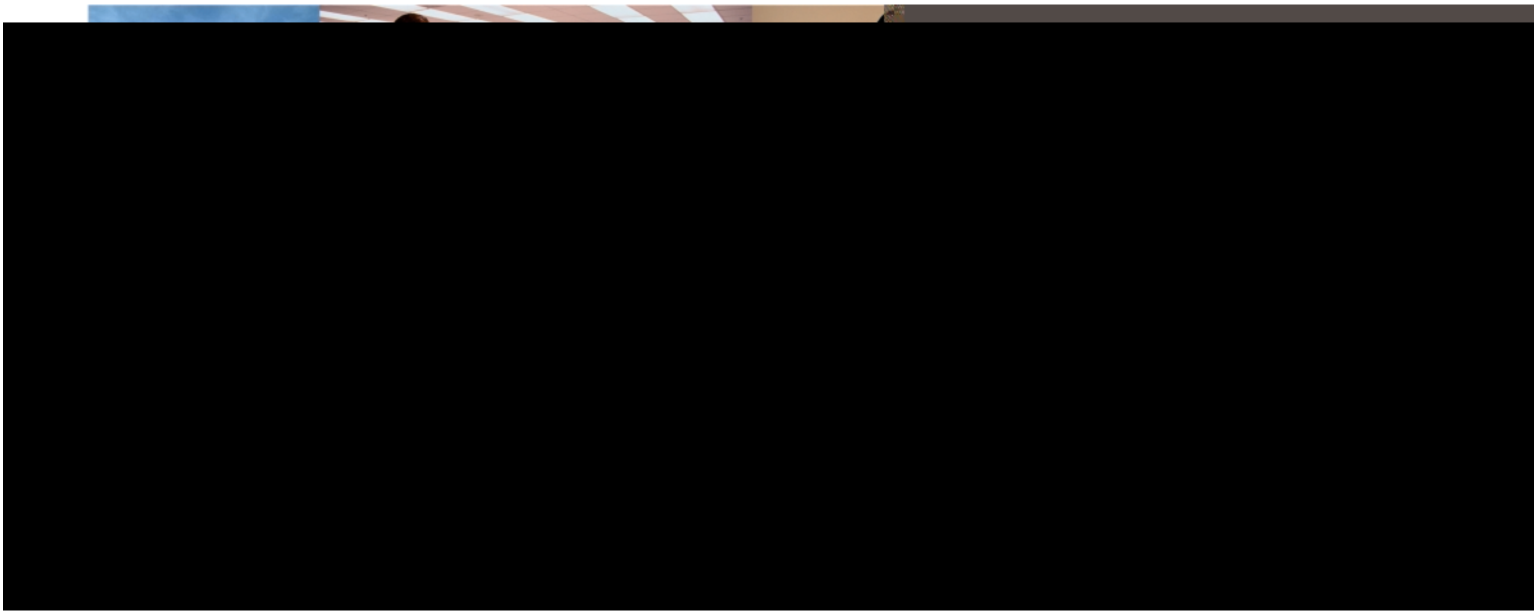
Biofuel potentials in the EU



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BIOFUEL POTENTIALS IN THE EU

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January 2004

PREFACE

This report represents an integral part of the overall research activity of IPTS in the field of alternative fuels for transport. Building on the findings from previous IPTS studies: “Techno-economic analysis of Bio-diesel production in the EU: a short summary for decision-makers” [15], “Techno-economic analysis of Bio-alcohol production in the EU: a short summary for decision makers”, [16], “Biofuel production potential of EU-candidate countries“ – Final Report [17] and Addendum to the Final Report [18], this report investigates the internal production potential of the EU for transport biofuel under different assumptions.

This report has been written by B. Kavalov. Significant contribution to the report has been given by Antonio Soria (IPTS). Other contributors were Dimitris Papageorgiou (Q-Plan, Thessaloniki / Greece, formerly – Atlantis Consulting S.A., Thessaloniki / Greece) and Peder Jensen [European Environmental Agency (EEA), Copenhagen / Denmark, formerly – IPTS].

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List of used abbreviations

k – Thousand

M – Million

BD – Biodiesel

BE – Bioethanol

BF – Biofuel(s)

DG – Directorate-General of the European Commission

EC – European Commission

EU – European Union

FD – Fossil Diesel

FF – Fossil Fuel(s)

FG – Fossil Gasoline

GJ – Giga Joule

ha – Hectare

l - litre

MJ – Mega Joule

t – ton (1 ton = 1000 kg.)

Mtoe – Million tons oil equivalent

EXECUTIVE SUMMARY

The European Commission has identified biofuels as an energy carrier that can contribute to the security and diversity of energy supply for the EU transport in an environmentally friendly way. In this context, the Directive 2003/30/EC of the European Parliament and the Council set up target shares of biofuels on the EU transport fuel market by 2010. Their reference values are 2% by the end of 2005 and 5.75% by the end of 2010 of all gasoline and diesel, used in transport, measured on energy content basis. Amongst different biofuel pathways available, producing bioethanol and biodiesel from agriculture-derived feedstock appears to be the most feasible, ready-to-market option. The production of such transport biofuels from agricultural feedstock is however constrained by one core limitation – the availability of land, since the use of land for biofuel purposes competes with other, prime applications of land. Devoting enough land to biofuel production is therefore a crucial factor to meet the biofuel targets.

The goal of this report is to investigate the internal production potential of the EU for transport biofuel under different assumptions. Part

land area requirements to meet the transport biofuel targets. This would be due to the larger relative biofuel crop potential of these two candidate countries, compared to the present EU-15 member states and the 10 New Acceding Countries.

The above conclusions are drawn, considering the following key preliminary assumptions and limitations:

Biofuel production from agriculture-derived feedstock is only assessed. Biofuel production from ligno-cellulosic material and/or biodegradable waste is not investigated.

The two most appropriate for transport application fuels – bioethanol (used either directly or in the form of bioETBE – Ethyl-Tetrio-Butyl-Ether) and biodiesel – are the only ones assessed.

The potential benefits from by-products of transport biofuel production with regards to other energy, agricultural and other policy objectives, are not taken into account.

The investigation and recommendation of policy options, such as how the land area needed to meet the transport biofuel targets can be made available for this purpose, is not subject to assessment.

