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# On the Future Prospects of Alternative Fuels in Europe from Environmental and Economic Point-of-View in a Dynamic Framework up to 2020

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***Abstract:*** *The core objective of this paper is to conduct a comprehensive ecological and economic investigation of alternative fuels from environmental and economic point-of-view based on a dynamic framework till 2010. The ecological assessment is based on a dynamic improvement based on a Well-to-Wheel (WTW)-approach. In 2010 1st generation biofuels had overall only about 45% lower $CO_2$ emissions (on a WTW basis) than the corresponding fossil fuels. By 2020 this figure should increase to 70%. Based on these figures we use a $CO_2$ tax for all fuels which is equivalent to current fossil fuel taxes in Europe. The analysis focuses on Europe yet the major perceptions can be applied virtually world- wide.*
*The major results and conclusions are: With respect to the ecological performance of 1st generation biofuel the best option corresponds to biogas with lowest specific emissions. Biomass-to–liquid performs better than 2nd generation bioethanol in terms of delivered costs and in terms of $CO_2$ emissions per Megajoule (MJ). This is very arguable as 1st generation technologies are already at commercial level and their economic performance depends highly on feedstock cost management and by-product value. The values provided here for 2nd generation biofuels are still disputable as they are based on R&D or demonstration figures, but still no scalable experience has been obtained.*

**Keywords:** alternative fuels, biofuels, economics, well-to-wheel-emissions

## 1. INTRODUCTION

With the increasing environmental and energy supply security problems alternative fuels are becoming more and more important for the future sustainable developments of energy systems. Currently mostly used alternative fuels are biofuels. Due to the targets and different governmental incentive programs share of biofuels in total transport fuel demand has significantly increased over the past decade. This trend can be noticed all over the world but especially in Brazil, the United States and Europe.

The future success of biofuels (as well as other alternative fuels) is depend on different factors such as public acceptance, economics, developments in auto industries and changes in technology, availability and price development of fossil fuels, distribution and marketing systems. Biofuels are broadly classified into three generations based on the production and feedstock utilization.

- 1st generation biofuels are biofuels made from sugar, starch, vegetable oil, or animal fats. The basic feedstock for the production of 1st generation biofuels are often seeds or grains such as wheat, corn etc. that yield starch which is then fermented into bioethanol, or sunflower seeds or rapeseeds, which are pressed to yield vegetable oil that can be used to transform into biodiesel. Moreover, sugarcane for example in Brazil is the most common feedstock for bioethanol. 1st generation biofuels show benefits in terms of GHG emission reduction and energy balance but still give many concerns especially food vs fuel debate [1].
- 2nd generation biofuel are produced from a huge variety of non-food crops feedstock. These include waste biomass, wheat straw, the stalks of corn, wood, and energy plants such as jatropha, miscanthus etc. 2nd generation biofuels use biomass-to-liquid technology (BTL), including ligno-cellulosic biofuels, syngas-based fuels etc. Many 2nd generation biofuels under development are biohydrogen, DME, Bio-DME, Fischer-Tropsch diesel, biohydrogen and mixed alcohols.
- 3rd generation biofuels seek to improve the feedstock rather than improving the fuel-making process. Algae fuel which is being considered to be the 3rd generation biofuels, is a biofuel from cellulosic algal feedstock. This generation of biofuel has the potential for lower biofuel production costs due to simpler feedstock processing, lower energy inputs, and higher conversion efficiencies and hence is economically attractive [2]. However these biofuels are still in labour stage.

Compared to other alternative fuels (e.g. electricity or hydrogen) biofuels have the advantage that they can be implemented without any fundamental changes in fuel distribution and end use: biofuels can be blended with gasoline or diesel and used with only minor changes to fuelling points and vehicles.

However, till 2020 hydrogen, electricity and 3rd generation biofuels will not have significant share in total fuel consumption, mostly due to high costs, missing infrastructure and still inmature technology. So the focus in this paper is on biofuels 1st and 2nd generation.

The core objective of this paper is to conduct a comprehensive ecological and economic investigation of alternative fuels from environmental and economic point-of-view based on a dynamic framework till 2020. The analysis focuses on Europe but the major perceptions can be applied virtually world- wide.

