# On the future relevance of biofuels for transport in EU-15 countries

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## Abstract

The discussion on the promotion of biofuels in the EU-countries is ambiguous: benefits like reduction of greenhouse gas emissions and increase of energy supply security are confronted with high costs and bad ecological performance. On the one hand the EU has set the goal of reaching 10% biofuels by 2020. On the other hand there are continuous persisting discussions to undermine this goal. The core objective of this paper is to investigate the market prospects of biofuels for transport in the EU-15 in a dynamic framework till 2030.

While the economic prospects for the 1st generation of biofuels are rather promising – cost-effectiveness under current tax policies exists already – their potentials are very restricted especially due to limited crops areas. Moreover, the environmental performance of 1st generation biofuels is currently rather modest.

2nd generation biofuels will –in a favourable case – enter the market between 2020 and 2030. However, their full potentials will be achieved only after 2030.
*Keywords: biofuels, costs, potentials, $CO_2$-emissions.*

## 1 Introduction

The discussion on the promotion of biofuels is ambiguous: benefits like reduction of greenhouse gas emissions and increase of energy supply security are confronted with high costs and bad ecological performance. Great hopes are currently put on biofuels 2nd generation. The major advantage of the 2nd generation of biofuels is that they can also be produced from resources such as ligno-cellulose based wood residues, waste wood or short-rotation copies, which are not dependent on food production-sensitive crop areas.

The core objective of this paper is to investigate the market prospects of biofuels for transport in the EU-15 in a dynamic framework till 2030. This work

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extends the analysis conducted in Ajanovic and Haas [1]. With respect to the literature the most important analyses are summarized by Panoutsou et al. [2] and Ajanovic and Haas [3].

We consider the following categories:

- Biofuels 1st generation: biodiesel from rapeseed, sunflowers, soybeans (BD-1); bioethanol from maize, wheat, sugar beet (BE-1); biogas (BG-1) from manure, grass and green maize.
- Biofuels 2nd generation: biodiesel from biomass-to liquids (BTL) with Fischer-Tropsch process (BD-2); bioethanol from lingo-cellulose (BE-2); biogas (BG-2) from synthetic gas from biomass.

These biofuels are analysed with regard to potentials, costs and market prospects, and the environmental impacts. This analysis is based on:

- possible developments of fossil energy price levels and energy demand;
- technological learning effects (based on global developments);
- environment, energy and transport policies on EU level.

# 2 Method of approach

The method of approach of our analysis consists of the following major steps:

## 2.1 Assumptions

Major assumptions for the modelling analysis are:

- Increases in fossil fuel prices are based on IEA [4].
- The development of alternative fuel costs is based on international learning rates of 25% and national learning rates of 15% regarding the investment costs of theses technologies.
- International learning corresponds to world-wide quantity developments in the Reference Scenario (RS) and the Alternative Policy Scenario (AS) in IEA [4] up to 2030.
- All cost figures are in prices of 2008.
- No explicit carbon costs are included.
- Regarding the future land use we have assumed that maximal 30% of arable land, 10% of pasture land, 10% of meadows and 3% of wood and forest wood residues could be used for feedstock production for biofuels by 2030. Additional 5% of wood industry residues could be used for biofuels production.

## 2.2 Calculation of biofuel costs

Next the biofuel production costs are calculated. We consider the following components are considered to calculate the costs of biofuels (see also Ajanovic and Haas [1]):

- Net feedstock costs ($C_{FS}$)
- Gross conversion costs (GCC)

- Distribution and retail costs (DC)
- Subsidies for biofuels ($Sub_{BF}$)

Firstly, the feedstock costs are identified for every year as the minimum production costs of all possible feedstocks considered for a specific area category (e.g. crop area) as:

$$C_{FS_t} = Min(C_{FS_{i\_t}}; i = 1...n)$$

n… number of possible feedstocks

Finally total biofuel production costs ($C_{BF}$) for year t are calculated as follows (note, that in these analyses no explicit carbon costs are included):

$$C_{BF} = C_{FS} + GCC + DC - Sub_{BF}$$

## 2.3 Considering technological learning

Future biofuel production costs will be reduced through technological learning. Technological learning is illustrated for many technologies by so-called experience or learning curves. In our model we split up specific investment costs $IC_t(x)$ into a part that reflect the costs of conventional mature technology components $IC_{Con\_t}(x)$ and a part for the new technology components $IC_{New\_t}(x)$.

