

(2) *How do these impacts change if uncertain assumptions are varied (availability of 2^nd^ generation technologies, existence of biofuel support and trade policies, changes of fossil fuel prices)?*

(3) *What are the impacts of shifts in agricultural production caused by an increasing biofuel production on the environment?*

8.1. Modelling approach

For the quantitative analysis a behavioural market model for biofuels and biofuel feedstocks is developed extending the agricultural sector model CAPRI. This modified CAPRI version permits to analyse impacts of different European and global biofuel policies on the global biofuel and agricultural sector by benefitting from the already existent and well developed representation of agricultural markets in the core CAPRI system. The CAPRI biofuel model incorporates behavioural functions for 1st generation biofuel supply and feedstock demand as well as biofuel demand and global bilateral biofuel trade. In addition, functions approximating total fuel demand behaviour are introduced in the model as biofuel quota obligations (for example defined as a percentage share of total domestic fuel consumption) are important drivers for biofuel demand which is consequently closely linked to total fuel demand. As the CAPRI database does not allow for the estimation of biofuel and fuel demand functions, the required functions are derived from other specialised models. For the derivation of biofuel demand functions, the existing specification in the OECD/FAO agricultural sector model AgLink-COSIMO is taken as a starting point. Information from the

European energy sector model PRIMES allow for estimating total demand functions for gasoline and diesel depending on fuel prices and economic growth.

Biofuels covered in the CAPRI biofuel model are ethanol and biodiesel. Feedstocks considered for biofuel production are different cereals (wheat, barley, maize, oats, rye and meslin), sugar and table wine for ethanol as well as rape oil, sunflower oil, soy oil and palm oil for biodiesel. Considered by assumptions but not by a behavioural model are 2^{nd} generation biofuel supply and feedstock demand.

8.2. *Key findings and conclusions*

Different scenarios are simulated to investigate the research questions. Thereby, the reference scenario (biofuel baseline) represents a situation where the EU27 achieves the target of the RED in 2020 assuming a certain share of biofuels produced by 2^{nd} generation production technologies, the currently applied European import tariffs and by taking into account probable future non-European biofuel market developments. The counterfactual scenarios simulated in the analysis deviate from the baseline by (1) abolishing all European biofuel support policies implemented by Member States (2) introducing higher fossil fuel prices (3) reducing the European biofuel import tariffs and (4) assuming lower EU27 total energy demand in 2020 resulting for example from an increased energy efficiency. The results are cross checked with projections from alternative biofuel models and show that both, global biofuel and agricultural markets are significantly affected by the current European biofuel policy up to 2020.

Impacts on global biofuel markets

By reaching an energy share of 10% biofuels in total fuel consumption in 2020, the EU27 demands to about 25Mn tons of biodiesel and 15Mn tons of ethanol and produces to about 21Mn tons of biodiesel and 13Mn tons of ethanol. EU27 biofuel demand exceeds domestic production leading to a net-import situation for both, biodiesel (3.6Mn t) and ethanol (3.9Mn t). This corresponds to an import share in total EU27 biofuel consumption of about 20%. Imports mainly come from Argentina and the U.S. in the case of biodiesel (each 1.5Mn tons) and from Brazil in the case of ethanol (2.5Mn tons). Driven by own national policies as well as by the increasing biofuel demand of the EU27, non-European production also increases until 2020. This appears mainly for the U.S. and Brazil where domestic ethanol production in 2020 amounts to about 48Mn tons and 50Mn tons, respectively. The U.S. and Argentina become most important biodiesel exporter for the European market. It is assumed that biofuels produced by 2^{nd} generation technologies are only supplied in the EU27 and the U.S..

The growth of European biofuel markets, as described, strongly depends on supporting policy instruments implemented by individual European Member States. Without these support measures, EU27 biofuel production declines by 70-80% and the share of biofuels in EU27 fuel consumption declines to about 1.8% compared to the baseline. Imports of ethanol decrease by more than 70% and imports of biodiesel decline by nearly 90% which has also significant impacts on non-European biofuel production.

The scenario results show that a higher share of biofuels produced by 2nd generation technologies in total EU27 biofuel production (50%) leads to decreasing biofuel prices and therefore to an increasing European biofuel consumption. Non-European biofuel markets are only marginally affected.

The abolishment of the European import tariffs for biofuels shows stronger impacts on the ethanol market than on the biodiesel market due to the fact that the current specific tariff for ethanol (300€/Ton Oil Equivalent) is much more effective than the ad valorem tariff for biodiesel of 6.5%. EU27 ethanol imports nearly double compared to the baseline while domestic production of ethanol decreases by more than 20%. Hence, the EU27 consumer price for ethanol declines by 11% and ethanol consumption increases by 20% while the biodiesel price remains at the initial level.

Higher fossil fuel prices have basically two effects: (1) a decrease of total fuel demand which subsequently leads to decreasing biofuel consumption as both markets are strongly connected by fuel blendings. (2) The ratio of biofuel to fossil fuel prices changes for the benefit of biofuels which increase their demand share in total fuel consumption. These two effects compensate each other to some extent. However, the results show that even in a situation where fossil fuel prices exceed the baseline forecasts for 2020 by 40%, European biofuel markets are diminished if biofuel support measures are not in place.

Alternative assumptions regarding total EU27 fuel consumption in 2020 are taken into account to consider, for example, the efforts make by European Commission to increase energy efficiency. Here, lower total fuel demand (about 10% less than in the baseline) and a slightly lower biofuel share in total fuel consumption (about 1.5% less than in the baseline) lead to a decrease of EU27 biofuel demand and production between 20-30%.

Impacts on global agricultural markets

By achieving the RED target in 2020 (baseline situation) the EU27 processes to about 25Mn tons of cereals, 4Mn tons of sugar and 15Mn tons of vegetable oils to biofuels. While EU27 biofuel production mainly relies on rape oil, wheat, barley and maize, non-European production is dominated by sugar cane and maize. By accumulating biofuel feedstock demand of the EU27, Brazil, USA, Canada, and

Argentina in 2020, it can be observed that maize becomes the most important feedstock at global level, followed by sugar.

The scenario results show that domestic production of agricultural products within the EU27 is only moderately affected by European biofuel policies in 2020 relative to the significant shifts on the European biofuel market. Without European biofuel support policies in 2020 EU27 domestic production of wheat is 2%, maize 3% and sugar 6% lower than in the baseline. The highest shifts can be observed on the vegetable oil markets where EU27 domestic production of rape oil is 12% lower in 2020 if no biofuel support policies are in place. These comparatively moderate shifts can be explained by two basic effects: (1) the increasing biofuel feedstock demand leads to an under proportional increase of total demand if feed demand declines simultaneously. This is especially true for cereals as biofuel by-products (like DDGS) are used as substitutes for traditional feeding crops in the livestock sector. (2) A notable share of biofuel feedstock demand is met by imports from non-European countries. This is in particular true for vegetable oils in EU27, where imports of rape oil, for example, are to about 20% less if no European biofuel policies are in place. Without biofuel policies the EU27 market price for wheat is about 2% lower than in the baseline. Vegetable oil markets are affected more. Here, in the case of rape oil, prices are up to 30% lower without the European biofuel support regime. This difference can be explained by the much higher share of biofuel feedstock demand for vegetable oils in total EU27 vegetable oil demand (70%) compared to wheat (6%). The same trend as for wheat can be observed for maize where an abolishment of the European biofuel policies leads to a comparatively small price decrease of 3%. Global maize markets might be much more affected by the U.S. ethanol industry which processes more than 20% of global maize production to ethanol.

Impacts on European environment

Based on the observations made in the scenario analysis, which indicates that agricultural production within the EU27 is only moderately affected by the European biofuel polices, environmental impacts caused by potential shifts in EU27 agricultural production are limited. This is true for the *crop share* (share of land used by an individual crop activity relative to total arable land used) which gives a hint on losses of biodiversity as well as for *N_2O emissions* per hectare caused by potential production intensification. However, it is likely that environmental impacts caused by an increasing EU27 demand for biofuels and biofuel feedstocks notably occur outside the EU27, especially in those countries which increase their production, processing, or exportation of biofuels or biofuel feedstocks under the European biofuel support policy regime until 2020. For example, this is true for Brazil, Argentina, U.S. and Canada.