The option to increase the EU biofuel supply via imports, which respectively will reduce the internal EU land area requirements for biofuel production, is not considered.

1. BACKGROUND

regulatory and market forces for food production. In addition, some non-food and non-biofuel applications of land (e.g. for growing flowers, pharmaceutical plants, wood for construction, etc.) normally earn higher profit than biofuels. Respectively, they are more competitive on the land market. Last, but not least, land can be employed for other bioenergy purposes, e.g. production of fuel for Combined Heat and Power (CHP) and/or for electricity generation. All together, these facts mean that the feasible size of land, which can be dedicated to production of transport biofuels, depends on a number of inter-related frameworks.

In this context, the goal of this report is to investigate the internal production potential of the EU for transport biofuel under different assumptions. Particular emphasis is given on the implications on the land area, which the indicative targets for transport biofuel would have. The identification of those land area requirements would allow further analysis how these land areas could be secured for producing transport biofuels, with regard to the alternative applications of land. However, such type of assessment is not performed herein, since it goes beyond the scope and the goal of the report, dealing with non-transport and non-energy issues and frameworks.

2. WORK DESCRIPTION

The report assesses the land area requirements to meet the transport biofuel targets within two enlarged scopes of the EU – 25 countries (EU-25) and 27 countries (EU-27). EU-25 includes the EU 15 member states[3] by the end of 2003 (EU-15), plus the 10 New Acceding Countries (NAC), which will join the EU in 2004[4]. EU-27 includes EU-25 plus 2 Candidate Countries (CC)[5], which may join the EU in 2007.

Referring to the stipulations in [2], the time frame of the analysis is 2005-2010.

Several preliminary assumptions and limitations have to be made explicit.

First, the focus is put on the agriculture-derived production of biofuels only, obtained via fermentation or oil extraction. Biofuel production from ligno-cellulosic material (wood, wood residues, fast growing trees and grass, straw, etc.) and/or all kinds of biodegradable waste, and/or via other technologies, e.g. Gas-To-Liquid (GTL) processing, is not considered. The reason is that currently all these options are at an experimental stage of development. For various techno-economic reasons, their potential market application seems feasible in a medium-term period, probably – beyond 2010 [20], [21].

Considering the typical climate conditions in Europe for agriculture, wheat, potato, sugar beet, rapeseed and sunflower are included in the analysis as potential feed-stocks for transport biofuels.

Only two biofuels with possible application in transport – bioethanol and biodiesel – are investigated, since they appear to be the most feasible by the time horizon of the analysis. Bioethanol and biodiesel can be mixed with conventional gasoline and diesel. When blended in low concentrations, these two biofuels can be handled over the existing infrastructure for liquid fossil fuels and can be used in current engines without engine modifications. Other biofuels with potential use in transport – pure vegetable oil, bio-Methanol, biogas (bio-Methane), bio-DME (bio-DiMethylEther) and bio-Hydrogen, are not considered. Pure vegetable oil has poor market prospective for large-scale application, because its use entails engine modifications[6]. Bio-Methanol, biogas, bio-DME and bio-Hydrogen are obtained mainly from ligno-cellulosic material and/or biodegradable waste, these raw materials are not subject to assessment in this report. Moreover, for various techno-economic reasons, these 4 bio-products are usually considered as feasible industrial-scale fuel options in a more long-term prospective, beyond 2010 [20]. On the other hand, the opportunity to use bioethanol in the form of bio-ETBE (bio-EthylTetrioButylEther) is included. Bio-ETBE is produced from bio-ethanol and isobutylene (a product from crude oil refining), where the bioethanol content

[3] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden and the United Kingdom

[4] Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovak Republic and Slovenia

[5] Bulgaria and Romania

[6] A more complete discussion on the transport application of pure vegetable oil can be found in "Unmodified vegetable oil as an automotive fuel", IPTS Report, http://www.jrc.es/home/report/report_main.html, Volume 74 – May 2003.

normally is 47% [2], [20]. Similar to neat ethanol, bio-ETBE can be blended with fossil fuels and if so – there is no need of infrastructure and engine modifications.

Due to the specifics in production pathways, it is assumed that bioethanol is obtained via fermentation of wheat, potato and sugar beet, while biodiesel comes out of oil extraction from rapeseed and sunflower.

[1] specifies only the total energy amount of biofuel that replaces gasoline and diesel. The baseline scenario in this report makes however a distinction between different biofuels connected to which fossil fuels they substitute for. It is assumed that bioethanol (either pure or as ETBE[7]) substitutes gasoline, while biodiesel replaces fossil diesel. The distinction is due to the differences in fuel properties – compatibility or incompatibility of one fuel to another, engine performance, etc. Those differences make difficult the simultaneous comparison of all fuels, e.g. biodiesel with gasoline. Consequently, the biofuel indicative targets are interpreted as meaning equal values for each fuel combination – "bioethanol / gasoline" and "biodiesel / fossil diesel". The corresponding land area requirements are calculated taking into account this distinction.

[1] sets up indicative targets for transport biofuel only for 2005 and 2010. Nevertheless, in order to describe better the process of moving from the starting to the final milestone, virtual intermediate biofuel targets by years (from 2006 to 2009) are included in the report – Figure 1. These intermediate targets identify the land resource, which gradually should be reserved for production of transport biofuels, in order to reach the final biofuel target, assuming a linear growth[8].

Figure 1
Policy-defined and virtual biofuel indicative targets

Year	Biofuel share, %	Source
2005	**2.00**	**Directive 2003/30/EC**
2006	2.75	Virtual
2007	3.50	intermediate shares,
2008	4.25	included in
2009	5.00	the report
2010	**5.75**	**Directive 2003/30/EC**

For the purposes of the report, a detailed forecast about the transport gasoline and diesel consumption in the EU within 2005-2010 is elaborated, based on the projections in [3] – Annex 1. The conversion factors, applied to different fuels assessed in the report, where needed, are given in Annex 2.

