Dragan M. Stevanović

Engineering & Consulting, Sulzbach-Rosenberg, Germany

Bio-Fuels: Second Generation

Technical paper

Biomass has a unique position among the renewable energy sources. In contrary to wind and solar energy, it enables a constant supply. Moreover: it is only from biomass, that one can produce even more valuable bio-fuels based on hydro-carbons (biogas, bio-diesel, bio-methanol, synthetic natural gas, biomass to liquid). Therefore, the usage of biomass for producing liquid fuels is the most promising one – it could be economical even without special support measures of energy policy (like feed-in tariff). There is a constant threat that such an energy usage will have a negative influence (directly or indirectly) on the food market. Due to already experienced mal-developments, there are very strict criteria for a new generation of the bio-fuels, the so-called second generation bio-fuels:

- *no interference with the food production chains,*
- *usage of the complete biomass,*
- *positive CO_2 balance, and*
- *increased conversion efficiency.*

Biomass to liquid based on Fischer-Tropsch synthesis is characterised by diesel and kerosene of excellent quality. Especially for aviation it is the only reliable possibility for introducing the renewable energy and improving the CO_2 foot-print of that sector. Some main process developments and projects of the second generation bio-fuels are presented. Some of them may be very interesting applications of the biomass usage in Serbia.

Key words: *renewable energy, bio-fuels second generation, biomass to liquid, Fischer-Tropsch synthesis, aviation fuels*

Introduction

Renewable energy has an important role in the energy mix of the near future. Especially in the present situation of rapid economic growth in some countries, followed by an even higher growth of the energy consumption and a corresponding increase in fossil (and nuclear) fuel demand, it will be a stabilisation factor on the energy market. On the other hand, due to its limitations and economical factors, renewable energy alone can not solve all problems of energy demand. Therefore the right mix and the right matrix of decentralised plants will support the stability of energy supply.

Author's e-mail: office@pebble-heater.com

Biomass has a unique position among the renewable energy sources. Contrary to wind and solar energy it enables a constant supply, *e.g.* of power and heat from combined heat and power (CHP) plants. Moreover: only from biomass one can produce even more valuable bio-fuels based on hydro-carbons – biogas, bio-diesel, bio-methanol, synthetic natural gas (SNG), biomass to liquid (BtL). From all fossil fuels, the oil market is the most volatile and the most influenced by political circumstances and increase of demand. Therefore is the usage of biomass for producing liquid fuels the most promising one – it could be economical even without special support measures of energy policy (like feed-in tariff *etc*.).

This paper gives the main criteria for defining the second generation of bio-fuels, their importance for the transportation sector and especially for aviation. At the end, some main process developments and projects of the second generation bio-fuels are presented. Some of them may be very interesting for a biomass application in Serbia.

Second generation – what does it mean?

Due to its good characteristics for energy production, biomass is a very valuable resource. However, it is clear that there is not enough biomass for all potential energy usages, like heat, power, gas and liquid fuels. It is to expect that the most profitable usage, *i. e.* liquid bio-fuels, will decide its energy destiny.

Thus, the prices for biomass experience a steady increase. In Germany, the prices for wood chips have been doubled in the last 8 years (fig. 1). Even the heating oil prices have not performed the same relative increase. The same has been observed with the prices for corn silage, which is more and more used for bio-gas and bio-methanol production. In recent days a new bio-gas facility in Bavaria has not got the required permit, as the local farmer population was strongly against it. The reason was that they were afraid that the prices for the farmland and the corn silage would con- tinue to increase and that their business with cattle breeding would be in danger.

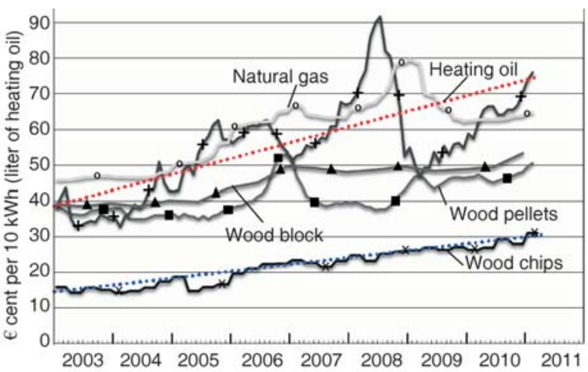

Figure 1. Development of wood, oil and gas prices in Germany 2003-2011 (× – wood chips, ■ – wood pellets, + – heating oil, ○ – natural gas, ▲ – wood blocks) [1]
(full color figure is available in electronic version)

Further on, a very intensive land usage for biomass production is not really sustainable. It requires the intensive application of fertilizers and of mechanisation and increases the indirect emissions of CO_2 and other green house gases.