8.3. Limitations and research outlook

The results described in this thesis contribute to the evaluation of biofuel policies by focussing on the linkage between the energy and the agricultural sector with a detailed view on the EU27. However, the following limitations have to be considered when interpreting the results of the described modelling approach:

- Due to the fact that the biofuel market has mainly developed within the last ten years, the availability of detailed ex-post information is still very limited. This is in particular true for biofuel feedstock demand quantities differentiated by single agricultural crops. Since complete and consistent ex-post data is essential to reproduce realistic market behaviour within the market simulation, ex-post data collected or assumed by existing models (for example AgLink-COSIMO or PRIMES) are taken into account in addition to own collection efforts and still existent data gaps are filled by assumptions. The assumptions which are done or which are adopted from other models consequently imply various uncertainties. It is likely that the availability and the quality of biofuel related data will be improved within the next years which will permit to verify and upgrade the biofuel database and thereby decrease the amount of uncertain assumptions within the CAPRI biofuel model and its projections.

- The estimated functions for total fuel demand derived from the PRIMES energy model are only rough approximations of fuel demand behaviour. Only the fuel price and the GDP influence on fuel demand are estimated as the available data are limited. Thus, the use of these estimated functions does not replace the capability of an explicit energy model which covers the full set of fuel demand drivers and detailed energy policies. As the linkage between the energy and the agricultural sector will become more and more important due to the continuously increasing share of renewable energies and fuels in global energy production, the options for a permanent model interface between CAPRI and an established European energy or general equilibrium model with a detailed representation of the energy sector should be discussed.

- Another aspect is that the CAPRI biofuel model only incorporates biofuel markets while renewable energy production based on agricultural products (like biogas production for electricity generation or biomass combustion for the production of heat) is neglected. Thus, this part of feedstock demand for bioenergy production is not considered. As these energy sources are also continuously increasing within the EU27, a consideration within agricultural market projections should be pursued in the future. A further model extension with respect to these additional demand components would supplement the consideration of renewable energy markets and thus, upgrade the linkage to the energy sector within CAPRI system.

- Given the results of the modelling exercise, it is likely that notable environmental impacts of an increasing biofuel feedstock production caused by increasing European biofuel demand occur in non-European regions. As the current CAPRI version covers only environmental effects which are caused in European Member States, an additional implementation of environmental indicators for non-European regions, at least for those who are strongly affected by the growing European biofuel and biofuel feedstock demand, will deliver a useful tool for further detailed evaluation of the impact of European biofuel support policies.

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10. ANNEX

10.1. Database tables

Annex 10.1: Biofuel market balance for EU Member States: BaseYear

		Fuel demand	Industrial demand	Imports	Exports	Total production	Total demand
	1000 tons	*HCOM*	*INDM*	*IMPT*	*EXPT*	*MAPR*	*DOMM*
Belgium / Luxemb.	Ethanol	0.7	66.9	129.3	61.7	0.0	67.5
	Biodiesel	0.6	0.0	0.0	0.0	0.3	0.6
Denmark	Ethanol	0.3	32.3	26.5	9.3	15.5	32.6
	Biodiesel	5.9	0.0	-2.3	54.1	62.3	5.9
Germany	Ethanol	105.3	329.1	302.1	78.4	210.6	434.4
	Biodiesel	1,284.0	0.0	333.8	0.0	950.3	1,284.0
Greece	Ethanol	0.0	3.0	3.0	0.0	0.0	3.0
	Biodiesel	0.4	0.0	0.8	1.6	1.2	0.4
Spain	Ethanol	58.1	211.2	49.5	35.0	254.8	269.3
	Biodiesel	126.6	0.0	137.6	39.4	28.4	126.6
France	Ethanol	40.2	467.6	153.5	286.2	640.5	507.8
	Biodiesel	371.6	0.0	31.3	34.7	375.0	371.6
Ireland	Ethanol	0.1	9.0	9.5	0.4	0.0	9.1
	Biodiesel	0.6	0.0	1.0	1.8	1.3	0.6
Italy	Ethanol	1.7	167.6	138.6	76.5	107.2	169.3
	Biodiesel	131.0	0.0	51.3	200.2	279.9	131.0
Netherlands	Ethanol	0.9	64.0	156.5	93.5	1.8	64.9
	Biodiesel	0.0	0.0	0.0	0.0	0.0	0.0
Austria	Ethanol	0.4	36.3	32.6	1.8	5.9	36.7
	Biodiesel	34.4	0.0	11.6	23.6	46.4	34.4
Portugal	Ethanol	0.1	6.5	12.7	6.2	0.0	6.5
	Biodiesel	0.1	0.0	0.3	0.5	0.4	0.1
Sweden	Ethanol	176.0	9.8	109.0	13.1	89.8	185.7
	Biodiesel	5.7	0.0	4.9	0.0	0.8	5.7
Finland	Ethanol	0.2	18.3	18.5	0.0	0.0	18.5
	Biodiesel	0.0	0.0	0.0	0.0	0.0	0.0
United Kingdom	Ethanol	22.9	204.9	202.2	181.4	206.9	227.7
	Biodiesel	17.9	0.0	4.8	8.7	21.8	17.9
Cyprus	Ethanol	0.0	0.0	0.0	0.0	0.0	0.0
	Biodiesel	0.1	0.0	0.5	0.7	0.3	0.1
Czech Republic	Ethanol	0.1	1.9	3.2	4.5	3.3	2.0
	Biodiesel	4.1	0.0	7.0	59.3	56.4	4.1
Estonia	Ethanol	0.0	1.3	3.6	2.2	0.0	1.4
	Biodiesel	0.3	0.0	0.4	2.0	1.9	0.3
Hungary	Ethanol	0.3	32.6	1.3	10.3	42.0	33.0
	Biodiesel	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	Ethanol	0.0	1.8	2.2	2.3	1.9	1.8
	Biodiesel	1.9	0.0	0.7	2.5	3.2	1.9
Latvia	Ethanol	0.1	4.9	2.9	4.1	6.2	4.9
	Biodiesel	1.9	0.0	2.0	2.0	1.8	1.9
Malta	Ethanol	0.0	0.0	0.0	0.0	0.0	0.0
	Biodiesel	0.1	0.0	0.1	0.6	0.5	0.1
Poland	Ethanol	46.8	115.0	-9.2	13.5	184.5	161.8
	Biodiesel	8.9	0.0	14.6	35.7	29.9	8.9
Slovenia	Ethanol	0.1	4.9	4.9	0.0	0.0	4.9
	Biodiesel	0.4	0.0	0.2	2.2	2.5	0.4
Slovakia	Ethanol	0.1	4.9	5.3	0.4	0.0	4.9
	Biodiesel	8.0	0.0	17.4	24.1	13.0	8.0
Bulgaria	Ethanol	0.0	1.3	2.9	1.7	0.0	1.3
	Biodiesel	0.0	0.0	0.0	0.0	0.0	0.0
Romania	Ethanol	0.0	0.0	0.0	0.0	0.0	0.0
	Biodiesel	0.0	0.0	0.0	0.0	0.0	0.0
EU27	***Ethanol***	***454***	***1,795***	***531***	***52***	***1,771***	***2,249***
	Biodiesel	***2,004***	***0***	***251***	***124***	***1,878***	***2,004***
EU15	***Ethanol***	***407***	***1,626***	***524***	***24***	***1,533***	***2,033***
	Biodiesel	***1,979***	***0***	***229***	***19***	***1,768***	***1,979***

Source: CAPRI biofuel model, Biofuel database, 18.11.10

Annex 10.2: Ethanol market balance for EU15, EU10 and non-EU countries: BaseYear

	Fuel demand	**Industrial demand**	**Imports**	**Exports**	**Total production**	**Total demand**
1000 tons	*HCOM*	*INDM*	*DOMM*	*IMPT*	*EXPT*	*MAPR*
EU15	407	1,626	2,033	524	24	1,533
EU10	47	167	215	6	29	238
Rest of Europe	27	0	27	18	0	9
Russia, Belarus, Ukraine	754	0	754	7	60	807
USA	10,934	247	11,181	1,292	384	10,272
Canada	174	193	367	111	21	277
Mexico	150	0	150	120	4	35
Argentina	48	30	78	0	48	127
Brazil	7,547	1,615	9,162	138	2,115	11,139
Bolivia	15	0	15	0	27	41
Rest of South America	151	0	151	78	145	218
India	94	1,318	1,412	369	10	1,052
China	391	2,268	2,659	7	148	2,800
Japan	460	0	460	370	6	96
Australia, New Zealand	16	45	62	51	17	27
LDC countries	17	22	39	6	4	37
ACP countries	0	11	11	8	9	12
Rest of world	131	476	606	220	298	684