$$IC_t(x) = IC_{Con\_t}(x) + IC_{New\_t}(x)$$

For $IC_{Con\_t}(x)$ no more learning is expected. For $IC_{New\_t}(x)$ we use the following formula to express an experience curve bys using an exponential regression:

$$IC_{New\_t}(x) = a \cdot x_t^{-b}$$

where:

| | |
|---|---|
| $IC_{New\_t}(x)$ | Specific investment cost of new technology components (€/kW) |
| $x_t$ | Cumulative capacity up to year t (kW) |
| b | Learning index |
| a | Specific investment cost of the first unit (€/kW) |
| $IC_{Con\_t}(x)$ | Specific investment cost of conventional mature technology components (€/kW). |

## 2.4 Maximum additionally usable areas

Then, for every area category considered, the maximum additional feedstock area per year ($A_{FS\_ADDt}$) is calculated as:

$$A_{FS\_ADD\_t} = \varphi \ (A_{FS\_MAX\_t} - A_{FS\_t-1})$$

with
φ … maximum percentage to be added or reduced per year.

### 2.5 Actual additional areas used

Additional feedstock areas are used for biofuels under the following conditions:

$$A_{FS\_t} = A_{FS\_t-1} + A_{FS\_Addt} \mid C_{BFt}(C_{FSt})[1+\tau_{BF}] < p_{FFt}[1+\tau_{FF}]$$

where

| | |
|---|---|
| $\tau_{BF}$ | tax on biofuels |
| $\tau_{FF}$ | tax on fossil fuels |
| $p_{FF}$ | price of fossil fuels (excl. tax). |

In contrast, the feedstock area is reduced when

$$A_{FS\_t} = A_{FS\_t-1}(1-\varphi) \mid C_{BFt}(C_{FSt})[1+\tau_{BF}] > p_{FFt}[1+\tau_{FF}]$$

### 2.6 Assigning feedstock areas to biofuel categories

Feedstocks as well as feedstock areas may also be used for different biofuel categories. For example, some crop areas are suitable for oilseeds for 1st generation biodiesel (BD-1), for wheat for 1st generation bioethanol (BE-1) and for corn stover for 2nd generation bioethanol (BE-2). In this case the feedstock potentials or the feedstocks' area are dedicated to the biofuels category which leads to the cheapest production costs per kWh biofuel:

$$C_{FS_t} = Min(C_{FS_{j\_t}}; j = 1...m)$$

m… number of possible biofuels categories

## 3 Potential

In the following we present the results of cost development and corresponding quantities produced for 1st and 2nd generation biofuels in EU-15 up to 2030. These alternative energy carriers are based on bioenergy resources. An increasing use of biomass in the future in Europe could raise basically two questions: (i) the use of biomass requires large amounts of land which otherwise could be used for other purposes (e.g. food production); (ii) increasing biomass production might be in contradiction with sustainable issues.

The total land area in EU-15 is about 313 Mill. hectares. This total land area could be divided in five groups: arable land (23%), permanent crop (3%), permanent meadows and pastures (16%), forest area (39%) and other land (19%), see Figure 1.

The conventional biofuels are based on the feedstocks grown on arable land, which is very limited in EU-15, 71 Mill. hectares. In this analysis we assume that a maximum of 30% of all arable land, about 21 Mill. hectares, can be used for growing biofuels. Of this area a maximum of 20%, about 4 Mill. hectares, can be used for growing oil seeds.

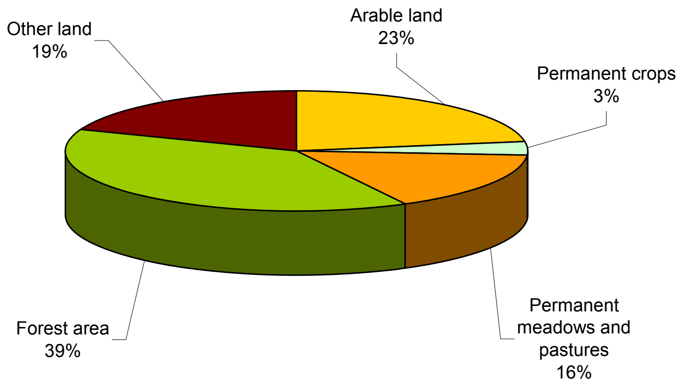


Figure 1: Land area in EU-15, 2008 [5].