It can bee seen in fig. 2 that bio-gas (or bio-methane) based on corn silage has a negative reduction of greenhouse gases (GHG) emissions (*i. e.* the emissions are higher

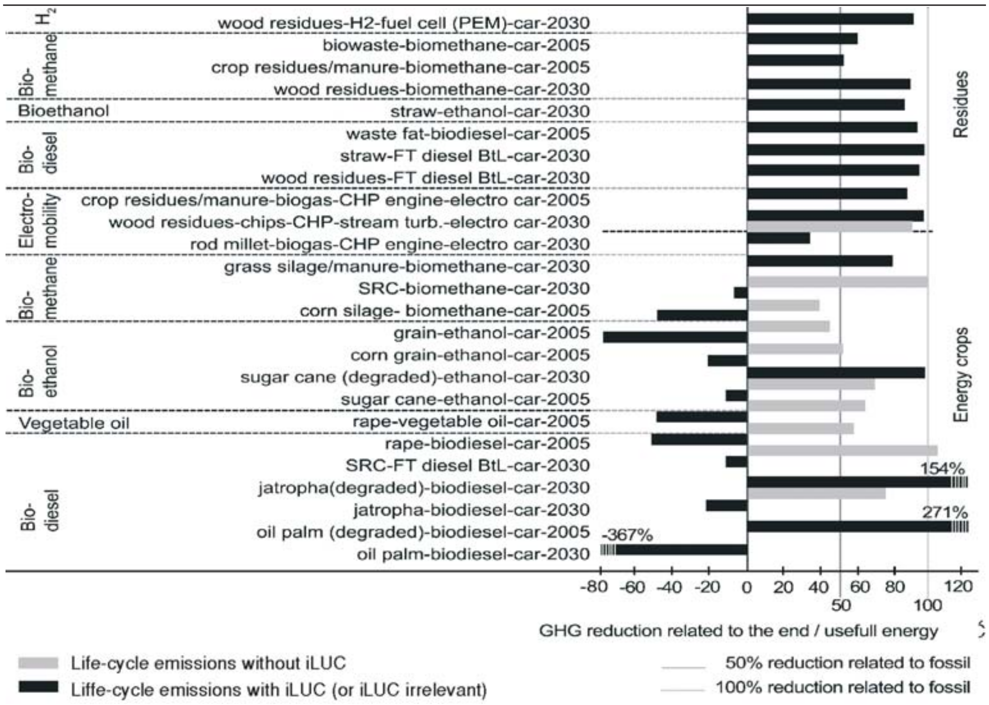

Figure 2. Reduction of GHG emissions for different bio-fuels for mobility (with and without iLUC) [2]

than in case of fossil fuels!) when all relevant factors including indirect land usage change (iLUC) are considered. The same is valid for the bio-ethanol based on corn and cereals, and especially for bio-diesel based on raps and oil-palms from tropical forests.

On the other hand there is a constant threat that the energy usage will have a very negative influence (directly or indirectly) on the food market. Due to those already experienced mal developments, there are very strict criteria for a new generation of the bio-fuels, the so-called second generation bio-fuels:

– no interference with the food production chains,
– usage of the complete plants (not just oils, sugars and proteins, but also cellulose and lignin),
– positive CO_2 balance, and
– increased conversion efficiency.

The emphasis lies on the agricultural waste – the residues from the food production process. On that way the interference with food chains will be eliminated and the GHG emissions will be considerably reduced (see the upper part of the diagram in fig. 2).

Further on it is clear that cultivation of biomass on devastated and degraded land has an extremely high potential for GHG reductions (see the cases of jatropha and oil-palms in fig. 2), even above 100%! This is due to the formation of a new humus layer on degraded lands which follows the new biomass cultivation. That layer is in fact storage of CO_2 from the air.