Source: CAPRI biofuel model, Biofuel database, 18.11.10

Annex 10.3: Biodiesel market balance for EU15, EU10 and non-EU countries: BaseYear

	Total demand	**Imports**	**Exports**	**Total production**
1000 tons	*DOMM*	*IMPT*	*EXPT*	*MAPR*
EU15	1,979	229	19	1,768
EU10	26	22	106	109
USA	133	8	187	312
Canada	4	0	0	4
Rest of world	55	55	0	0

Source: CAPRI biofuel model, Biofuel database, 18.11.10

Annex 10.4: Global bilateral trade of ethanol: BaseYear

1000 tons		***Exporter***												
Importer	***Total imports***	EU15	EU10	Russia, Belarus, Ukraine	USA	Canada	Argentina	Brazil	Bolivia	Rest of South America	India	China	Australia, New Zealand	Rest of world
EU15	***524***	~	20	11	0	0	4	272	0	78	1	0	0	129
EU10	***6***	3	~	1	0	0	1	1	0	0	0	0	0	1
Rest of Europe	***18***	4	6	3	1	0	0	0	0	3	0	0	0	1
USA	***1,292***	7	0	0	~	11	11	1,152	0	46	0	22	4	39
Canada	***111***	0	0	0	72	~	0	20	0	0	0	0	0	15
Mexico	***120***	2	1	0	58	0	2	20	0	8	0	5	0	23
Brazil	***138***	0	0	0	120	0	0	~	0	0	0	3	0	16
Chile	***21***	0	0	0	0	0	17	1	2	0	0	0	0	1
Rest of South America	***78***	0	0	0	0	3	9	19	16	~	0	27	0	4
India	***369***	0	0	0	72	1	0	255	0	0	~	8	2	32
Japan	***370***	0	0	0	15	1	0	282	0	9	3	34	3	24
Australia, New Zealand	***51***	0	0	0	38	4	0	0	0	0	0	0	~	10
Rest of world	***220***	2	0	43	1	2	5	92	8	0	4	49	7	~
Total exports		***24***	***29***	***60***	***384***	***21***	***48***	***2,115***	***27***	***145***	***10***	***148***	***17***	***298***

Source: CAPRI biofuel model, Biofuel database, 18.11.10

Annex 10.5: Global bilateral trade flows of biodiesel: BaseYear

1000 tons		***Exporter***			
Importer	***Total imports***	EU15	EU10	USA	India
EU15	***229***	~	104	126	0
EU10	***22***	16	~	6	0
USA	***8***	3	2	~	3
Rest of world	***55***	0	0	55	0
Total exports		***19***	***106***	***187***	***3***

Source: CAPRI biofuel model, Biofuel database, 18.11.10

Annex 10.6: Biofuel feedstock demand by EU Member State: BaseYear

	Rye, Meslin	**Barly**	**Oats**	**Maize**	**Other cereals**	**Table wine**	**Wheat**	**Sugar**	**Rape oil**	**Sunfl. Oil**	**Soy oil**	**Palm oil**
1000 tons	*RYEM*	*BARL*	*OATS*	*MAIZ*	*OCER*	*TWIN*	*WHEA*	*SUGA*	*RAPO*	*SUNO*	*SOYO*	*PLMO*
Belgium / Lux.	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	0	31	0	0	0	0	1	4	51	0	0	16
Germany	77	0	120	94	40	0	148	0	824	0	0	206
Greece	0	0	0	0	0	0	0	0	0	0	0	1
Spain	0	133	31	153	0	139	44	80	0	24	0	6
France	0	0	0	293	0	0	325	400	313	20	0	73
Ireland	0	0	0	0	0	0	0	0	0	0	0	1
Italy	0	0	0	114	0	0	89	0	204	39	0	60
Netherlands	0	1	0	0	0	0	3	0	0	0	0	0
Austria	0	6	0	6	0	0	0	0	34	0	16	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	207	0	1	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0
UK	0	0	0	0	0	0	438	0	15	0	0	9
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech Rep.	0	0	0	1	1	0	5	0	40	0	18	3
Estonia	0	0	0	0	0	0	0	0	1	0	1	0
Hungary	0	69	0	0	0	0	19	9	0	0	0	0
Lithuania	0	3	0	0	2	0	0	0	0	0	0	3
Latvia	0	6	0	2	3	0	4	0	2	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	1
Poland	0	223	0	198	0	0	0	0	22	3	2	6
Slovenia	0	0	0	0	0	0	0	0	1	1	1	0
Slovakia	0	0	0	0	0	0	0	0	0	8	4	2
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0	0	0	0	0	0
EU27	***77***	***474***	***151***	***862***	***47***	***139***	***1,282***	***493***	***1,508***	***97***	***42***	***390***
% of DOMM	*0.9%*	*0.9%*	*1.2%*	*1.4%*	*0.4%*	*0.8%*	*1.1%*	*2.6%*	*28.5%*	*3.4%*	*2.0%*	*9.9%*
EU15	***77***	***172***	***151***	***661***	***40***	***139***	***1,254***	***484***	***1,443***	***84***	***16***	***374***
% of DOMM	*1.8%*	*0.4%*	*2.5%*	*1.6%*	*0.6%*	*0.9%*	*1.4%*	*3.2%*	*31.4%*	*4.4%*	*0.9%*	*10.0%*

Source: CAPRI biofuel model, Biofuel database, 18.11.10

Annex 10.7: Market balance of biodiesel feedstocks in sel. EU Member States: Baseline

Quantities in 1000 t and *absoltue changes compared to baseyear*		**Biofuel feedstock demand**	**Human demand**	**Industrial demand**	**Feed demand**	**Imports**	**Exports**	**Total demand**
		BIOF	*HCOM*	*INDM*	*FEDM*	*IMPT*	*EXPT*	*MAPR*
Germany	Rape oil	4,432	987	353	75	2,363	0	3,427
		3,608	*152*	*-23*	*30*	*2,206*	*-602*	*959*
	Sunfl. Oil	0	184	19	1	238	47	0
		0	*19*	*0*	*-1*	*58*	*-8*	*-49*
	Soy oil	281	0	20	37	30	594	890
		281	*-198*	*0*	*27*	*-25*	*157*	*292*
	Palm oil	1,059	0	201	0	1,260	0	0
		853	*0*	*-254*	*0*	*498*	*-101*	*0*
	Rape cake	0	3	0	2,743	355	2,381	4,652
		0	*0*	*0*	*872*	*3*	*772*	*1,600*
Spain	Rape oil	65	0	1	0	35	0	25
		65	*-18*	*0*	*0*	*24*	*-8*	*15*
	Sunfl. Oil	500	415	28	0	96	106	850
		475	*-109*	*0*	*0*	*1*	*41*	*406*
	Soy oil	32	249	15	0	31	236	475
		32	*55*	*0*	*0*	*8*	*-4*	*75*
	Palm oil	142	0	319	0	461	0	0
		136	*0*	*52*	*0*	*157*	*-31*	*0*
	Rape cake	0	0	0	55	51	14	35
		0	*0*	*0*	*5*	*-13*	*5*	*23*
France	Rape oil	2,479	1	327	31	966	0	1,860
		2,166	*-80*	*-1*	*4*	*803*	*-284*	*1,000*
	Sunfl. Oil	331	262	36	31	243	136	556
		311	*-40*	*0*	*4*	*66*	*-133*	*76*
	Soy oil	166	2	12	10	36	21	169
		166	*-91*	*0*	*2*	*-34*	*-30*	*79*
	Palm oil	616	36	105	0	756	0	0
		543	*6*	*-63*	*0*	*481*	*-4*	*0*
	Rape cake	0	0	0	1,999	0	616	2,566
		0	*0*	*0*	*656*	*-356*	*520*	*1,493*
Italy	Rape oil	676	2	17	1	678	0	12
		472	*-49*	*0*	*0*	*426*	*-1*	*-4*
	Sunfl. Oil	114	372	23	8	279	0	247
		75	*91*	*0*	*2*	*107*	*-14*	*47*
	Soy oil	49	422	16	22	295	0	227
		49	*100*	*0*	*2*	*141*	*-22*	*-12*
	Palm oil	201	30	292	0	523	0	0
		141	*-10*	*63*	*0*	*155*	*-39*	*0*
	Rape cake	0	0	0	35	22	4	17
		0	*0*	*0*	*-37*	*-33*	*1*	*-2*

