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HOW SUSTAINABLE ARE BIOFUELS FOR TRANSPORTATION?

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Introduction and goal & scope

Early comprehensive life cycle assessments (LCAs) that compared the environmental implications of biofuels with fossil fuels already appeared in the beginning of the 1990s. Since then the public, scientific and political interest in biofuels has continuously grown and also the number of biofuels and assessed parameters has increased and the methodology for assessments has improved. After the ambitious target of 5.75% of biofuels by 2010 had been set in Europe [1], critical voices were raised questioning the sustainability of biofuels, regarding land use changes, land use competitions and CO_2 avoidance costs in particular. The European Commission has now proposed a new directive on the promotion of the use of energy from renewable sources [2] which is taking into account some of the sustainability issues, e.g. mandatory requirements concerning life cycle greenhouse gas emissions.
This paper gives an overview on the state of the art concerning the environmental impacts associated with the production and use of biofuels for transportation in the context of LCA discussions and deals with different sustainability aspects of biofuels.

Biofuels versus fossil fuels: life cycle comparisons

Environmental implications are assessed commonly via a so called Life cycle analysis (LCA) defined in the ISO norms 14040 & 14044 [3]. In such assessments the complete life cycle comparison from “the cradle to grave” is considered – see Figure 1 for the schematic comparison of the life cycles of a fossil fuel compared to a biofuel.
Figures 2 and 3 give examples of results comparing biofuels versus their fossil counterpart taking into account full life cycle comparisons.
The main result is that the energy and greenhouse gas balances of the biofuels considered are mostly favorable as compared to fossil fuels. Since most biofuels, however, also show disadvantages in other environmental impact categories (see Figure 2) an objective decision in favor of one or another fuel cannot be made. To go for a final decision, subjective weighing is necessary. If, for instance, energy savings of fossil resources as well as greenhouse gases are given the highest ecological importance, almost all investigated biofuels compare favorably to their fossil alternatives.

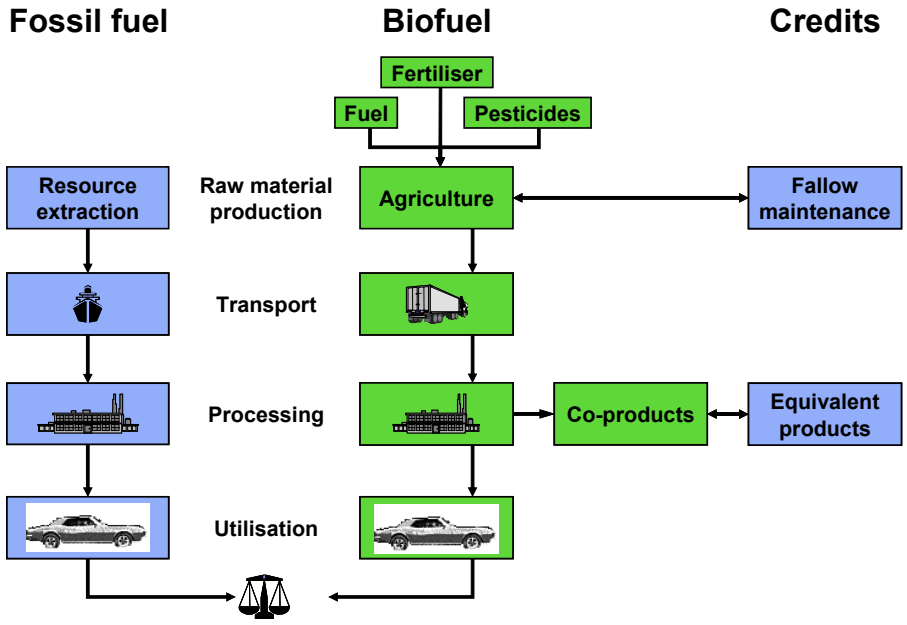

Figure 1: Schematic life cycle comparison of fossil fuel and biofuel.