There are several bio-fuels, BtL which could fulfil those criteria.

Fischer-Tropsch BtL

It is the most famous way for producing bio-fuels of the second generation, known as the "real" BtL. Biomass is firstly converted into synthesis gas through gasification. Afterwards the hydrocarbons are formed through the Fischer-Tropsch (FT) synthesis at higher pressure and temperatures, in the presence of Fe or Co based catalysts. A typical product spectrum is given in fig. 3 [3]. Due to the gasification path, all kind of biomass and biomass residues may be theoretically used. BtL based on FT synthesis is characterised by diesel and kerosene of excellent quality, without polycyclic aromatics. Combustion properties are considerably better in comparison to the fossil fuels. Hence, they are also referred to as "designer fuels".

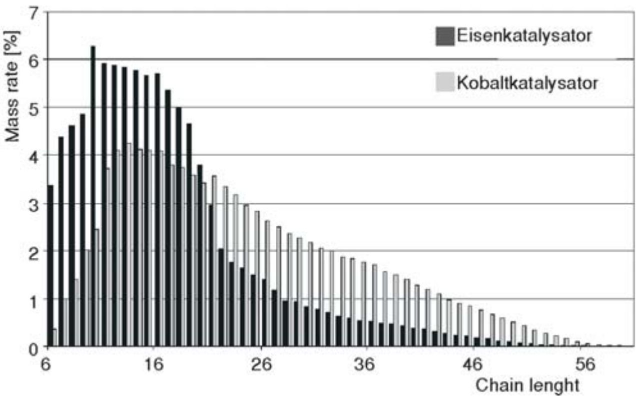

Figure 3. Typical product spectrum of FT synthesis with Fe and Co catalyst [3]

Hydro-treated vegetable oil (HVC)

This is a further development of bio-diesel and vegetable oil (or animal fat) production. Through hydro-treatment and isomerisation one can get a sulphur-, oxygen-, nitrogen- and aromatics-free diesel and/or kerosene. Thanks to a high cetane number, it combusts efficiently, keeping engines clean. However, it has the same disadvantage as bio-diesel: not the complete plant is used, just the oil rich fruit. The CO_2 balance is not clear – it could be very positive, but also even negative (see fig. 2). There are a lot of critics for this fuel and even some voices against its denotation as a second generation bio-fuel. However, that is the only second generation, high quality bio-fuel available in large quantities on the market.

Pyrolyse oil and other products of direct liquefaction

There are several developments in this pretty wide segment, like flash pyrolysis (*e. g.* "bioliq", "BTG"), thermolysis (low pressure DoS), or high pressure processes (HP DoS) [4]. The main idea is to produce oils directly from biomass and not to destroy all complex molecules into CO and H_2 and then to synthesize hydrocarbons from the very beginning. Therefore the process efficiency is higher, at least theoretically, than in the case of FT synthesis. However, the product is a mixture of a wide spectrum of different hydrocarbons which has to be further treated (*e. g.* in refineries) in order to get the desired fuel quality. In case of "bioliq" it is foreseen to make a gasification of the gained slurry of pyrolysis oil and char and then to synthesize methanol (MeOH) and dimethylether (DME) as a basis for further chemical products. However, on that way, the advantages of direct liquefaction are lost.

Bio-ethanol made through the digestion of the whole plants is also a new option for the second generation bio-fuel (development of new enzymes in tests) [5].

Although there is some competition between different routes and products of second generation bio-fuels, most of them will find some specific field of application.

Aviation

Bio-fuels are very important as a potential substitute for the liquid fossil fuels and for the corresponding reduction of the CO_2 footprint in the traffic sector. This is valid for land (personal cars, trucks, trains), see (ships) and air (airplanes) transport. However, for all those transportation systems there are other, at least theoretical, possibilities for implementing renewable energy source (*e. g.* electricity from renewable energy or bio-gas). The only exception is the air transport: the liquid fuels are the only energy form which can be used for aviation in the near future.

Moreover, the quality standards for the aviation fuels are so high, that those can be produced just from fossil and bio-fuels. The most rigid standards define among others:
– heat value,
– density,
– water content / absorption ability, and
– solidification temperature (<–47 °C).

