Biofuels in the European Context: Facts and Uncertainties

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JRC 43285

FOREWORD

"Biofuels" is currently the subject of a wide ranging societal and political debate. Questions of costs, security of energy supply, green house gas emissions, sustainability of production systems, impact on food production and on biodiversity are some of the many issues which have been associated with a renewed interest in that source of energy.

Together with other stakeholders, the Joint Research Centre has been studying aspects relevant to biofuels in different contexts for a number of years. In order to provide an up-to-date analysis of policy issues and thereby contribute to the current debate, it has pulled together these results and other available studies. This has resulted in the present report which is presented as a contribution to an ongoing debate. It has not been adopted by the Commission and does not represent official policy of the Commission.

The report presents facts, findings and models regarding biofuels in a broad context. It points out the associated uncertainties. The document identifies scenarios which may evolve in either a predictable or non predictable way in the future but which in turn may considerably influence the debate. Finally, this report has identified open issues.

The draft report was prepared as a contribution to the January 2008 Commission proposal for a Directive on the promotion of the use of energy from renewable sources which was made against the background of the commitment by the European Council of March 2007 to a set of targets on energy and climate change. In particular, the European Council agreed to a target of a 20% share of renewable energies in overall Community energy consumption by 2020, and a specific target on biofuels:

"a 10 % binding minimum target to be achieved by all Member States for the share of biofuels in overall EU transport petrol and diesel consumption by 2020, to be introduced in a cost-efficient way. The binding character of this target is appropriate subject to production being sustainable, second-generation biofuels becoming commercially available and the Fuel Quality Directive being amended accordingly to allow for adequate levels of blending."

Findings in the report confirm the need for the inclusion of environmental sustainability criteria for the use of biofuels and the need for close monitoring of sustainability performance during the implementation phase as foreseen in the proposed Directive. This should include actual greenhouse gas savings, including emissions from land use change.

This report is not a final product. The Biofuels Task Force (BTF) created by the JRC to pool its knowledge and address future challenges will continue to work on these issues to improve our capacity to respond to complex requests in an integrated manner. JRC will also continue to work with relevant partners and stakeholders. This includes our institutional customers, mainly DG TREN, DG ENV, DG AGRI, DG RTD, and DG ENTR, as well as major industrial partners.

Giovanni F. De Santi
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1. INTRODUCTION

This report examines the question of biofuels use in Europe from the following perspective:

1. What are the objectives of pursuing a biofuels programme?
2. Will a biofuels programme achieve its objectives?
3. Will the benefits of a biofuels programme exceed its cost?

The report starts with a description of current and future biofuels technologies and a brief description of their advantages and disadvantages, and follows with a description of the objectives of the biofuels programme. Then the likelihood of meeting the objectives is considered, as are the costs of doing so. The impact of the programme on food prices is considered next, and finally the results of a cost benefit analysis are presented.

2. WHAT ARE BIOFUELS?

2.1. Conventional Biofuels (1st generation)

Bioethanol is made by conventional fermentation and distillation of sugar and starch

***Bioethanol** is made by conventional fermentation and* distillation of sugar and starch. In EU the main feed-stocks in EU are sugar beet, feed-wheat, barley and some maize. The by-product (“stillage” or “DDGS”) is usually used for animal feed. The reform of the sugar regime concentrates sugar beet production in the most efficient areas and allows expansion of production there for ethanol. Bioethanol is produced more cheaply in Brazil from sugar cane, and generally with a better green-house gas (GHG) balance. In US bioethanol is produced from maize with a generally worse GHG balance.

Up to 5% ethanol can be blended in gasoline without technical or emissions problems.

Higher blends (10 or perhaps 15% ethanol in gasoline) require small car-modifications and derogation of hydrocarbon emissions limits. Blends deliver the same car-km for a given energy content as pure gasoline, but ethanol has a lower energy density. Ethanol-rich fuels (85% or more of ethanol) require adapted engines, but can give improved engine efficiency.

Biodiesel is easiest to make from rapeseed (colza), which grows well in Europe.

Biodiesel meeting fuel specifications is easiest to make from rapeseed (colza), which grows well in Europe. This is separated into oil and cake, which at present is used for animal feed. The oil is reacted with methanol to produce biodiesel (rapeseed methyl ester, RME) and glycerine by-product, which temporarily has problems to find a market.

Rapeseed is already grown in most EU areas where it makes agro/economic sense, but there are limits due to rotation. According to [DG-AGRI 2007b], the annual projection of agricultural production in EU by DG-AGRI to 2013, the production of rapeseed in EU will only increase slowly despite much higher demand: in fact increased EU oilseed production can only just keep pace with the foreseen increase in food demand. Therefore EU rapeseed oil is being diverted from the food market, to be replaced by imported oilseeds and oils, particularly the cheaper palm oil.

It is possible to replace methanol by bioethanol to produce REE (rapeseed ethyl ether).

The direct use of pure vegetable oil is not approved by car manufacturers as they say it can form damaging deposits in the engine and fuel system.

Biodiesel has the advantage over bioethanol that it replaces diesel rather than gasoline.

Neste Oil Company recently introduced “neXt” diesel, made by treating vegetable oil with hydrogen, to produce a pure hydrocarbon diesel. The process itself is more expensive than the conventional (trans-esterification) biodiesel process, but it works on any vegetable oil (e.g. palm oil).or animal fat

Biodiesel has the advantage over bioethanol that it replaces diesel rather than gasoline. EU is increasingly short of diesel: refineries must spend energy and money to increase the ratio of diesel to gasoline.

Making biogas from wastes saves much greenhouse gas. However, its best use is not in transport

Compressed Biogas. Anaerobic digestion of wet manure (slurry) and organic waste from food-industry and municipal sources produces methane which, purified, can replace natural gas, and be compressed for road fuel. The existing natural gas grid would be used for distribution, except where the biogas plant is not on the grid. However, the biogas supply is limited by feedstock availability: the marginal source of methane is still natural gas imports. Whichever methane is used for road-fuel, the marginal effect is an increase of natural gas imports. So the marginal GHG benefit of running cars on gas from the grid is the same whether the gas originated from biogas or natural gas.

Making biogas itself saves GHG emissions because it avoids methane release from stored manure, but it is more economic to use biogas locally, to generate electricity and heat. This saves the cost of purification, distribution, compression, storage, and vehicle modifications.

2.2. Second Generation Biofuels

Second generation biofuels can be made from almost any form of biomass…

Second generation biofuels can be made from almost any form of biomass. If made from forest- or crop-residues, they do not compete with food for feedstock. However, if made from dedicated energy crops, they compete for land and water resources. Some energy crops (switchgrass, poplar...) can be also grown (at reduced yield) on present grassland. It is not known how much soil carbon would be released by this change in land use. Much depends on ground cover and how much soil is disturbed in planting.

…but are still at the pilot plant stage…

Second generation processes are still at the pilot plant stage. They are complex and very expensive, but can use cheaper feedstock. They emit much less GHG than typical 1st generation biofuels because the growing the feedstock has low inputs, and the processes use biomass waste streams for process heat

Thermochemical processes ("biomass to liquids", BTL) work by gasifying wood then synthesizing road-fuel from the gas. The sub-units (gasifier, gas separation, Fischer-Tropsch synthesis…) already exist in other industrial processes: they only need integration. This means one can predict performance and cost, but scope for future improvement is limited.

The cellulose-to-ethanol process (which best uses straw and wet biomass), is more innovative. Technology breakthroughs are needed to make it competitive, and these are unpredictable.

…and are unlikely to be competitive by 2020.

It is unlikely that 2nd generation biofuels will be competitive with 1st generation by 2020, and will anyway use largely imported biomass. Techno-economic analysis [JEC 2007] indicates 2nd generation biofuels will be much more expensive than first generation biofuels. Costs are dominated by investment cost of the plant. In order to arrive at overall production costs competitive with first generation biofuels, one would have to assume very significant "learning" to reduce the capital cost by 2020. However [JEC 2007] used detailed costings for full-size plant in series production, not for the present pilot plants. Further reduction of these costs by learning will not start until after several plants have been built. Even if targeted high subsidies result in the construction of several full-size plants by 2020, the learning will not have an effect until after 2020. Therefore 2nd generation biofuels will be still much more expensive even than 1st generation ones in 2020.

Also its inputs will be imported to a large extent.

The latest authoritative study on EU wood supply[1] indicates that there will not be enough wood available to meet both the renewable electricity/heat plans and the needs of the existing wood industries. Therefore rather than forest sources contributing wood to 2nd generation biofuels, the electricity sector will compete for bioenergy crops produced on agricultural land.

The PRIMES model, used to estimate the energy mix in 2020, assumed a constant cost for wood. By the time 2nd generation plants come on line, the more accessible

[1] see the background paper for UNECE/FAO-European Forestry Commission joint policy forum Oct. 2007 at: http://www.unece.org/trade/timber/docs/tc-sessions/tc-65/policyforum/documents.htm

EU wood will already be used in local district heating/electricity plants, so only the most remote and expensive sources will still be available. JRC has generated the first estimate of a cost-supply curve for energy-wood resources in EU (see Appendix 2). This shows how the cost of wood rises as demand increases, and that it will be cheaper to import wood than exploit much of the assumed EU supply.

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2nd generation plants are sophisticated and therefore expensive. They can only hope to become commercial on very large scale: e.g. 1 GWth. To gather enough wood without high transport costs, they have to be at a port. Then it would mostly be cheaper to buy imported wood (see Appendix 2), in competition with the electricity sector

3. PRINCIPAL OBJECTIVES OF BIOFUELS POLICY

The Commission has identified the following main objectives of biofuels policy:

1. **Greenhouse Gas Saving**. The biofuels directive review argues that since GHG emissions in the transport sector continue to grow whilst those in other sectors are shrinking, future emissions reductions must specifically target the transport sector. Biofuels policy should respect other environmental objectives.
2. **Security of Supply**. Transport sector is almost completely dependent on imported crude oil. This restricts the potential sources of supply, and makes supply susceptible to political instability. Biofuels should help.
3. **Employment**. Biofuels are claimed to bring economic benefits to EU because they increase employment, especially in rural areas, and to underdeveloped countries because they open new export markets.

3.1. Greenhouse Gas Savings

3.1.1. Direct effects

If we ignore indirect effects, biofuels produced in Europe generally save greenhouse gases

If biofuels are from crops grown on unused arable land in EU, they generally save some GHG, according to most analysts including [JEC 2007],(see Appendix 1). The emissions from making this category of biofuel we call "direct emissions". The fraction they save varies greatly, depending on the processes, what use is made of by-products, and the methodology used. JRC was responsible for the rigorous methodology and biofuels data in [JEC 2007], (used as a reference by DGs) according to which most EU commercial processes save between 18 and 50% GHG. Other, less rigorous, methodologies may give more favourable results for some biofuels.