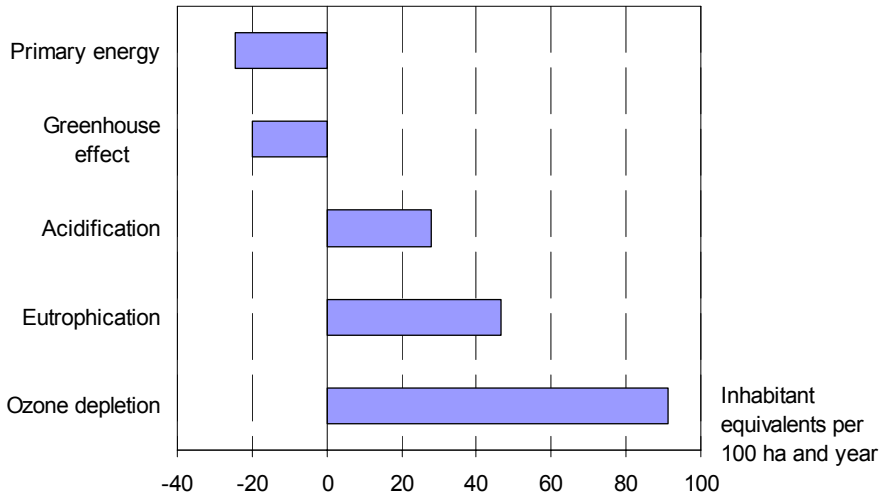

Figure 2: Results of environmental impacts of biodiesel from rape seed compared to conventional diesel fuel (Source: Own calculations and updates based on [4]). Example how to read: if rape seed is grown on 100 ha of land and used for biodiesel substituting conventional diesel, as much greenhouse gases is saved as 20 German inhabitants emit yearly on average (for more information see literature cited)

