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The future relevance of alternative energy carriers in Austria

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ABSTRACT – A transition from the current energy system which is mainly based on limited, carbon-emitting fossil fuels towards a sustainable one relying on alternative energy carriers (AEC) such as 1st and 2nd generation biofuels, biogas and hydrogen, is of central importance for a sustainable energy and economic system.

The core objective of this paper is to analyze under which circumstances, to which extent and when different types of alternative energy carriers could be economically competitive in Austria. To answer these questions potentials, costs and necessary promotion strategies are analysed in various scenarios up to 2030. This scenario 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 national and EU level.

The major preliminary result is that in a scenario with continuously increasing fossil fuel prices some AEC could become cost-effective and contribute to total transport energy demand in Austria by 2030 as follows:

- 1st generation biofuels, biodiesel and bioethanol, with 16 TWh;
- 2nd generation biofuels with additional 30 TWh;
- Hydrogen will not become competitive before 2030 and currently no maximum future potentials can be estimated reliably.

Keywords: *alternative fuels, costs,scenarios.*

I. INTRODUCTION

Due to the problems such as increasing greenhouse gas emissions, climate change, energy supply security, a transition from the current energy system which is mainly based on limited, carbon-emitting fossil fuels towards a sustainable one relying on alternative energy carriers (AEC) such as 1st and 2nd generation biofuels, biogas and hydrogen, is of central importance for a sustainable energy and economic system.

The overall range of alternative options to fossil energy is quite broad. Since the transport sector is fastest increasing source of CO_2 emissions with an overall dependency on fossil fuels of about 95% in this paper we focus mainly on alternative energy carriers, such as biofuels, synthetic fuels, natural gas and hydrogen, which could be used in transport.

The core objective of this paper is to analyze under which circumstances, to which extent and when different types of alternative energy carriers could be economically competitive in Austria. To answer these questions potentials, costs and necessary promotion strategies are analysed in various scenarios up to 2030.

Future alternative options have to be assessed with regard to technical properties and potentials, costs and market prospects, and the environmental impacts. The analysis in this paper 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 national and EU level.

In order to provide a sound assessment of the future prospects of alternative energy carriers, we have analyzed in scenarios up to 2030 under which circumstances, to which extent and when these alternative energy carriers could be economically competitive in Austria. What is presented in this paper are the results of a scenario which corresponds to the assumptions of international deployments of biofuels and hydrogen in the WEO 2006 [1] and the WEO 2009 [2] of the IEA.

1. *A short survey on possible future alternative energy carriers*

The most important alternative energy carriers used nowadays are electricity from renewable energy sources and first generation biofuels. The use of conventional biofuels in transport sector is forced by policy. In the EU the goal is to have 5,75% of biofuels in transport by 2010. Although, this biofuels are already mature, they are not able to solve all the existing problems in transport, such as increasing energy import dependency or increasing GHG emissions. At the same time, using these biofuels some new problems have appeared. Currently, the most discussed problems are sustainability and biofuels competition with food production.

Some of these problems could be solved with the 2^{nd} and 3^{rd} generation biofuels. These, advanced biofuels could be produced from wood residues from industry and other ligno-cellulose feedstocks (e.g. woody and herbaceous plants such as perennial grasses and fast growing tree species). Advanced biofuels have also higher energy yields and higher GHG reduction potential. The only problem is that these biofuels are still in the developing stage and may become commercially available only in the next 10 to 20 years [3].

The all alternative energy carriers could be divided in four groups: (i) mature AEC which are already in use; (ii) immature AEC which are still in the developing stage; (iii) AEC in the labour stage; and (iv) technology surprise, see Figure 1.

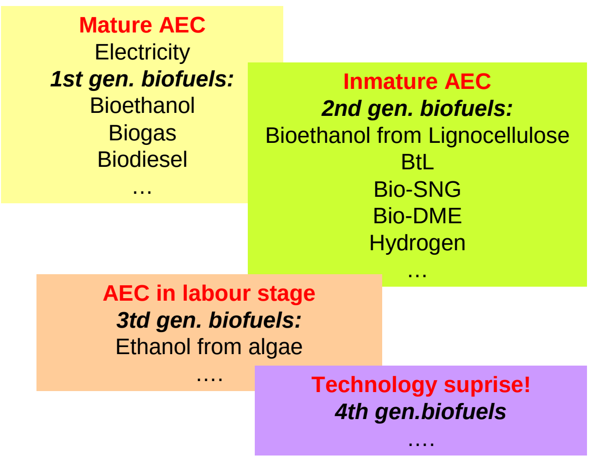

Figure 1 - Alternative energy carriers.