## 2. ECOLOGICAL ASSESSMENT

Biofuels are expected in many policy directives and scientific papers to have the potential to contribute significantly to replacing fossil fuel consumption and corresponding $CO_2$ emissions. Indeed, in recent years biofuels 1st generation (BF-1) – biodiesel (BD-1), bioethanol (BE-1), – have entered the market in significant amounts. Of further interest are bio-methane (BM), bioethanol from lignocellulose (BE-1) and BTL-Fischer-Tropsch-Diesel (BD-2).

Yet, biofuels are still under discussion mainly because of their currently poor ecological and energetic performance. In this context it is very important to consider the whole fuel chain by means of a so-called Well-to-Wheel (WTW) assessment for the ecological assessment. The WTW-balance adds Well-to-Tank (WTT) and Tank-to-Wheel (TTW), see Fig. 1.

The calculation of WTT-net $CO_2$ emission balances used in Fig. 1 is described in detail in Fig. 2 based on the following equation:

$$WTT_{net} = WTT_{minus} + WTT_{plus} \tag{1}$$

Where
$WTT_{plus}$ …. $CO_2$ fixation due to biomass planting
$WTT_{minus}$… $CO_2$ emissions during fuel production
Note that in this calculation no land-use changes are considered.

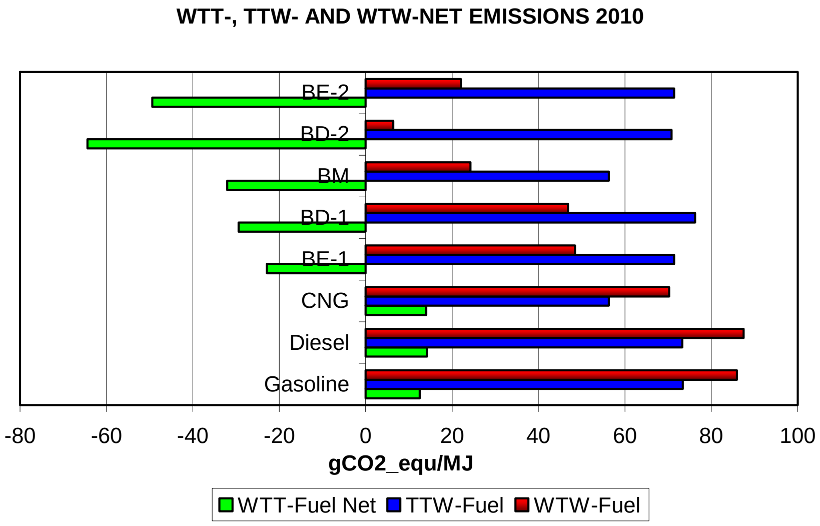


**Fig. 1** WTT-, TTW- and WTW net $CO_2$ emissions of fossil fuels vs biofuels in 2010 for the average of EU-countries [3-4]

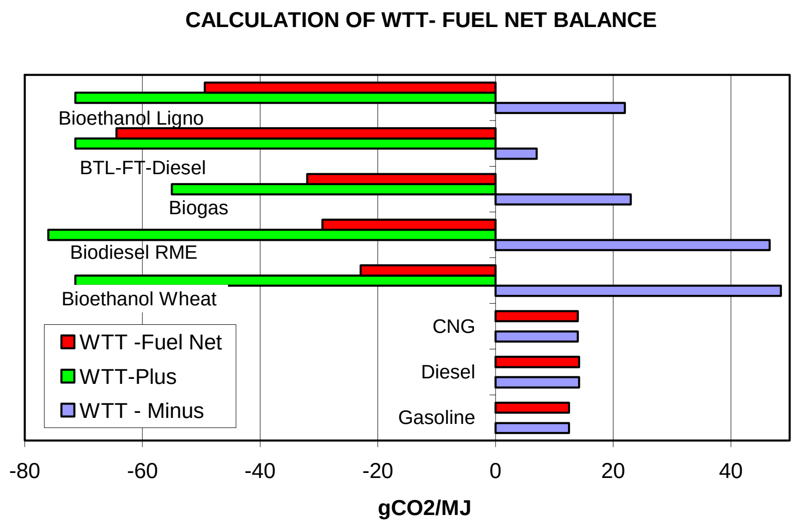


**Fig. 2** Calculation of WTT-net $CO_2$ emission balances (Source: [3-4])

In 2010 BD-1 and BE-1 had overall only about 45% lower $CO_2$ emissions (on a WTW basis) than the corresponding fossil fuels. Fig. 3 depicts the expected development of $CO_2$ emissions of fossil fuels and biofuels in 2010 and 2020 for the average of EU countries on a WTW basis. For the ecological and economic analysis it is important to note that for all fuels by-products were considered in all cases as they result to have a positive influence on costs and emissions performance.