Since the amount of GHG which can be saved is not limited by the amount of transport fuel there is to replace, this fraction is not useful for policy analysis. Better measures are the GHG saved per hectare and the GHG saved per euro (see section 4).

3.1.2. Indirect effects

But the more ambitious biofuels target…

However, if crops which otherwise would be used for food or feed (inside EU or exported) are instead used for biofuels, the emissions in EU are unchanged, but there are *indirect emissions* due to farming for food/feed which is displaced outside EU.
Looking at direct effects alone was acceptable for low rates of biofuel substitution in EU road fuel, when most of the extra crops for biofuels could come from production on set-aside or other unused arable land in EU, but with the current more ambitious 10% target most of the EU biofuel feedstock will be removed from world commodity markets.

[DG-AGRI 2007] projection of the sources of biofuels for the 10% biofuels target (see Appendix 3) gives figures which show that most feedstock will be from:-

…will result in increased agricultural output outside the EU,

1. EU production diverted from exports
2. Indirect imports, mostly to replace vegetable oils otherwise used for food
3. Direct imports.

…which will give rise to two additional kinds of GHG emissions:

Assuming that people do not change eating habits because of biofuels, diverting EU production from food or animal feed markets will result in increased food imports. Together with directly imported feedstock, these will add to world food demand, and the reduction in EU exports will detract from world food supply. The result will be increased agricultural production and emissions in the marginal food and feed producing countries of the world, outside EU.

There are two sorts of indirect farming emissions: indirect annual emissions and emissions due to indirect land use change.

1. Annual emissions

Indirect **annual emissions** are due to fuel and fertilizer use as well as the change in nitrous oxide release from farm soils in the countries where the extra production will take place.

2. One-off land use change emissions

Indirect **land use change** can lead to extra GHG emissions if the area of arable land in countries outside EU is increased in order to provide the extra crops needed as a result of EU biofuels policy. This is because part of the carbon stored in undisturbed natural soils and forests or is released as carbon dioxide if the land is cleared and the soil disturbed.

There is as yet no systematic estimate of either of these indirect emissions for EU biofuels.

Research is underway to estimate the size and location of these effects, but full results are not yet available. First, one needs a global model of world agricultural markets and possibilities for expansion of production. This will show in which areas the expansion of production will take place. Then one needs to estimate:

1. the annual farming emissions (per unit of production) in each of these areas
2. the characteristics of the land which would be converted, and how much carbon would be released as a result.

There are only some initial indications on where in the world the marginal production will come from.

10% replacement of EU diesel by conventional biodiesel would account for ~19% of world vegetable oil production in 2020[2]. At the same time 10% replacement of EU gasoline by bioethanol would use about 2.5%[3] of the world's cereals production. [OECD 2008] expects average world agricultural yield improvement to remain about 1% per annum, which is less than half their forecast of world demand increase (2.3%p.a.). So more land will be planted with crops, and extra demand from biofuels will cause more land use change.

Global agronomic models should forecast where the extra land use change would occur. Initial results for different biofuels scenarios [Searchinger 2008] [Banse 2007] [Kløverpris 2007] are quite diverse. However, the largest increase in crop area resulting from either bioethanol or biodiesel expansion would seem to be for soybeans in Brazil. A detailed GIS study shows that soybean is encroaching directly and by displacement on rainforest and "refutes the claim that agricultural intensification does not lead to new deforestation" [Morton 2006]. Expanding biodiesel would also cause expansion of palm oil production, principally in Malaysia and Indonesia If ethanol is imported from Brazil, sugar cane area will also expand.

These preliminary model results include expected increases in yield but may have underestimated the potential to re-activate disused arable land, especially in the Commonwealth of Independent States.

[2] [DG-AGRI 2007] (using a fuel demand scenario from DG-TREN) shows that 10% of 2020 diesel demand is ~19.2 Mtoe. Data in [JEC 2007] shows that it takes 1.59 tonnes vegetable oil to make one toe biodiesel (mostly because of the difference in energy density). So 10% biodiesel would take 30.6 Mtonnes vegetable oil (without 2nd generation production). FAPRI (for US Congress) forecast 150Mt world vegetable oil production in 2017; extrapolating their trend to 2020 gives 162Mt. So the fraction needed for 10% EU biodiesel is 30.6/162= 18.8%.

[3] Taking into account use of animal-feed byproducts of biofuels production, (following DG-AGRI, see app.3).

Indirect annual emissions may be lower or higher than equivalent production in EU

The **annual** farming emissions attributable to soy-bean oil are uncertain[4], but probably comparable to those for rapeseed oil in EU, whilst those for palm oil are lower in the best cases. Brazilian sugar cane production also has relatively modest greenhouse gas emissions. On the other hand, [Mortimer 2006] says that marginal rapeseed and cereals production in Australia emits roughly twice the GHG per tonne for EU production. This is due mainly to the energy used for irrigation, and lower yields, leading to more tractor-km per tonne of crops. We also know from studies of corn-ethanol [Farell 2006] that US corn emissions are higher than EU wheat .

However, emissions due to indirect land use change are much more worrying…

Disturbing natural soil or applying fertilizer provides air and nutrients for microbes to oxidize stored organic matter in the soil to CO_2. The release happens once, within a few years of the land use change, but can be very large. Unfortunately, abandoning arable land does *not* lead to a rapid increase in soil carbon.

…there will not be much land use change in EU, but if/where it happens, the emissions can be significant

In EU expansion of arable area is limited by present CAP rules, but if it occurs it would be mostly onto permanent grassland. [JEC 2007] estimated that, according to current knowledge, this would give an initial emission of soil carbon which would take roughly 20 to 110 (+/-50%!) years to recover by the annual GHG saved using the biofuels produced on the same land. Similar results can be expected if there is expansion of cereals or oilseed area in other temperate zones like US, Canada, Argentina and Australia.

The indirect effect on tropical peatlands is critical.

Peat land contains much more stored carbon, which is released by decomposition when land is drained for cultivation.. The press and NGOs have highlighted the huge emissions of soil carbon which result from planting oil palms on tropical peat-forest[5] or from cutting the Amazonian rainforest. According to the latest analysis [Rieley 2008], the CO_2 losses from oil palm plantations on drained peat-forest are about 170 tonnes/ha/y. An average palm oil yield of 4 t/ha/y would substitute enough rapeseed oil from the food market to make 2.5 toe/y of biodiesel. That would save ~4 tCO_2e/ha/y (data from JEC 2007). So if roughly ~4/170= 2.4% of biodiesel comes directly or indirectly from palm oil grown on peatland, the GHG savings from EU biodiesel are cancelled out..

This is not the worst case, because the calculation assumes that the plantation is renewed at the end of its 25-year life. But in practice, the plantations are often abandoned because of soil exhaustion, and new areas of forest are drained instead. The peat on the abandoned land then releases CO2 at an even faster rate by fires as well as decomposition, and this could also be attributed to the palm oil. Furthermore, this calculation does not take into account the carbon which would otherwise be sequestered by the peat-forest, and the assumed palm oil yield is optimistic for this type of land.

Now let us estimate how much of the extra vegetable oil would actually come from palm oil grown on peat-forest. Palm oil production overtook soy in 2004 to become the world's largest source of vegetable oil. [FAPRI 2007] expect palm oil to account for half the growth in world vegetable oil production between now and 2017. 88% of this will be from Indonesia and Malaysia. So these countries can be expected to supply ~44% of the extra vegetable oil demand caused by its use in biofuel. According to [Hooijer 2006] ~27% palm-oil concessions (planned plantations) in Indonesia are on peat-forest, with a similar figure expected for Malaysia (although in Malaysia only ~10% of *present* plantations are on former peat forest). Therefore, unless there are large changes in the pattern of palm oil development, one could expect that roughly 0.44x0.27 = 12% of the extra vegetable oil for biodiesel would come indirectly from palm oil on peat land (more than enough to negate the GHG savings from *all* EU biofuels). This figure is a very rough approximation[6], but serves to illustrate the magnitude of land use change effects..

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[4] …because JRC's sophisticated nitrous oxide emission model only applies to EU

[5] e.g. http://www.greenpeace.org/international/press/reports/cooking-the-climate-full

[6] This assumes that most of the incremental production comes from area expansion rather than incremental yield increases due to higher prices. FAPRI expect a 47% increase in production in Indonesia and Malaysia even without a 10% EU biofuels target; which is already far beyond any reasonable estimate of yield increase.

Strong local regulation would be needed to prevent GHG-damaging land use change.

In fact, there is plenty of scope for expanding palm oil production onto degraded forest land and rubber tree plantations, without provoking loss of soil carbon, but this is less productive and economic than cutting the primary forest; local land use regulations need to be adjusted accordingly. There is a similar problem in Brazil, where soybean expansion is mostly onto ranches, and ranchers then further cut the rainforest, because ranching is still cheaper than feeding their cattle on soybean-meal, which can be exported.

Sugar cane expansion in Brazil could take place partly onto degraded pasture, but largely onto the natural Cerrado or ranch land bordering it. The Cerrado does not have a huge store of soil carbon, but is extremely biodiverse. [Dufey 2004].

Certification schemes are not an instant solution.

Certification schemes are being organized (the Round Table on Sustainable Palm Oil and its soy-oil and sugar-cane equivalents). They will have a positive but probably limited impact:-

1. Clearly certification must apply to imports for food as well as biofuels, otherwise the unsustainable product will just be displaced from fuel to food market.
2. Unless all consuming (or all producing) countries adopt the certification scheme for all production, the uncertified production will be bought by non-participants.
3. The schemes will take time to implement, and will exclude some present producers. Therefore the volume of certified production will be much less than the EU import requirement for food and biodiesel for very many years.
4. Certification can only hope to encourage growth of sustainable production by creating a price premium for certified material, not to stop unsustainable practices by 2020.

We know that indirect GHG emissions could be larger than direct ones. How much they can be reduced depends critically on the policy and effectiveness of control by the world's food and feed producing nations. Certification schemes help, but cannot prevent indirect emissions.

These emissions cannot be calculated separately for individual batches of biofuel, but since they are a product of world market displacements, one could estimate representative values for the main feedstocks (vegetable oil, cereals, wood…), to be added to the direct emission estimates.

Indirect land use change could potentially release enough greenhouse gas to negate the savings from conventional EU biofuels.

3.1.3. Nitrous oxide emissions

Nitrous oxide emissions from farm soils significantly worsen GHG balance of biofuels.