The big advantage of biofuels is that they can be used in conventional internal combustion engines and that no additional infrastructure is needed. The most important alternative energy carriers used nowadays are still conventional – 1^{st} generation - biofuels.

A. *Mature AEC*

These 1^{st} generation biofuels are mostly produced from agricultural feedstocks, such as sugar cane, corn, soy, palm oil, rapeseed, sunflower and wheat. There are still some problems associated with conventional biofuels ranging from GHG emissions to the competition with food production.

The most important 1^{st} generation biofuels are bioethanol, biodiesel and biogas.

Bioethanol could be used directly as a motor fuel or blended with gasoline. It is produced through fermentation of sugar of starch. Most important feedstocks for bioethanol production are sugar cane in Brazil, corn in the US and wheat in the Europe.

Bioethanol can also be used for the production of ETBE which blends more easily with gasoline.

Biodiesel is a substitute of fossil diesel. It is derived from vegetable oils, mostly rapeseed oil, sunflower oil, soybean oil, through transesterifiction. Also residual oils and fats are suitable for biodiesel production.

Biogas (biomethane) could be produced through anaerobic digestion of liquid manure and other digestible feedstocks. With slight adoptions, biogas can be used in gasoline vehicles.

B. *Inmature AEC*

High expectations for a future are from the 2^{nd} generation biofuels. These advanced biofuels could be produced from different ligno-cellulosic materials (e.g. woody and herbaceous plants such as perennial grasses and fast growing tree species). 2^{nd} generation biofuels have also higher energy yields and significantly higher GHG reduction potential. The only problem is that these biofuels are still in the developing stage and may become commercially available only in the next 10 to 20 years [3].

The most important 2^{nd} generation biofuels are 2^{nd} generation bioethanol, BtL (Fische-Tropsch diesel), Bio-SNG (Synthetic Natural Gas) and Bio-DME (Dimethyl Ether).

Advanced bioethanol could be used on the same way as conventional bioethanol. In this case with hydrolysis, sugars are at first extracted from ligno-cellulosic materials, and then fermented into ethanol.

Fischer-Tropsch diesel could be a full substitute of fossil diesel. In this case ligno-cellulosic feedstocks are gasified to produce syngas which in than transformed into liquid hydrocarbons, mostly diesel and kerosene.

Bio-SNG is a fuel that can be used in gasoline vehicles with slight adaptations. It is produced in two steps, ligno-cellulose materials are gasified to produce syngas which is than transformed into methane.

Bio-DME is produced on the very similar way as bio-SNG, but bio-DME can be used as a fuel in diesel vehicles. Some slight modifications of vehicles are needed.

Hydrogen is considered as one of the cleanest and most innovative energy carrier to supply energy services. It is the simplest, lightest and most abundant element in the universe. It constitutes about three-quarters of the mass of the universe, but it does not exist on the earth in elemental form in quantities associated with energy use. However, it can be produced from different energy sources: fossil energy, nuclear energy as well as renewable energy sources. The main requirement for worldwide hydrogen energy long term vision is the production of hydrogen from renewable energy sources.

Hydrogen has potential to reduce greenhouse gas emissions, climate change, global warming, and to increase energy diversity and supply security.

Nevertheless, beside ecological advantage of hydrogen it is also important that new carbon-free energy carrier is affordable, reliable, safe, accepted, and economically viable.

In the last fifteen years the number of hydrogen vehicles, stationary fuel cell systems and refuelling stations is growing. But the largest part of produced hydrogen is used in chemical-, petrochemical industry, in process engineering, and NASA's space program. [4]

C. AEC in labour stage

Algae fuel is being considered to be the third generation biofuel. Third generation biofuels seek to improve the feedstock rather than improving the fuel-making process.

According to the U.S. Department of Energy, algae can produce up to 30 times more energy per acre than land crops such as soybeans, which are curreltly used for biofuel production. The main reason is that they have a simple cellular structure, a lipid-rich composition and a rapid reproduction rate. Many algae species also can grow in saltwater and other harsh conditions - whereas soy and corn require arable land and fresh water. To replace all diesel in the USA with soy biodiesel, it would be necessary half the land mass of the U.S. to grow those soybeans. On the other hand, if algae fuel replaced all the petroleum fuel in the United States, it would require 15,000 square miles (38,849 square kilometers), which is roughly the size of Maryland [5].