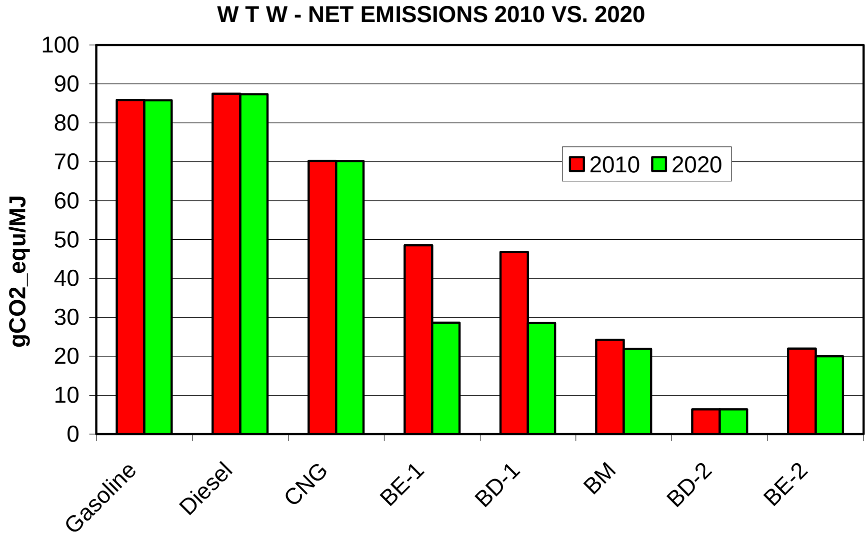


**Fig. 3** $CO_2$ emissions of fossil fuels versus biofuels in 2010 and 2020 for the average of EU countries on a WTW basis [3, 5-6]

Since different resources can be used for hydrogen and electricity production, WTT $CO_2$ emissions could be very different. For example, currently the largest part of hydrogen is produced by steam reforming of natural gas – this is the cheapest solution. However, in this case, WTT emissions are more than two times higher than by BF-1, and about five times higher comparing to BF-2. Hydrogen from renewable energy sources is one of the best solutions from an environmental perspective, but the problems are high costs and still missing infrastructur.

## 3. ECONOMIC ASSESSMENT

Biofuels production costs are dependent on several factors, such as feedstock price, conversion costs, and different promotion policies. The largest part of the biofuels' costs is feedstock cost and these are currently largely dependent on prices of agricultural markets. Feedstock costs differ as per the type of crop used, harvesting technologies, and agricultural subsidies for crops and regions and currently very volatile.

Besides feedstock costs, the scale of the conversion facility have a considerable impact on biofuel production costs.

The following components are used to calculate the costs of biofuels:

- Feedstock costs – $C_{FS}$
- Other energy inputs costs (e.g. electricity, heat etc) – $C_i$
- Annual capital costs – CC
- Operations and maintenance costs – $C_{O\&M}$
- Distribution and marketing costs – $C_{DIST}$
- Total by-product credit – $R_{PB}$

Finally specific biofuel production costs ($C_{BF}$) for year t are calculated as follows:

$$C_{BF} = C_{FS} + C_i + CC + C_{O\&M} + C_{DIST} - R_{BP} \qquad \text{[c€/kWh Biofuel]} \qquad (2)$$

However, it has to be noted that distribution and retail costs as well as policies (subsidies, taxation respectively tax exemption of biofuels) are not included in specific biofuel production costs. Net feedstock costs are calculated for every year as:

$$C_{FS} = P_{FS} \cdot FQ \cdot f_{TC} \qquad \text{[c€/kWh Biofuel]} \qquad (3)$$

Where:
$P_{FS}$......................Feedstock market price [c€/kWh feedstock]
FQ……………...Feedstock quantity used per quantity of biofuels [kWh FS/kWh BF]
$f_{TC}$ .....................Factor for considering feedstock transaction costs

Annual capital costs are calculated as:

$$CC = \frac{IC \cdot \alpha}{P \cdot T} \quad \text{[c€/kWh Biofuel]} \qquad (4)$$

Where:
IC……Investment costs [€]
α…….Capital recovery factor
P…….Capacity [kW]
T…….Full load hours

Revenues from by-products (i.e. the sales value of rapeseed-cakes, electricity, glycerine, animal feeds etc.) produced in the chain of different biofuels processing ways play a minor role regarding the overall biofuels costs. However, the way in which by-products are used has a significant impact on total greenhouse gas emissions. The role of by-products could be even lower in the future due to oversupply. For example, currently demand for glycerine is limited for a number of food, beverage, personal care and oral products, as well as pharmaceutical and other industrial uses. With the increasing biodiesel production it will be necessary to create additional markets for the by-products like glycerine.