The most significant GHG emissions from farming are from making nitrogen fertilizer (which are relatively well-known) and from nitrous oxide release from farmed soils. These are important because N_2O has nearly 300 times the global warming potential of the same mass of CO_2. [JEC 2006] results show that N2O contributes 15-60% of the GHG emissions from making biofuels on set-aside land in EU, (i.e. not considering indirect effects).

Recent reports of nitrous oxide release attributed to biofuels are probably exaggerated.

Recently Nobel laureate P.J. Cruzten et al. released a discussion paper[*] which makes a rather simple calculation (starting from what is known of N_2O balance in the atmosphere) to show that the IPCC defaults underestimate N_2O emissions from global agriculture by a factor of 3 to 5. They conclude biofuels emit more GHG in the form of N_2O than they save as CO_2 in fossil fuel. Reviewers noted that the paper failed to consider several factors, which would reduce this estimate. However, everyone agrees that there is a high degree of uncertainty in estimating global nitrous oxide emissions from farming.

JRC improved estimates of average nitrous oxide

To reduce the enormous uncertainties in this top-down approach, for the JEC WTW study [JEC 2007], JRC made a sophisticated bottom-up estimate of nitrous oxide emissions at 9000 sites in EU 15, based on a soils chemistry model. It gives a

* under open review at http://www.cosis.net/members/journals/df/article.php?paper=acpd-7-11191

emissions for biofuels crops in EU.

"snapshot" of N_2O emissions each day in the year 2000. Annual emissions per crop were averaged[8], giving an estimated uncertainty *in the EU average* of ± 30%[9].

The EU-average emissions were significantly higher (depending on the crop) than would be simplistically estimated from IPCC default factors[10], but much less than indicated by Crutzen et al.

There is a VARIATION of more than 100x in N2O emissions between EU fields

In the JRC model results, emissions varied by a factor of more than 100 from one EU wheat-field to another, depending firstly on the organic content of the soil (this conclusion is confirmed by field measurements (e.g. [Regina 1996]). This means some fields would produce far more GHG in the form of nitrous oxide than is saved by the biofuel they produce. However, it is no better to grow food on those fields and grow biofuels elsewhere. Rather, this is an indication that significant GHG reductions could be achieved by incentivising a shift away from intensive farming on soils with higher organic contents.

Uncertainty in N2O emissions outside EU also means that we do not know if the EU biofuels programme saves GHG,

Outside well-characterized areas like EU, the best one can do to estimate nitrous oxide emissions is to use the default factors IPCC recommend for national GHG inventories. However the IPCC's range of **uncertainty** is greater than a factor 9, *for national averages*. This means that if the indirect effect of displacement of food production outside EU is taken into account, it is generally impossible to say whether biofuel saves GHG or not.

We described three large sources of uncertainty in the GHG effect of EU biofuels, which are not quantified in biofuels directive impact assessment:-

1. uncertainty in soil carbon release from indirect land use change outside EU
2. uncertainty in emissions of farming inputs indirectly caused outside EU
3. uncertainty in nitrous oxide emissions indirectly caused outside EU

Any *one* of these uncertainties has the potential to negate GHG savings from the 10% biofuel target.

3.1.4. Conclusions

Most types of biofuels **can** save GHG in the best circumstances. However, the only major biofuels which we can say are likely to save greenhouse gas (considering indirect effects) are bioethanol from sugar cane from Brazil, compressed biogas and second generation biofuels. For 1st generation biofuels made in EU it is clear that the overall indirect emissions are potentially much higher than the direct ones whilst they are unlikely to be much lower.

Indirect land use change could potentially release enough greenhouse gas to negate the savings from conventional EU biofuels. However, we do not know even roughly the magnitude of these effects. It depends critically on the policy and effectiveness of control in the regions of the world where the extra demand for crops will result in expansion of farmed area. Certification schemes help, but cannot expect to prevent the problem on a global scale.

DOES US CORN-ETHANOL CAUSE GLOBAL WARMING?

The debate over biofuels sustainability is often led by discussion of the large US corn-ethanol programme.

In general, direct emissions from producing corn-ethanol in US are higher than from biofuels in EU. This is because the US uses more energy for irrigation, and more farming inputs, to support maize monoculture. A respected metastudy [Farell 2006] concluded that despite some claims to the contrary, modern corn-ethanol production in US does save a small fraction of the GHG of the gasoline substituted.

However, [Farell 2006] used default values in IPCC guidelines to calculate N2O emissions. The uncertainty according to IPCC is considerably greater than the amount of GHG saved. So actually they cannot say for sure whether direct emissions from corn ethanol are greater or less than those from gasoline.

Indirect emissions were not considered: increased US corn production is largely at the expense of soybean, and the compensating soybean production moves largely to Brazil, where it encroaches on ranchland, which is partly replaced by cutting rainforest. If this indirect effect were considered, even the central values of GHG saved would probably be negative. *Because of indirect emissions, US corn-ethanol is judged more likely than not to cause global warming.* This conclusion has been confirmed by the recent publication [Searchinger 2008].

[8] now JRC is making another model capable of forecasting N2O implications of EU agricultural changes

[9] Details are in [JEC 2007], WTT section of pp 31-33

[10] Actually, there were as many JRC results below the IPCC default values as above, and most fell within the IPCC range of a factor 3 higher or lower. However, the arithmentic average of points which are 3 times higher and 3 times lower is greater than the default value.

3.2. Security of Supply

3.2.1. Estimating the value of security of supply

Exposure to imports would be reduced.

One of the advantages attributed to a biofuels programme is enhanced security of supply. The reason why security of supply would be improved by a biofuels programme is that it would reduce the use of imported fossil fuels, and diminish the percentage of the EU's fuel supply that would be subject to any disruption in the supply of fossil fuels.

Estimating the cost of a precautionary strategic fuel reserve providing an equal amount of fuel as the proposed biofuels programme, JRC estimated that…

In principle it is not difficult to compute an upper bound on the estimated cost of obtaining an identical security of supply benefit by other means. This equivalent degree of security of supply enhancement can be achieved by holding a strategic stock of fossil fuels that would provide, litre for litre, the same volume of fuel than the biofuels programme at a time of supply disruption, for long enough allow for the ramping up of a biofuels programme similar to the one proposed. Should fossil fuel prices rise significantly in the future and stay high, biofuel production would become commercially viable and be produced spontaneously by the market. The size of the equivalent strategic stock that would be able to fill such a gap has been estimated, and on the basis of the corresponding costs upper bound of the value of the security of supply provided by the biofuels programme can be calculated.

…EU produced biofuels yield security of supply benefits of about €130/ toe

Assuming that the significant price increase could come any time between now and fifteen years from now, and assuming further that it would take eight years to recognize the problem and fully develop a biofuels industry thereafter, JRC estimated in 2006 that the security of supply benefit of biofuels produced in Europe is worth approximately 11-13 cents/litre, or about €130 per toe.

But this is probably an overestimate….

In fact, this is probably an overestimate: the fact that EU in not planning a huge oil storage project means that society does not value security of supply as highly as this. Furthermore it does not consider fossil fuel use to make biofuels and the insecurity of the biofuel feedstock imports.

Biodiesel reduces crude oil requirements more than bioethanol

The proportion of diesel in the EU demand is greater than refineries can economically supply, so EU exports gasoline to US. Bioethanol replaces gasoline, so it only increases exports and does not reduce crude EU crude oil requirement. Conversely, 1toe marginal biodiesel reduces crude oil imports by roughly 2toe because it also reduces gasoline exports. On the other hand, a greater proportion of biodiesel will be from imported feedstock…

Security of supply is better if the feedstock is not imported

The proportion of imports is analysed in note-to-the-file [DG AGRI 2007] which projects the impact of the 10% biofuel target on EU-27 agricultural markets and land use in 2020. The projection is based on the ESIM model, which calculates EU agricultural production, imports and prices as a function of different crops as a function of crop demand. It takes into account the effects of biofuels by-products in the animal-feed sector.

3.2.2. What % of biofuels would be effectively imports?

*If we include indirect imports, **32-64%** biofuels would be imported.*

A "headline" from the note is that the share of *direct* imports will be 20%. However, the note expects an equal amount of feedstock comes from "diversion of domestic use" (see Appendix 3). This means using material which would otherwise be used for food or feed. In the case of biodiesel, this is almost all EU-rapeseed oil which would otherwise be used for food. If we assume that people and animals do not eat less because of biofuels targets, this would be replaced by imported vegetable oil and oilseeds, especially palm oil[11]. This is cheaper than rapeseed oil but less suitable for making biodiesel. Therefore instead of using palm oil for making biodiesel, manufacturers prefer to buy rapeseed off the EU food market, where it is replaced by palm oil imports. These are therefore indirect imports which result from biodiesel production.

In the case of bioethanol, "diversion of domestic use" reflects the contribution of byproducts of both bioethanol and biodiesel production in the animal feed sector, which free-up feed-cereal supplies for use in bioethanol manufacture.

[11] Palm oil is less healthy because it has higher saturated fat.

If we include indirect imports, the overall % of biofuel imported rises to between 32 and 39%, if we believe the given scenario that 30% of biofuels will come from 2nd generation production in 2020. Of biodiesel feedstock, 50% would be imported in this scenario.

*Without 2nd generation biofuels, **>60%** would be effectively imported.*

If 2nd generation biofuels do **not** make a significant contribution by 2020, these figures would rise to 56-64% overall, and **80%** of biodiesel. DG-AGRI's regular agricultural projection [DG-AGRI 2007b] confirms that EU oilseed production will hardly keep pace with the increasing *food* demand, so that they foresee practically all the *expansion* of biodiesel production will be met directly or indirectly by imports of feedstock.

Finally, we note that the DG-AGRI projection assumes that EU ethanol industry is protected from cheaper imports from Brazil by tariff barriers. If WTO stops this, the % of imports would rise even further.

Because of these added uncertainties, the security of supply benefits of biofuels were valued at 10-130 €/toe.

3.3. Employment

An Input-output model of the EU was used to trace the employment effect of the biofuels programme.

The employment effects of a set of predetermined biofuels penetration scenarios were analysed with an approach based on input-output analysis. Input-output methods provide a relatively simple modelling framework that relates final demand components to value added components through the interrelations between all sectors that constitute an economy.

The effects of price changes and imports were taken into account.

The assumptions needed to do the calculations were done on the basis of model runs done by DG TREN and DG AGRI. On this basis changes in product prices and their effects were considered. The share of imports in various induced product flows were taken into account. This is the principal factor affecting the results, as under high import scenarios employment losses were forecast to occur.

The incremental cost of biofuels production was compensated through taxation.