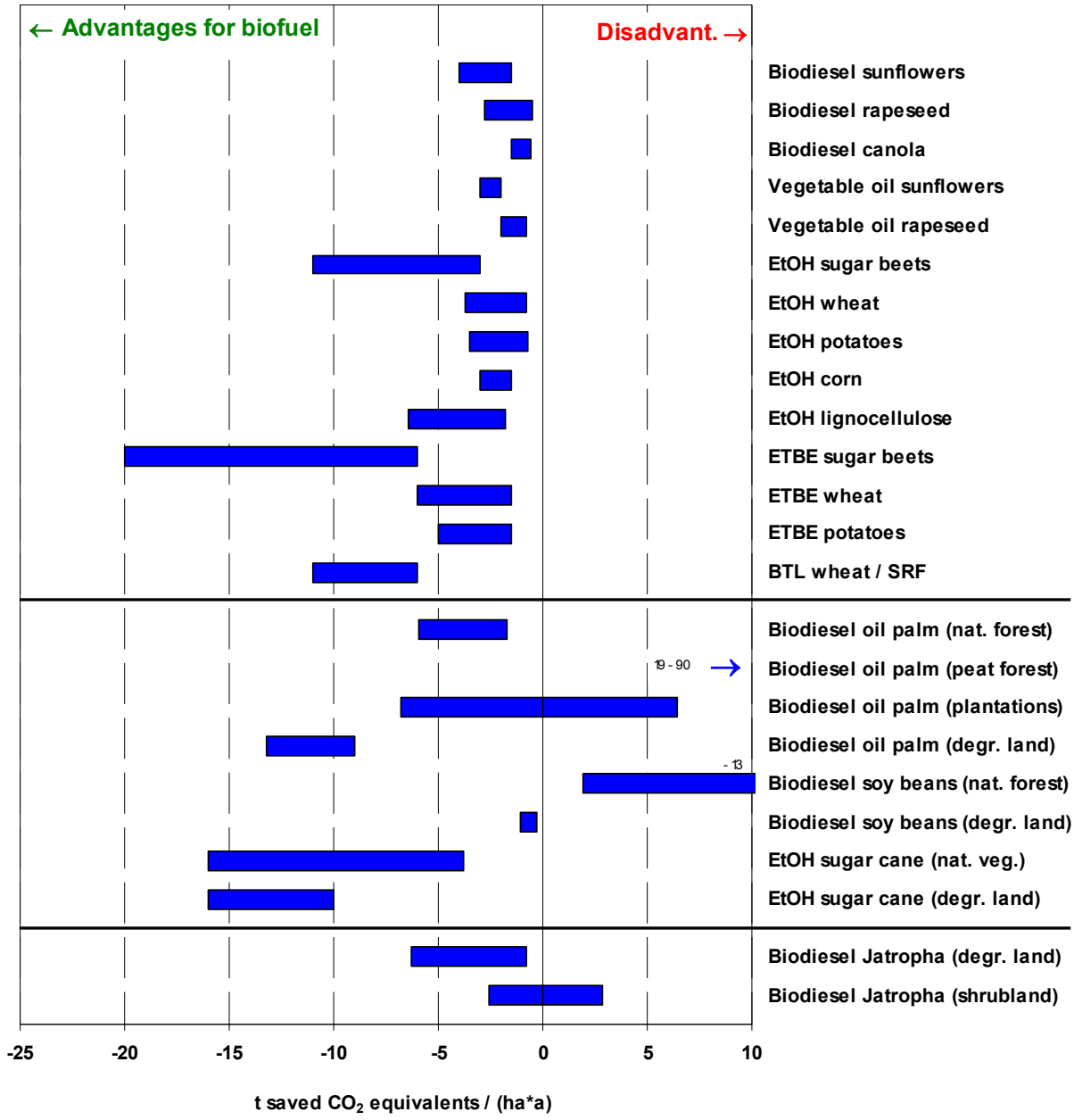

Figure 3: Advantages and disadvantages for greenhouse gases for biofuels from agriculture compared to their fossil counterpart (Sources: [5], [6], [7], and [8])

The following additional conclusions can be made from the presented results:

- *A ranking of biofuels can be undertaken for some examples:*
  - Regarding the area-related consideration for biofuels from agriculture, ETBE (Ethyl-tertiary-butyl-ether, an additive) shows advantages compared to most other biofuels.
  - Bioethanol scores better or worse in dependency on resource basis than biodiesel and vegetable oil.
  - Biodiesel from palm oil shows a huge bandwidth and can even lead to disadvantages com-pared to fossil fuel if land cover changes are taken into consideration. The same is true for biodiesel from Jatropha but to a much lesser extend.
  - BTL (biomass to liquids) shows higher advantages - again: if looked at area related - compared to biodiesel and to ethanol, if ethanol is produced with conventional technologies from wheat, maize or potato. However, ethanol shows advantageous results compared to BTL if produced from sugar cane.
- *Geographically specific advantages.* The advantages of a few biofuels are not found in all geographical areas. For example, bioethanol production from sugar cane is only limited to (sub-)tropical climatic conditions while the cultivation of sugar beets in the temperate regions is only found on particularly fertile soils.
- *High variability of the results*. An examination of various studies in energy and greenhouse gas balances of biofuels shows a high level of variability in the findings. A direct comparison between the different biofuel options is not always possible. The high level of variability arises from the different conditions associated with different goal and scope concerns, e.g. those related to the cultivation, the conversion or valuation of the co-products (for details see [5]). In order to make direct comparisons among different biofuel options, the same system boundaries for both fuels must be used for calculating the results.

Nevertheless, biofuels for transportation show a high potential in saving greenhouse gases and fossil energy carriers which should be developed in accordance with other goals towards a sustainable development. Goals should include alternative uses of biomass for chemical or pharmaceutical industry or for the generation of electricity and heat generation Special emphasis should be put on avoiding land use changes: Furthermore, energy crops should be grown predominantly on unfertile soils where no food production is possible. Regarding the latter issue, palm oil or Jatropha could play an important role in future as they can be grown on marginal or waste lands. This goes in line also with other publications such as [9].

Further impacts on sustainable development

- *Competition on land use*. The dimension of future substitution of fossil fuels depends on the amount of biofuels available and thus on the land area available for biomass production. The land for the production of biofuels can compete with the production of food or other sustainability goals such as organic farming, nature conservation or soil sealing. Figure 4 shows the discrepancy between area demand for reaching different goals and area available for the same purpose in Germany. Also on European level there is a significant reduction in technical potentials for biofuel production due to nature conservation (including water and soil conservation) [10].
- *Competition on biomass use.* Besides being processed into biofuels, biomass can be used for various alternative processes. It can be used either energetically for the generation of power and/or heat or as raw material in

the pharmaceutical or chemical industry or for construction. Especially in the chemical industry biomass will play an important role in future as it is the only possible substitute for fossil raw materials [12]. [13] has shown for German level that competing biomass usages highly affect the potential of biomass. On European and global level similar findings may be true.