Last, but not least, the report makes an analysis of the land area, needed to meet the transport biofuel targets. The estimation and prop report. Consequently, the report does not deal with eventual changes in the EU frameworks (fuel taxation, agricultural regulations, et9ho[

values for EU-15, rather than by countries. This is due to the availability of enough input data with a satisfactory level of disaggregation for EU-15. Next, the calculations of the land area requirements in EU-15 are made in two variants, depending on whether the SNF or the OTP production output of NAC and CC is considered beforehand. For comparative purposes, the land area requirements out of EU-15 are juxtaposed to the EU-15 set-aside land. This is done, since it is sometimes assumed that a large part of the EU-15 set-aside land could potentially be employed for (transport) biofuel production [20].

Finally, the aggregated land area in enlarged EU, required to meet the corresponding transport biofuel targets, is calculated. This is done via summarising the land area in NAC and CC, which can be made available for production of biofuels, with the land area in EU-15, calculated using the approach from the previous paragraph. The enlarged EU requirements of land are again assessed in two cases, depending on whether the SNF or the OTP production output of NAC and CC is used as a starting point.

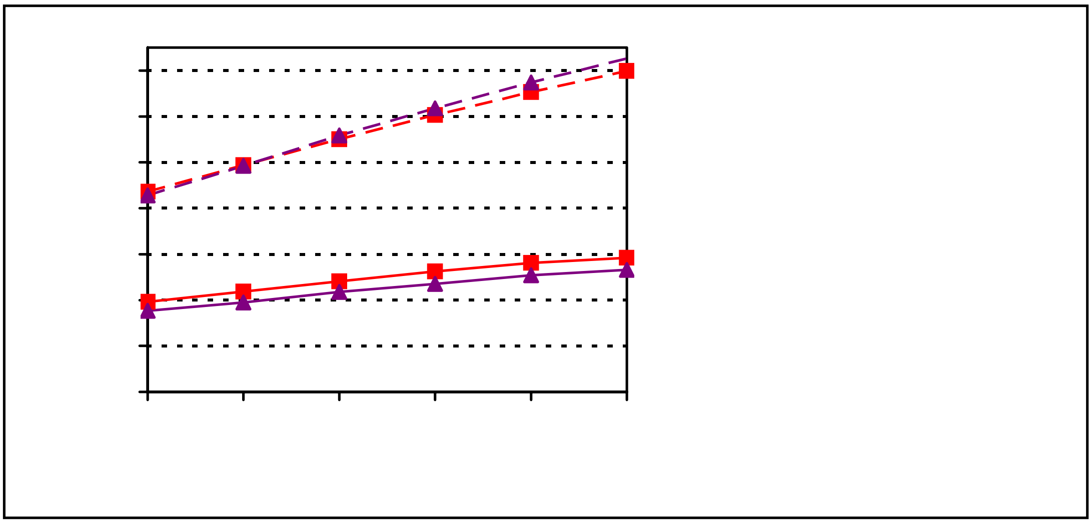
The land area requirements in all scenarios are expressed in relative terms, as a percentage of the corresponding arable land. The arable land is selected as criteria, since it represents the whole area under crop rotation schemes, i.e. used for agricultural production. The projections about the size of the arable land in EU-15, NAC and CC within 2005-2010 are enclosed in Annex 3.

3. FINDINGS

3.1. PRODUCTION POTENTIAL OF NAC AND CC

The land area in NAC and CC, corresponding to the SNF and the OTP scenarios for their biofuel production potential, are presented in Figure 2.

Figure 2
Land area in NAC and CC under the SNF and the OTP scenarios, which could be made available for production of transport biofuels (% of the NAC and CC arable land)



Since the biofuel production potential of NAC and CC is analysed in detail in [17] and [18], only a summary of the most important facts is presented herein. It is projected that the share of land for growing biofuel feedstock in NAC and CC could reach about 14% of their arable land at the maximum. The gradual increase of the land, which could be used for biofuel production, is due to assumed continuous improvement in cultivation patterns and agricultural management. Although, as it has been already pointed out in Section 2, achieving such levels will require significant resource support, mainly – funding, from outside e.g. from EU-15.

Another important conclusion, indicated by Figure 2, is that the relative reserves to expand the production of biofuels in CC are larger than in NAC. One reason for this is that the idle land in NAC is mainly motivated by the poor quality of soil for agriculture, rather than by economic problems. On the contrary, the non-utilisation of land in CC is due exclusively to economic drawbacks, which can be overcome via external financial support, e.g. from EU-15. For the same reason, the reserves to increase the crop yields per hectare in CC are generally larger than the reserves to increase the crop yields in NAC. Nonetheless, despite the identified reserves to increase the land area and the crop yields, the biofuel production potential of NAC and CC appears relatively moderate in general. Thus, NAC and CC could be considered as a positive, but small complement to the enlarged EU biofuel production, rather than as a large reserve of biofuel supply for the EU.

3.2. BIOFUEL YIELDS

The projections about the average transport biofuel yield per crops assessed in EU-15 over the period 2005-2010 are presented in Figure 3[11].

Figure 3
Prospective average biofuel yield from different crops in EU-15 over 2005-2010 (GJ/ha)

