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Tax Exemption for Biofuels in Germany: Is Bio-Ethanol Really an Option for Climate Policy?

by

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Tax Exemption for Biofuels in Germany: Is Bio-Ethanol Really an Option for Climate Policy?*

Abstract:

Last year the German Parliament exempted biofuels from the gasoline tax. The promotion of biofuels is being justified by allegedly positive effects on climate, energy, and agricultural policy goals. The paper takes a closer look at bio-ethanol as a substitute for gasoline. We analyze the basic conditions that provide the setting for the production and promotion of biofuels and show that the production of bio-ethanol in Germany is not competitive. Using energy and greenhouse gas balances we demonstrate that a possible increased use of bio-ethanol to reduce greenhouse gas emissions is inefficient and that there are preferred alternative strategies. In addition, scenarios on the development of the bio-ethanol market are derived from a model that allows for variations in decisive variables and reflects the production and trade chain of bio-ethanol.

Keywords: biofuels, ethanol, climate policy, agricultural policy, gasoline tax, energy balances, GHG balances

JEL classification: D61, H23, Q25, Q42

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Contents:

1. Introduction

Last year the German Parliament decided to exempt all biofuels from the gasoline tax. The exemption is limited until the end of 2008 and a report by the government on the progress in the market introduction of biofuels and on the price development of biomass, crude oil and fuels is required every other year to allow for adaptations if necessary (Bundesgesetzblatt 2002). The coalition parties and also the opposition party CDU/CSU consider it as a decisive contribution to the goals of reducing greenhouse gas emissions in the transport sector, of protecting natural resources, becoming less oil-dependent, and of securing incomes and jobs in the agricultural sector. Overall they believe that an increased use of biofuels can contribute to sustainability. Only the liberal party FDP rejected the law, arguing that the promotion of biofuels is controversial from an environmental point of view, causes tax losses and leads to new long lasting subsidies because the competitiveness of biofuels is not conceivable (Deutscher Bundestag 2002).

The European Commission as well declared its intention to promote biofuels in different statements and proposals for directives concerning consistent Europe-wide tax breaks and constraints to admix minimum amounts of biofuels (European Commission 2001a, 2001b).

The political rationale behind the increased promotion of biofuels is the alleged positive effect on climate policy but also on agriculture and the security of energy supplies. Today climate policy consists of a large number of policies that are intended to increase the efficiency of energy use, i.e. through reducing energy intensities of economies, by reducing energy intensive activities and finally by substituting the use of fossil energy by renewable energy sources. In addition to renewable energy made from wind, water or sun, biomass also provides a possibility to substitute fossil energy sources.

Biomass can either be produced directly from the cultivation of agricultural resources or from waste material accumulated during agricultural production and processing. There are different options to use this biomass energetically. The tax exemption for biofuels aims at a strategy that produces agricultural products which can be converted to non-fossil fuels that substitute for fossil fuels. Today, diesel fuels can be substituted by rape oil produced from rape or after another level of conversion by rape methyl ester (RME), whereas normal fuels can only be substituted by bio-ethanol. Technologically this is possible today up to a volume share of 10%. Bio-ethanol can be made of different agricultural products of which sugar beets and wheat are of special importance in Germany.

Whereas the use of rape-oil and RME has been tested in detail for its impacts on energy and climate policy (Umweltbundesamt 1999) there are many studies on bio-ethanol that are often not up to date, refer to different countries and use different methods and assumptions and therefore can be characterized by an impressive divergence of results.

In this study we will only address bio-ethanol as a substitute for gasoline. The basic question will be whether the strategy to use farmland for the production of the basic materials for bio-ethanol is reasonable option of climate policy. The focus will be on aspects of climate policy but it turns out that the tax exemption for biofuels affects a multitude of policy areas. Besides climate policy this includes energy and agricultural policy but also trade policy because bio-ethanol is a tradable product for which Germany does not have a competitive advantage.

Therefore, we at first analyze the goals and basic conditions that provide the setting for the promotion of biofuels. An economic valuation on the basis of energy balances for bio-ethanol and alternative energy sources made from biomass follows. Finally, we try to assess the promotion of biofuels from an overall economic aspect and take a closer look at some scenarios for the future development of the German market for bio-ethanol.

2. Objectives of and Basic Conditions for the Promotion of Biofuels

2.1 Climate Policy Issues

Today the predominant part of energy use is based on fossil fuels which contribute considerably to greenhouse gas emissions. Especially the transport sector is still a major problem. CO_2-emissions in Germany between 1990 and 1999 were reduced by 36% in the sector trade, commerce and services, by 32% in industry, by 19% in the sector of energy production and conversion and by 4% for private households. Only in the transport sector they rose by 15% (German Federal Ministry of Economic and Technology 2002). Consequently the transport sector features the most disadvantageous development and is one of the greatest challenges for climate policy.

Facing the objective to reduce emissions from the six greenhouse gases, agreed on in the Kyoto Protocol, the European Union must reduce its emissions until the time span of 2008 to 2012 compared to 1990 by eight percent. Germany, within the scope of its national climate protection strategy, aims at reducing emissions of CO_2 by 25% until 2005, compared to 1990. Additionally, the six greenhouse gases of the Kyoto Protocol shall be reduced within the European-wide burden sharing by 21% until the time span of 2008 to 2012 compared to 1990 (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2000). The substitution of fossil fuels by renewable fuels made of biomass shall contribute to these aims.

From a climate policy point of view it must be analyzed whether the European and German policy measures to promote biofuels can contribute significantly to the reduction of greenhouse gas emissions and whether this strategy is efficient. Therefore the production of biofuels must be compared to other, possibly more favorable options of greenhouse gas reduction which can also take place outside the fuel sector (see Chapter 3).

2.2 Energy Policy Issues

The White Book of the European Commission "Energy for the Future" names some precise objectives of the European energy policy. The share of renewable energy sources of total final energy consumption shall double from 6% in 1997 to 12% until 2010 (European Commission 1997). Besides the Green Book of the European Commission "Towards a European strategy for the security of energy supply" sets the objective to substitute 20% of traditional fuels by renewable fuels until 2020 (European Commission 2000a). The German government strives for a doubling in its national climate protection program (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2000).

The entire energy policy however has to go beyond this one sided perspective of substituting fossil fuels. It takes place in a triangle with the objectives of securing energy supply, cost effectiveness and environmental sustainability. These three objectives which are often contradictory must always be maximized jointly.

Both Germany and the European Union are heavily dependent on imports to guarantee energy supply. This holds especially for crude oil where the import dependency keeps rising and already amounts up to more than 70% for Europe (European Commission 2000a). The dependency on petroleum exporting countries, on world market prices for oil and on fossil energy shall be reduced by an increased use of renewable energy sources and by a diversification of the energy source matrix. Biofuels made of European agricultural products are of domestic origin to 100%. Therefore they can at least theoretically contribute to an increased security of energy supplies, to a reduction of import risks and to the protection of fossil energy sources. In an optimistic development scenario the European Union assumes that biofuels can reach a maximum share of 8% in the fuel sector if 10% of the total agricultural area would be used for the production of biofuels (European Commission 2001b). In Germany the fuel sector accounts for about 30% of final energy consumption so that biofuels could only cover 2.4% of the final consumption of energy. This would be a very small contribution to the first objective of energy policy, namely securing energy supply. Thus, energy security does not seem to be a very sound argument for the promotion of biofuels.