Algae could be used for making vegetable oil, biodiesel, bioethanol, biomethanol, biobutanol and other biofuels.

In the last decades biofuels are considered to be a good way to reduce GHG emissions. But, the problems with first generation biofuels are numerous and well-documented in the last few years, ranging from net energy losses, high greenhouse gas emissions to increasing food prices. Taking into account the sustainability and economic factor biofuel from algae seems to be very promising fuel for future.

D. Technology surprise

Although 2nd generation biofuels is still in developing stage and 3rd generation in labour stage, there already efforts toward 4th generation biofuels.

Fourth generation technology combines genetically optimized feedstocks, which are designed to capture large amounts of carbon, with genomically synthesized microbes, which are made to efficiently make fuels. Key to the process is the capture and sequestration of CO_2, a process that renders fourth generation biofuels a carbon negative source of fuel. However, the weak link is carbon capture and sequestration technology, which continues to elude the coal industry [6].

However, scientists at the University of Essex have discovered a new mechanism that regulates the process of carbon fixation in plants. This research could lead to improvements in so-called fourth generation biofuels by letting scientists design feedstocks that capture more carbon.

2. Structure of this work

Based on the above documented description of various AEC in the following we focus on analyses up to 2030. In this context all 3rd generation and beyond going surprise technologies will not play a role in the market. That is to say only R&D triggered installations of capacity production will take place. With respect to hydrogen we state that it is included in our analysis but before 2030 it will not enter the competitive fuel markets. So the major part of the investigation presented in the following focuses on 1st and 2nd generation biofuels.

II. METHOD OF APPROACH

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

1. Assumptions

Major assumptions for the modelling analysis are:

- Increases in fossil fuel prices are based on IEA (2006) [1] and IEA (2009) [2].
- 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 (2009) [2] 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. 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 et al, 2010 [7]):

- 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 (CBF) for year t are calculated as follows[1]:

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

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. The usual formula to express an experience curve is using an exponential regression:

$$IC_t(x) = a \cdot x_t^{-b}$$

where:

$IC_t(x)$ ……….Specific investment cost
x_t …………...Cumulative capacity up to year t
b ……………Learning index
a ……………Specific investment cost of the first unit

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

5. Actual additional areas used:

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

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

Where
τ_{BF}……..tax on biofuels
τ_{FF}……..tax on fossil fuels
p_{FF}……..price of fossil fuels (excl. tax)

On contrary the feedstock area is reduced when

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

6. Assigning feedstock areas to biofuel categories

Feedstocks as well as feedstocks areas may also be used for different biofuel categories. E.g 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 feedstocks and / 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

III. POTENTIAL

In the following we present the results of cost development and corresponding quantities produced for 1st and 2nd generation biofuels in Austria up to 2030. These alternative energy carriers are based on bioenergy resources. An increasing use of biomass in the future in Austria 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 Austria is 8.2 Mill. hectares. This total land area could be divided in five groups: arable land (17%), permanent crop (1%), permanent meadows and pastures (22%), forest area (46%) and other land (14%), see Figure 2.

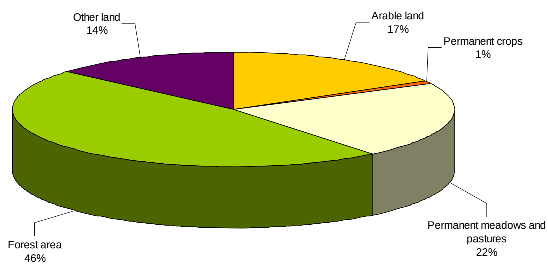

Figure 2 – Land area in Austria.

The conventional biofuels are based on the feedstocks grown on arable land, which is very limited in Austria, 1.4 Mill. hectares. 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

[1] Note, that in these analyses no explicit carbon costs are included!

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 3 total energy from biomass in 2030 could be four times higher than now, 46.5 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.