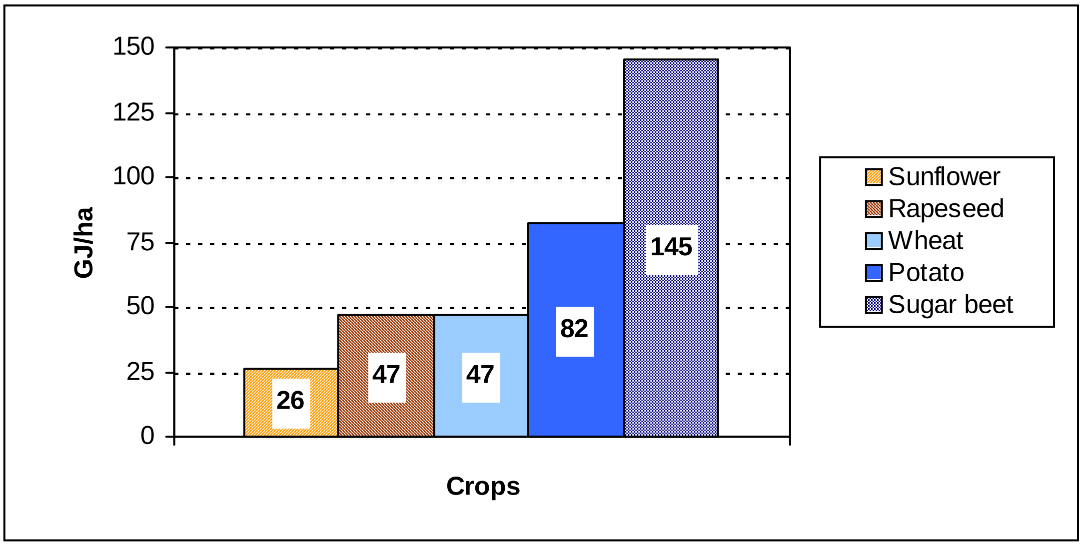


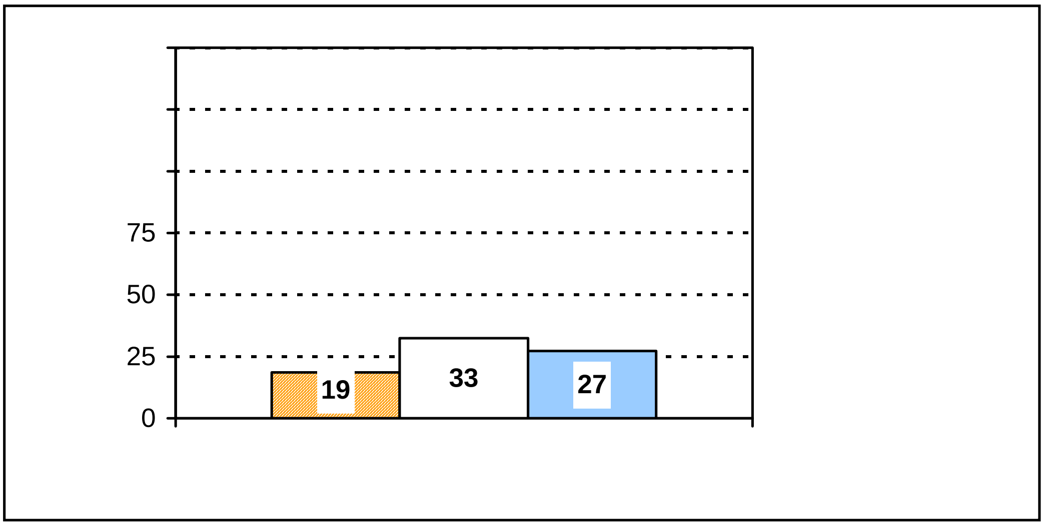
Figure 3 indicates that the bioethanol yield in EU-15 normally is higher than the biodiesel yield. Only under most optimistic estimates, the highest biodiesel yield may reach the amount of the lowest bioethanol yield from the crops considered. On equal terms, this means that a smaller land area will be needed to produce the same amount of transport biofuel, if this biofuel is bioethanol, rather than biodiesel.

Under prevailing conditions, the average yields from biofuel crops in NAC and CC are projected to be significantly lower, compared to those ones in EU-15 – Figure 4[12]. Whilst for oilseeds the average yields in NAC and CC will represent about 70% of the EU-15 average, for cereals (wheat) this proportion decreases to less than 60%. For this reason, the highest biodiesel yield per hectare in NAC and CC, in contrast with EU-15, is larger than the bio-ethanol revenue from the lowest ethanol-yielding crop – wheat.

On the other hand, the OTP scenario, constructed in [18], assumes that under most optimistic estimates, the oilseed yields in the NAC and CC could reach the EU-15 average by 2010. For bioethanol, the average maximal NAC and CC yields from wheat, potato and sugar beet are feasibly projected to reach 60-65% of the EU-15 average by 2005. This percentage might further increase up to 70-80% by 2010. Consequently, the assumed improvement of oilseed yields in NAC and CC related to reaching the EU-15 average yields, compared to the yields from bioethanol crops, is greater. This is due to the smaller gap between current oilseed yields in NAC and CC, and in EU-15.

[11] The calculating approach, the values by years and the information sources referred to are given in Annex 4.
[12] The calculating approach, the values by years and the information sources referred to are given in Annex 5.

Figure 4
Prospective average biofuel yield from different crops in NAC and CC over 2005-2009[13] (GJ/ha) – EC estimates



All together, it could be roughly considered that under most optimistic estimates, the average yields from sunflower and rapeseed in NAC and CC over the 2005-2010 period could reach 90% of the EU-15 average yields. For wheat, potato and sugar beet, this proportion could reach 70%. The corresponding approximate absolute biofuel yields by crops in NAC and CC, taken on average for the period 2005-2010, are presented in Figure 5. Figure 5 indicates that the bioethanol yield in the OTP scenarios for NAC and CC normally would be larger than the biodiesel yield – a situation, similar to the EU-15 one.

Figure 5
Projected approximate average biofuel yield from different crops in NAC and CC over 2005-2010 under most optimistic estimates (GJ/ha) – OTP estimates

[13] Projections for 2010 were not found. Projections about potato and sugar beet yields have not been found either. However, the IPTS study "Biofuel production potential of EU-candidate countries" has identified some current values and trends [18]. At present, the potato yield per hectare is about 20 tons – roughly 60% of the EU-15 average. The figures for the sugar beet yields vary substantially from year to year and is difficult to come up with an average figure. Even so, in all cases the prevailing sugar beet yields in NAC and CC are well below the EU-15 yields.

Bering in mind the results from Figure 3 and Figure 5, the scenarios, defined in Section 2, are further refined and complemented. Amongst all potential combinations of crops to meet the transport biofuel targets simultaneously by fuel brands (bioethanol / gasoline and bio-diesel / fossil diesel), for the sake of simplicity 3 variants are selected for further assessment only.

The first scenario ("Upper" case) assumes that the biofuel production will come from the crops with the lowest biofuel yield (wheat for bioethanol and sunflower for biodiesel). In such case, the "Upper" case defines the largest land area requirements to meet the transport biofuel targets simultaneously by fuel brands.

The second scenario ("Lower" case), on the contrary, assumes that the biofuel production will come from the crops with the highest biofuel yield (sugar beet for bioethanol and rapeseed for biodiesel). Consequently, the "Lower" case defines the lowest land area requirements to meet the transport biofuel targets simultaneously by fuel brands. The difference between the "Lower" and the "Upper" scenarios represents the range of variations, where all other potential crop combinations would fall within.