Many studies omit this and thus overestimate employment benefits

In all cases it was assumed that the additional cost of biofuels compared to fossil transport fuels were compensated by fuel tax reductions, recollected in turn from private consumers through an increase of general taxation (and disposable income) of equal amount to ensure government budget neutrality. (Other studies of biofuels effect on employment often are NOT tax-neutral: increased government expenditure uncompensated by taxation can be expected to increase employment). Fuel prices at the filling station were consequently unaffected; however, the price of agricultural products (for both energy and food uses) surged due to increased demand.

Even in the best of cases the net employment effect is only 0.1% of EU employment, which is less than the margin of error of the methodology used.

Agricultural employment was shown to grow in all cases (e.g. 190 000 jobs), but this was mostly compensated by losses elsewhere in the economy (e.g. 35 000 in services, etc.). The model takes into account both the positive knock-on employment effects in all economic sectors, as well as the negative employment effects of taxes need to subsidize biofuels (many studies leave out this crucial point). For further details see **Appendix 4.** The main effect of biofuels is an increase in employment in agriculture and biofuels offset by a decrease in employment in other sectors. Obviously this benefits rural areas but not urban ones. Overall employment effects were calculated to be modest in all cases (roughly in the range +/- 250,000 against a base of 200 million jobs in the EU25) except the 100% imports case, in which more significant negative values were calculated as a result of foregoing the whole chain of direct and indirect positive effects associated with the production of biofuels. **The main conclusion is that the net EU employment effects, under the technology and market assumptions specified in the scenarios, are neutral or close to neutral.** Obviously, EU imports of biofuel or feedstock will help employment in the exporting countries, outside EU. The same applies for imports of woody biomass for bioenergy use. Underdeveloped countries may be able to compete better in this market than in the one for intensive arable crops, although different sustainability questions are opened up. More analysis is needed here.

4. COST OF GHG SAVING

The fraction of GHG saved by biofuels is highly variable…

Many studies estimate what fraction of greenhouse gas emission emissions from fossil road fuels are saved by using different biofuels instead. Even ignoring indirect effects and uncertainties in nitrous oxide emissions, the fraction is hugely variable even for one type of biofuel and feedstock. It depends on the use of by-products, the methodology adopted, the configuration of the processing plant and the fuel used to heat the process. Studies agree that for *direct* emissions from EU production the fraction is generally positive. [JEC 2007] gives a range of about -10 –to +70% GHG savings for bioethanol processes, 40-43% for rapeseed-biodiesel. Brazilian cane-ethanol and 2nd generation biofuels save more than 80% GHG.

…but this is not a useful parameter anyway: we need to know GHG savings per € and ha.

Apart from needing to be positive, the fraction of GHG saved is also not a useful parameter for policy-making: the amount of GHG EU can save is not limited by the amount of road-fuel there is to substitute. Rather, it is limited by the money available and perhaps (at a later stage) by the availability of agricultural and forest land. Thus the important parameters are the GHG saved per euro and the GHG saved per hectare of arable land (or per tonne of wood).

GHG saving by biofuels cost over 100 €/tonne CO2eq

Fig. 1 combines the (relatively well-defined) **direct** emissions for **pure EU** production with JRC's best estimate of biofuel production costs. Note that these costs do not include any valuation of possible knock-on benefits such economic growth, as employment etc., nor taxes, tax breaks or subsidies. We see that the typical cost of saving one tonne of CO2 equivalent of GHG in 2020 is well over 100€, for both first and second generation biofuels. These costs depend on the *difference* in production cost between biofuel and fossil fuel, so the results are sensitive to oil and feedstock prices. Considering indirect effects would most likely increase these costs by decreasing the tonnes of GHG saved.

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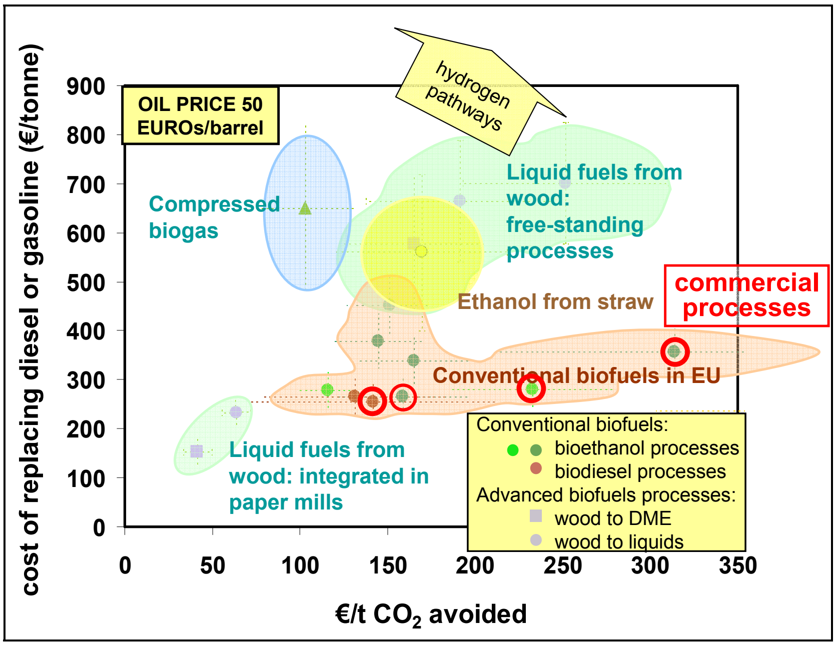

Fig. 1: Cost of replacing fossil fuel and of reducing CO_2 emissions

Biofuels generally are expensive to produce; therefore the cost of avoiding CO2 emissions through them is high.

Figure 1 shows the cost of replacing fossil road-fuel by EU-biofuels made in different ways and what this means in terms of GHG-saving cost (x-axis). Indirect emissions are not considered. This graph by JRC uses the JEC-WTW spreadsheets updated for latest projections of crop prices in 2007[12], conservatively adjusted for the market effects of the 10% policy and reduced to 2007-Euros. The cheapest biofuels are potentially made by modifying existing paper/pulp mills,

[12] From FAPRI, http://www.fapri.iastate.edu/outlook2007/ who make them for US congress.

because of synergies with the pulp process, but this cannot replace more than about 0.7% of EU road-fuel. Furthermore, modifying paper mills in a similar way to produce bio-electricity saves GHG even more cheaply.

Other ways of saving GHG are much cheaper.

This is much higher than alternative ways to save GHG, as indicated by the cost of green certificates, where the cost has rarely exceeded 20 €/tonne, and are not projected to reach anywhere near this value even by 2020. Therefore, justification for making biofuels from EU sources now rests on the basis of the additional benefits from security of supply and employment.

Other uses of biomass save more GHG per hectare.

Fig. 2 shows the amount of GHG (in tonnes CO2eq) that are saved by using one hectare of arable land in different ways. Farming wood (or other energy crops) and processing it to 2nd generation saves more GHG than conventional biofuels, but not more than generating electricity, which is much cheaper than both.

Limited volumes of selected imports would be a cheaper and more GHG-efficient solution for transport fuels

Amongst imports, Brazilian ethanol from sugar cane is the one which most probably saves GHG (even if potentially affecting biodiversity). However, if EU increases its imports from Brazil faster than the industry can expand there, the imports will simply be diverted from the Brazilian market and so will not save any greenhouse gas.

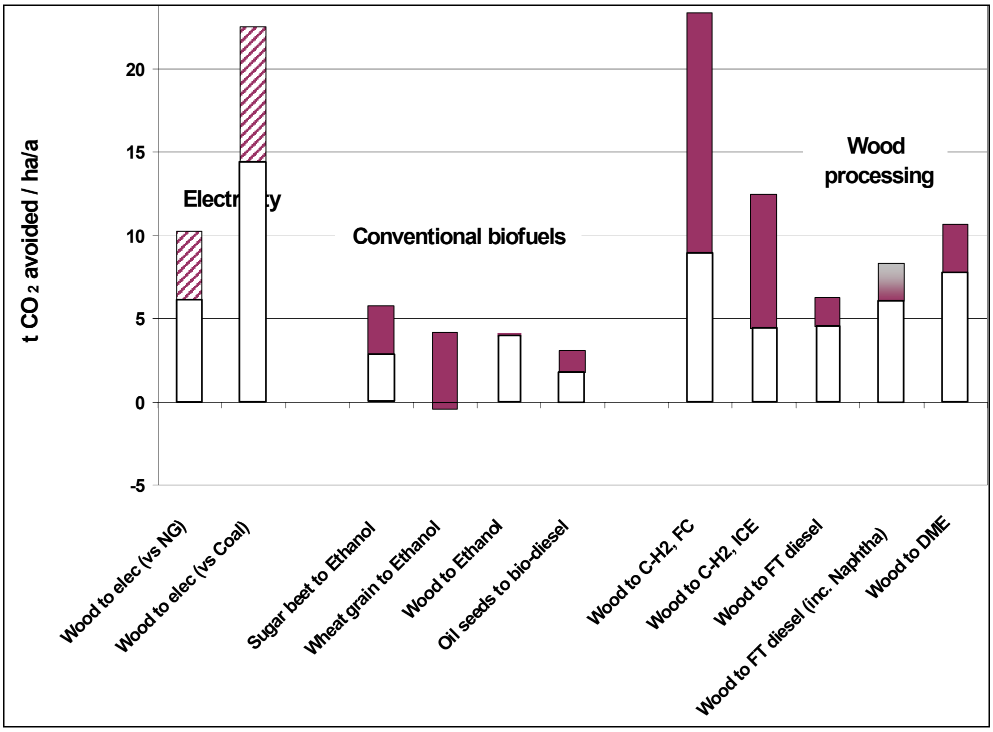

Fig. 2: Annual GHG saved using 1 ha arable land with EU-average wheat yield. The coloured bars represent the spread between different processes as well as uncertainty.

5. EFFECT OF BIOFUELS ON AGRICULTURAL COMMODITY PRICES

Biofuels demand is not the main cause of recent food price rises.

The recent large increases in world crop prices are primarily caused by poor harvests, and secondly by faster-than-expected increases in consumption. The main effect of biofuels is seen in the vegetable oil sector, especially rapeseed oil. Here the effects were exaggerated by the sudden increase in biodiesel profitability caused by the oil price shock coupled with a delay in reducing the amount of (detaxation) subsidy on biofuels consumption.

Price effects are easy to estimate by order of magnitude.

10% 1st generation ethanol in EU gasoline would use, ~2.5% of world 2020 cereals[13]. On the basis of the market flexibility, that would cause a world cereals price change of at least +4%, whilst 10% 1st generation biodiesel in EU diesel would use ~19% of world 2020 vegetable oils, which would cause a world price change of at least +24%[14].. The price of oilseed meals (used for animal feed) fall by at least this proportion. Note: these price changes are compared to the case of **no** EU biofuels in 2020.