Source: CAPRI biofuel model, Biofuel baseline, 18.11.2010

Annex 10.8: Ethanol market balance for EU15, EU10 and non-EU countries: Baseline

Quantities in 1000 t and *absoltue changes compared to baseyear*	**Industrial demand**	**Fuel demand**	**Total production**	**Total demand**	**Imports**	**Exports**	**Non-agricult. production**	**1st generation production**	**2nd generation production**
	INDM	*HCOM*	*MAPR*	*DOMM*	*IMPT*	*EXPT*	*NAGR*	*FSTG*	*SECG*
ACP countries	22	503	521	524	49	46	0	521	0
	11	*503*	*510*	*513*	*41*	*38*	*0*	*510*	*0*
Australa, New Zealand	23	404	447	427	42	62	0	447	0
	-23	*388*	*420*	*365*	*-10*	*46*	*0*	*420*	*0*
Argentina	28	115	392	144	1	249	0	392	0
	-2	*67*	*265*	*65*	*1*	*201*	*0*	*265*	*0*
Brazil	1,480	35,030	50,156	36,510	64	13,711	0	50,156	0
	-135	*27,483*	*39,018*	*27,348*	*-74*	*11,595*	*0*	*39,018*	*0*
Bulgaria, Romania	1	155	151	156	84	79	0	126	25
	0	*155*	*151*	*155*	*83*	*79*	*0*	*126*	*25*
Canada	97	1,916	1,818	2,012	301	107	163	1,655	0
	-96	*1,742*	*1,541*	*1,646*	*190*	*86*	*5*	*1,536*	*0*
China	1,134	4,281	4,035	5,415	1,436	56	0	4,035	0
	-1,134	*3,890*	*1,235*	*2,756*	*1,429*	*-91*	*0*	*1,235*	*0*
EU10	179	1,285	3,051	1,464	433	2,020	95	2,618	339
	12	*1,238*	*2,814*	*1,250*	*427*	*1,991*	*13*	*2,462*	*339*
EU15	1,777	13,355	9,628	15,132	5,541	37	664	6,692	2,272
	151	*12,948*	*8,095*	*13,099*	*5,017*	*13*	*69*	*5,754*	*2,272*
India	1,177	1,770	2,991	2,948	87	129	0	2,991	0
	-140	*1,677*	*1,938*	*1,536*	*-283*	*120*	*0*	*1,938*	*0*
Russia, Belarus, Ukraine	0	2,087	2,247	2,087	11	172	0	2,247	0
	0	*1,332*	*1,440*	*1,332*	*4*	*112*	*0*	*1,440*	*0*
Rest of world	466	2,667	3,368	3,133	498	733	0	3,368	0
	-10	*2,536*	*2,684*	*2,527*	*277*	*435*	*0*	*2,684*	*0*
USA	123	57,800	48,854	57,923	9,482	412	1,037	42,643	5,174
	-123	*46,866*	*38,582*	*46,743*	*8,190*	*28*	*648*	*32,760*	*5,174*

Source: CAPRI biofuel model, Biofuel baseline, 18.11.10

Annex 10.9: Biodiesel market balance for EU15, EU10 and non-EU countries: Baseline

Quantities in 1000 t and *absoltue changes compared to baseyear*	**Fuel demand**	**Total production**	**Total demand**	**Imports**	**Exports**	**Non-agricult. production**	**1st generation production**	**2nd generation production**
	HCOM	*MAPR*	*DOMM*	*IMPT*	*EXPT*	*NAGR*	*FSTG*	*SECG*
ACP countries	134	134	134	0	0	0	134	0
	134	*134*	*134*	*0*	*0*	*0*	*134*	*0*
Australa, New Zealand	211	211	211	0	0	0	211	0
	207	*207*	*207*	*0*	*0*	*0*	*207*	*0*
Argentina	289	1,780	289	162	1,652	0	1,780	0
	289	*1,780*	*289*	*162*	*1,652*	*0*	*1,780*	*0*
Brazil	2,874	2,874	2,874	0	0	281	2,593	0
	2,874	*2,874*	*2,874*	*0*	*0*	*281*	*2,593*	*0*
Bulgaria, Romania	261	543	261	25	308	104	420	19
	261	*543*	*261*	*25*	*308*	*104*	*420*	*19*
Canada	474	474	474	0	0	254	220	0
	470	*470*	*470*	*0*	*0*	*250*	*220*	*0*
EU10	2,646	1,516	2,646	1,317	187	254	1,127	134
	2,621	*1,406*	*2,621*	*1,295*	*81*	*254*	*1,018*	*134*
EU15	21,927	19,194	21,927	3,120	387	2,543	12,401	4,250
	19,948	*17,426*	*19,948*	*2,891*	*369*	*2,543*	*10,633*	*4,250*
India	7,295	7,825	7,295	0	531	0	7,825	0
	7,295	*7,823*	*7,295*	*0*	*528*	*0*	*7,823*	*0*
LDC countries	17	155	17	0	139	0	155	0
	17	*155*	*17*	*0*	*139*	*0*	*155*	*0*
Rest of world	3,949	4,328	3,949	310	689	0	4,328	0
	3,894	*4,328*	*3,894*	*255*	*689*	*0*	*4,328*	*0*
USA	3,315	4,357	3,315	798	1,840	1,398	2,960	0
	3,182	*4,045*	*3,182*	*790*	*1,653*	*1,383*	*2,662*	*0*

Source: CAPRI biofuel model, Biofuel baseline, 18.11.10

10.3. Scenario tables

Annex 10.10: Bilateral trade of biodiesel for selected countries: Scenarios

Quantities in 1000t and ***absolute changes to baseline*** --- **Importer** / **Exporter**	**Baselline**								**no EU support**								**high fuel price**							
	EU15	EU10	Bulgaria, Romania	USA	Canada	Argentina	India	LDC countries	EU15	EU10	Bulgaria, Romania	USA	Canada	Argentina	India	LDC countries	EU15	EU10	Bulgaria, Romania	USA	Canada	Argentina	India	LDC countries
EU15	~	76	25	1,489	0	1,112	168	54	~	2	0	32	0	55	2	1	~	5	1	41	0	91	5	2
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***~***	***-74***	***-24***	***-1,457***	***0***	***-1,058***	***-166***	***-53***	***~***	***-71***	***-24***	***-1,448***	***0***	***-1,021***	***-163***	***-52***
EU10	378	~	12	350	0	431	59	11	220	~	1	26	0	73	2	1	323	~	1	31	0	112	5	1
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***-158***	***~***	***-12***	***-324***	***0***	***-358***	***-57***	***-10***	***-55***	***~***	***-11***	***-320***	***0***	***-319***	***-54***	***-10***
Bulgaria, Romania	0	0	~	0	0	20	2	1	0	0	~	0	0	18	0	0	0	0	~	0	0	37	1	0
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***0***	***0***	***~***	***0***	***0***	***-2***	***-2***	***0***	***0***	***0***	***~***	***0***	***0***	***17***	***-1***	***0***
Argentina	0	1	101	0	0	~	0	0	0	1	103	0	0	~	0	0	0	2	136	0	0	~	0	0
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***0***	***1***	***2***	***0***	***0***	***~***	***0***	***0***	***0***	***2***	***36***	***0***	***0***	***~***	***0***	***0***
USA	9	2	0	~	0	88	270	74	114	5	0	~	0	313	198	128	151	9	0	~	0	435	441	126
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***105***	***3***	***0***	***~***	***0***	***225***	***-72***	***54***	***141***	***7***	***0***	***~***	***0***	***346***	***171***	***52***