The major reason for the continuously increasing market share of biofuels is that biofuels were so far exempted from excise taxes. To identify further future cost reduction prospects it is important to identify the shares of cost categories.

Fig. 4 provides a snapshot of the production costs of fossil fuels and biofuels excluding taxes in 2010 for the average of EU countries compared to fossil fuels. The costs documented also reflect the current size categories installed. Especially for BM, BD-2 and BE-2 the currently small sizes contributes to rather high specific capital costs. Scaling could bring the costs down. As can be seen clearly from Fig. 4 the by far largest cost share of BD-1 and BE-1 are feedstock costs. Feedstock costs for BE-2 are rather low mainly because of straw is used. We can see that biofuels are still considerably more expensive than fossil fuels. So it is clear that their economic performance has to be improved.

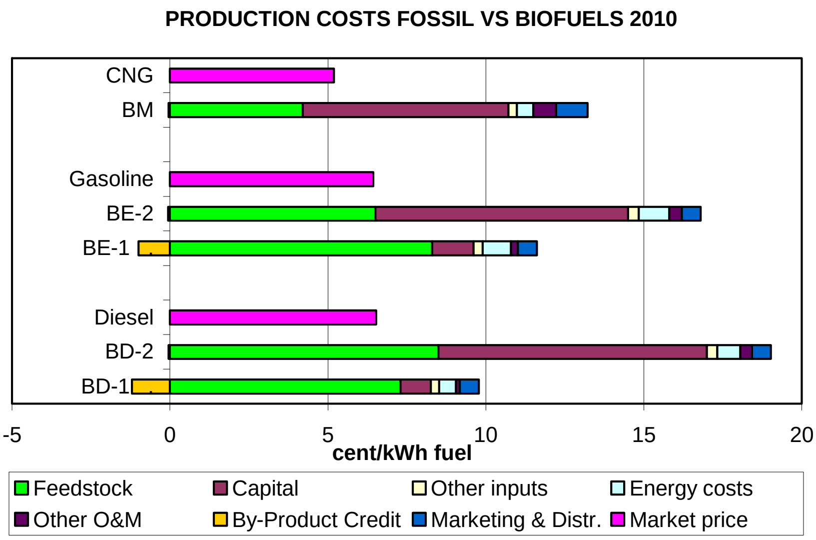


**Fig. 4** Production costs of fossil fuels versus biofuels excl. taxes in 2010 for the average of EU countries [4]

Fig. 5 depicts the costs of fossil fuels and biofuels inclusive and exclusive taxes in 2010 versus 2020 for the average of EU countries. We can see that when the excise tax is replaced by a $CO_2$ based tax the economic attractiveness of all biofuel fractions - except BE-1 - increases. Note that for biogas the costs are a mix of biogas from grass, green maize and manure.

Fig. 6 shows an aggregated picture of the development of fossil fuels versus biofuels production costs and WTW $CO_2$ emissions [g $CO_{2eq}$/MJ] from 2010 to 2020. We can see that only the costs of BF-2 can be expected to decrease moderate, while BF-1 will become slightly more expensive. Yet, the potential for ecological improvements is highest for BF-1.