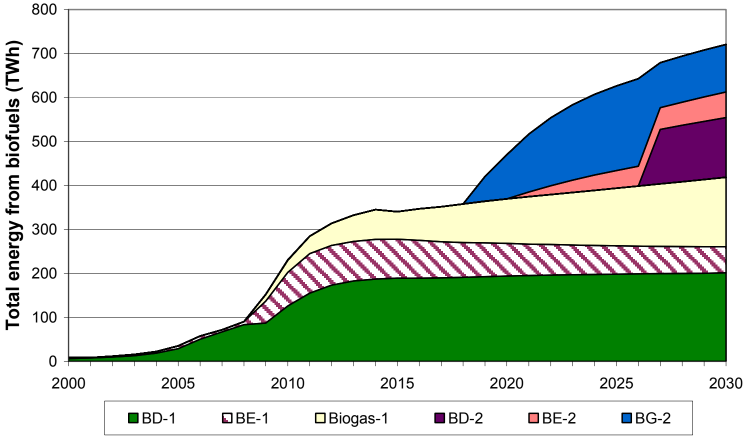


Figure 2: Total energy from biofuels by biofuels category.

However, with the second generation of biofuels, other land areas such as meadows, pastures and forest area could also be used for biofuels production, so that total land potential for alternative energy carriers could be significantly higher.

Due to the EU targets regarding biofuels share in total transport fuel consumption could be expected that total energy from biofuels by 2030 could be significantly higher than now.

As shown in Figure 1 total energy from biomass in 2030 could be more than three times higher than now, 720 TWh. After about 2023 a significant and continuously increasing share of the 2nd generation bioethanol could be noticed. The share of 2nd generation biodiesel could be significant starting from 2027 due to the lower costs than conventional diesel, see Figure 6.

The increasing biofuels production based on domestic produced feedstock will occupy additionally land use, see Figure 3. However, for 2nd generation biofuels mainly non-crop area dependent resources will be used. These are: straw, waste wood and wood residues from the industry.

Due to the switch to the 2nd generation biofuels up to 2030 also significant poplar areas will be used for feedstock production, see Figure 4. Total land area for biofuels production by 2030 will be 64.2 Mill. hectares.

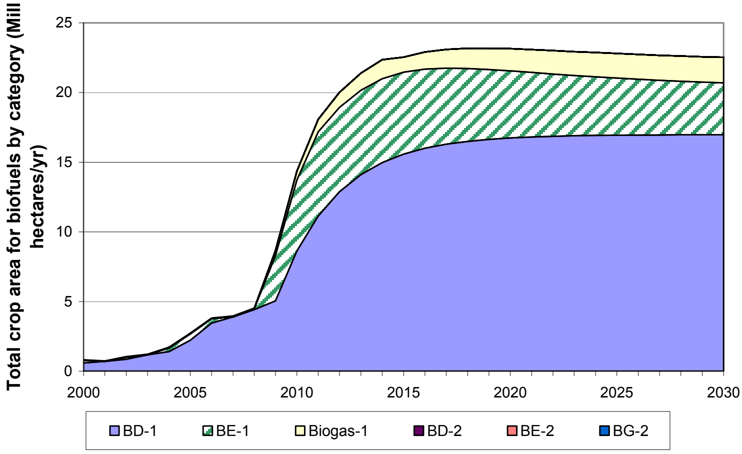


Figure 3: Total area for biofuels by biofuels category.

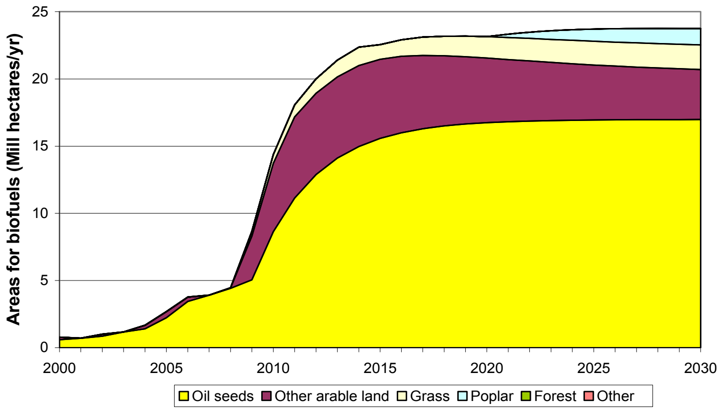


Figure 4: Areas for biofuels by area type.