The third scenario is based on the identified here above general yield advantage of bioethanol over biodiesel. This scenario assumes that all biofuel, replacing fossil fuel, is bioethanol, produced from sugar beet – "Lowest" case. Due to this, the "Lowest" scenario defines the absolute least land area requirements to meet the aggregated targets for transport biofuel, without making distinction between fuel brands.

The selection of the above 3 scenarios is based on the use of land only for production of transport biofuels. Nonetheless, within a broader range of techno-economic criteria and policy frameworks, the relative utility of the feedstocks selected may change. For instance, the production of transport biofuels from wheat and rapeseed generates significant quantities of straw as a by-product. Straw can be used for other energy purposes, as a fuel in combined heat & power (CHP) or electricity generation. As a result, straw would improve the security and diversity of the overall energy supply, will lower the GHG emissions and will contribute to other energy policy objectives[14]. Other, non-energy and non-transport policy concerns, e.g. use of by-products as animal feed, suitability to crop rotation, other ecological concerns (e.g. preserving biodiversity) etc., may also favour one or another crop. Thus, the selection of biofuel crops may depend in practice on a number of inter-related policy objectives.

3.3. LAND AREA REQUIREMENTS IN EU-15 WITHIN EU-25

The land area requirements in EU-15 to meet the transport biofuel targets from Figure 1 for EU-25, considering the feasible biofuel production of NAC and CC (Section 3.1), are presented in Figure 6.

[14] More complete discussion on different EU policy targets in the field of renewable energies in general and bioenergy in particular, and their inter-relations can be found in "Land area requirements to meet the targets of the renewable energy policies in the European Union", IPTS Report, Volume 80 – December 2003.

Figure 6
Upper, lower and lowest land area requirements in EU-15 to meet the transport biofuel targets in EU-25, considering the NAC biofuel output (% of the EU-15 arable land)

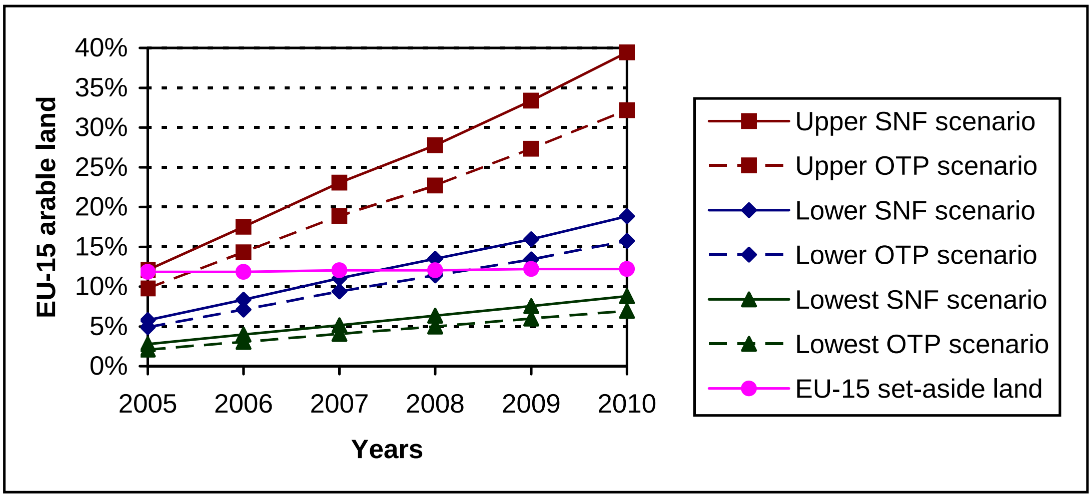


Figure 6 indicates that meeting the 2005 biofuel target simultaneously by fuel brands can be achieved with the usage of a relatively moderate land area – between 5% and 12% of the EU-15 arable land. Although, a much larger area – between 16% and almost 40% of the EU-15 arable land – should be reserved to reach the 2010 biofuel target. If the whole transport biofuel production comes as bioethanol, significant reductions in the land area requirements can occur. In such a case, 7-9 % of the EU-15 arable land will be sufficient to meet the 2010 biofuel target, i.e. a land area, which is less than the EU-15 set-aside land. Unlike the case from Section 3.1, here the gradual increase in the land area, which should be reserved for biofuel production, is due to the smaller growth in crop yields, compared to the combined increase in the gasoline and diesel consumption (affecting the amount of biofuel needed) – Annex 1 and in the biofuel targets (Figure 1). On the other hand, the slower growth in the land area requirements in the OTP scenarios, compared to the SNF cases, is due to the larger relative increase of the OTP crop yields.

3.4. LAND AREA REQUIREMENTS IN EU-15 WITHIN EU-27

The land area requirements in EU-15 to meet the transport biofuel targets from Figure 1 for EU-27, considering the feasible biofuel production of NAC and CC (Section 3.1), are presented in Figure 7. Basically, the results and the conclusions for EU-27 from Figure 7 are similar to those ones for EU-25 in Figure 6. However, the land area requirements for EU-27 are slightly lower than those ones for EU-25, due to the larger reserves to expand the biofuel production in CC, compared to NAC (see Section 3.1). Another consequence from this larger biofuel potential of CC is that the gap between the OTP and the SNF projections, describing the slowing down growth in the land area requirements, expands faster and becomes wider in the case of EU-27, compared to EU-25. This wider gap is due to the larger relative increase both in the land area for biofuel crops and in the biofuel crop yields in CC, compared to NAC.

Figure 7
Upper, lower and lowest land area requirements in EU-15 to meet the transport biofuel targets in EU-27, considering the NAC & CC biofuel output (% of the EU-15 arable land)

Similar to the case of Figure 6, meeting the 2005 transport biofuel target simultaneously by fuel brands requires the employment of a relatively moderate land resource – between 5% and slightly more than 9% of the EU-25 arable land. Nevertheless, a much larger land – between 14% slightly more than 27% of the EU-25 arable land – should be reserved for growing biofuel feedstock to meet the 2010 biofuel target. If bioethanol is the only biofuel produced, those land area requirements may drop significantly to 8-9% of the total EU-25 arable land, i.e. a land area, which is similar in size to the assumed set-aside land. The major difference between the findings from Figure 6 and Figure 8 is that within EU-25 the “Lower” and the “Lowest” OTP land area requirements are larger than the SNF requirements. This fact is due to the higher crop yields in EU-15, compared to those ones in NAC. From this point of view, in order to reduce the overall EU-25 land area requirements, it appears more reasonable to put the emphasis on developing biofuel production in EU-15, rather than in NAC. The larger “Upper” SNF land area requirements, compared to the OPT ones, from Figure 8 ensue from the assumed much lower crop yields in NAC, compared to EU-15. This is also reconfirmed by the much larger gap between the OTP and SNF “Upper” estimates, compared to the corresponding “Lower” and “Lowest” forecasts in Figure 6.