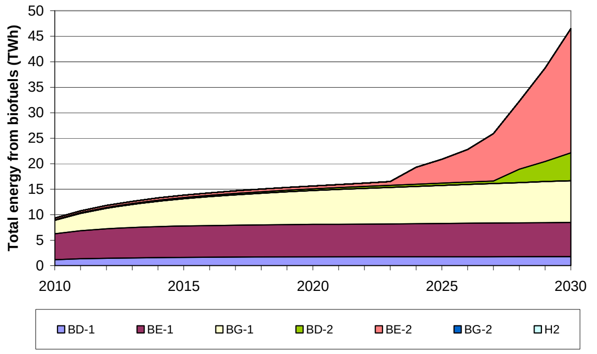

Figure 3 – Total energy from biofuels by biofuels category 2010-2030.

The increasing biofuels production based on domestic produced feedstock will occupy additionally land use, see Figure 4. However, for 2nd generation biofuels mainly non-crop area dependent resources will be used.

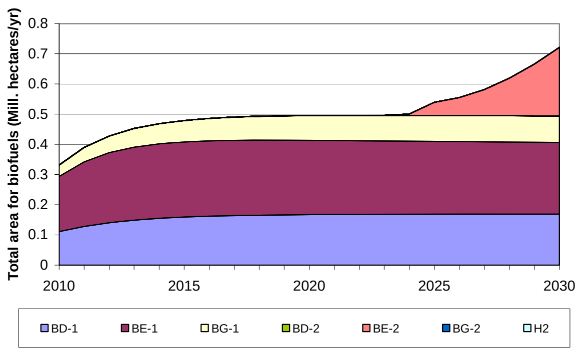

Figure 4 – Total area for biofuels by biofuels category 2010-2030.

Due to the switch to the 2nd generation biofuels up to 2030 also significant poplar areas will be used for feedstock production, see Figure 5. Total land area for biofuels production by 2030 will be 0.72 Mill. hectares.

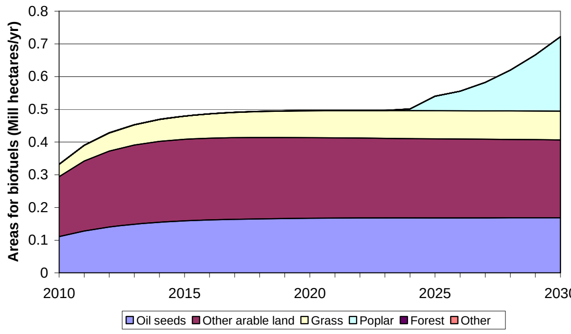

Figure 5 – Areas for biofuels by area type.

IV. COSTS

The following Figures 6 and 7 depict the corresponding development of production costs (inclusive and exclusive 20% VAT) and the prices of fossil fuels, gasoline and diesel, inclusive and exclusive taxes.

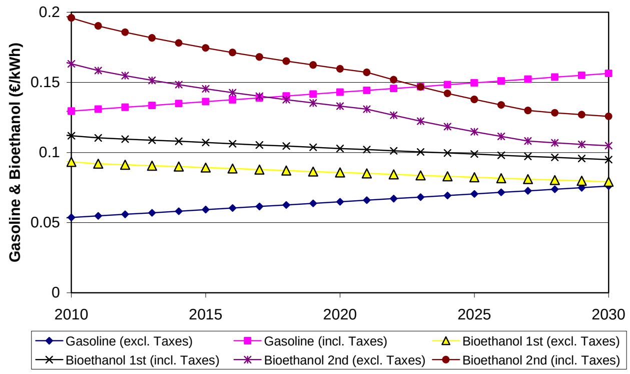

Figure 6 – Price versus costs of gasoline and bioethanol.

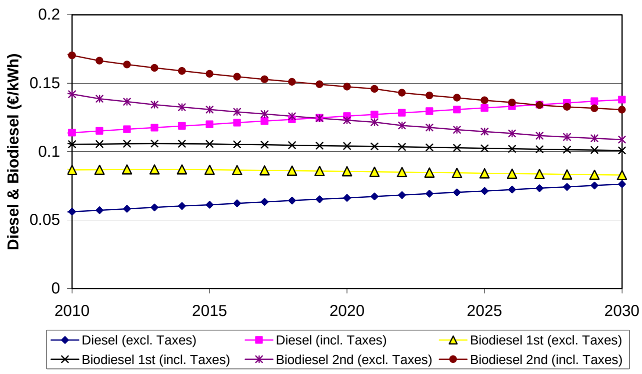

Figure 7 – Price versus costs of diesel and biodiesel.

As can be seen from Figure 6 and Figure 7 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, see Figure 8 and Figure 9.

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 [2].