In practice the faster increase in vegetable oil price will persuade some farmers to switch from cereals to oilseeds, which will tend to moderate the price rise in vegetable oils but increase cereals prices compared to the first-order approximation above. This is why we need models for accurate results.

Falls in real crop prices in the baseline mask gains in crop prices due to EU biofuels.

The most respected projections of future prices come from FAPRI (for US Congress) and OECD; they already include some demand from biofuels. The effects of 10% EU biofuels compared to the prices in these projections depends on what % biofuels is already assumed in the baseline projection. (for example, FAPRI assume 4.2% biofuels in EU in 2017).

*But if the rest of the world **also** adopts ambitious biofuels targets, the effect on crop prices will be large.*

In 2007 OECD projected significant falls in **inflation-adjusted** world crop prices by 2020, whereas FAPRI projected a much gentler fall. [DG-AGRI 2007] bases its projection on OECD, so the rise in prices due to biofuels is partly masked by the overall fall in real prices in the background projection. Of course, if the **whole world** made ambitious biofuels targets, the effect on prices would be multiplied.

6. COST-BENEFIT ANALYSIS[15]

6.1. Direct benefits

The direct benefit of biofuels is its value as a propellant….

The direct benefit derived from using biofuels is its value as a propellant. It was assumed that this is equivalent to the benefit provided by the fossil fuel that it displaces. But rather than estimating this benefit separately and then taking also the cost of producing biofuels, the incremental costs of producing biofuels, over and above the value of the displaced fossil fuel, was taken to be the net cost to be offset against the additional benefits of a biofuels programme, further discussed below.

6.2. Cost of producing biofuels

…but it costs more to produce…

The detailed analysis undertaken to estimate the **cost of producing biofuels** is not detailed here. Capital, production and distribution costs and technical parameters of different biofuels pathways were taken from the TRIAS project. They are close to the costs provided by the JRC/EUCAR/CONCAWE study "Well-to-wheel analysis of

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[13] Or 15% of EU cereals, both based on extrapolation of FAPRI projected production for 2017.

[14] There is poor data on long-term area-response supply flexibilities. Conservatively, JRC used literature values of 0.8 for oilseeds and 0.62 for cereals, but one could argue for much lower values, and hence larger price effects, because much of the extra production would normally come from farmers switching production between oilseeds and cereals. This cannot happen if production of both is increasing simultaneously. Demand is assumed inelastic (no change in eating patterns).

[15] Based on a "Cost Benefit Analysis of Selected Biofuels Scenarios" by JRC/IPTS (2006). This study was prepared as a contribution to the inter-service consultation on the review of the biofuels directive, and considered the scenarios that were considered at the time of its writing. DG TREN changed the scenario finally proposed after this study was written, so its conclusions do not pertain exactly to the 10% target proposed. The conclusions of the study would not change, however, if the calculations were to be repeated for that scenario.

future automotive fuels and power trains in the European context", version 2b. The feedback of increased biofuel demand on feedstock prices was assessed within the PREMIA project. It included estimations regarding expected technological change, as well as a consideration of the effects of a biofuels programme on the evolution of feedstock prices.

…by between -40 to 300 €/TOE

The fact that producing biofuels is more expensive than producing conventional fuels has been amply discussed in this report, so we will not repeat it. In our cost benefit calculations **we have estimated this additional cost to range between -40 and 300 €/toe.**

6.3. External benefits of biofuels production

Cost-benefit analysis takes external costs and benefits into account.

Cost benefit analysis differs from straight financial or commercial calculation in that it also attempts to quantify cost and benefits that do not necessarily have a market price. These are often called external costs or external benefits, and in this case, the relevant ones are

1. environmental benefits
2. employment benefits, and
3. security of supply benefits.

GHG savings were quantified through the price of carbon…

Environmental benefits of the various biofuel types and their alternatives have been estimated largely through the quantification of their life cycle greenhouse gas emission values, which is driven principally by the "price of carbon"[16], given that it would be inappropriate to attribute a higher benefit than the cost at which similar reductions in emission gases can be achieved. This implies an overestimation of the environmental benefits, at least for conventional biofuels, as some adverse environmental effects (including indirect emissions) are ignored. On these assumptions, external costs due to avoided greenhouse gas emission are the dominant environmental externality.

…estimated at 44 €/T CO_2, ranging between 30 and 60 €/T

The "carbon price" used was obtained from a POLES model simulation run, which yielded a 2006 market price of 16 €/ t CO_2, increasing to 35 and some 50 EUR/ t CO_2 by 2010 and 2020, respectively. As this price results from an assumed CO_2 market that does not include the transport sector – which is likely to have relatively high CO_2 avoidance costs – we set our central CO_2 price above the mean, at **44 €/T CO_2, with a range from 30 to 60 €/T between 2010 and 2020.**

6.4. Employment benefits

Employment benefits are the difference between the wage bill of the newly created jobs and the value of what the unemployed did before.

Employment benefits have been calculated assuming that some but not all of the feed stocks for biofuel production would originate in Europe. We used estimates provided by DG AGRI for this purpose. These scenarios varied in their assumptions relative to both imports of biofuels and of their feed stocks, which has a bearing on the number of jobs created.

The number of jobs created is not yet the employment benefit. That is the difference between the wage earned by the newly employed worker and the value to him of his previous activity (another kind of work or leisure time). We had no data for this difference, so we assumed it to be 50% of the wage earned.

It was estimated at between -5 and 33 € per TOE.

To calculate the employment benefit we multiplied the number of jobs estimated for the various scenarios by the estimated average wage in EU and by 0.5. Taking into account the data relative to alternative scenarios, and dividing this result by the number of tons of oil equivalent biofuels produced, **we obtained an estimate of the employment benefit ranging between -5 and 33 € per TOE**.

[16] Market value of CO_2 emission rights.

6.5. The security of supply

…we should not pay more for enhanced security of supply than the price at which a similar level of security of supply can be obtained through other means…

The security of supply benefit has been estimated on the basis on the notion that we should not pay more for enhanced security of supply than the price at which a similar level of security of supply can be obtained through other means. The estimate has been made on the basis of calculating the cost of building a precautionary stock of conventional fuel of a size such that it would provide the same security of supply benefit as a programme to enhance biofuel production as proposed.

The calculation is based on the costs of keeping the stocks, the expected duration of the period during which the stocks need to be held, and the length of time it would take to start a biofuels programme from the time it became financially feasible (meaning that it could be competitive with fossil fuels without subsidy) and the length of time it would take for it to ramp up to full capacity of production.

For all EU production of biofuels this is about € 130 per toe.

Because various biofuels scenarios had differing percentages of imports of both biofuels and their feed stocks, we used a range of values in the calculation of up to € 130 per toe. It is very important to add that this is an upper bound estimate of this benefit because it is the cost of obtaining equivalent security, but not necessarily the optimal level of security.

But this is an overestimate…

The fact that actual precautionary stocks of fuel held by Member States are relatively small would indicate that they do not value security of supply as highly as these values imply.

…and the likelihood of imported feedstock reduces it further.

Furthermore, the fact that producing biofuels requires the use of fossil fuel based energy and the fact that there will be significant imports of both biofuels and of their feed-stocks reduces this benefit further**. We have estimated it to lie between 10 and € *130 per toe.***

In the absence of a comprehensive study of alternatives, one cannot even be sure that the net security of supply effect will be positive

But absent a comprehensive study of alternative ways of addressing the security of supply problem one cannot even be sure that the security of supply benefit, in the sense of saving crude oil imports, will be positive, for two reasons:

1. Given the gasoline (petrol) glut in Europe part of additional supplies of ethanol will result in increased gasoline (petrol) exports rather than a decline in crude oil imports.
2. If the biofuels programme were to divert biomass away from stationary burners that could substitute fossil fuel the net impact of the biofuels programme would be to increase crude oil imports.

6.6. Discounting future benefits

Discount rate 2%

Because costs and benefits incurred at different points in time are not directly comparable, the cost benefit analysis results have been converted to net present values using a discount rate of 2%.

6.7. Treating uncertainty

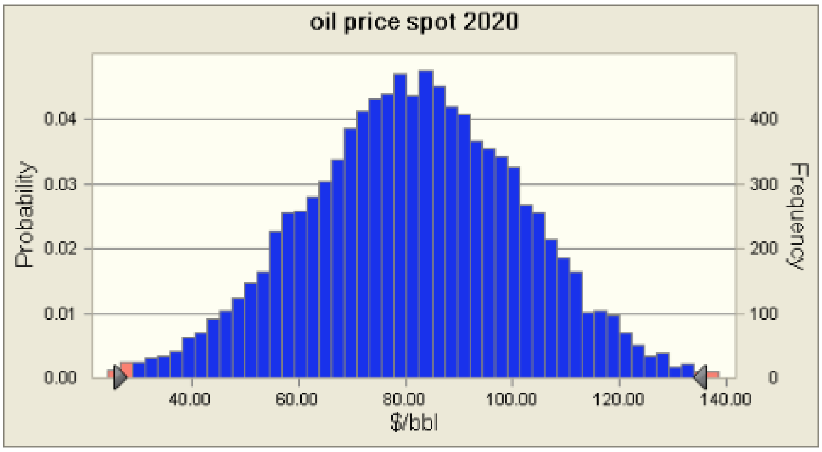
Cost benefit analysis requires making projections of future values…

Finally it is worth mentioning that cost benefit analysis requires forecasts of the future to be made. The decision taken with respect to biofuels will have an economic and financial impact for many years to come, and will involve costs and generate benefits, year after year. For this reason decision makers have to know the forecast consequences of the alternatives they consider.

…which cannot be made with precision.

Perfect forecasts are impossible to make, given that we are trying to forecast the future and the future is by nature inherently uncertain. We have quantified many of the uncertainties involved in this analysis trough probability distributions. A sensitivity analysis performed showed that the single most critical assumption of the analysis is the forecast of future crude oil prices. We have assumed the following for 2020 (values are lower for earlier years).