Quantities in 1000t and ***absolute changes to baseline*** --- **Importer** / **Exporter**	**no EU tariffs**								**high 2nd gen.**								**low fuel demand**							
	EU15	EU10	Bulgaria, Romania	USA	Canada	Argentina	India	LDC countries	EU15	EU10	Bulgaria, Romania	USA	Canada	Argentina	India	LDC countries	EU15	EU10	Bulgaria, Romania	USA	Canada	Argentina	India	LDC countries
EU15	~	73	23	1,623	0	1,165	201	49	~	78	24	1,123	0	925	100	41	~	47	13	910	0	795	72	33
	~	***-3***	***-2***	***134***	***0***	***53***	***33***	***-5***	***~***	***2***	***-1***	***-367***	***0***	***-188***	***-68***	***-13***	***~***	***-29***	***-12***	***-580***	***0***	***-317***	***-95***	***-21***
EU10	366	~	11	380	0	450	71	10	549	~	14	307	0	417	41	9	457	~	9	284	0	409	34	9
	-12	***~***	***-1***	***30***	***0***	***19***	***11***	***-1***	***171***	***~***	***1***	***-43***	***0***	***-14***	***-18***	***-1***	***79***	***~***	***-4***	***-67***	***0***	***-23***	***-25***	***-2***
Bulgaria, Romania	0	0	~	0	0	22	2	1	0	0	~	0	0	21	1	1	0	0	~	0	0	18	1	1
	0	***0***	***~***	***0***	***0***	***2***	***0***	***0***	***0***	***0***	***~***	***0***	***0***	***1***	***0***	***0***	***0***	***0***	***~***	***0***	***0***	***-3***	***-1***	***0***
Argentina	0	1	103	0	0	~	0	0	0	1	147	0	0	~	0	0	0	1	120	0	0	~	0	0
	0	***0***	***3***	***0***	***0***	***~***	***0***	***0***	***0***	***0***	***46***	***0***	***0***	***~***	***0***	***0***	***0***	***0***	***19***	***0***	***0***	***~***	***0***	***0***
USA	11	3	0	~	0	80	279	79	18	3	0	~	0	113	246	85	17	3	0	~	0	129	236	92
	1	***0***	***0***	***~***	***0***	***-9***	***9***	***6***	***9***	***1***	***0***	***~***	***0***	***24***	***-24***	***12***	***8***	***1***	***0***	***~***	***0***	***40***	***-34***	***19***

Source: CAPRI biofuel model, 26.11.2010

Annex 10.11: Bilateral trade of ethanol for selected countries: Scenarios

Quantities in 1000t and ***absolute changes to baseline*** --- **Importer** / **Exporter**	**Baseline**								**no EU support**								**high fuel price**							
	EU15	EU10	Bulgaria, Romania	USA	Brazil	Rest of South America	India	Australia and New Zealand	EU15	EU10	Bulgaria, Romania	USA	Brazil	Rest of South America	India	Australia and New Zealand	EU15	EU10	Bulgaria, Romania	USA	Brazil	Rest of South America	India	Australia and New Zealand
EU15	~	1,927	10	188	2,192	244	41	25	~	619	2	42	523	65	9	6	~	865	2	63	653	84	5	5
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***~***	***-1,308***	***-8***	***-146***	***-1,669***	***-179***	***-32***	***-19***	***~***	***-1,062***	***-8***	***-125***	***-1,538***	***-160***	***-35***	***-20***
EU10	27	~	2	10	254	31	4	2	9	~	0	2	62	8	1	0	16	~	1	4	97	13	1	0
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***-18***	***~***	***-2***	***-8***	***-192***	***-22***	***-3***	***-2***	***-11***	***~***	***-2***	***-6***	***-158***	***-17***	***-3***	***-2***
Bulgaria, Romania	0	39	~	0	33	3	3	0	0	52	~	0	32	4	3	0	0	106	~	0	59	7	2	0
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***0***	***13***	***~***	***0***	***-1***	***0***	***0***	***0***	***0***	***66***	***~***	***0***	***26***	***4***	***-1***	***0***
USA	10	2	67	~	8,710	299	0	2	13	2	63	~	9,206	358	0	2	14	2	48	~	7,940	325	0	1
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***3***	***1***	***-4***	~	***495***	***59***	***0***	***0***	***4***	***1***	***-19***	~	***-771***	***26***	***0***	***-1***
Japan	0	0	0	3	644	7	6	0	0	0	0	3	670	8	6	0	0	0	0	7	1,252	17	5	0
	0	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***0***	***0***	***0***	***0***	***26***	***1***	***0***	***0***	***0***	***0***	***0***	***4***	***608***	***10***	***-2***	***0***

Quantities in 1000t and ***absolute changes to baseline*** --- **Importer** / **Exporter**	**no EU tariffs**								**high 2nd gen.**								**low fuel demand**							
	EU15	EU10	Bulgaria, Romania	USA	Brazil	Rest of South America	India	Australia and New Zealand	EU15	EU10	Bulgaria, Romania	USA	Brazil	Rest of South America	India	Australia and New Zealand	EU15	EU10	Bulgaria, Romania	USA	Brazil	Rest of South America	India	Australia and New Zealand
EU15	~	1,240	5	417	6,531	364	54	54	~	2,160	11	174	2,045	231	38	23	~	1,444	6	122	1,456	172	26	16
	~	***-687***	***-4***	***229***	***4,340***	***121***	***14***	***29***	***~***	***233***	***1***	***-14***	***-147***	***-13***	***-3***	***-2***	***~***	***-483***	***-3***	***-66***	***-736***	***-72***	***-14***	***-9***
EU10	18	~	1	23	770	46	5	4	31	~	3	10	249	30	4	2	27	~	2	8	211	27	3	2
	-9	***~***	***-1***	***13***	***515***	***16***	***1***	***2***	***4***	***~***	***0***	***0***	***-5***	***0***	***0***	***0***	***0***	***~***	***0***	***-2***	***-43***	***-4***	***-1***	***0***
Bulgaria, Romania	0	29	~	0	110	6	4	0	0	44	~	0	31	3	3	0	0	44	~	0	32	3	3	0
	0	***-10***	***~***	***0***	***77***	***2***	***2***	***0***	***0***	***5***	***~***	***0***	***-2***	***0***	***0***	***0***	***0***	***4***	***~***	***0***	***0***	***0***	***0***	***0***
USA	13	2	77	~	7,725	233	0	2	11	2	78	~	8,757	305	0	2	11	2	68	~	8,897	327	0	2
	3	***1***	***10***	~	***-985***	***-66***	***0***	***0***	***2***	***0***	***11***	~	***46***	***6***	***0***	***0***	***2***	***0***	***1***	~	***187***	***27***	***0***	***0***
Japan	0	0	0	3	594	6	7	0	0	0	0	3	647	7	6	0	0	0	0	3	654	8	6	0
	0	***0***	***0***	***0***	***-50***	***-1***	***1***	***0***	***0***	***0***	***0***	***0***	***3***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***10***	***1***	***0***	***0***

Source: CAPRI biofuel model, 26.11.2010

Annex 10.12: Biofuel market balances for selected European Member States: Scenarios