# 4 Costs

The following Figures 5 and 6 depict the corresponding development of production costs (inclusive and exclusive of 20% VAT) and the prices of fossil fuels, gasoline and diesel, inclusive and exclusive of taxes.

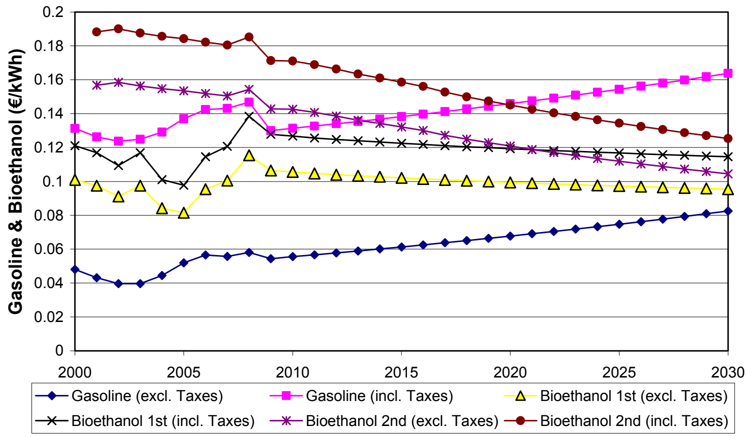


Figure 5: Price versus costs of gasoline and bioethanol.

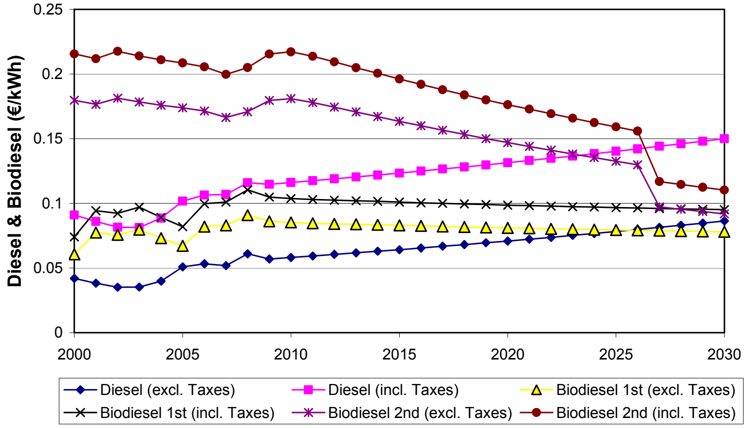


Figure 6: Price versus costs of diesel and biodiesel.

As can be seen from Figure 5 and Figure 6 the costs of 1st generation biofuels are decreasing only slightly even in the most favourable scenario. The major cost reduction is caused by learning effects for capital costs.

As described above, these learning effects are trigged mainly by international learning. They are in our work based on the quantities development in the Referent (RS) and Alternative Policy Scenario (AS) of IEA [4].

The major results of this analysis are: (i) 2nd generation bioethanol will become competitive when including current tax schemes by about 2020, see Figure 5; (ii) Biodiesel (BD-2) will compete with fossil diesel only close after 2025, see Figure 6; (iii) Yet, if no taxes are considered, neither 1st nor 2nd generation bioethanol will be cheaper then fossil fuels before 2030. Close before 2030 biodiesel 1st generation could become competitive with fossil diesel without tax exemptions.

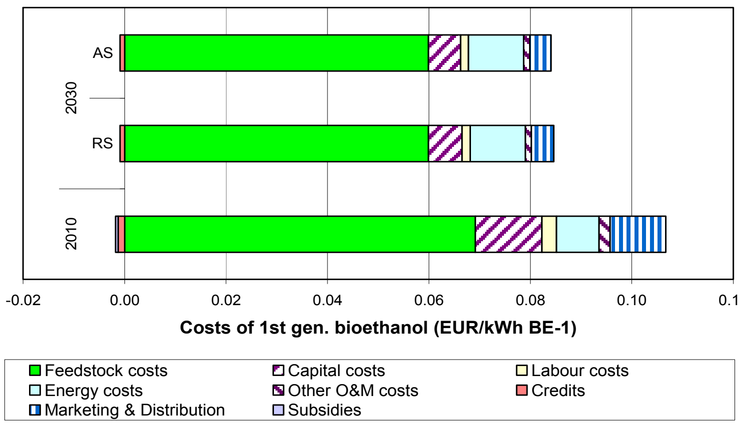


Figure 7: Costs of 1st generation bioethanol (2010 vs. 2030).