Therefore most key assumptions were represented with probability distributions reflecting a lot of uncertainty…



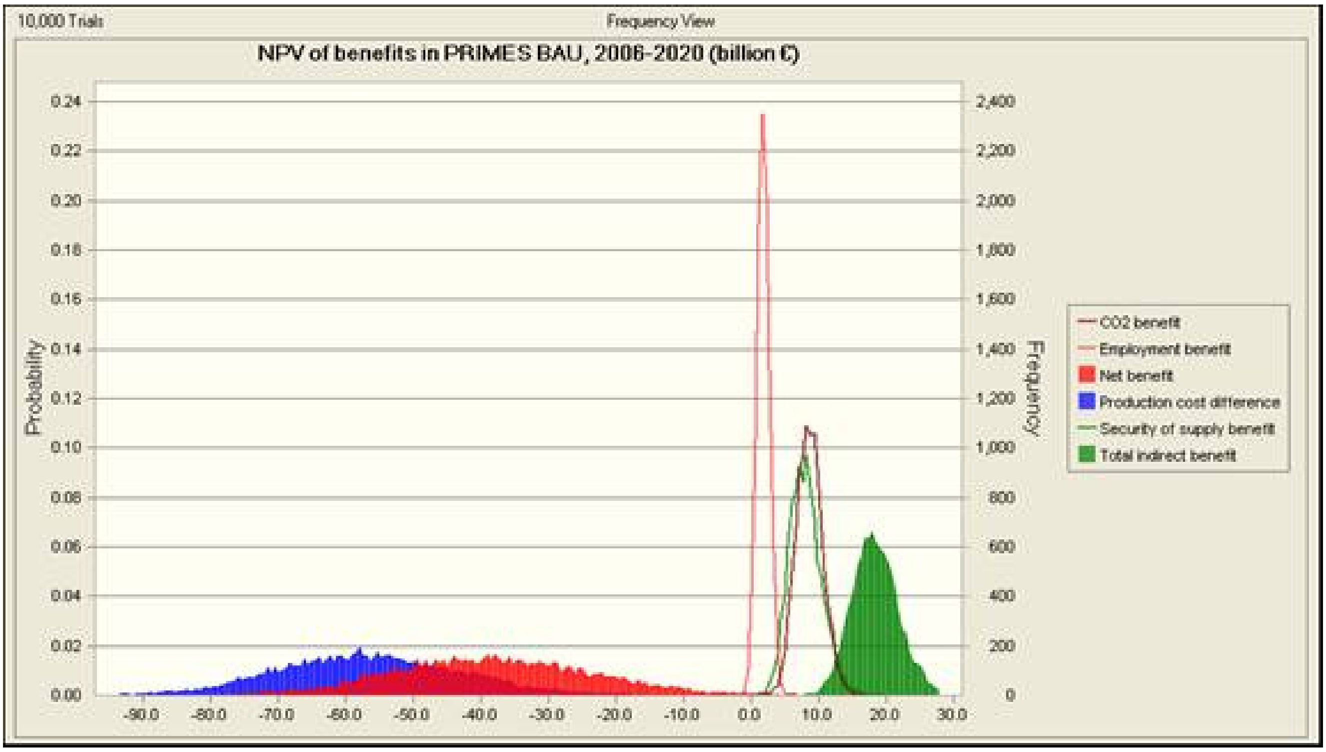
…and the results were derived using Monte Carlo Simulation.

Many other assumptions were specified probabilistically as well, to ensure that no reasonable value of any parameter be left out of the realm of possible future scenarios. The conclusions were derived through a process of Monte Carlo simulation, which aggregates the effects of all those uncertainties.

6.8. Conclusions

Despite all the uncertainty the conclusion is very solid: ***there is virtually no chance of benefits exceeding costs!***

Interestingly, while the level of uncertainty is great, robust conclusions can be derived nevertheless. This is because, over the overwhelming majority of the uncertainty range, the basic conclusions will stand. The following chart depicts this graphically and clearly. It shows the probability distributions of the external benefits of security of supply, environmental benefit, employment benefit, and the excess cost of producing bioethanol over the equivalent quantity of conventional fuel, at the prices expected to prevail in 2020. **It is obvious that the cost disadvantage of biofuels is so great with respect to conventional fuels (at least in the mix foreseen in the scenarios analysed), that even in the best of cases, they exceed the value of the external benefits that can be achieved.**



The **net welfare loss (i.e. net cost to society)** that even the best alternative considered by the original study (2006) would impose on the taxpayers of Europe throughout time horizon 2007-2020 ranges between 33 and 65 billion EUR with an 80% probability. The expected values of these results(for the BAU scenario, with 6.9% biofuels share[17]) are summarized as follows:

	billion €
CO2 benefit	8,6
Employment benefit	1,8
Security of supply benefit	8,0
Total indirect benefit	**18,4**
Production cost difference	**-56,7**
Net benefit	**-38,5**

This magnitude suggests that a biofuels programme is not the best way to achieve its stated objectives.

[17] The cost-benefit analysis was prepared as a contribution to the inter-service consultation on the review of the biofuels directive, and considered the scenarios that were considered at the time of its writing. The Commission decided to propose a 10% share after this cost-benefit analysis was made, so its conclusions do not pertain exactly to the 10% target. The conclusions of the analysis would not change, however, if the calculations were to be repeated for that scenario.

7. CONCLUSIONS

7.1. Will a biofuels policy achieve its objectives ?

7.1.1. Greenhouse gas savings

It cannot be asserted that the net effect would be positive

The uncertainties of the emissions due to indirect effects, much of which would occur outside the EU, mean that it is impossible to say with certainty that the net GHG effects of the biofuels programme would be positive.

7.1.2. Security of supply

There would be a positive effect, but its value is small compared to the costs

The security of supply effect derives from the fact than with a 10% share of biofuels in transport the impact of a fossil fuel restriction would only have 90% of the effect that it otherwise would. This advantage is degraded by a number of factors, however: fossil fuels are used in the production of many types of biofuels, which lessens the protection afforded by the programme. Further, there is a strong imbalance in EU refinery capacity because diesel is demanded in proportions above what the refineries can economically deliver. This makes the EU a net exporter of gasoline (petrol). Consequently incremental production of ethanol will result in increased gasoline exports, with no reductions in the quantity of crude that needs to be refined. The opposite is true for biodiesel, however.

Further, a substantial fraction of biofuels and their feed stocks will also be imported, also creating a security of supply issue, but presumably that would be weakly correlated with the risk of fossil fuel disruption, hence it is not a very serious disadvantage.

7.1.3. Employment creation

The net employment effect of the programme would be insignificant

Rural employment will benefit[18], but the taxation need for the subsidies will cause job losses elsewhere. Overall employment effects were calculated to be modest in all cases (roughly in the range +/- 250,000 against a base of 200 million jobs in the EU25) except the 100% imports case, in which more significant negative values were calculated. The main conclusion to be drawn form this exercise is that the net employment effects, under the technology and market assumptions specified in the scenarios, are neutral or close to neutral.

7.2. Will the benefits of a biofuels programme exceed its cost?

The costs of using biofuels outweigh the benefits of doing so.

The cost disadvantage of biofuels is so great with respect to conventional fuels (at least in the mix foreseen in the scenarios analysed), that even in the best of cases, they exceed the value of the external benefits that can be achieved.

This is what explains the fact that despite a very large uncertainty regarding many of the data needed to compute the cost-benefit analysis, the conclusions can be very robust and unequivocal. Even for the most favourable possible combination of assumptions, the benefits fail to exceed the costs.

The **net discounted welfare loss (net cost to society)** that even the best alternative considered by the original study (2006) would impose on the taxpayers of Europe throughout time horizon 2007-2020 **ranges between 33 and 65 billion EUR**, **with 80% probability.**

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[18] The main farming beneficiaries are intensive farmers of cereals and oilseeds.

7.3. Final Conclusions

Biomass and money are limited resources in EU. They should be directed to where they give the greatest impact.

From an economic point of view, decisions on where to allocate resources should be taken on the basis of "opportunity cost": that is, comparing the effects of using resources in different ways. What the cost benefit analysis shows, is that there are better ways to achieve greenhouse gas savings and security of supply enhancements than to produce biofuels. And as explained below, there are better uses for biomass in many cases.

The transport sector relies most on crude oil for strong technical reasons.

Electricity and heat can be easily generated from a variety of energy sources; solid liquid and gas. However, in vehicles (except electric ones) there is a large advantage in having a liquid fuel: cheap distribution, easy refuelling, dense storage, direct use in the engine. Making liquid fuel from coal or natural gas costs energy and money. That is why transport continues to rely on crude oil, even though it is more expensive than other fossil fuels.

Biomass saves much more fossil fuel and GHG emissions in other sectors.

The efficiency of modern biomass burners is nearly as high as fossil fuel burners, so in heating and electricity production, 1MJ biomass replaces about 0.95 MJ fossil fuel. However, transforming biomass into liquid fuel for transport is typically only 30-40% efficient in energy terms. This compares with ~93% efficiency in oil refineries. Thus 1 MJ biomass replaces only around 0.35-0.45MJ crude oil in the transport sector. Also, using biomass to make materials generally saves more GHG than biofuels.

Much oil goes into other sectors where it can be replaced by biomass much more cheaply and efficiently.

40% of EU refinery products are used outside the transport sector, and EU burns almost as much oil in stationary applications as it does in transport diesel engines. A unit of biomass saves more than twice as much greenhouse gas substituting oil in these applications than in transport sector.

Furthermore, stationary biomass burners are much cheaper than the sophisticated plant needed to convert biomass into biofuels. This means that the cost of replacing a given amount of oil with solid biomass in these sectors must be much less than half that of replacing it using liquid biofuels in the transport sector..

The costs of EU biofuels outweigh the benefits.

The decision to specifically target GHG reductions in the transport sector reduces the benefits which could be achieved in other ways with the same EU resources, as the cost benefit analysis indicates.

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APPENDIX 1: GHG Savings of biofuels

JEC WTW report: download from http://ies.jrc.cec.eu.int/WTW

Different life-cycle studies report different GHG saved by biofuels. Results differ because of different methodologies and assumptions on use of by-products. Most reports are not transparent enough to allow comparison or auditing. The JEC WTW report is used as a reference by DGs and many others because it is comprehensive, transparent and has consistent rational methodology. JRC is responsible for biofuels data and methodology. The report evolves by reporting all input data and assumptions, and inviting stakeholders to suggest improvements for the next version.

Abbreviations in charts:
EtOH ethanol
NG natural gas
DDGS "distiller's dried grains with solubles" (= fermentation sludge)
AF Animal Feed
CCGT Combined-cycle Gas Turbine (an efficient electricity generating configuration),
CHP Combined Heat and Power
RME Rapeseed methyl ether (biodiesel from rapeseed)
REE Rapeseed ethyl ether (biodiesel from rapeseed and bioethanol))
SME Sunflower-seed methyl ether (biodiesel from sunflower)
Gly glycerine (by-product of biodiesel)
F wood: Farmed wood
W wood: "waste" wood – forest residues.