		Baseline								**no EU support**								**high fuel price**							
Quantities in Mn t		**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports
France	Biodiesel	**4.4**	3.3	0.8	0.3	**3.9**	**9.1**	0.0	0.5	**0.9**	0.9	0.0	0.0	**0.4**	**0.8**	0.0	0.6	**1.2**	1.2	0.0	0.0	**0.6**	**1.7**	0.0	0.6
	Ethanol	**3.2**	2.5	0.4	0.3	**1.3**	**8.2**	0.2	1.5	**1.2**	0.9	0.0	0.3	**0.3**	**2.1**	0.2	0.5	**1.7**	1.4	0.0	0.3	**0.4**	**2.7**	0.2	0.9
Spain	Biodiesel	**1.2**	0.7	0.4	0.2	**3.9**	**8.6**	2.8	0.1	**0.0**	0.0	0.0	0.0	**0.4**	**0.8**	0.4	0.1	**0.1**	0.1	0.0	0.0	**0.7**	**1.7**	0.7	0.1
	Ethanol	**0.9**	0.8	0.0	0.1	**1.2**	**10.5**	0.5	0.0	**0.4**	0.2	0.0	0.1	**0.1**	**0.5**	0.5	0.6	**0.5**	0.4	0.0	0.1	**0.3**	**2.2**	0.5	0.6
Italy	Biodiesel	**1.5**	1.0	0.3	0.2	**3.0**	**9.2**	1.7	0.2	**0.0**	0.0	0.0	0.0	**0.2**	**0.5**	0.4	0.2	**0.3**	0.3	0.0	0.0	**0.3**	**1.1**	0.3	0.2
	Ethanol	**0.4**	0.4	0.0	0.0	**1.7**	**7.1**	1.5	0.1	**0.1**	0.1	0.0	0.0	**0.6**	**2.6**	0.8	0.1	**0.2**	0.1	0.0	0.0	**0.9**	**3.8**	0.9	0.1
UK	Biodiesel	**0.1**	0.1	0.0	0.0	**2.3**	**7.4**	2.2	0.0	**0.0**	0.0	0.0	0.0	**0.0**	**0.1**	0.0	0.0	**0.0**	0.0	0.0	0.0	**0.0**	**0.1**	0.1	0.0
	Ethanol	**1.4**	0.7	0.6	0.1	**2.7**	**9.4**	1.7	0.2	**0.4**	0.3	0.0	0.1	**1.3**	**4.5**	1.3	0.2	**0.5**	0.4	0.0	0.1	**1.8**	**6.8**	1.7	0.2
Germany	Biodiesel	**9.2**	5.3	2.6	1.4	**4.8**	**11.0**	0.0	4.4	**1.7**	1.7	0.0	0.0	**0.4**	**0.8**	0.0	1.3	**2.4**	2.4	0.0	0.0	**0.6**	**1.7**	0.0	1.8
	Ethanol	**2.2**	1.2	0.9	0.1	**3.7**	**11.7**	2.0	0.1	**0.6**	0.5	0.0	0.1	**0.0**	**0.0**	2.0	2.2	**0.8**	0.7	0.0	0.1	**0.0**	**0.0**	2.0	2.5

		no EU tariffs								**high 2nd gen.**								**low fuel demand**							
Quantities in Mn t		**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports
France	Biodiesel	**4.4**	3.3	0.8	0.3	**3.9**	**9.1**	0.0	0.5	**5.3**	2.8	2.2	0.3	**4.2**	**9.8**	0.0	1.1	**3.8**	2.7	0.8	0.3	**3.2**	**7.4**	0.0	0.7
	Ethanol	**2.5**	1.8	0.4	0.3	**1.6**	**10.0**	0.2	0.6	**3.7**	1.9	1.6	0.3	**1.4**	**8.7**	0.2	2.0	**2.5**	1.8	0.4	0.3	**0.9**	**5.6**	0.2	1.2
Spain	Biodiesel	**1.2**	0.7	0.4	0.2	**3.9**	**8.6**	2.8	0.1	**1.3**	0.5	0.6	0.2	**4.3**	**9.2**	3.1	0.1	**1.0**	0.5	0.4	0.2	**3.2**	**7.1**	2.3	0.1
	Ethanol	**0.7**	0.5	0.0	0.1	**1.5**	**12.4**	1.0	0.0	**1.2**	0.6	0.5	0.1	**1.3**	**11.2**	0.4	0.0	**0.6**	0.5	0.0	0.1	**0.8**	**7.1**	0.4	0.0
Italy	Biodiesel	**1.5**	0.9	0.3	0.2	**3.0**	**9.2**	1.7	0.2	**1.8**	0.8	0.7	0.2	**3.2**	**9.9**	1.7	0.2	**1.3**	0.8	0.3	0.2	**2.4**	**7.5**	1.4	0.2
	Ethanol	**0.3**	0.2	0.0	0.0	**2.1**	**8.8**	2.1	0.1	**0.5**	0.2	0.2	0.0	**1.8**	**7.5**	1.6	0.1	**0.3**	0.2	0.0	0.0	**1.3**	**5.5**	1.3	0.1
UK	Biodiesel	**0.1**	0.1	0.0	0.0	**2.3**	**7.5**	2.2	0.0	**0.1**	0.0	0.0	0.0	**2.5**	**8.1**	2.4	0.0	**0.1**	0.0	0.0	0.0	**1.9**	**6.1**	1.8	0.0
	Ethanol	**1.2**	0.5	0.6	0.1	**3.1**	**10.6**	2.3	0.2	**1.3**	0.6	0.7	0.1	**2.8**	**9.6**	1.8	0.2	**1.2**	0.5	0.6	0.1	**1.8**	**6.4**	1.0	0.2
Germany	Biodiesel	**9.2**	5.3	2.6	1.4	**4.8**	**11.1**	0.0	4.4	**10.4**	4.5	4.6	1.4	**5.3**	**12.1**	0.0	5.1	**8.3**	4.4	2.6	1.4	**3.8**	**8.7**	0.0	4.5
	Ethanol	**1.9**	0.9	0.9	0.1	**4.4**	**13.6**	2.9	0.1	**2.1**	1.0	1.1	0.1	**4.0**	**12.4**	2.3	0.1	**1.9**	0.9	0.9	0.1	**2.5**	**8.0**	1.1	0.1

Source: CAPRI biofuel model, 24.11.2010

Annex 10.13: Biofuel market balances for selected non-European countries: Scenarios

		Baseline								**no EU support**								**high fuel price**							
Quantities in Mn t		**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports
Argentina	Biodiesel	**1.8**	1.8	0.0	0.0	**0.3**	**2.3**	0.2	1.7	**0.8**	0.8	0.0	0.0	**0.5**	**3.8**	0.1	0.5	**1.1**	1.1	0.0	0.0	**0.7**	**6.5**	0.2	0.7
	Ethanol	**0.4**	0.4	0.0	0.0	**0.1**	**1.8**	0.0	0.2	**0.4**	0.4	0.0	0.0	**0.1**	**2.0**	0.0	0.2	**0.4**	0.4	0.0	0.0	**0.1**	**2.6**	0.0	0.2
USA	Biodiesel	**4.4**	3.0	0.0	1.4	**3.3**	**1.2**	0.8	1.8	**3.8**	2.4	0.0	1.4	**4.7**	**1.6**	1.0	0.1	**4.4**	3.0	0.0	1.4	**6.0**	**2.6**	1.6	0.1
	Ethanol	**48.9**	42.6	5.2	1.0	**57.8**	**7.9**	9.5	0.4	**48.8**	42.6	5.2	1.0	**58.5**	**8.0**	10.1	0.3	**49.3**	43.1	5.2	1.0	**57.3**	**9.0**	8.5	0.5
Canada	Biodiesel	**0.5**	0.2	0.0	0.3	**0.5**	**1.3**	0.0	0.0	**0.5**	0.3	0.0	0.3	**0.5**	**1.4**	0.0	0.0	**0.5**	0.3	0.0	0.3	**0.5**	**1.8**	0.0	0.0
	Ethanol	**1.8**	1.7	0.0	0.2	**1.9**	**3.4**	0.3	0.1	**1.8**	1.6	0.0	0.2	**1.9**	**3.4**	0.3	0.1	**2.1**	1.9	0.0	0.2	**2.4**	**4.8**	0.5	0.1
Brazil	Biodiesel	**2.9**	2.6	0.0	0.3	**2.9**	**4.8**	0.0	0.0	**3.0**	2.7	0.0	0.3	**3.0**	**4.9**	0.0	0.0	**3.0**	2.7	0.0	0.3	**3.0**	**6.4**	0.0	0.0
	Ethanol	**50.2**	50.2	0.0	0.0	**35.0**	**77.0**	0.1	13.7	**49.9**	49.9	0.0	0.0	**36.0**	**79.2**	0.1	12.5	**51.5**	51.5	0.0	0.0	**35.8**	**88.2**	0.1	14.3