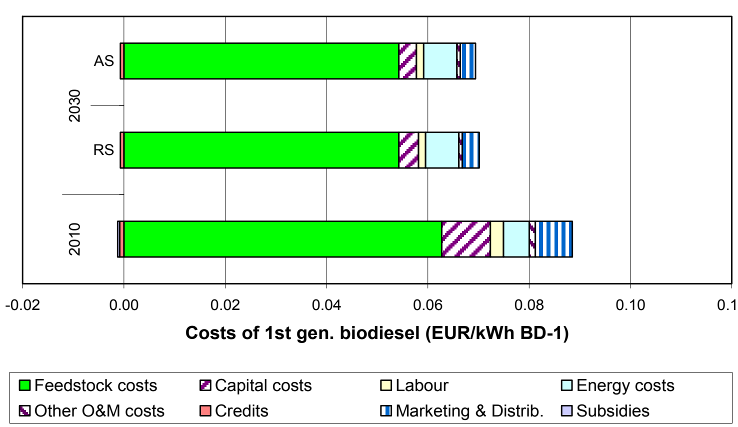


Figure 8: Costs of 1st generation biodiesel (2010 vs. 2030).

Figures 7 and 8 depict the underlying detailed cost structures. It can be seen that the largest part of the total biofuels costs are feedstock costs. In the future, the major cost reduction could be caused by capital costs. But the actual cost differences between RS and AS are rather small.

## 5 Environmental performance

A very sensitive issue with respect to the future relevance of biofuels is their energetic and environmental performance.

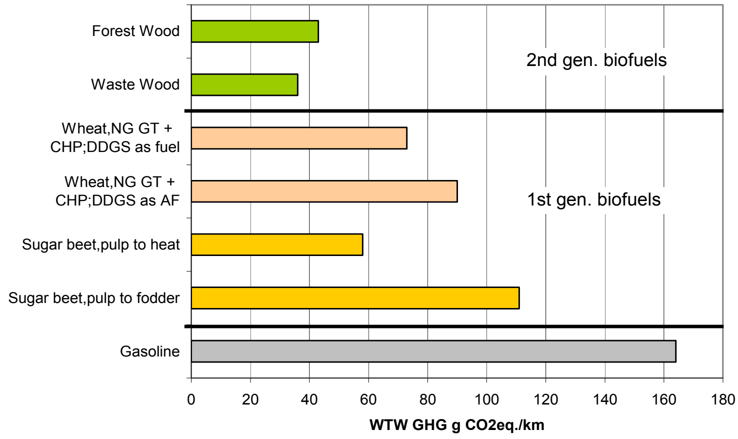


Figure 9: Bioethanol: total WTW GHG emissions [6].

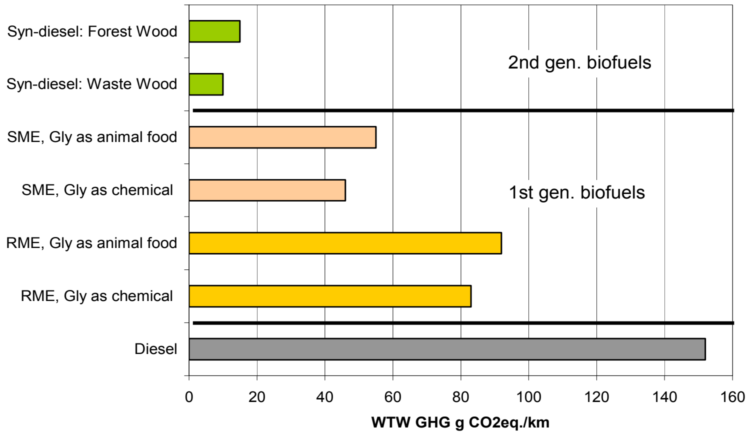


Figure 10: Biodiesel: total WTW GHG emissions [6].

The range of the GHG emissions is very wide due to the different production technology, different feedstocks and the way of using by-products. As shown in Figure 9 and Figure 10 conventional biofuels have moderate reduction of GHG emissions. Higher GHG emission reductions could be achieved in case of by-products being used as fuel instead of as animal feed. However, GHG emission reductions for the 2nd generation biofuels could be much higher, mostly because these processes use part of the biomass intake as fuel and therefore involve less input of fossil energy [7].