The second objective, cost effectiveness, shall be reached by a further liberalization of the energy sector in Germany and Europe with the aim of promoting an efficient supply and use of energy sources for industry and final consumers. This criterion should, of course, also hold for bio-ethanol as a substitute for fossil fuels. However, German bio-ethanol is neither competitive compared to traditional fuels nor compared to imported bio-ethanol.

The biggest challenge within the third objective of energy policy, namely environmental sustainability, is to guarantee an effective and efficient climate protection. Increasing the share of renewable energies can be an important aspect of climate protection. Whether this is also true for bio-ethanol as a renewable energy will be analyzed in Chapter 3.

To jointly maximize the triangle of energy policy different policy measures have been implemented in Germany. The objective to guarantee supply is promoted by a diversified import structure and by the subsidization of coal extraction. Germany's import dependency varies significantly between the different energy sources. For crude oil it amounts to almost 100%, for natural gas to around 80% and for hard coal to 43%. In contrast lignite and renewable energy sources are almost entirely produced in Germany. The German strategy to subsidize coal extraction which is often justified with the argument of guaranteeing security of supply is questionable from an environmental point of view. The OECD for example asks for a faster reduction of subsidies in this sector to allow for a successful climate protection policy (OECD 2001, Kirkpatrick and Klepper 2001). It is obvious that the different objectives of energy policy are often contradictory, and that it is difficult if not impossible to reconcile them.

2.3 Agricultural Policy Issues

The European Common Agricultural Policy (CAP) which supports the production of many agricultural products by market regulations and market interventions is highly relevant for the production of biofuels. The CAP influences the domestic production of the energy feedstock and also international trade with biofuels and their raw materials.

According to article 33 of the Treaty Establishing the European Community the CAP shall increase agricultural productivity, ensure a fair standard of living for the agricultural community, stabilize markets, assure supplies and ensure that supplies reach consumers at reasonable prices. To achieve these objectives the CAP includes a variety of ways to regulate production and sales of agricultural products. The common market organization is the basic element of the CAP. First, it shall guarantee the free movement of agricultural products in the single market and the application of uniform instruments in the member states. Second, domestic producers shall be protected from low-price third country products and from major variations of the world market.

Striving for these goals created problematic side effects. The system of guaranteed purchases, quotas, intervention prices and import protection has created a significant excess supply of most products, and as a consequence expenditures for protecting and supporting the agricultural sector have increased continuously. Several reforms have tried to tackle these problems. The recent decisions of the Agenda 2000 aim at allowing the market mechanisms to function by reducing guaranteed prices and initiating structural adjustment.

So far the common market organization for sugar which is relevant to the energy feedstock sugar beet and therefore to the production of bio-ethanol has been largely exempted from these reforms and was extended in 2001 until the end of June 2006. It is still characterized by a system of guaranteed prices and purchases which are differentiated according to quotas so that the price on the common market clearly exceeds the world market price. Liberalizing the sugar market would lead to a decrease of prices for the energy feedstock and to a reduced domestic production.

For wheat as an energy feedstock, prices in the common market have almost reached the level of world market prices due to the reorganization of support from high price guarantees to direct payments. Nevertheless the direct payments keep domestic production artificially high.

Rules that determine the set-aside of agricultural land are also relevant to the production of bio-ethanol. Beneficiaries of direct payments are obliged to set aside land. Nevertheless farmers are allowed to grow products on the set-aside land that are “not primarily intended for human or animal consumption” (European Commission1999). This also holds for grains as a raw material for biofuels. Farmers can receive the set-aside premium and at the same time sell grain for the production of biofuels. This creates a form of double subsidization. First, through the premium and second, indirectly, through the tax exemption for biofuels. However, this premium does not exist for the cultivation of sugar beets although they might even be better suited for the production of biofuels.

It is debatable how long the European Union will be able to continue its current agricultural policy. There is great internal and external pressure to reform the CAP. Internally, the European Union is forced to reform its agricultural policy due to the eastern expansion, and externally, pressure through the negotiations at the WTO is increasing. Claims are raised especially by developing countries to reduce export subsidies and to improve market access for developing countries. In the long run the European Union will not be able to maintain the current system of agricultural support.

Therefore, the future supply structure and the corresponding prices for agricultural energy feedstocks are highly uncertain. In the light of an opening of agricultural markets, it is an open question as to how sufficient incentives can be created for a domestic production of energy feedstocks. Given the likely abolition of the premium for set-aside land, the reducing of direct payments and a possible expiration of the market organization for sugar, farmers will probably not receive prices that cover their costs.

The tax exemption for biofuels is also often justified by the allegedly positive effects on the agricultural sector. The production of energy feedstock for bio-ethanol shall contribute to the multi-functionality of agriculture, to the development of new income sources for farmers and to the assurance of employment opportunities. However, the agricultural sector faces a dilemma. As mentioned, a sufficient supply of energy feedstocks requires prices high enough for inducing farmers to expand production or to substitute food production by production for energy feedstocks. This is unlikely to be maintained during the next WTO negotiations of liberalizing agricultural markets. But even if it were possible, high feedstock prices raise the cost of bio-ethanol produced in Germany. Hence, foreign supplies can gain in competitiveness such that the market for bio-ethanol might be dominated by imports, In either case, an effective support of agriculture through bio-ethanol production is at least difficult to achieve if not impossible.

2.4 The German Market Organization for Ethanol

In Germany the “Bundesmonopolverwaltung für Branntwein”, a national market organization responsible for buying and marketing ethanol produced in the agricultural sector, has a strong influence on the market for bio-ethanol. It was designed to protect German, mainly small and medium-sized producers of bio-ethanol against foreign competitors and help to preserve ecologically valuable landscapes. Prices paid to the producers by the “Bundesmonopolverwaltung” exceed market prices and most producers would not survive without this support. The resulting deficits are covered by the federal budget. However, this form of government aid contradicts to the rules for government aid in the Single Market and the German market organization violates the rules for a free movement of agricultural goods and for the application of uniform instruments in the member states.

The reforms in the “Haushaltssanierungsgesetz” of 1999 (Haushaltssanierungsgesetz 1999) have already determined that the deficits covered by the federal budget will be reduced and industrial producers are excluded from price supports. Additional pressure comes from the proposal of the European Commission for a regulation on the common organization of the market in ethyl alcohol of agricultural origin (European Commission 2001a). This regulation calls the whole German market organization for ethanol into question. The German government however insists on a regulation that still allows for government aid.

2.5 International Competition

Analyzing the chances and risks of the promotion of biofuels the next rounds of negotiations within the World Trade Organization (WTO) need to be taken into account. It seems clear that in the light of these processes the introduction of new or higher tariffs and non-tariff barriers to trade for the protection of bio-ethanol is impossible. Therefore, foreign producers of bio-ethanol can in principle benefit from the tax exemption in Germany as do German producers.

Tariff barriers on trade with ethanol have already been reduced during the past years. Table 1 shows the development of import tariffs on ethanol that apply for imports from the most important producing countries Brazil and USA but also for accession countries to the European Union like Poland. Only the African, Caribbean and Pacific countries (ACP) are allowed to export tariff-free to the European Union but due to a lack of production capacities increasing imports from these countries are unlikely. Further tariff reductions of 15% which are also valid for ethanol exports were introduced for developing countries at the beginning of 2002 (European Council 2001).