3.6. LAND AREA REQUIREMENTS IN EU-27 WITHIN EU-27

The aggregated land area requirements in EU-27 to meet the transport biofuel targets from Figure 1 for EU-27 are presented in Figure 9. In fact, Figure 9 summarises the findings from Figure 2 and Figure 7.

Figure 9
Upper, lower and lowest land area requirements in EU-27 to meet the transport biofuel targets

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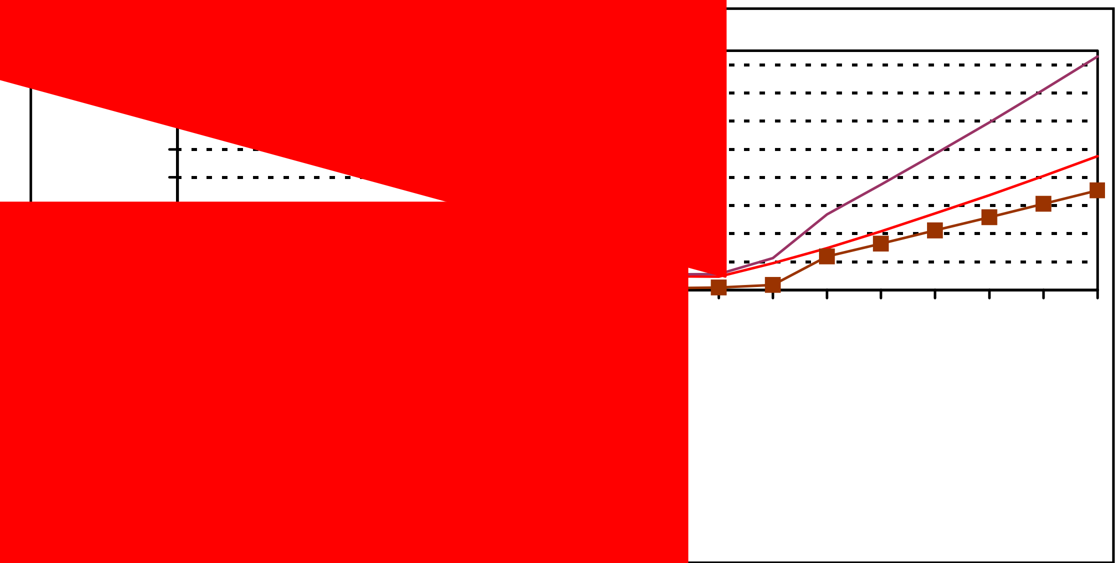

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NAC and CC [17] [18]. Such large growth could be constrained not only by the availability of land for growing biofuel feedstock, but by other factors as well, e.g. building new processing capacities takes time. If such large expansion in the biofuel processing capacities happens simultaneously, it could be delayed also by from the already mentioned straw, an eventual expanded production of biodiesel from rapeseed will earn significant amounts of glycerol as by-product. At present, there is not enough market demand capacity, which can absorb such large quantities of glycerol. In this aspect, the oleo-chemical industry is afraid that an eventual large-scale application, respectively – production of biodiesel may lead to a destruction of the glycerol market balance [20].

Last, but not least, the above calculations of the land area requirements presume that the whole biofuel produced will be used only in transport. While for bioethanol this assumption could be considered as generally correct, for biodiesel this could not be the exact situation in real market conditions, due to the availability of alternative energy applications of biodiesel. For example, currently 90% of biodiesel production in Italy (the 3

Such high bioethanol content will most probably require some engine modifications. Consequently, it will not be possible to use bioethanol as a mass fuel in conventional vehicles any longer. On the other hand, adapting vehicles to the new qualities of this mixed fuel will be always accompanied by additional costs, which will reduce its market attractiveness. For these reasons, the use of bioethanol blends, higher than 10% by volume, is not a wide-spread practice for the moment [16] [23] [24].

Blending bioethanol with gasoline in the form of ETBE does not appear to solve the above drawbacks either. In general, the application of bioethanol as ETBE is preferred, rather than its neat use [23]. This is due to the avoidance of some engine performance penalties of direct ethanol blending, mainly – the increased volatility of the mixed fuel, beyond the limits, defined by current standards [24] [28]. However, the acceptable upper limit of the ETBE content into gasoline is 15% in volume [20] [29]. Considering the ethanol share in ETBE, this means that the bioethanol content in gasoline will be about 7% in volume at the maximum. As it can be seen from Figure 11, this proportion is still far away from the blending share needed, if all biofuel comes as bioethanol. Last, but not least, the feasible quantity of ETBE is constrained by the technological availability of isobutylene, obtained from oil refining [16] [20].

Another solution could be blending bioethanol (up to 10-15%) with fossil diesel, which fuel mix is known as "E-diesel", "Oxydiesel" or "Diesohol". At a first glance, this option seems quite appropriate and promising. It would lead to a reduction in the overall land area requirements, because bioethanol yield is normally larger than biodiesel yield. Furthermore, some recent experimental results indicate that Oxydiesel could offer emission savings [20] [27]. Even so, for the moment Diesohol is generally not considered as a convenient transport fuel option. Its key drawback is the very low flash point – about 13 C [23]. Such low flash point poses high explosion risks. Until the problem with the low flash point of Oxydiesel, together with some other performance question-marks (e.g. reduced lubricity and fuel economy, lack of sufficient experimental results about emission performance and health impacts, etc.), is solved, any commercial application of E-diesel appears therefore not feasible [23].

From the supply point of view, an eventual expansion of bioethanol production from sugar beet raises a number of techno-economic complications as well.