Like most LCA studies, JEC-WTW does not yet include indirect effects; unlike most, it includes cost. This is direct cost to "EUincorporated", which does not include internal subsidies or taxes, or indirect effects on GDP etc. It includes all costs from well (or field) to wheel. That includes the cost of maintaining the distribution infrastructure (but not the one-off cost of building a new one). Discount rate is 8%.

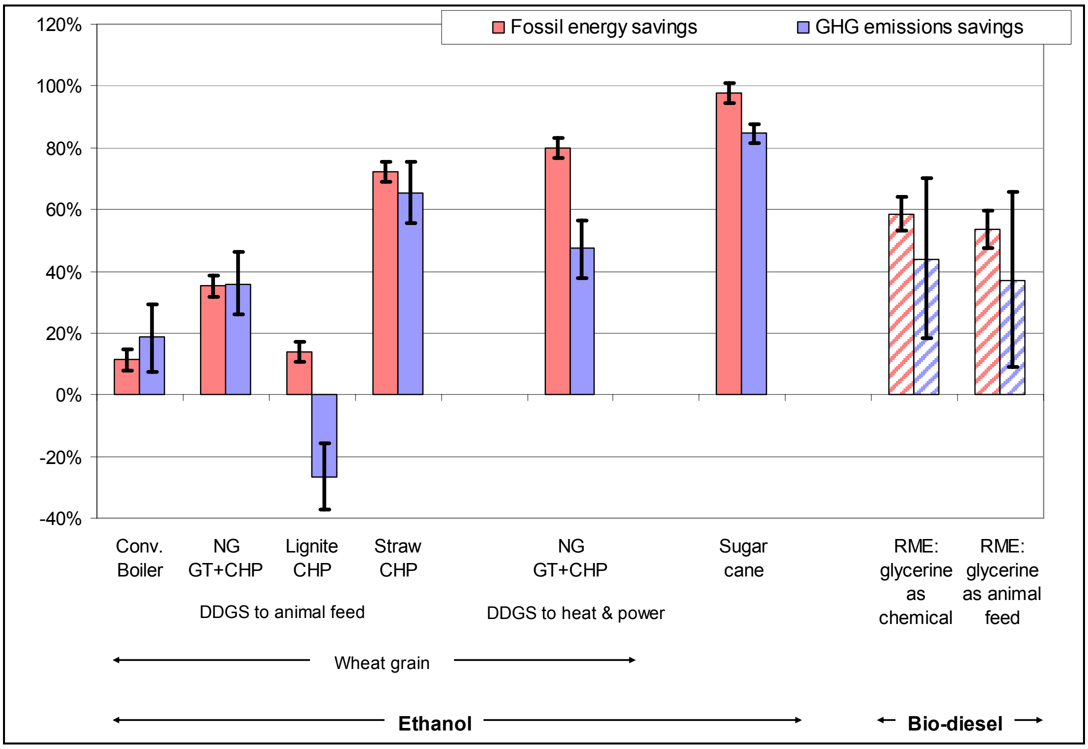

Fig. A1.1: JEC-WTW estimates of direct GHG saving and fossil-energy savings from replacing fossil fuel with different biofuels. Indirect effects are not included. Results depend on plant configuration and use of by-products. Brazilian sugar cane is better because bagasse waste heats the process. Error bars represent technical uncertainties, mainly from estimation of nitrous oxide emissions.

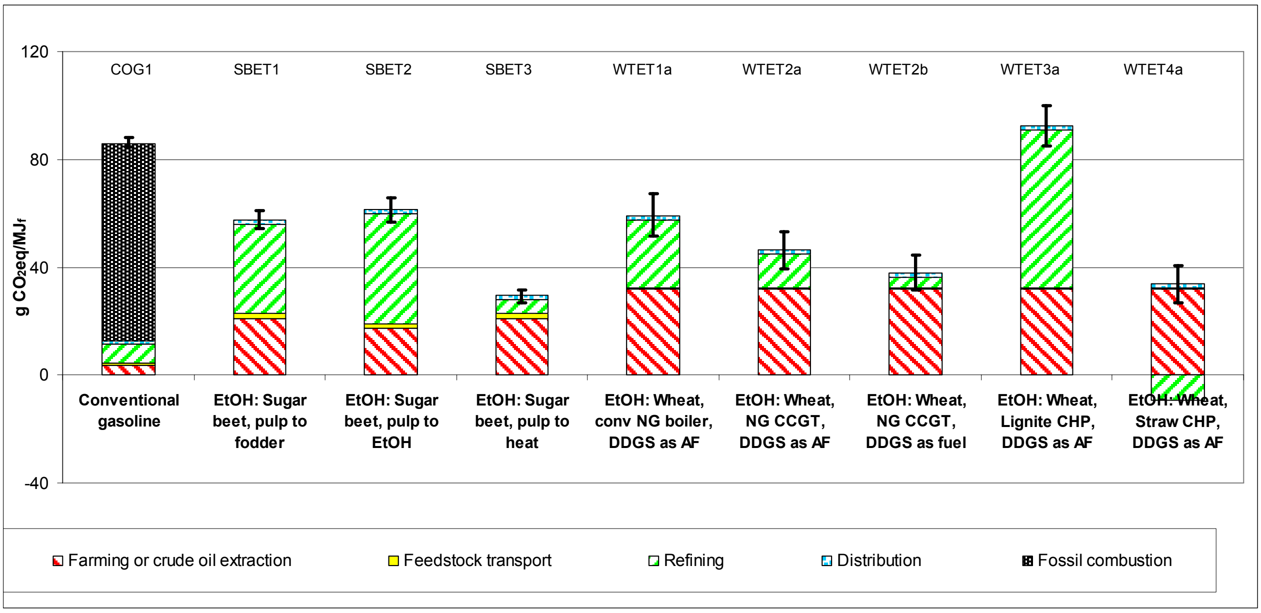

Fig. A1.2: Direct GHG emissions from gasoline and various bioethanol pathways. The main emissions from biofuels are from farming and processing. Unless lignite (brown coal) is used, the GHG balance is positive if no indirect effects are considered (only for biofuels produced from crops grown on set-aside land in EU can be said to be free of indirect effects).

APPENDIX 2: Cost-supply curves

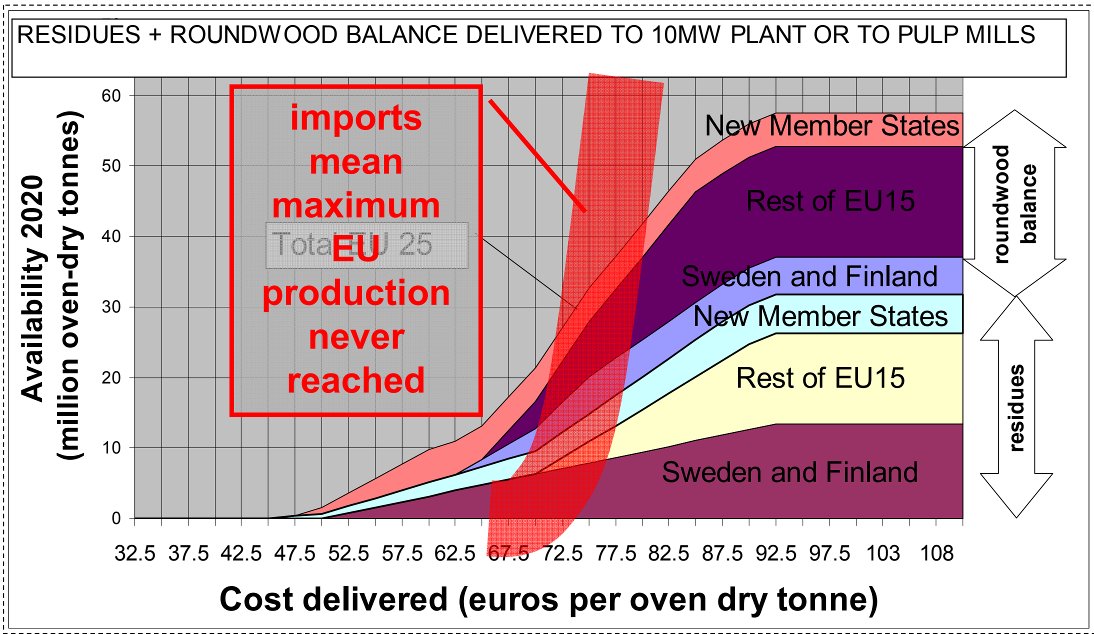

Fig. A2.1: Example of a cost-supply curve for energy-wood constructed by JRC on the basis of wood availabilities from METLA and cost data from various sources. As demand increases, the cost passes the point where imports will increase much more rapidly (schematic red curve). The maximum EU availability can never be realized. The EU availability assumed in the renewable energies roadmap is off the top end of the supply scale. The wood price assumed in PRIMES is constant.

The width of the stripes show the availability from different sources: the order of stripes is not meaningful. The input data and methodology have been endorsed as approximately correct in a consultation with leading EU forestry experts.

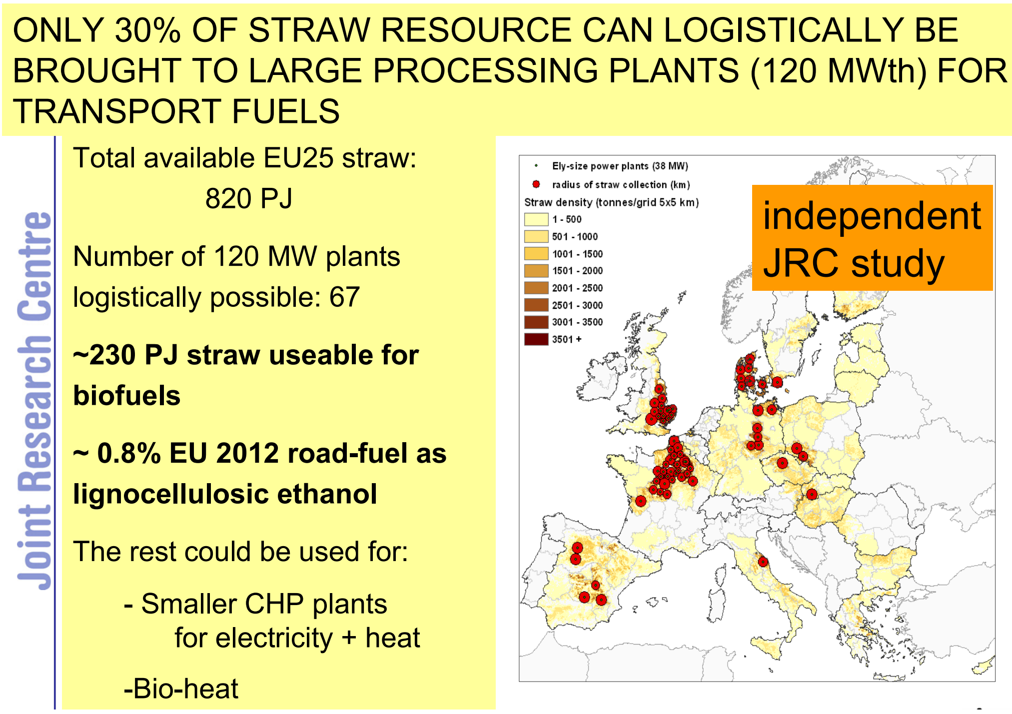

Fig. A2.2: In a GIS-based study JRC showed that only about one third EU excess straw can logistically and economically be brought to large plants for processing. Industry experts say even this is optimistic. The Renewable Energy road-map considers the theoretical availability of biomass in EU without such practical considerations.