Table 1 — European Union tariffs on imports from Brazil, USA and Poland [a]

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Methanol (TARIC: 2905110000) Ecu/hl resp. €/hl as of 1999	12.3	10.8	10.8	10.0	9.3	8.5	7.8	7.0	6.3
Undenatured ethyl alcohol of an alcoholic strength by volume of 80% vol or higher (TARIC 2207100000); Ecu/hl resp. €/hl as of 1999	30.0	28.2	26.4	24.6	22.8	21.0	19.2	19.2	19.2
Ethyl alcohol and other spirits, denatured, of any strength (TARIC 2207200000) Ecu/hl resp. €/hl as of 1999	16.0	15.0	14.1	13.1	12.1	11.2	10.2	10.2	10.2
Undenatured ethyl alcohol of an alcoholic strength by volume of less than 80% vol, in containers holding more than 2 liter (TARIC 2208909900) in Ecu/%vol/hl resp. €/%vol/hl as of 1999	1.6	1.5	1.4	1.3	1.2	1.1	1.0	1.0	1.0

[a] tariff rates are always given for 1st January.

In spite of increasing liberalization pressures the Council of the European Union laid down specific measures concerning the market in ethyl alcohol of agricultural origin in a Council Regulation of April this year which allow for import licences, tariff quotas to stabilize the Community market and also for emergency measures in case the Community market in bio-ethanol is disturbed (European Council 2003). Although this regulation has to be consistent with the WTO-agreement it is clearly an attempt to protect the European market from foreign suppliers that are more competitive.

In addition, member states of the WTO may include non-trade objectives into negotiations. These can include environmental protection, the promotion of certain structural developments, of rural area development, or programs that directly support incomes of certain population groups. These objectives may serve as justifications for governmental support and trade protection for biofuels. Nevertheless, governments would still have to prove that less trade-distorting measures are not available.

3. Can an Increased Use of Bio-Ethanol Contribute to Energy and Climate Policy Goals?

3.1 The Concept of Energy and Greenhouse Gas Balances

A substitution of traditional gasoline by bio-ethanol will not take place without economic, respectively fiscal policy support. Production costs for bio-ethanol in Germany amount to 0,45 to 0,55 € per liter gasoline-equivalent even in the best case scenario. More likely is a range of 0,80 to 0,90 € per liter of gasoline-equivalent[1] (Schmitz 2003). In contrast, tax-free prices for gasoline only amount to 0,20 € per liter (Schmitz 2003). Therefore bio-ethanol is not competitive at all without the tax exemption. The political preference for bio-ethanol can only be justified if the measures support important policy objectives other than the protection of agriculture. These are mainly the protection of fossil energy sources and climate protection. Energy and greenhouse gas balances can be used to analyze the contribution of bio-ethanol to these objectives. The energy balance compares the input of fossil energy necessary for the production of bio-ethanol to the energy content of the gasoline that is substituted by bio-ethanol. This comparison computes the net-savings of fossil fuels. Greenhouse gas balances compare the greenhouse gas emissions during the production of biofuels with the emissions from the use of traditional fossil gasoline. As greenhouse gas emissions can be reduced by a variety of different strategies the abatement costs of alternative strategies can also be compared. Different studies on the costs of reducing greenhouse gas emissions in the most efficient way show that the objectives of the Kyoto-Protocol can be reached with costs of reducing one ton of CO_2 of around 30 € (Böhringer and Löschel 2002, Klepper and Peterson 2002]. Assuming the implementation of emissions trading in the European Union the European Commission also estimates abatement costs of maximum 30 € per ton (European Commission 2000b).

Should the substitution of traditional gasoline by bio-ethanol and the strategy to promote bio-ethanol be justified two premises must be

[1] In the best case scenario a large-scale production and a 1:1 ratio of substitution between gasoline and bio-ethanol is assumed. The more likely scenario reflects current conditions of production and ratio of substitution.

fulfilled. First of all bio-ethanol must result in significant energy-savings and a reduction of greenhouse gas emissions. At the same time the costs of greenhouse gas reductions by using bio-ethanol must not be greater than those of alternative climate policy measures. To analyze whether these two premises are fulfilled we compute energy and greenhouse gas balances and we evaluate whether the strategy to promote bio-ethanol is efficient from an economic point of view.

3.2 Energy Balances for Bio-Ethanol

3.2.1 Problems in the Generation of Energy Balances for Bio-Ethanol

To generate energy balances for bio-ethanol the entire input of energy during the complete production chain needs to be estimated. The production process can be separated into two stages, the production of the agricultural energy feedstock and the conversion of these feedstock into bio-ethanol. In Germany mainly sugar beet, grain and potatoes are used as feedstock. Fossil energy input during the production of the feedstock mainly results from the energy content of fertilizer and pesticides, from the use of agricultural machinery and from the energy input for the transport of the feedstock. Energy input necessary for both, agricultural production and conversion vary between different feedstock.

The detailed studies of feedstock production (Austmeyer and Röver 1999, CCPCS 1991, Ecotraffic 1994, ERL 1990, IEA 1994, Marrow et al. 1987, Stephan 1999) show varying results for the energy inputs.[2] In

[2] We have analyzed all available studies, which offered adequate data and consistency concerning our objectives. In addition we relied on communication with experts from the Suedzucker AG and with Klaus Buercky from the Bodengesundheitsdienst GmbH. Thereby we analyzed the production of bio-

general, grain production needs less energy input per hectare compared to sugar beets. Nevertheless this is compensated by a greater yield of sugar beets per hectare. Therefore the decisive figure is the ratio of energy input in agricultural production of the feedstock compared to one liter of bio-ethanol produced from the feedstock. For both, wheat and sugar beets the fossil energy input varies between 4 and 8 MJ per liter of ethanol. The fluctuation is due to different assumptions on fertilizer input and on outputs per hectare.

The second stage of production, the conversion of the feedstock to ethanol demands the biggest part of the entire fossil energy input. The size, technological standard, type of energy input and the efficiency of energy use of the facility used for conversion are the decisive factors for the amount of overall energy input in this stage of production.

To determine the net-savings of fossil energy when bio-ethanol substitutes for traditional gasoline we have to compare the entire energy input of traditional gasoline with the energy input of bio-ethanol. The different characteristics of combustion must be taken into account as well. In the end the fossil energy input of bio-ethanol is compared to the fossil energy input that is substituted, i.e. to the calorific value equivalent of bio-ethanol as a substitute for traditional gasoline.

Studies that have generated energy balances for bio-ethanol show strongly varying results because of three critical variables that have a decisive impact on the energy balance. First, energy input during production of the agricultural feedstock depends on the amount of

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ethanol based on wheat and sugar beets. Studies on the production based on sugar cane and corn are not important for Germany due to the natural conditions of cultivation. For the production based on potatoes there is no adequate study and this option is not taken into account.