Therefore just the best bio-fuels may fulfil those requirements: FT kerosene and hydrated vegetable oil (HVO) kerosene.

On the other hand, the expected rate of transportation growth is 4.5% per year, till 2050. It means, that the aviation transport will rise from 0.5 billions of revenue ton kilometres (RTK) nowadays to 3 billions of RTK (fig. 4) [6]. Most of that increase will happen in the so-called BRICS countries, while the growth in the western countries is expected to be very moderate.

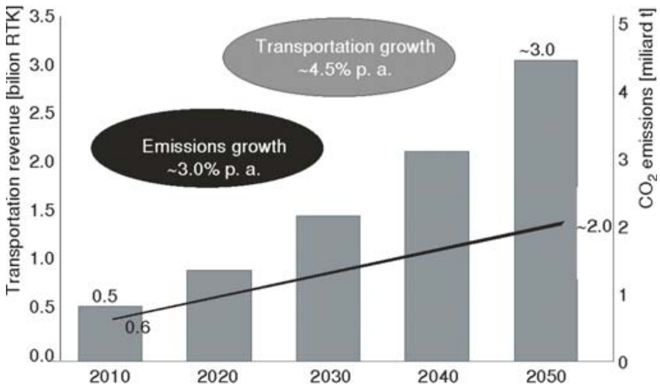

Figure 4. "Base case" prediction for the transportation and CO_2-emissions growth in the aviation sector [6]

In the same time, the predicted rise of CO_2 emissions is just 3% per year, due to measures which will be taken in order to reduce the climate change effects of the aviation. However, it means that the emissions will increase significantly from 0.6 milliard tons of CO_2 nowadays towards 2 milliard tons. Figure 5 shows how dramatically the amount of CO_2 increases, that has to be reduced acording to

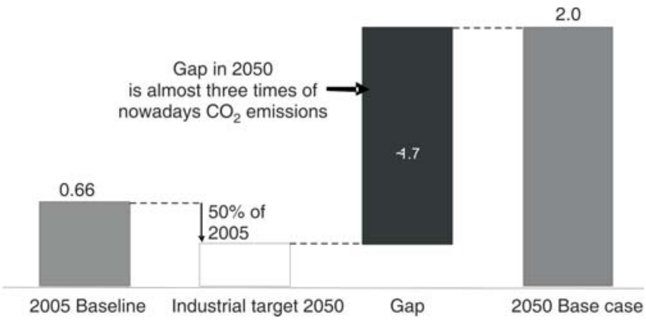

Figure 5. Discrepancy between the proclaimed industrial target for CO_2 emissions in 2050 and the expected emissions (in milliard t CO_2) [6]

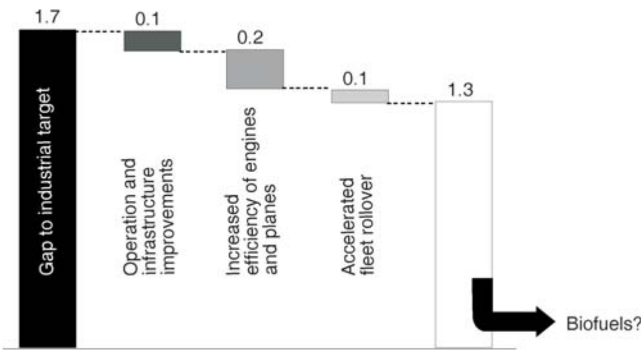

Figure 6. Potentials for closing the gap between emissions and industrial target for 2050 (milliard t CO_2) [6]

the proclamation of industrial targets for 2050 (50% reduction up to 2050 relative to the baseline emission of 2005). This amounts 1.7 milliard tons, *i. e.* it is almost 3 times higher than emissions today!

The only possible way to reach such important reduction is the usage of bio-fuels, as shown in fig. 6 [6]. Even if the maximum of all other reduction measures is reached (*e. g.* 0.1 milliard t through operations and infrastructure improvements, 0.2 milliard tons through increased efficiency of future engines and planes, and 0.1 milliard tons through accelerated renewal of the fleet – rollover), there is still a gap of 1.3 milliard tons of CO_2 emissions which could be closed just trough the usage of bio-fuels (corresponding to ~410 million tons of jet fuel per year).