The CO2 emissions profile of biofuels production depends very much on the type of feedstock used and the production process. With the increasing use of

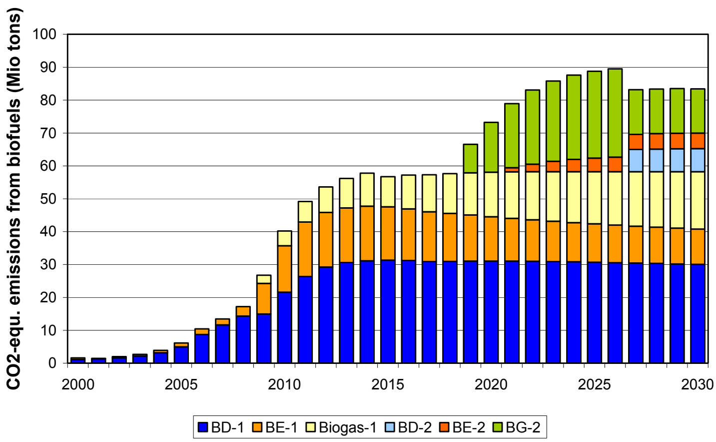


Figure 11: $CO_{2\text{-eq}}$ emissions from biofuels [7].

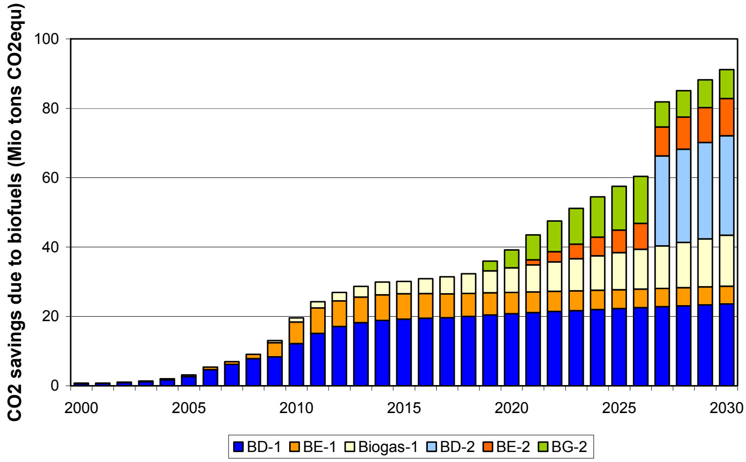


Figure 12: $CO_2$ savings in EU-15 due to biofuels [7].

biofuels in EU-15 total emission from biofuels will be in 2030 significantly higher than now, about 83 Mill. tons $CO_{2\text{-eq}}$, see Figure 11.

However, using biofuels considerable $CO_2$ saving in EU-15 could be noticed, see Figure 12. An increase in CO2 saving after 2026 is due to the increasing share of biofuels $2^{nd}$ generation.

In this context it is very important to state that it has to be ensured by monitoring and certification processes that the ecological performance of biofuels $1^{st}$ generation improves continuously.

# 6 Conclusions

The major conclusions are:

- Under current policy conditions – mainly exemption of excise taxes – the economic prospects of biofuels 1st generation in Europe are rather promising; the major problems of biofuels 1st generation are lack of available land for growing proper feedstocks and the modest ecological performance; the indigenous potentials for BF-1 in EU-15 are limited at a level of about 2 to 3 times the volume of today (without endangering food supply and without imports of feedstocks for biofuels like palm oil);
- The environmental performance of the 1st generation biofuels is currently rather modest;
- Biofuels 1st generation will reach their maximal potential by about 2020. Since up to 2030 they are still cheaper than 2nd generation biofuels they will remain in the market at least until 2030 without significant reductions.
- Large expectations are put into advanced 2nd generation biofuels production from ligno-cellulosic materials like whole plants, wood and wood residues; So the major advantage of BF-2 is that the potential will be significantly higher at levels of more than ten times of today's BF production; (vi) Regarding the future costs of BF-2 it can be stated that in a favourable case by 2030 they will be close to the costs of BF-1; So by 2030 in Europe neither for BF-1 nor for BF-2 significantly lower costs can be expected. Yet, if prices of fossil fuels continue to increase at least slightly given current tax policies BF-1 will become competitive already in the coming years, BF-2 about a decade later.
- 2nd generation biofuels will – in a favourable case – enter the market between 2020 and 2030. However, their full potentials will be achieved only after 2030.

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