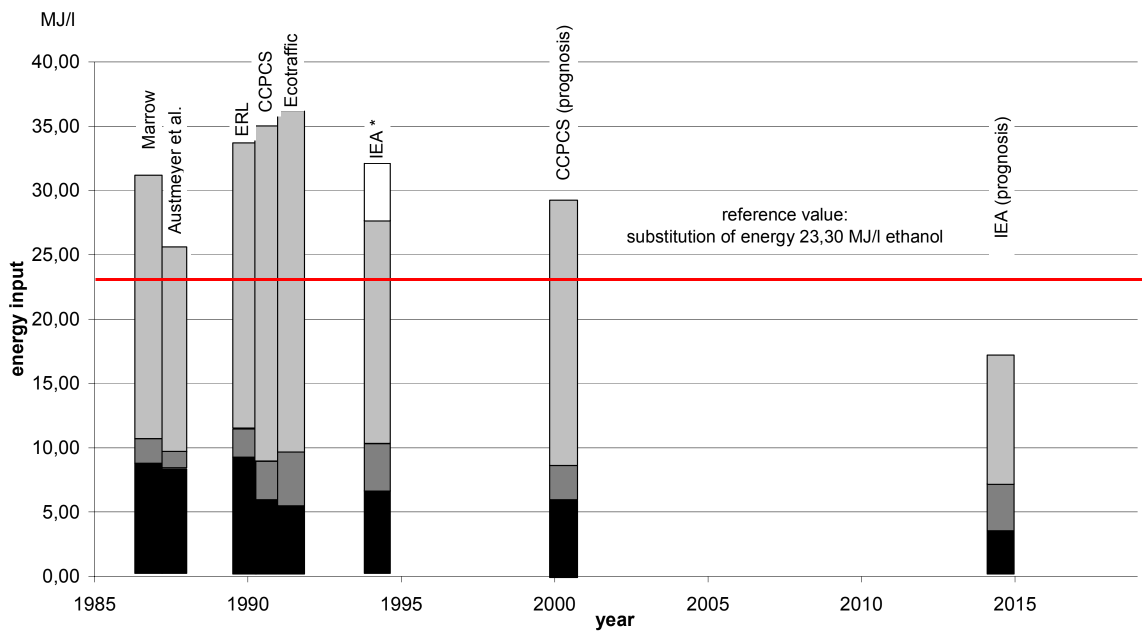
fertilizer and pesticides used and on the energy needed for transport and for farming machines. Besides yields per hectare determine the energy input per liter of bio-ethanol. Second, the conversion of feedstock to bio-ethanol is very energy-intensive. During conversion different by-products that have a relevant energy content themselves accumulate. To some extent they can be sold or they might be used again during the production process itself. An assessment of the use of by-products in terms of energy savings and profitability is only possible to a limited extent. Third, the type of agricultural feedstock used for the production of ethanol also influences the energy balance. Worldwide most production of bio-ethanol is based on sugar cane and corn whereas in Germany bio-ethanol relies on wheat and sugar beets. Therefore energy balances for bio-ethanol from different countries are not transferable to Germany. Obviously different assumptions on these three critical variables can easily change energy balances and are one reason for the variation between different studies.

In the following we will focus on energy balances for the production of bio-ethanol based on wheat and sugar beets, respectively. The different results of the studies (Austmeyer and Röver 1999, CCPCS 1991, Ecotraffic 1994, ERL 1990, IEA 1994, Marrow et al. 1987, Stephan 1999) reflect the different assumptions about the above mentioned variables.

3.2.2 Energy Balances for the Production of Bio-Ethanol Based on Wheat and Sugar Beets

Figure 1 gives an overview of different studies on the input of fossil energies necessary for the production of ethanol based on wheat. The studies are sorted according to the year they refer to. The lower segment of the different bars reflects the fossil energy input for the production of the feedstock wheat. They amount to 6 to 8 MJ per liter of ethanol for fertilizers and pesticides. The prognosis for future technologies by the International Energy Agency (IEA) (IEA 1994) assumes the input can be cut by one half. Adding the energy input for farm machinery and transport (middle segment of the bars) increases the overall input to around 10 MJ. The primary energy necessary to convert wheat into ethanol (upper segment of the bars) represents the largest part of the overall energy input although studies vary considerably. Austmeyer and Röver (1998) estimate fossil energy demands of 16 MJ whereas the study by the CCPCS (1991) estimates 26 MJ and the IEA (1994) predicts less than 10 MJ per liter of bio-ethanol. This range is due to the varying output and energy efficiency of different facilities.

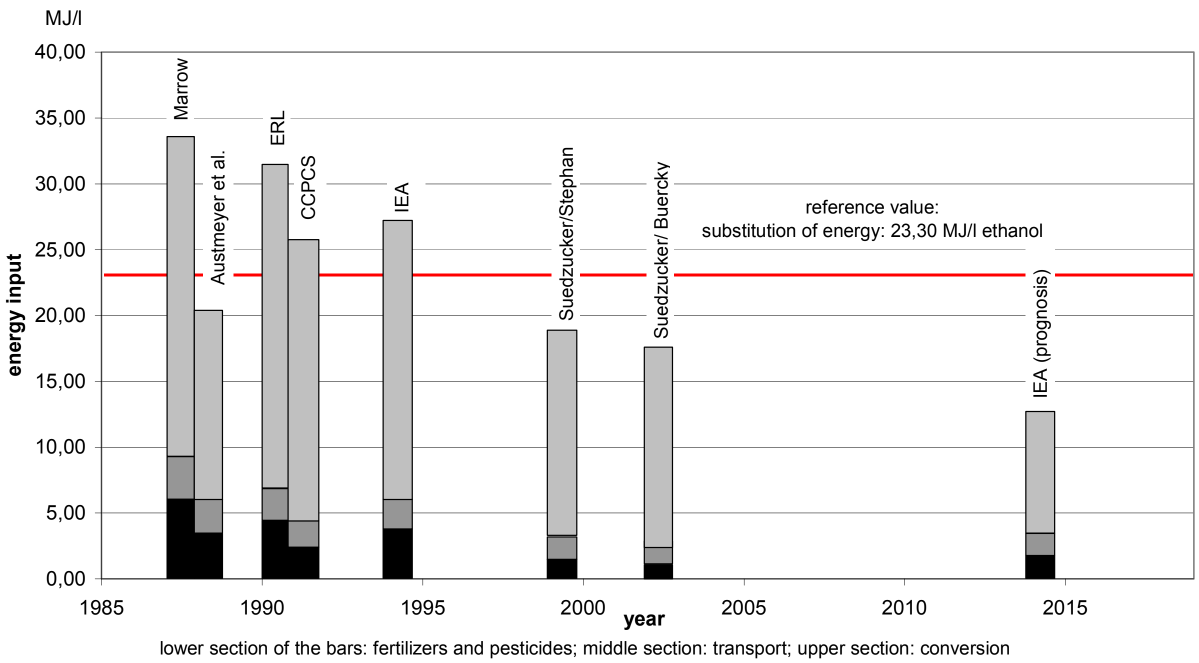
Figure 1 — Fossil energy input in the production of bio-ethanol based on wheat



lower section of the bars: fertilizer and pesticides; middle section: transport; upper section: conversion
* additional section refers to the range mentioned in the study

Figure 2 gives an overview of different studies on the input of fossil energies needed for the production of bio-ethanol based on sugar beets. The variation between the different studies is bigger than the one for bio-ethanol produced from wheat. The agricultural production of sugar beets needs less fossil energy input per liter of bio-ethanol produced, mainly due to lower fertilizer requirements, whereas energy input for the conversion is about the same.