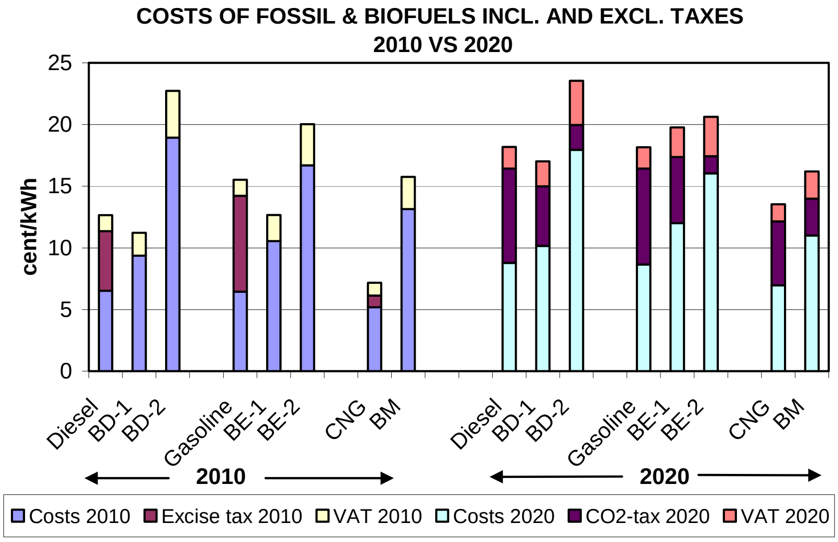


**Fig. 5** Cost of fossil fuels vs biofuels incl. and excl. taxes in 2010 vs 2020 for the average of EU-countries

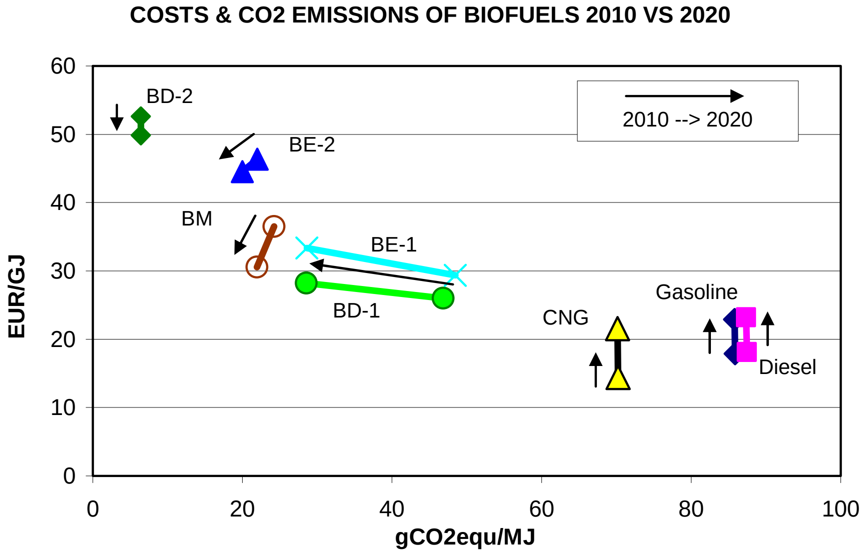


**Fig. 6** Fossil vs. biofuels production costs (exclusive taxes) and WTW $CO_2$ emissions, 2010 and 2020 [4]

## 4. CONCLUSIONS

The major conclusions of this analysis are:

The major problems of BF-1 are the limited available feedstocks – their potentials are very restricted especially due to limited crop areas - and the modest ecological performance due to relatively high share of fossil fuel inputs. The largest expectations are currently put into advanced BF-2. However, 2nd generation biofuels are still immature. Currently their costs are still rather high, mainly because of high investment costs and still rather low conversion efficiencies of feedstocks into biofuels.

With respect to the ecological performance of BF-1 the best option corresponds to biogas with lowest specific emissions. Biomass-to–liquid (BTL) performs better than 2nd generation bioethanol in terms of delivered costs and in terms of $CO_2$ emissions per Megajoule (MJ). This is very arguable as 1st generation technologies are already at commercial level and their economic performance depends highly on feedstock cost management and by-product value. The values provided here for 2nd generation biofuels are still disputable as they are based on R&D or demonstration figures, but still no scalable experience has been obtained.

The most important result of this analysis is that for the EU-27 BF-2 will not become economically competitive up to 2020. However, in the long term competitiveness could be achieved only if the following aspects are achieved: (i) achievement of significant learning effects leading to considerable lower plant costs; (ii) significant improvement of conversion efficiency from feedstock to fuel leading to lower feedstock prices and better ecological performance; (see also EU [12]); (iii) increases in conventional diesel and gasoline prices, e.g. due to $CO_2$ based taxes.

Although environmental performance of BF-2 and also some other alternative fuels (e.g. hydrogen and electricity from RES) are better than that of BF-1, it can be stated that by 2020 in Europe BF-1 will remain most important alternative fuel due to the lower costs. Till 2020 neither for BF-1 nor for BF-2 significant cost reductions can be expected. But proper tax policies and continuous increases of fossil fuel prices could make biofuels (BF-1 and/or BF-2) more competitive in the market.

## 5. ACKNOWLEDGMENTS

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