First, a significant growth in the land area with sugar beet will be needed to reach the 2010 transport biofuel target. At present, the land area in EU-15, sown with sugar beet for all types of applications, occupies about 2.5% of the EU-15 arable land [8] [10]. In order to meet the 2010 biofuel target in the "Lowest" scenarios, the size of this land area, reserved only for transport biofuel purposes, should be multiplied by a factor of 2 or 3. This extended land area, however, does not include the remaining, non-transport biofuel usages of sugar beet. On the other hand, over the past decade the land area with sugar beet in EU-15 was steadily declining – by 1.6% per year on average [8].

The above situation does not improve when looking at enlarged EU either. Currently, 2.2% of the arable land in enlarged EU is sown with sugar beet [7] [8]. To reach the 2010 transport biofuel target, this land area, dedicated only to biofuel production, should grow by a factor of 3 or 4. Again, this extended land area does not include any other, non-biofuel usages of sugar beet.

The significant growth in the land area with sugar beet to meet the 2010 transport biofuel target is likely to be constrained in practice by several factors. Due to its cultivation specifics, sugar beet should be included into crop rotation schemes, similar to oilseeds. This fact automatically complicates the required huge expansion of the land for sugar beet, since

5. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

Based on the analysis, performed in the previous sections, the following conclusions about the production of transport biofuel in the EU could be highlighted:

Meeting the 2% transport biofuel target in 2005 is not likely to cause significant distortions to the agricultural production patterns in the EU. Although, considering the recent production of biofuels (0.3% of the EU automotive fuel demand), substantial efforts will be needed to achieve the 2% target in 2005.

Meeting the 5.75% transport biofuel target in 2010 most probably will require significant changes in the agricultural production patterns in the EU. Considering a larger framework of techno-economic concerns and agriculture policy objectives, implementing such changes might be quite challenging in practice.

On equal terms, the production of bioethanol requires less land than that of biodiesel, due to a larger biofuel yield per hectare from the crops-potential feedstock for bioethanol. Consequently, producing all biofuel as bioethanol would lead to a significant reduction in the land area, needed to meet the transport biofuel targets. Nevertheless, other techno-economic and policy-related drawbacks, associated with crop cultivation specifics and agricultural regulations, are likely to appear in this case.

Blending bioethanol with fossil diesel appears as a promising tool to reduce the land area requirements, in view of meeting the transport biofuel targets. A number of technical drawbacks, related to fuel qualities and engine performance, should however be solved before this fuel option becomes feasible in practice.

A potential further enlargement of EU-25 (EU-15 plus 10 NAC) with 2 CC – Bulgaria and Romania, would reduce the relative land area requirements to meet the transport biofuel targets. This would be due to the larger relative biofuel crop potential of these 2 CC, compared to EU-15 and NAC.

Building on the above conclusions, several suggestions for further research could be identified:

Trends in improving processing technologies for ligno-cellulosic feedstock.

Progress in the development of other biofuels (F-T biodiesel, bio-DME, bio-Methanol, biogas, bio-Hydrogen) and related technologies (GTL processing) with potential transport application, in view of their market prospects.

Assessment of the EU biofuel production potential, based on ligno-cellulosic feedstock, with regard to the land area availability in the EU. Due to the specifics of the ligno-cellulosic feedstock, it would be more appropriate for the analysis to consider as a basis for comparisons the Utilised Agriculture Area[20], rather than the arable area.

Assessment of potential technical and technological solutions to overcome the drawbacks of ethanol blending with fossil diesel.

[20] The utilized agricultural area comprises all lands, which can potentially be used for biomass production – arable land, permanent grasslands, permanent crops, crops under glass and kitchen gardens.

6. ANNEXES

Annex 1

Projections for gasoline and diesel consumption in transport for EU-25 and EU-27 for the period 2005-2010; Amount of biofuel needed to meet the indicative and virtual transport biofuel targets[21]

EU-25[22]	2005	2006	2007	2008	2009	2010
FG, Mtoe	133.0	134.2	135.4	136.6	137.8	139.1
FD, Mtoe	159.9	163.3	166.8	170.4	174.1	177.8
FG+FD, Mtoe	292.9	297.5	302.2	307.0	311.9	316.9
BF, %	2.00	2.75	3.50	4.25	5.00	5.75
BE, Mtoe	2.7	3.7	4.7	5.8	6.9	8.0
BD, Mtoe	3.2	4.5	5.8	7.2	8.7	10.2
BE+BD, Mtoe	5.9	8.2	10.6	13.0	15.6	18.2
EU-27[23]	2005	2006	2007	2008	2009	2010
FG, Mtoe	136.2	137.6	139.1	140.5	142.0	143.5
FD, Mtoe	162.7	166.3	170.0	173.8	177.6	181.6
FG+FD, Mtoe	298.9	304.0	309.1	314.3	319.6	325.1
BF, %	2.00	2.75	3.50	4.25	5.00	5.75
BE, Mtoe	2.7	3.7	4.7	5.8	6.9	8.0
BD, Mtoe	3.2	4.5	5.8	7.2	8.7	10.2
BE+BD, Mtoe	6.0	8.4	10.8	13.4	16.0	18.7

Annex 2

Properties of fuels assessed

Fuel	Density (kg/1000 l)	Energy content (MJ/l) [19]	Energy content ratio[24]
Bioethanol	798[25]	21.2	1.472 (BE/FG)
Gasoline	745 [26]	31.2	0.679 (FG/BE)
Biodiesel	880[27]	32.8	1.088 (BD/FD)
Fossil diesel	837.5	35.7	0.919 (FD/BD)

[21] Differences, if any, in the cumulative values are due to rounding.

[22] The forecast for EU-25 is based on the projected in [3] 2010 net values (without the amount of biofuel), discounted for the period 2009-2005 with the average annual growth rate of consumption – 0.9% for gasoline and 2.1% for diesel (Table 4-15 on page 121 in [3]).

[23] Since a forecast for the transport gasoline and diesel consumption in EU-27 is not explicitly performed in [3], some approximations are established for the 2 CC – Bulgaria and Romania. First, the amount of their total transport fuel consumption for 2005 and 2010 is taken from the Tables on page 188 and 208 in [3]. Second, these values for 2005 and 2010 are used to extrapolate the 2006-2009 transport fuel consumption, assuming linear growth. Third, the consumption of gasoline and diesel is derived as a share of total transport fuel consumption – 47.18% and 40.67% respectively. These shares are calculated from the 2010 estimates for total transport fuel, gasoline and diesel consumption in the EU candidate and neighbour countries (Table 3-16 on page 94 in [3]).