Figure 2 — Fossil energy input in the production of bio-ethanol based on sugar beets



The energy input for the production of traditional gasoline, including the calorific value and the energy needed for refining is shown as a reference in both figures. In addition, the engine performance with ethanol compared to traditional gasoline is taken into account. The mineral oil industry assumes that one liter of ethanol produces the same performance as 0,65 liter of traditional gasoline (ARAL 2002, Umweltbundesamt)[3]. This gives us a reference value of 23.3 MJ per liter.[4] However, on these numbers a consensus has not been found yet as some studies use a one-to-one correspondence.

3.2.3 Net Energy Balances

To receive the net surplus or loss resulting from the production of bio-ethanol we compare the fossil energy input during the production process of bio-ethanol with the input of fossil energy that is avoided because of the substitution of traditional gasoline by bio-ethanol. The resulting net energy balances are shown in *Figure 3 and 4*.[5]

Overall, sugar beet as a feedstock for the production of bio-ethanol shows better results in the net energy balance. In some, mainly older studies the net energy balance for wheat even turns out to be negative. This implies that more fossil energy is needed for the production of bio-ethanol than substituted by the use of bio-ethanol instead of traditional gasoline. The IEA predicts that productivity gains in agricultural production as well as energy savings during the conversion will make the net energy balances more positive in the future. Nevertheless net energy savings are rather low.

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3 The number is the result of the ratio of the different calorific values of bio-ethanol (21.2 MJ per liter) and traditional gasoline (32.4 MJ per liter).

4 The gross energy content of gasoline (35.6 MJ per liter) is the calorific value of gasoline (32.4 MJ per liter) plus a 10% surcharge for the production process (32.4 x 1.1 = 35.6). This number multiplied by the ratio of the different calorific values of ethanol and gasoline (21.2/32.4 = 0.65) gives us the reference value of 23.3 MJ per liter.

5 To guarantee comparability of the different studies we refer to the described reference value for the energy content of gasoline that is substituted.

Figure 3 — Net energy balance for the substitution of gasoline by bio-ethanol based on wheat

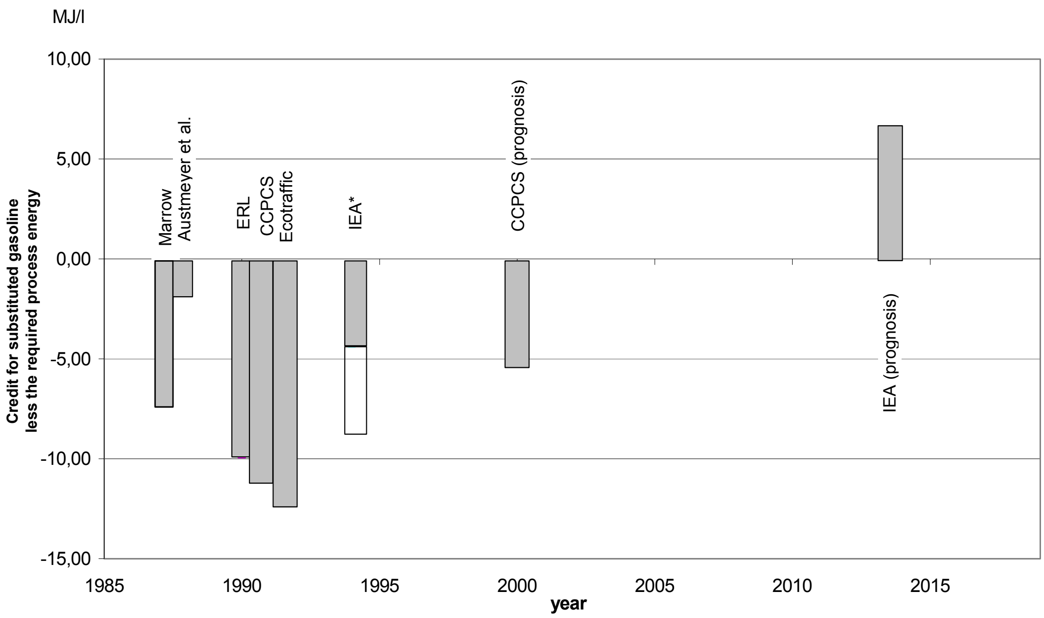
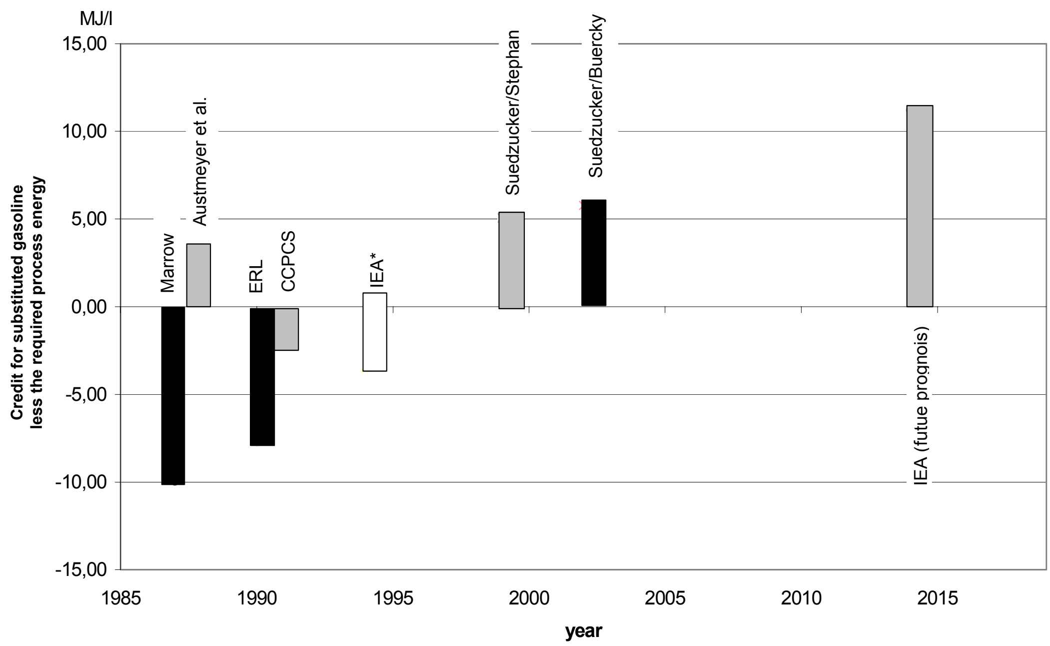


Figure 4 — Net energy balance for the substitution of gasoline by bio-ethanol based on sugar beets