APPENDIX 3: Inspection of DG-AGRI results

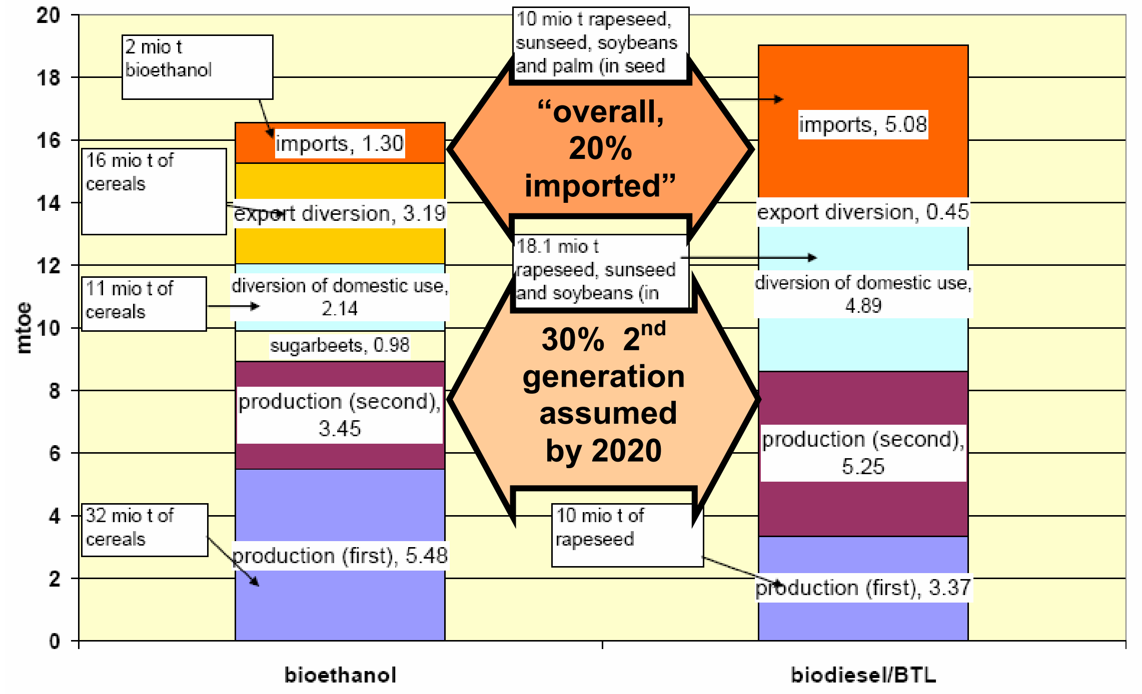

Fig. A3.1, copied from [DG-AGRI 2007], shows where the feedstock for the 10% EU biofuels target is expected to come from in 2020, assuming 30% is second generation.

The "diversion of domestic use" category is EU production which is used for biofuel but which would go to other uses if there was no biofuel. In the case of biodiesel, this is almost all EU-rapeseed oil which would otherwise be used for food. If we assume that people and animals do not eat less because of biofuels targets, this would be replaced by imported vegetable oil and oilseeds, especially palm oil. These are therefore indirect imports which result from biodiesel production. I

In the case of cereals, "diversion of domestic use" is largely due to replacement of cereals for animal feed by by-products from biofuel manufacture (DDGS from ethanol and oilseed cake from biodiesel); this does not necessarily mean more imports.

The bottom "production (first)" blocks are first-generation biofuels from EU production. In the case of cereals, about half of this comes from production on set-aside land, some from intensification due to higher prices and the rest from growing cereals on land formerly used for other crops (including fodder crops). The last category would lead to more meat and feed imports, but since cereals yields are higher, the replacement is less than 1:1.

If we add the indirect imports to the direct ones, for biodiesel the % imports (in this 30% 2nd generation scenario) rises to about 50%, and to ~80% without the contribution from 2nd generation. For bioethanol, the numbers are more difficult to estimate[19]: with 30% 2nd generation total direct+indirect imports lie between 8 and 24%; without 2nd generation it is between 29 and 45%.

The overall direct+indirect imports are then **32-39%** for 30% 2nd generation, and **56-64%** without second generation.

[19] Because we do not know exactly how much of the "production 1st" cereals come from land diverted from growing other crops, and also the ratio of yields between cereals and the alternative crops.

APPENDIX 4: Employment Effects

The employment effects of a set of predetermined biofuels penetration scenarios were analysed with an approach based on input-output analysis. Input-output methods provide a relatively simple modelling framework that relates final demand components to value added components through the interrelations between all sectors that constitute an economy. The analysis was conducted at the level of the whole EU-25 and the dataset was based on year 2001 national accounts, without attempting to produce a hypothetical explicit representation of the EU economy in the year 2020, benchmark year for the biofuels substitution targets.

The basic I/O model was complemented with a number of extensions necessary to represent the variables essential to determining the impact of the policy scenarios, including consumers' responses to prices and income changes, and agricultural production constraints.

The main price and quantity parameters for the sectors energy and agriculture, including domestic/imported feedstock shares, were calculated separately with sectoral models (mainly PRIMES, by DG TREN, for energy and ESIM, by DG AGRI, for agricultural commodities); biofuels substitution scenarios and bottom-up technology/cost specifications for the production of biofuels were provided by DG TREN.

In all cases it was assumed that the additional cost of biofuels compared to fossil transport fuels were compensated by fuel tax reductions, recollected in turn from private consumers through an increase of general taxation (and disposable income) of equal amount to ensure government budget neutrality. Fuel prices at the filling station were consequently unaffected; however, the price of agricultural products (for both energy and food uses) surged due to increased demand. It was further assumed that world crude oil price would drop by ~1-3% depending on the biofuels substitution rate and consequent crude demand reduction. Oil price was fixed to 48 USD/bbl.

Total net employment effects may be described as the balance between the following employment components: **1)Reduction in conventional fuel sectors**; **2) Increase in biofuels sectors**; 3) **Increase in the sectors producing the capital goods** for biofuels production both in the EU production and for exports, as the scenarios assumed export opportunities for those capital goods to arise for EU firms from increased diffusion in the EU; **4) Increase in agriculture**; **5) Overall decrease of production** (and related employment) due to reduced household disposable income. The model calculated the largest absolute employment losses in the service sectors, since specific employment gains are absent in the services, and the largest overall employment base is in the services sectors. **6) Effects of price changes** and ensuing changes in consumers' expenditure.

Five different scenarios for biofuels penetration in year 2020 were analysed: **Business as usual (BAU)**: 6.9% total biofuels share, mostly first generation, **Maincase (MAIN)**: 14% total biofuels share, mostly first generation, **Biodiesel case (BIOD)**: 14% total biofuels share, of which 90% produced in the EU and 80% biodiesel, and two "extreme" scenarios: **100% Import case (S100IMP)**: 14% total biofuels share, with all biofuels imported, and **100% 2nd generation case (S100SEC)**: 14% total biofuels share, with all biofuels produced in the EU being from 2nd generation processes

A series of sensitivity runs was also conducted on all scenarios to single out the effect of certain assumptions/parameters; the sensitivity runs were specified as follows: **Sensitivity run S1**: total results without exports of biofuels technologies; **Sensitivity run S2**: total results without crude oil price reductions; **Sensitivity run S3**: total results without considering any price changes; **Sensitivity run S4**: total results with vegetable oil price increase locked to the lower level experienced by oil seeds. This sensitivity case was examined since the agricultural simulation model calculated by far the largest price changes (as high as threefold increase in the MAIN scenario) for vegetable oils.

Table 1 summarises the results in thousand people employed expressed as full time job equivalents, as a difference with respect to a hypothetical reference scenario in which biofuels are absent. Sectoral results are aggregated to 8 macro sectors (AGRICULTURE; ENERGY including the power sector; FOOD; INDUSTRY including the production of capital goods for fuel production; SERVICES; TRANSPORT sectors; conventional petrol and diesel FUELS; BIOFUELS) for the base simulation case as well as total variations for the different sensitivity runs.

Table.1: Aggregate results for different scenarios and sensitivity cases:

Macro sectors	BAU	MAIN	BIOD	S100IMP	S100SEC
AGRICULTURE	156.421	192.367	127.544	3.372	95.401
ENERGY	-4.616	-13.857	-16.722	-12.457	-24.049
FOOD	10.557	14.456	15.536	8.124	13.508
INDUSTRY	-3.494	-22.152	-75.867	-153.728	-5.313
SERVICES	-51.219	-34.935	-103.493	-309.478	-7.155
TRANSPORT	-8.026	-16.284	-29.370	-18.311	-15.533
FUELS	-11.144	-20.830	-19.145	-18.092	-20.557
BIOFUELS	16.635	45.731	39.548	0.000	61.875
TOT base	105.114	144.496	-61.967	-500.571	98.178
TOT S1	76.726	111.306	-95.444	-500.571	44.156
TOT S2	12.519	-32.297	-235.211	-669.948	-78.852
TOT S3	101.096	48.394	-261.594	-669.948	-78.852
TOT S4	199.639	252.271	96.855	-500.571	98.178

Overall employment effects were calculated to be modest in all cases (roughly in the range +/- 250,000 against a base of 200 million jobs in the EU25) except the 100% imports case, in which more significant negative values were calculated as a result of foregoing the whole chain of direct and indirect positive effects associated with the production of biofuels. In the more balanced scenarios, the results indicate that a substitution rate of 14% could be achieved without negative overall employment effects. The absolute figures should however be looked at against a significant margin of uncertainty, as the absolute variations are small enough (typically 0.1% of the benchmark) to challenge the accuracy of models even much more sophisticated than the method utilised in this instance. The main conclusion to be drawn form this exercise is that **the net employment effects, under the technology and market assumptions specified in the scenarios, are neutral or close to neutral.**