The major results of this analysis are: (i) 2nd generation bioethanol will become competitive when including current tax schemes by about 2023, see Figure 6; (ii) Biodiesel (BTL-FT) will compete with fossil diesel only close before 2030, see Figure 7; (iii) Yet, if no taxes are considered neither 1st nor 2nd generation biofuels will be cheaper then fossil fuels before 2030.

Figure 8 and Figure 9 depict the underlying detailed cost structures. At 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.

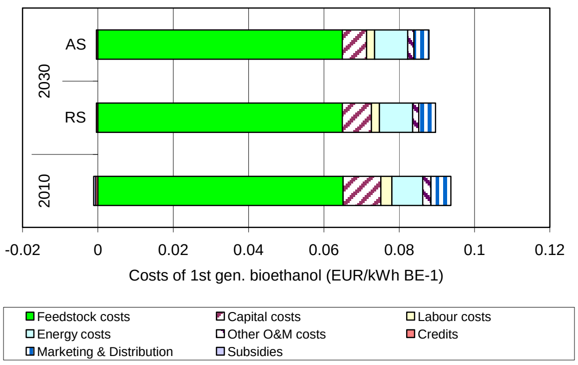

Figure 8 – Costs of 1st generation bioethanol (2010 vs. 2030).

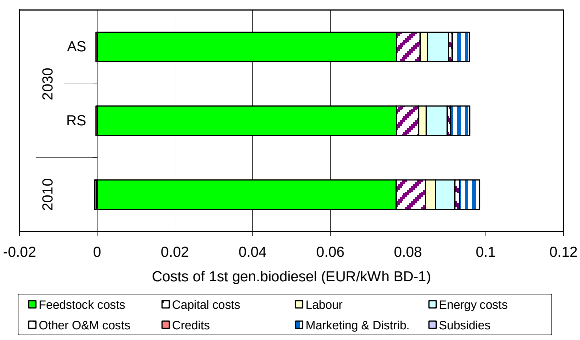

Figure 9 – Costs of 1st generation biodiesel (2010 vs. 2030).

V. LIFE-CYCLE CO_2 BALANCES

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

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 10 and Figure 11 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 [8].

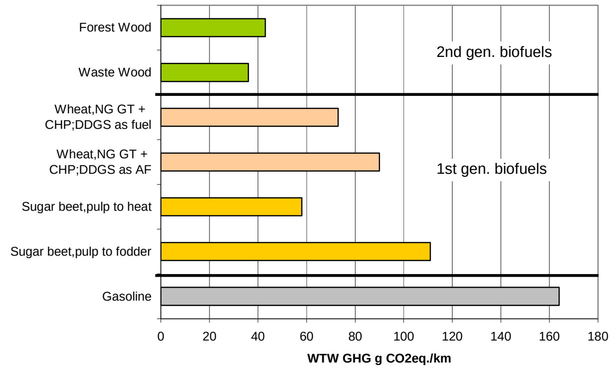

Figure 10 – Bioethanol: total WTW GHG emissions [8].

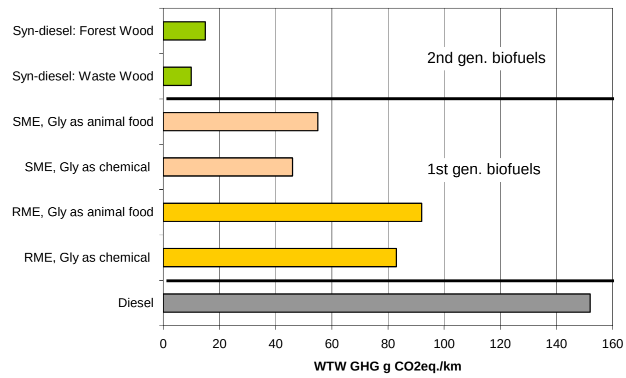

Figure 11 – Biodiesel: total WTW GHG emissions [8].

VI. CONCLUSIONS

The major conclusions are:

- While the economic prospects for the 1st generation 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 the 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. Yet, the major advantage of the 2nd generation biofuels is that they can be produced also 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.
- Since up to 2030 the 1st generation biofuels are cheaper than 2nd generation biofuels they will remain in the market at least until 2030.

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BIOGRAPHIES

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He works in these fields since more than 15 years and has published various papers in reviewed international journals. Moreover, he has coordinated and coordinates projects for Austrian institutions as well as the European Commission and the International Energy Agency ("World Energy Outlook").