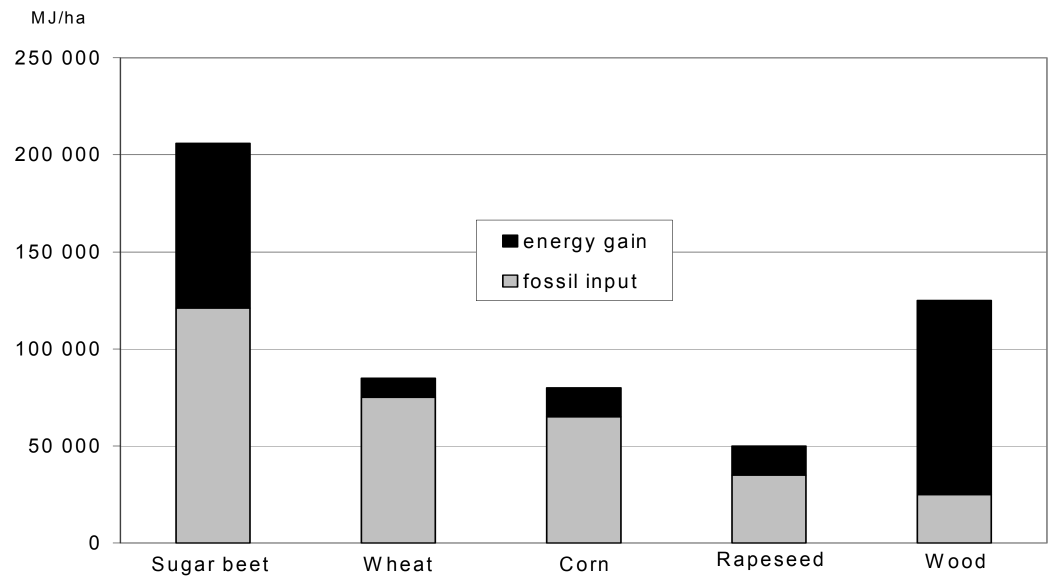
Assuming a more favorable ratio of the performance between gasoline and bio-ethanol than 0.65, the net energy balances would improve. Balances for wheat would become slightly positive. The balances for sugar beets would even double under the unrealistic assumption of a substitution of one to one.

3.3 The Economic Perspective: There are Better Strategies to use Agricultural Land

The assessment of the energy balances in the previous section shows that indeed the bio-ethanol production at current technological options can save fossil energy. For a large scale introduction of biofuels significant areas of agricultural land then need to be devoted to the production of the feedstocks. As fertile land is of limited supply the question is whether other forms of producing renewable energy could be even more successful in replacing fossil fuels.

In fact, from an overall economic perspective there are better strategies. The crucial question is how much fossil energy can be saved on a certain amount of agricultural land with a particular strategy. Besides the production of biofuels like bio-ethanol or diesel made of rape there are also options to substitute other fossil energy sources. E.g., gas, oil or coal for the production of electricity or heat can be replaced by biomass. *Figure 5* compares different options of replacing fossil energy with agricultural feedstock. The bars for sugar beets, wheat and corn refer to the cultivation of these feedstock for the production of bio-ethanol, the bar for rape refers to the production of RME and the bar for wood to the production of electricity by burning wood. To reach the objective of maximum savings of fossil energy on a certain given amount of agricultural land the best option would be to use the agricultural land for the cultivation of fast-growing woods to produce electricity and not for the substitution of traditional gasoline.[6]

Figure 5 — Fossil energy savings per hectare for different agricultural feedstock and the substitution of different energy sources



3.4 Is the Bio-Ethanol Strategy an Alternative for Climate Policy?

3.4.1 Net Greenhouse Gas Balances for Bio-Ethanol

For the analysis of an increased use of bio-ethanol from a climate policy point of view we need to determine greenhouse gas emissions during the production process of bio-ethanol, i.e. during the cultivation of

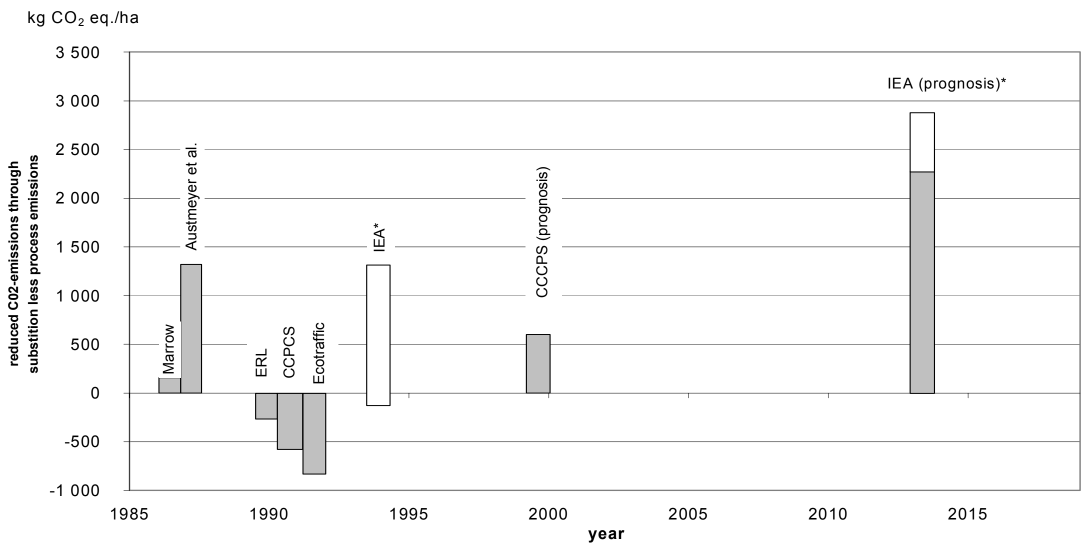
6 The results of Figure 5 are based on different assumptions concerning the ratio of substitution and energy content of gasoline than used in the studies mentioned above. Therefore, net energy savings for the production of bio-ethanol based on wheat are positive and for sugar beets greater than shown above. If we would use the data explained earlier the advantage of using woods would be even bigger.

agricultural feedstock and the process of conversion. Emission figures for the six greenhouse gases defined in the Kyoto-Protocol are weighted according to their global warming potential and summed to give a single figure for emissions which is expressed in CO_2-equivalents. CO_2-equivalents range between about 4000 and 14000 kilogram per hectare in the different studies. Then the effect of a substitution of traditional gasoline on greenhouse gas emissions is evaluated and presented in net greenhouse gas balances. They can show whether the substitution of traditional gasoline by bio-ethanol really reduces greenhouse gas emissions.

Figure 6 presents the net greenhouse gas balance for the production of bio-ethanol based on wheat. The considerable variation is mainly due to different assumptions on greenhouse gas emissions during conversion. The IEA (1994) for example assumes the use of coal and gas as fuels for the process of conversion in one case and the use of gas, electricity and power-heat coupling in another. In the first case the net greenhouse gas balance turns out to be negative and in the second case greenhouse gas emissions can be reduced by approximately 1300 kilogram of CO_2-equivalent per hectare. Altogether some studies show little reductions in greenhouse gas emissions, others even an increase. Only the IEA (1994) predicts a remarkable reduction of emissions in the future which is due to a strongly reduced energy input during conversion.