Especially for aviation the usage of bio-fuels is the only reliable possibility to introduce renewable energy and improve the CO_2 foot-print of that sector. Lufthansa will start a regular operation between Frankfurt and Hamburg with 50% HVO blending on one engine for 6 months, starting from April 2011 [7].

Economics of bio-fuels

High quality second generation bio-fuels are produced on an industrial scale only by a big Finnish oil company in the form of HVO. There are two big facilities in Finland, each of 190.000 t/a, and one in Singapore of 800.000 t/a. Another one is in construction in Rotterdam, also 800.000 t/a, and the commissioning is scheduled for 2011 [8]. Those products are already used for blending fossil fuels under economical conditions.

However, due to the mentioned critics to the way of HVO production, it can not be counted as a long-term solution. On the other hand, the economics of the FT bio-fuels are not so obvious as those of HVO, not at least due to the more expensive input biomass (European instead of Asian prices). According to Stahlschmidt [9], the most favourable price for BtL on FT-basis is 17.89 ct/kWh. Many other authors, as well as the investors and operators of many test facilities state that the expected price is even lower. The general opinion is that under present conditions (100-110 US$/barrel crude oil) BtL could be competitive if it is exempted from the mineral oil taxes. Without that exemption the break-even price for the crude oil is in the range of 140-150 US$/barrel.

It is obvious that the economics of BtL are not a long-term problem. Still the main problem is that there are not long-term large-scale experiences with the BtL production. Therefore, there exist very intensive activities in building such demonstration and pilot facilities (not only throughout Europe) like:
– Germany (Choren, bioliq, bioethanol in Straubing-Sand...),
– France (Futurol – Champagne-Ardene, Bio T Fuel, Bure – Saudron),
– Sweden (Chemrec AB),
– Finland (NES Biofuels Oy – including FT-synthesis),
– The Nederland (BTG, CleanFuels), and
– Austria (Gussing).

Serbian case

The relative importance of biomass for Serbia is bigger then for some highly developed European countries. As an example, Germany has a surface area of 357.000 km^2 (121.400 km^2 or 34% arable, 107.000 km^2 or 30% woods), a population of 81.7 million and crude-oil consumption of 109 million tons per year. In Serbia, those figure are: area 88.400 km^2 (33.550 km^2 or 38% arable, 24.300 km^2 or 27.5% woods), population of about 9.1 million, crude-oil consumption of 2.9 million tons per year (crude-oil import 2.3 million tons, total consumption of all derivates 4.3 million tons) [10, 11].

It means that Germany has roughly 4 times greater biomass potential, 9 times bigger population and even 25 times higher oil consumption. Germany is very active in using that potential and in developing corresponding technologies, although even in the best case less than 10% of fossil oil could be substituted by bio-fuels of domestic origin. In the case of Serbia, that potential is considerably higher, so that this substitution could be even more than 50%!

Those potentials could be even higher by using degraded and devastated land for cultivating energy plants or woods (*e.g.* short rotation plants). There are already some excellent studies for the re-cultivation of mine-spoil banks of opencast mines in the Kolubara basin [12]. The concrete measures are still missing.

Due to the low electricity price and high prices for oil derivates in Serbia, it is clear that for the national economy the usage of biomass for bio-fuels could be much more attractive. However, that does not mean that the activities on CHP biomass plants should be stopped – such projects will demonstrate the importance of biomass for Serbia.

Conclusions

The production of bio-fuels is the most rational and justified usage of biomass in the long-term. For the second generation bio-fuels it is crucial to avoid the interference with food production chains, as well as to secure the positive reduction of GHG emissions. A very big market for such fuels is already there, not just for road transportation – an even bigger and stable market is arising for aviation (substitution of jet fuels). However, a technology with a long-term record of reliability and efficiency is still missing. Biomass and bio-fuels are surely a very big opportunity for Serbia. The economics may be considerably better than in most of developed western countries, due to lower prices of input biomass, labour and domestic equipment. With the right energy and technology policy Serbia should use this great opportunity. The target should be not just the substitution for oil imports, but the export of high quality fuels, too.