		no EU tariffs								**high 2nd gen.**								**low fuel demand**							
Quantities in Mn t		**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports	**Total production**	1st gen. production	2nd gen. production	Non-agri. production	**Fuel demand**	**Biofuel share in %**	Imports	Exports
Argentina	Biodiesel	**1.8**	1.8	0.0	0.0	**0.3**	**2.2**	0.2	1.7	**1.6**	1.6	0.0	0.0	**0.4**	**2.8**	0.2	1.5	**1.5**	1.5	0.0	0.0	**0.4**	**2.8**	0.2	1.3
	Ethanol	**0.4**	0.4	0.0	0.0	**0.1**	**1.3**	0.0	0.3	**0.4**	0.4	0.0	0.0	**0.1**	**1.9**	0.0	0.2	**0.4**	0.4	0.0	0.0	**0.1**	**1.9**	0.0	0.2
USA	Biodiesel	**4.4**	3.0	0.0	1.4	**3.2**	**1.1**	0.8	2.0	**4.2**	2.8	0.0	1.4	**3.6**	**1.3**	0.8	1.4	**4.2**	2.8	0.0	1.4	**3.7**	**1.3**	0.8	1.2
	Ethanol	**49.2**	43.0	5.2	1.0	**56.8**	**7.8**	8.4	0.7	**48.9**	42.6	5.2	1.0	**57.9**	**7.9**	9.6	0.4	**48.8**	42.6	5.2	1.0	**58.1**	**7.9**	9.7	0.3
Canada	Biodiesel	**0.5**	0.2	0.0	0.3	**0.5**	**1.3**	0.0	0.0	**0.5**	0.2	0.0	0.3	**0.5**	**1.3**	0.0	0.0	**0.5**	0.2	0.0	0.3	**0.5**	**1.3**	0.0	0.0
	Ethanol	**1.9**	1.7	0.0	0.2	**1.9**	**3.4**	0.3	0.2	**1.8**	1.7	0.0	0.2	**1.9**	**3.4**	0.3	0.1	**1.8**	1.6	0.0	0.2	**1.9**	**3.4**	0.3	0.1
Brazil	Biodiesel	**2.9**	2.6	0.0	0.3	**2.9**	**4.8**	0.0	0.0	**2.9**	2.6	0.0	0.3	**2.9**	**4.8**	0.0	0.0	**2.9**	2.6	0.0	0.3	**2.9**	**4.9**	0.0	0.0
	Ethanol	**51.5**	51.5	0.0	0.0	**32.7**	**72.0**	0.1	17.4	**50.2**	50.2	0.0	0.0	**35.1**	**77.3**	0.1	13.6	**50.0**	50.0	0.0	0.0	**35.4**	**77.9**	0.1	13.2

Source: CAPRI biofuel model, 24.11.2010

Annex 10.14: Biofuel feedstock demand in EU27 and selected non-EU countries: Scenarios

Quantities in Mn t and ***relative changes to baseline***	**Baseline**				**no EU support**				**high fuel price**			
	EU27	**Brazil**	**Argentina**	**USA**	**EU27**	**Brazil**	**Argentina**	**USA**	**EU27**	**Brazil**	**Argentina**	**USA**
Wheat	8.0	0.0	0.0	2.6	2.8	0.0	0.0	2.6	4.3	0.0	0.0	2.6
	0%	***0%***	***0%***	***0%***	***-65%***	***0%***	***0%***	***0%***	***-47%***	***0%***	***0%***	***2%***
Barley	6.5	0.0	0.0	3.3	2.4	0.0	0.0	3.3	3.7	0.0	0.0	3.4
	0%	***0%***	***0%***	***0%***	***-63%***	***0%***	***0%***	***0%***	***-43%***	***0%***	***0%***	***1%***
Maize	5.4	0.0	0.0	116.0	1.6	0.0	0.0	115.8	2.6	0.0	0.0	117.3
	0%	***0%***	***0%***	***0%***	***-71%***	***0%***	***0%***	***0%***	***-52%***	***0%***	***0%***	***1%***
Rape oil	9.5	0.0	0.0	0.2	3.0	0.0	0.0	0.0	4.6	0.0	0.0	0.3
	0%	***0%***	***0%***	***0%***	***-68%***	***0%***	***0%***	***-100%***	***-52%***	***0%***	***0%***	***56%***
Soy oil	1.1	2.5	1.9	3.1	0.2	2.8	1.0	2.8	0.0	2.6	1.2	3.1
	0%	***0%***	***0%***	***0%***	***-81%***	***15%***	***-48%***	***-10%***	***-97%***	***7%***	***-37%***	***-2%***
Sugar	4.0	87.7	0.2	0.5	1.8	87.2	0.2	0.5	2.6	90.1	0.3	0.5
	0%	***0%***	***0%***	***0%***	***-55%***	***0%***	***-20%***	***1%***	***-34%***	***3%***	***11%***	***1%***

	no EU tariffs				**high 2nd gen.**				**low fuel demand**			
	EU27	**Brazil**	**Argentina**	**USA**	**EU27**	**Brazil**	**Argentina**	**USA**	**EU27**	**Brazil**	**Argentina**	**USA**
Wheat	5.4	0.0	0.0	2.6	5.6	0.0	0.0	2.6	5.5	0.0	0.0	2.6
	-33%	***0%***	***0%***	***1%***	***-29%***	***0%***	***0%***	***0%***	***-31%***	***0%***	***0%***	***0%***
Barley	4.5	0.0	0.0	3.4	4.6	0.0	0.0	3.3	4.8	0.0	0.0	3.3
	-31%	***0%***	***0%***	***1%***	***-29%***	***0%***	***0%***	***0%***	***-27%***	***0%***	***0%***	***0%***
Maize	3.5	0.0	0.0	117.0	3.7	0.0	0.0	116.0	3.5	0.0	0.0	115.9
	-36%	***0%***	***0%***	***1%***	***-31%***	***0%***	***0%***	***0%***	***-35%***	***0%***	***0%***	***0%***
Rape oil	9.4	0.0	0.0	0.2	8.2	0.0	0.0	0.2	8.1	0.0	0.0	0.2
	-1%	***0%***	***0%***	***5%***	***-14%***	***0%***	***0%***	***7%***	***-15%***	***0%***	***0%***	***2%***
Soy oil	1.1	2.5	2.0	3.2	0.9	2.5	1.8	3.0	0.9	2.5	1.7	3.0
	-1%	***0%***	***3%***	***2%***	***-20%***	***1%***	***-8%***	***-4%***	***-20%***	***2%***	***-13%***	***-6%***
Sugar	3.3	90.1	0.3	0.5	3.4	87.7	0.2	0.5	3.2	87.4	0.2	0.5
	-18%	***3%***	***5%***	***0%***	***-16%***	***0%***	***-1%***	***0%***	***-20%***	***0%***	***-6%***	***0%***

Source: CAPRI biofuel model, 30.11.2010

Annex 10.15: Market balance of important biofuel feedstocks in selected countries: Scenarios