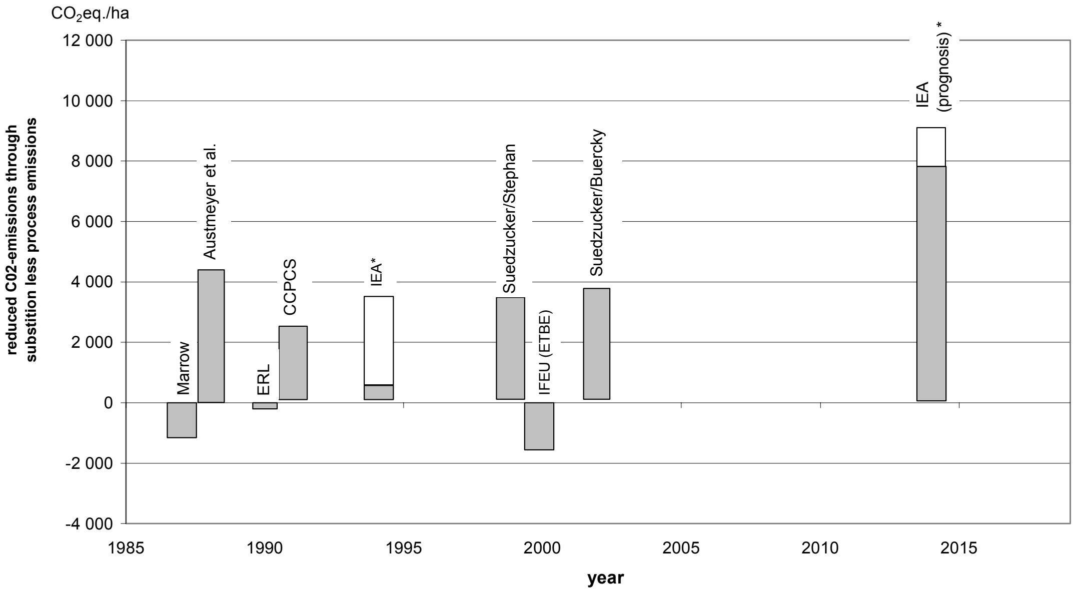
The net greenhouse gas balance for bio-ethanol based on sugar beets is more favorable *(Figure 7).* The use of traditional gasoline compared to the amount of bio-ethanol produced on one hectare of agricultural land causes 14000 kilograms of CO_2-equivalent emissions per hectare whereas the production of bio-ethanol only causes around 10000 kilograms of CO_2-equivalent emissions. This results in net savings of around 4000 kilograms in most of the studies. Again, the IEA-prediction assumes a reduction of fossil energy inputs during conversion which improves net greenhouse gas balances considerably.

Figure 6 — Net greenhouse gas balance in the production of bio-ethanol based on wheat



According to existing studies a comparison of the production of bio-ethanol based on wheat on the one hand and based on sugar beets on the other hand shows that concerning greenhouse gas emissions the cultivation of sugar beets for the production of bio-ethanol is more favorable.

Figure 7 — Net greenhouse gas balance in the production of bio-ethanol based on sugar beets

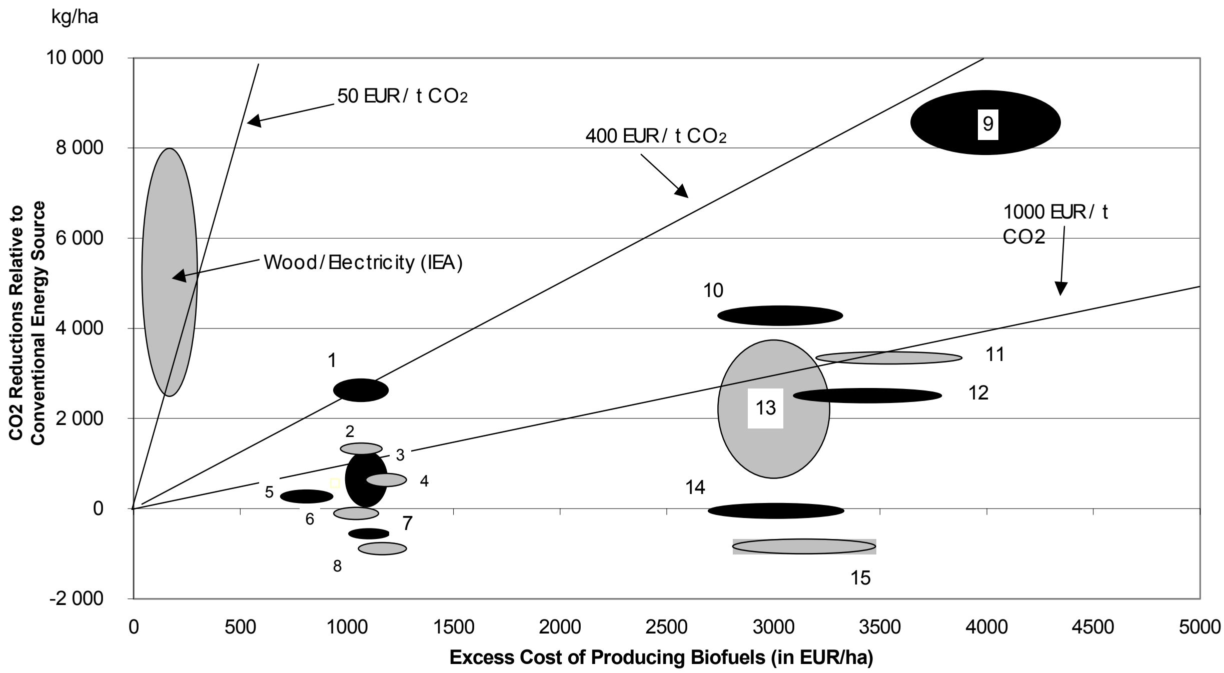


3.4.2 CO_2-Abatement Costs of the Bio-Ethanol Strategy

Results from the above energy and greenhouse gas balances show that under today's conditions of cultivation and conversion small savings of fossil energy sources and greenhouse gas emissions are possible if bio-ethanol is substituted for traditional gasoline. However, this does not justify the promotion of biofuels as a climate protection strategy. One still has to determine whether the bio-ethanol strategy could be a component of an efficient climate policy.

Greenhouse gas emissions have the same environmental impact no matter where and during what kind of process they are emitted. Therefore an efficient climate policy requires a reduction of greenhouse gas emissions at those sources where a reduction can be done at the lowest costs. The abatement costs of one ton of CO_2 in the European Union amount up to a maximum of 30 € given the European commitment in the Kyoto-protocol. Variations depend on the different climate policy instruments used (Böhringer and Löschel 2002, Klepper and Peterson 2002, European Commission 2000b). This figure should be used as the benchmark for the evaluation of the bio-ethanol strategy to reduce greenhouse gas emissions.

Figure 8 — Relationship between process costs and CO_2-abatement for producing biofuels



Wheat	1 IEA (Prognose)	2 Austmeyer)	3 IEA	4 CCPCS (Prognose)
	5 Marrow	6 ERL	7 CCPCS	8 Ecotraffic
Sugar beets	9 IEA (Prognose)	10 Austmeyer et al.	11 Suedzucker (Buercky & Stephan)	
	12 CCPCS	13 IEA	14 ERL	15 Marrow

Figure 8 gives an overview on the relationship between the amount of CO_2-reductions, the costs of bio-ethanol and the costs of reducing CO_2-emissions, as presented in the different studies on the production of bio-ethanol based on wheat and sugar beets, respectively. The y-axis shows possible CO_2-reductions in kilogram per hectare of cultivated land and the x-axis shows additional costs resulting from a substitution of traditional gasoline by bio-ethanol. Finally the straight lines show the combinations of CO_2-reductions and additional production costs that create a certain price for the reduction of one ton of CO_2. The left line for example illustrates the combination where the reduction of one ton of CO_2-costs around 50 €. Since some results of older studies do not show any reduction they fall below the x-axis. For the production of bio-ethanol based on wheat abatement costs of at least 1000 € per ton of CO_2 can be observed. Only the IEA predicts that with future technologies abatement costs of about 400 € per ton of CO_2 can be achieved. Abatement costs for the production based on sugar beets vary around 1000 € per ton of CO_2 and the IEA prediction lies around 500 €. *Figure 8* also shows that the additional cost of production per hectare are greater for sugar beets than for wheat. At the same time net greenhouse gas balances for sugar beets are more positive so that abatement costs turn out to be about the same. In order to illustrate alternative uses of agricultural land power generation based on fast-growing woods is also included. This alternative can save up to 5000 kilogram of greenhouse gas emissions per hectare, mainly because the GHG-emissions from conversion processes can be avoided. Therefore, the CO_2-abatement costs for this land use option amount to less than 50 € per ton (Nitsch, et al. 2001).