[24] The fuel consumption replacement ratio on energy content basis represents the volume of fuel, which is needed to replace 1 litre of another fuel.

[25] Source: REPSOL-YPF.

[26] The gasoline and fossil diesel densities represent average values, adopted from [23].

[27] Source: PSA Peugeot-Citroen

Annex 3

Projections about the size of the arable land in EU-15, NAC, CC, EU-25 and EU-27 over the period 2005-2010, and the size of the set-aside land in EU-15, EU-25 and EU-27

Land area (Mha)	2005	2006	2007	2008	2009	2010
EU-15 arable land [6]	53.2	53.2	53.2	53.2	53.2	53.2
EU-15 set-aside land [6]	6.3	6.3	6.4	6.4	6.5	6.5
NAC arable land[28]	29.2	29.2	29.2	29.2	29.2	29.2
NAC and CC arable land	42.5	42.5	42.5	42.5	42.5	42.5
EU-25 arable land	82.4	82.4	82.4	82.4	82.4	82.4
EU-25 set-aside land[29]	8.24	8.24	8.24	8.24	8.24	8.24
EU-27 arable land	95.7	95.7	95.7	95.7	95.7	95.7
EU-27 set-aside land[30]	9.57	9.57	9.57	9.57	9.57	9.57

Annex 4

Projections about the average transport biofuel yield (in GJ/ha) from different crops on year-by-year basis in EU-15 over the period 2005-2010

Biofuel feedstock	2005	2006	2007	2008	2009	2010
Wheat yield (t/ha) [6]	6.2	6.2	6.3	6.3	6.4	6.4
Bioethanol yield (l/ton) [16]	350	350	350	350	350	350
Bioethanol yield from 1 ton wheat (GJ)	7.42	7.42	7.42	7.42	7.42	7.42
Bioethanol yield – wheat (GJ/ha)	**46.0**	**46.0**	**46.7**	**46.7**	**47.5**	**47.5**
Potato yield (t/ha)[31]	40	41	42	43	44	45
Bioethanol yield (l/ton) [16]	91	91	91	91	91	91
Bioethanol yield from 1 ton potato (GJ)	1.93	1.93	1.93	1.93	1.93	1.93
Bioethanol yield – potato (GJ/ha)	**77.2**	**79.1**	**81.1**	**83.0**	**84.9**	**86.9**
Sugar beet yield (t/ha)[32]	66.0	67.0	68.0	69.0	70.0	71.0
Bioethanol yield (l/ton) [16]	100	100	100	100	100	100
Bioethanol yield from 1 ton sugar beet (GJ)	2.12	2.12	2.12	2.12	2.12	2.12
Bioethanol yield – sugar beet (GJ/ha)	**139.9**	**142.0**	**144.2**	**146.3**	**148.4**	**150.5**
Rapeseed yield (t/ha) [6]	3.4	3.4	3.4	3.5	3.6	3.6
Biodiesel yield (l/ton) – adopted from [15]	409	409	409	409	409	409
Biodiesel yield from 1 ton rapeseed (GJ)	13.42	13.42	13.42	13.42	13.42	13.42
Biodiesel yield – rapeseed (GJ/ha)	**45.6**	**45.6**	**45.6**	**47.0**	**48.3**	**48.3**
Sunflower yield (t/ha) [6]	1.7	1.7	1.7	1.8	1.8	1.8
Biodiesel yield (l/ton) – adopted from [15]	455	455	455	455	455	455
Biodiesel yield from 1 ton sunflower (GJ)	14.91	14.91	14.91	14.91	14.91	14.91
Biodiesel yield – sunflower (GJ/ha)	**25.3**	**25.3**	**25.3**	**26.8**	**26.8**	**26.8**

[28] The figures for NAC and CC represent average values from the 1996-2000 retrospective data, given in [7].

[29] Detailed projections about the size of the set-aside land in EU-25 have not been found. However, [10] states that the 10% mandatory set-aside will be kept in the future. On the other hand, the same source assumes that the growth in the voluntary set-aside after the accession of NAC will be limited, due to decoupling of the area payments. Based on these reasons, this report assumes that the size of the overall (mandatory and voluntary) set-aside land, as share of the arable land, will decrease after the enlargement of the EU in 2004. Therefore, the prospective percentage of the set-aside land in EU-25 in this report is taken at the level of the mandatory 10% set-aside.

[30] No projections about the set-aside in EU-27, if any, have been found. Therefore, the approach, applied to EU-25, is extrapolated to EU-27.

[31] Extrapolated from the recent trends (1998-2001), identified from [9].

[32] Extrapolated, based on input data from [16], [20] and [25]

Annex 5

Projections about the average transport biofuel yield (in GJ/ha) from different crops on year-by-year basis in NAC and CC over the period 2005-2010

Biofuel feedstock	2005	2006	2007	2008	2009
Wheat yield (t/ha) [4] [5]	3.58	3.62	3.67	3.71	3.82
Bioethanol yield (l/ton) [16]	350	350	350	350	350
Bioethanol yield from 1 ton wheat (GJ)	7.42	7.42	7.42	7.42	7.42
Bioethanol yield – wheat (GJ/ha)	**26.6**	**26.9**	**27.2**	**27.5**	**28.3**
Rapeseed yield (t/ha) [4] [5]	2.37	2.41	2.44	2.47	2.43
Biodiesel yield (l/ton) – adopted from [15]	409	409	409	409	409
Biodiesel yield from 1 ton rapeseed (GJ)	13.42	13.42	13.42	13.42	13.42
Biodiesel yield – rapeseed (GJ/ha)	**31.8**	**32.3**	**32.7**	**33.1**	**32.6**
Sunflower yield (t/ha) [4] [5]	1.25	1.25	1.25	1.25	1.25
Biodiesel yield (l/ton) – adopted from [15]	455	455	455	455	455
Biodiesel yield from 1 ton sunflower (GJ)	14.91	14.91	14.91	14.91	14.91
Biodiesel yield – sunflower (GJ/ha)	**18.6**	**18.6**	**18.6**	**18.6**	**18.6**

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