Quantities in Mn t and ***relative changes to baseline***		**no EU support**					
		Total production	**Human demand**	**Biofuel feedstock demand**	**Feed demand**	**Imports**	**Exports**
EU27	Wheat	139.1	59.2	2.8	50.5	6.3	28.7
		-2%	***0%***	***-65%***	***2%***	***-6%***	***2%***
	Maize	73.3	5.6	1.6	53.7	2.1	9.6
		-3%	***0%***	***-71%***	***2%***	***-8%***	***3%***
	Rape oil	6.7	3.3	3.0	3.2	5.6	1.2
		-12%	***11%***	***-68%***	***1067%***	***-21%***	***42%***
	Soy oil	3.5	1.7	0.2	0.9	0.6	0.8
		4%	***5%***	***-81%***	***380%***	***3%***	***26%***
	Sugar	16.5	18.3	1.8	0.1	7.3	2.8
		-6%	***2%***	***-55%***	***12%***	***-12%***	***-2%***
Brazil	Wheat	4.7	4.8	0.0	0.3	0.3	0.0
		0%	***0%***	***0%***	***1%***	***13%***	***-1%***
	Maize	70.7	7.9	0.0	53.0	0.1	10.0
		0%	***0%***	***0%***	***0%***	***-3%***	***-1%***
	Rape oil	0.0	0.0	0.0	0.0	0.0	0.0
		2%	***0%***	***0%***	***0%***	***23%***	***-93%***
	Soy oil	8.1	3.0	2.8	0.0	0.0	2.4
		0%	***1%***	***15%***	***0%***	***83%***	***-15%***
	Sugar	103.3	0.6	87.2	0.0	7.5	23.0
		-1%	***-14%***	***0%***	***0%***	***1%***	***-2%***
Argentina	Wheat	8.6	8.0	0.0	0.1	0.0	0.5
		0%	***1%***	***0%***	***1%***	***2%***	***-6%***
	Maize	25.1	3.8	0.0	17.3	0.2	4.1
		1%	***1%***	***0%***	***1%***	***-5%***	***2%***
	Rape oil	0.0	0.0	0.0	0.0	0.0	0.0
		2%	***0%***	***0%***	***0%***	***0%***	***2%***
	Soy oil	6.6	1.2	1.0	0.0	1.1	5.5
		-3%	***-5%***	***-48%***	***0%***	***-8%***	***15%***
	Sugar	2.9	1.8	0.2	0.0	0.0	1.0
		-1%	***0%***	***-20%***	***0%***	***0%***	***3%***
USA	Wheat	34.1	26.9	2.6	2.9	0.0	1.7
		0%	***0%***	***0%***	***-1%***	***5%***	***-1%***
	Maize	392.6	124.2	115.8	100.9	0.1	51.7
		0%	***0%***	***0%***	***0%***	***-1%***	***0%***
	Rape oil	0.7	0.4	0.0	0.0	0.2	0.2
		-19%	***12%***	***-100%***	***0%***	***-47%***	***-66%***
	Soy oil	12.6	9.0	2.8	0.0	0.0	0.8
		-1%	***2%***	***-10%***	***0%***	***-62%***	***2%***
	Sugar	8.6	10.6	0.5	0.0	2.6	0.0
		0%	***0%***	***1%***	***0%***	***1%***	***-7%***
Canada	Wheat	13.5	5.6	2.8	4.2	0.0	0.9
		1%	***0%***	***-1%***	***2%***	***-1%***	***7%***
	Maize	12.0	5.4	1.1	8.8	3.3	0.0
		1%	***0%***	***-2%***	***1%***	***-3%***	***3%***
	Rape oil	7.1	0.9	0.3	0.0	0.2	6.1
		-9%	***27%***	***38%***	***0%***	***-67%***	***-17%***
	Soy oil	0.3	0.0	0.0	0.0	0.0	0.0
		8%	***0%***	***-53%***	***0%***	***-23%***	***0%***
	Sugar	0.1	3.0	0.0	0.0	2.9	0.0
		0%	***1%***	***0%***	***0%***	***1%***	***0%***

Source: CAPRI biofuel model, 30.11.2010

10.4. Other tables

Annex 10.16: Significance of estimated regression coefficients

	Gasoline				**Diesel**			
	β (GDP)	**γ (trend)**	**α (price)**	***R2***	**β (GDP)**	**γ (trend)**	**α (price)**	***R2***
Austria	-1.14	0.38 ***	-0.83	*0.18*	-2.60	1.03 ***	-1.64	*0.18*
Belgium	0.25	-0.20 ***	-0.23 ***	*0.43*	-0.28	0.16 ***	-0.66	*0.36*
Luxembourg	-0.22 *	-0.15 ***	-0.18 *	*0.74*	-0.68 ***	0.49 ***	-0.57 ***	*0.34*
Netherlands	0.29 *	-0.23 ***	-0.40 ***	*0.47*	0.00	0.10 ***	-0.75 ***	*0.27*
Germany	-0.34	-0.11 ***	-0.52	*0.70*	-0.55	0.29 ***	-0.79 **	*0.34*
France	0.11	-0.22 ***	-0.25 ***	*0.58*	-0.04	0.17 ***	-0.89	*0.31*
Spain	0.36 ***	-0.29 ***	-0.22 ***	*0.46*	-0.37	0.27 ***	-0.61	*0.28*
Portugal	-0.02	-0.09 ***	-0.27 *	*0.44*	-0.26	0.34 ***	-0.74 ***	*0.27*
UK	0.46 ***	-0.22 ***	-0.54 ***	*0.35*	-0.01	0.07 ***	-0.80	*0.34*
Ireland	0.26 **	-0.22 ***	-0.48 ***	*0.36*	0.53 ***	-0.28 ***	-0.71 ***	*0.27*
Italy	0.50 ***	-0.26 ***	-0.25 ***	*0.42*	-0.43	0.25 ***	-0.62 **	*0.23*
Denmark	-0.27	-0.12 ***	-0.45	*0.62*	-0.24	0.16 ***	-0.68	*0.32*
Finland	-0.39	0.11 ***	-0.42	*0.34*	-0.73 *	0.26 ***	-0.62 *	*0.43*
Sweden	-0.02	-0.08 ***	-0.45	*0.42*	0.04	0.10 ***	-0.76	*0.28*
Greece	-0.55 *	0.36 ***	-0.51 **	*0.26*	-0.09	0.25 ***	-0.55 *	*0.26*
Poland	0.45 ***	-0.19 ***	-0.49 *	*0.20*	-0.43 ***	0.78 ***	-0.72 ***	*0.25*
Hungary	0.47 ***	-0.21 ***	-0.52 ***	*0.28*	0.31 *	0.06 ***	-0.84	*0.29*
Czech Rep.	0.22	0.01 ***	-0.39	*0.21*	-0.40	0.55 ***	-0.73 ***	*0.29*
Slovakia	0.01	0.05 ***	-0.39	*0.29*	-0.55 **	0.67 ***	-0.80 ***	*0.32*
Slovenia	0.06	0.05 ***	-0.45	*0.34*	-2.45 ***	1.70 ***	-0.55 ***	*0.46*
Lithuania	0.68 ***	-0.75 ***	-0.26 ***	*0.56*	0.46 ***	-0.19 ***	-0.65 *	*0.21*
Latvia	0.79 ***	-0.58 ***	-0.39 ***	*0.48*	0.69 ***	-0.19 ***	-0.77 **	*0.28*
Estonia	0.73 ***	-0.51 ***	-0.44 ***	*0.43*	0.71 ***	-0.20 ***	-0.75 **	*0.26*
Romania	0.68 ***	-0.27 ***	-0.45 ***	*0.62*	0.53 ***	0.01 ***	-0.66	*0.49*
Bulgaria	0.51 ***	-0.39 ***	-0.19 ***	*0.47*	0.05	0.44 ***	-0.72 ***	*0.29*
Cyprus	-0.91 ***	0.61 ***	-0.27 ***	*0.27*	-0.02	0.06 ***	-0.49	*0.33*
Malta	0.12	-0.03 ***	-0.16	*0.06*	-0.15 ***	0.21 ***	-0.43 ***	*0.24*
EU27	0.20	-0.16 ***	-0.42 **	*0.45*	-0.23	0.24 ***	-0.75 *	*0.28*

*Note: Significant level * 10%, ** 5%, *** 1%*
Source: Own calculation based on PRIMES simulation results 2008

Annex 10.17: Finally assumed elasticities of total fuel demand

	Gasoline		**Diesel**	
	β (GDP)	α (price)	β (GDP)	α (price)
Austria	0.52	-0.36	0.54	-0.68
Belgium	0.52	-0.23	0.54	-0.68
Luxembourg	0.52	-0.18	0.54	-0.57
Netherlands	0.29	-0.40	0.54	-0.75
Germany	0.52	-0.36	0.54	-0.79
France	0.52	-0.25	0.54	-0.68
Spain	0.36	-0.22	0.54	-0.68
Portugal	0.52	-0.27	0.54	-0.74
UK	0.46	-0.54	0.54	-0.68
Ireland	0.26	-0.48	0.53	-0.71
Italy	0.50	-0.25	0.54	-0.62
Denmark	0.52	-0.36	0.54	-0.68
Finland	0.52	-0.36	0.54	-0.62
Sweden	0.52	-0.36	0.54	-0.68
Greece	0.52	-0.51	0.54	-0.55
Poland	0.45	-0.49	0.54	-0.72
Hungary	0.47	-0.52	0.31	-0.68
Czech Rep.	0.52	-0.36	0.54	-0.73
Slovakia	0.52	-0.36	0.54	-0.80
Slovenia	0.52	-0.36	0.54	-0.55
Lithuania	0.68	-0.26	0.46	-0.65
Latvia	0.79	-0.39	0.69	-0.77
Estonia	0.73	-0.44	0.71	-0.75
Romania	0.68	-0.45	0.53	-0.68
Bulgaria	0.51	-0.19	0.54	-0.72
Cyprus	0.52	-0.27	0.54	-0.68
Malta	0.52	-0.36	0.54	-0.43
EU27	0.52	-0.42	0.54	-0.75

Source: Own calculation based on PRIMES simulation results 2008