The cost of reducing GHGs with the bio-ethanol strategy could be lowered if by-products resulting from the production process can be sold at sufficiently high prices, if the production processes are optimized and if economies of scale are used by building large-scale production facilities. But even in such a best-case scenario abatement costs could only be lowered to about 300 € per ton of CO_2 for wheat and for sugar beets (Schmitz 2003). This would still be ten times the estimated abatement costs of alternative climate strategies. Therefore, the bio-ethanol strategy is an expensive policy option and not a first best alternative for climate policy. With the same economic effort a larger amount of greenhouse gas emissions could be avoided elsewhere.

4. Scenarios for the German Bio-Ethanol Market

It is clear from Chapter 2 that the production of bio-ethanol will take place in a policy environment that is heavily regulated. Agricultural policies, energy and climate policy, and trade policy have an important impact on the profitability of biofuels. At the same time these policies, but also technologies, are likely to change in the coming years. It is therefore helpful to have at hand a simulation tool with which alternative scenarios can be assessed. For this purpose a simulation model covering the bio-ethanol process from cradle to grave was developed.

4.1 The Model

The model reproduces the entire life cycle of bio-ethanol from the agricultural production, to the production of bio-ethanol itself and to its use as a fuel. Costs, prices and environmental effects of an increased use of ethanol can be computed. The model can simulate different market conditions, thus allowing for the identification of key variables, the creation of different scenarios and the evaluation of different policy and technology decisions (Schmitz 2003). With the help of the model the impact of changes in agricultural support can be assessed, or the cost-effectiveness of different agricultural feedstocks for the production of bio-ethanol, the employment effects, the effects of different plant sizes, tax revenue effects, the impact of changes in crude oil prices, and energy balances and greenhouse gas abatement costs can be computed. In the following a few results of scenarios for the production of bio-ethanol based on sugar beets and wheat, will be presented.

4.2 Some Scenarios

Bio-ethanol made of sugar beets: In this simulation 2% of bio-ethanol substitutes traditional fossil gasoline on the market in 2005. Until 2020 this number rises up to 13.3%. Farmers receive premiums for the cultivation of sugar beets, ethanol is only produced in large-scale plants and by-products create 10% additional revenues in agricultural production and 20% in the conversion process. Prices for sugar beets are based on expected prices for feedstock. The simulation is run for new technologies with low energy consumption and for current technologies with higher energy consumption. In both simulations the domestic production of bio-ethanol increases by 0.59 mio. cubic meters in 2005 to an additional 2.83 mio. cubic meters in 2020. Employment increases are 794 (in 2005) and 2848 persons (in 2020). This is accompanied by the exemption from the mineral oil tax with an amount of 254 mio. € in 2005 which rises to 1009 mio. € in 2020. Most notably, energy balances and GHG-abatement costs are strongly influenced by the introduction of new technologies. Greater energy efficiency reduces the abatement costs in the best-case scenario somewhat more than 200 € in 2020.

Bio-ethanol made of wheat versus bio-ethanol made of sugar beets: Using the above scenario with new technologies, prices of bio-ethanol on the basis of wheat are lower than prices of bio-ethanol based on sugar beets. The production based on wheat has a larger employment effect than the production based on sugar beets. However, a disadvantage of using wheat for the production of bio-ethanol is the fact that the energy balance is not as favourable and greenhouse gas abatement costs are higher than in the case of production with sugar beets.

The influence of crude oil prices and plant size: Crude oil prices strongly effect prices for gasoline. The model can show how much oil prices would have to rise to balance the higher costs for bio-ethanol. Crude oil prices of 20 $ per barrel result in a price difference of 34 cents per liter of bio-ethanol compared to gasoline (without taxes). If crude oil prices would rise to 50 $ per barrel the price difference would almost disappear. Hence, greenhouse gas abatement costs would be reduced significantly. Plant-size is another decisive factor. Increased size leads to economies of scale and therefore to lower prices for bio-ethanol and thus requires less price support.

5. Conclusions

The promotion of bio-ethanol as a gasoline substitute in Germany is in line with the recommendations by the EU to increase the share of renewable energy sources in all energy sectors. In order to make bio-fuels competitive against fossil fuels the former are completely exempted from the mineral oil tax. However, this is not the only state intervention.

The bio-ethanol production is subject to many additional regulations and support programs such as the set-aside premium, the partial state monopoly for ethanol, and price controls for agricultural products.

The support for bio-ethanol production is justified by the government with objectives such as support of the farm sector, energy security, and climate policy. In this paper the main focus is on the climate policy aspects of the bio-ethanol policies. For this purpose a review of all the available evidence for Germany was done by looking at the energy balances of different strategies, at the greenhouse gas (GHG) balances, and on the GHG-abatement costs.

The energy balance for the production of bio-ethanol has in the past been found to be negative or only slightly positive. I.e., the fossil fuels necessary to produce bio-ethanol were almost as high as the gasoline they would have replaced. This negative result has been improved by increased yields of the main feedstock, wheat and sugar beet, by lower fertilizer use, and by improvements in the conversion technologies. The evidence points to the direction that sugar beet has a slightly better energy balance than wheat.

The results for the GHG-balances are similar, although not as positive since the additional emissions of non-CO_2 GHG-emissions result in another disadvantage of biofuels. The net energy and net GHG-balances are to a large degree determined by the ratio at which bio-ethanol and fossil gasoline can be substituted in the car engine and yield the same performance. Since this issue has not been resolved, the net energy savings from bio-ethanol can hardly be predicted with accuracy.

Bio-ethanol is one strategy for producing renewable energy on agricultural soils. A comparison of different land use options shows that the yield of fossil energy saved from producing bio-ethanol on a hectare of land is lower than some alternatives. E.g., a direct use of the energy in biomass would create larger savings of GHGs than the production of biofuels.

An efficient climate policy scenario would consist of all measures that reach a specific GHG- reduction goal at lowest cost. Estimates of the cost of achieving the commitments of the EU as stated in the Kyoto Protocol amount to at most 30 € per ton of CO_2-equivalents. The assessment of the likely GHG-abatement costs for the bio-ethanol strategy vary strongly as they depend on many assumptions. However, the variation of 200 € to 1000 € per ton of CO_2-equivalents avoided is still far above the many other policy instruments that can be used to reduce GHG-emissions. Therefore, the promotion of bio-ethanol is not an economically viable option for climate policy.

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