References

[1] ***, Preisentwicklung bei Hackschnitzeln, Pellets, Heizöl, Erdgas und Scheitholz von 2003-11, http://www.carmen-ev.de/dt/energie/images/hackschnitzel, C.A.R.M.E.N., Straubing, 2011
[2] Schubert, R., *et al*., Welt im Wandel: Zukunftsfähige Bioenergie und nachhaltige Landnutzung, Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Berlin, 2009
[3] Hofbauer, H., *et al*., Energiezentrale Güssing – Berichte aus Energie- und Umweltforschung, Report No. 79/2006, Bundesministerium für Verkehr, Innovation und Technologie, Wien, 2006
[4] Meier, D., Verfahren zur Biomasseverflüssigung – Möglichkeiten und Grenzen, Direktverflüssigung von Biomasse und Kunststoffen, FGK e.V. Fachtagung, Magdeburg, Germany, 2007
[5] ***, Süd-Chemie to build Germany's Largest Plant for the Biotechnological Production of bio-Fuels from Straw, http://www.sud-chemie.com/scmcms/web/page_en_7566, Süd-Chemie AG, Munich, Germany, 2010
[6] Buse, J., Synthetische Biokraftstoffe im Luftverkehr – Einordnung und Chancen (Lufthansa Aviation Biofuel), 4th BtL-Congress, Berlin, 2010
[7] Wenninger-Muhr, J., Lufthansa Tested Biofuel, Lufthanseat, No. 1369/57, 2011
[8] Lindfors, L.P., Overview of the NES Bio-Fuels Process for the Production of Synthesis Fuels from Residuals of Forest Industry, 4th BtL-Congress, Berlin, 2010
[9] Stahlschmidt, R., Evaluation of Recent BtL-Processes, 4th BtL-Congress, Berlin, 2010
[10] ***, Energetski bilans Republike Srbije za 2008. godinu, Government of Serbia, Ministry for Infrastructure and Energy, Belgrade, 2008
[11] ***, Energy Balance of Oil and Oil Derivates in 2009, Statistical Office of the Republic of Serbia, Belgrade, 2009
[12] Dražić, D., Polyfunctional Evaluation of the Landscape and Ecosystems Formed by the Re-Cultivation of Mine-Spoil Banks of Opencast Mines in the Kolubara Basin, Federal Secretariat for Labour, Health and Social Welfare – Department of the Environment, Belgrade, 2002

Апстракт

Драган М. СТЕВАНОВИЋ

Инжињеринг-консалтинг, Сулцбах-Росенберг, Немачка

Био-горива: Друга генерација

Биомаса има јединствену позицију међу обновљивим изворима енергије. За разлику од ветра и соларне енергије, она омогућава стабилно снабдевање. Још важније: само из биомасе се могу произвести још вреднија биогорива на бази угљоводоника (биогас, биодизел, био-метанол, синтетички природни гас, синтетичка течна горива из биомасе.). Коришћење биомасе за производњу течних горива је пут који највише обећава – може да буде економичан и без посебних мера подршке енергетске политике (као нпр. привилеговане тарифе). Постоји стална претња да ће такво коришћење енергије имати негативан утицај (директно или индиректно) на тржиште хране. Због већ искушених грашака у развоју, постоје веома строги критеријуми за нове генерације биогорива, тзв. друге генерације биогорива:

- нема преплитања са ланцима производње хране,
- коришћење комплетне биомасе,
- позитиван биланс угљен-диоксида, и
- повећана ефикасност конверзије.

Синтетичка течна горива из биомасе на основу Фишер-Тропш синтезе одликују се одличним квалитетом добијеног дизела и керозина. Посебно за авијацију је то једина поуздана могућност за увођење обновљивих извора енергије и побољшање биланса угљен-диоксида у том сектору. Неки основни процеси развоја и пројекти друге генерације биогорива су овде представљени. Неки од њих могу бити веома интересанатни за енергетску примену биомасе у Србији.

Кључне речи: *обновљиви извори енергије, биогорива друге генерације, синтетичка течна горива из биомасе, Фишер-Тропш синтеза, ваздухопловна горива*

Одговорни аутор; електронска адреса: office@pebble-heater.com

Paper submitted: May 7, 2012
Paper revised: August 3, 2012
Paper accepted: November 11, 2012