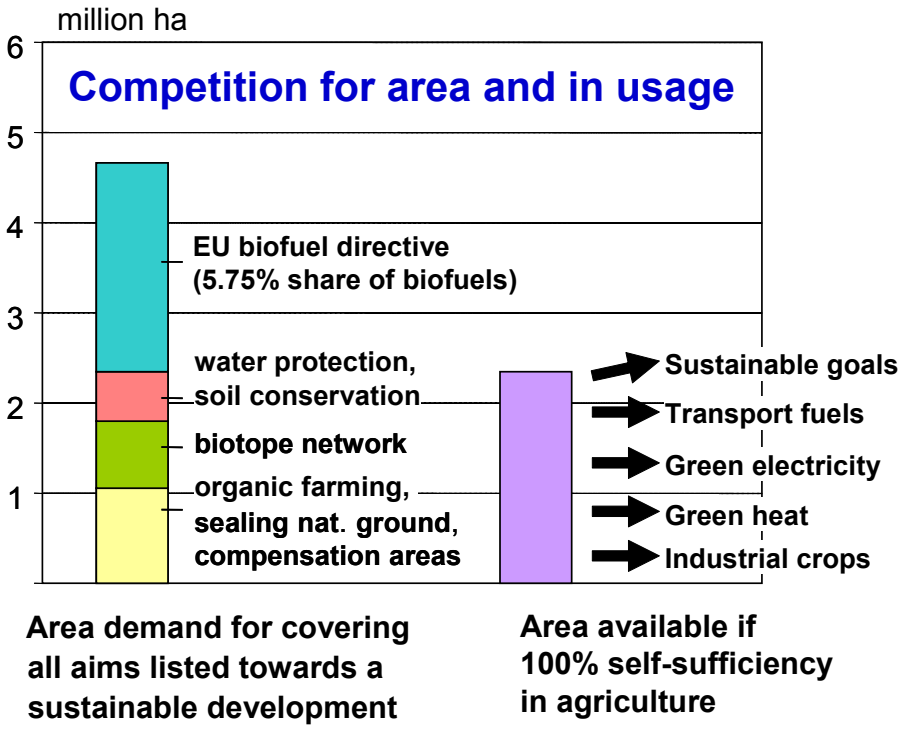

Figure 4: Area demand for covering all aims listed towards a sustainable development until 2010 and area available [11]

Further impacts on sustainable development (continued)

– *CO_2 avoidance costs.* Cost efficiency is of major relevance in decisions for political measures. Therefore CO_2 avoidance costs are important when it comes to the valuation of sustainability. As currently biofuels in Germany are partly exempted from tax, the social costs for the avoidance of one tonne of CO_2 are above the costs in other measures, for examples for pellet heating (see Table 1). It has to be taken into consideration that government aids often serve as start up financing or aim at political goals others than greenhouse gas reduction (e. g. the promotion of science).

Table 1: CO_2 avoidance costs in Euro per tonne CO_2 saved [14]

Field of measures	Costs (funding efficiency) in Euro per tonne CO_2 saved
Driving manner	6
Pellet heating	8
Zero energy houses	12
Vehicles	38
Refrigerators	100
Biofuels for transport	*200*
Photovoltaic	500-1000

Overall conclusions

Environmental assessment

- Biofuels have environmental advantages and disadvantages compared to fossil fuels In general, however, biofuels save fossil energy and greenhouse gases.
- The outcome of the energy and greenhouse gas balances depends on the geographical area where biofuels are grown.
- Different studies in energy and greenhouse gas balances of biofuels show a high level of variability in the findings.
- 2nd generation biofuels and palm oil on marginal degraded land have great potentials to save greenhouse gases.
- Biodiesel from palm oil and soy bean must be discussed in the context of tropical rain forest cuttings.
- Palm oil: If grown instead of existing plantations: fair to negative CO_2 balance.
- If energy crops are used for biofuels, biggest greenhouse gas savings are associated with high yield crops like SRF or sugar beet.
- Lignocellulose has by far the biggest sustainable mass potential (energy crops and residues) and therefore the second generation biofuels, too. This comes along additionally with very effective greenhouse gas savings. Nevertheless, these biofuels are not yet ready for the market.

Sustainable potentials and development

- Because of competition for land and competition in the use of biomass the potentials for energy crops are limited.
- Not all biofuels for transportation can be regarded as being sustainable: some of them are too costly compared to alternatives, some account for negative environmental side effects, some harm nature e.g. by the conversion of ecosystems with high biodiversity
- There is no “best choice of a biofuel”: Still, it is possible to point out the most appropriates for a given situation. Life cycle assessments and environmental impact assessments can help to determine them.
- Nevertheless, there is a great potential for biofuels for transportation which should be developed in accordance with other goals towards a sustainable development including alternative use of biomass for electricity and heat generation and for industry and chemistry.

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