Global developments of biofuels for transport

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Stockholm, September 2014

ABSTRACT

Conventional biofuels achieved a rapid growth in the first decade of this century. This growth is slowing down now, especially in Europe and Brazil, whereas in Asia and Africa biofuel production is increasing. Also in the coming years most of the biofuels produced will be conventional biofuels; the first advanced biofuels plants is just starting operation. Conventional biofuels have a big importance for the protein production, especially biofuels based on corn, canola and soybeans. Energy security and climate mitigation will remain the main drivers for conventional and advanced biofuels. It is expected that biofuels will reach a market share between 10 – 20% of transport fuel by 2035.

Keywords: first generation biofuels, advanced biofuels, renewable energy, climate mitigation

INRODUCTION

In recent years, several major challenges have become a focus of public interest. Key issues in this context are: worries about energy security, the need to mitigate climate change, efforts to stimulate economic development including the creation of jobs in agriculture and the renewable energy industry. As a consequence, biofuels as renewable fuels for transport have become part of a new energy in many countries.

In this paper, we refer to Biofuels as any liquid or gaseous fuels derived from organic material.

Sugar cane and sugar beet, grain such as corn and wheat, cassava and oilseeds are biomass sources for conventional biofuel production – they are often called first generation biofuels. Cellulosic biomass, organic waste and algae – for example derived from forest or field, organic wastes of many kinds, and algae have the potential to become an important basis for advanced biofuels – they are also called second generation biofuels. Also biogas transformed to bio-methane and pure vegetable oils are part of the biofuel portfolio.

In this paper the terms ”conventional” and “advanced” are used for the classification of biofuels instead of the terms first and second generation fuels.

GLOBAL BIOFUEL PRODUCTION

Biofuel production is a rather small part of the total contribution of biomass to energy. This total production of biomass reached 55.4 EJ whereas biofuel came up for 3 EJ, 5% of total biomass.

By 2013, the global biofuel production reached 115 billion litres.The global biofuel production was growing at a rate of 19% annually in the first decade of this century. In the period between 2010 and 2012 this growth slowed down, probably also as a consequence of the high commodity prices in the years 2008 and 2009. Meanwhile, by 2013 production increased again reaching 115 billion litres.

Table 1: Global production of liquid biofuels

year	Biofuel production	
	Billion litres	PJ
2000	17.8	430
2005	34.9	860
2009	91.0	2 340
2010	104	2 640
2011	107	2 760
2012	106	2 740
2013 *	115	2 960

Source: WBA GBS 2014, *IEA midterm review 2014

Ethanol and Biodiesel play an uneven role. The ethanol production, mainly based on corn and sugar cane is much more important than the biodiesel production; yet the biodiesel production, mainly based on soya oil and canola oil is growing continuously. The next table offers data until 2012.

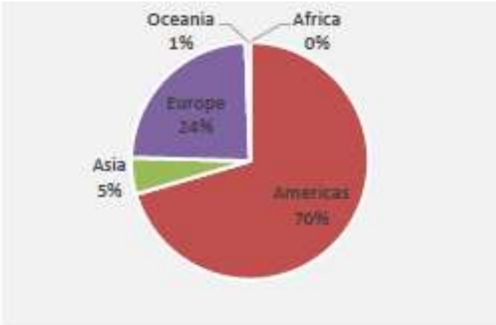
Table 2: Global production of ethanol and biodiesel

year	Bioethanol production		Biodiesel production	
	Billion litres	PJ	Billion litres	PJ
2000	17.0	398	0.80	28.2
2005	31.1	728	3.80	134
2009	73.2	1713	17.8	627
2010	85.0	1989	18.5	651
2011	84.2	1970	22.4	788
2012	83.1	1945	22.5	792

Source: WBA GBS 2014

The global biofuel production is dominated by the Americas. In 2011 about 70% of the global production came from North and South America, followed by Europe and Asia. In Africa the biofuel production of industrial scale just started recently, as graph 1 shows.

Graph 1: global distribution of biofuel production 2011 (Source: WBA GBS 2014)



In 2012 the leading producer of Ethanol was the USA with 50.4 billion litres, followed by Brazil (21.6 billion litres) and Europe (4.2 billion litres). Thailand had a production of 0.7 billion litres.

Concerning biodiesel the situation was different. Europe was the leading producer in 2012 with 9.1 billion litres, followed by USA (3.4 billion litres) and Argentina (2.98 billion litres). Argentina increased its biodiesel production over the last years rapidly using Soybeans as feedstock. The production in Thailand was 0.9 billion litres in 2012.

The use of upgraded biogas as transport fuel is not of importance so far. Europe used in 2011 about 0.4 billion m^3 bio-methane.

The production of commercially produced advanced biofuels is just starting.

Many activities are going on concerning the use of biofuels for the aviation sector. Biofuels are the only available alternative to fossil fuels for the aviation, and shipping sector.

As a summary: At the beginning of this decade conventional biofuel production was the leading biofuel source with a volume of slightly above 100 billion litres and a share of 2.7percent of the total consumption of transport fuel in 2010. This increased to 115 billion litres and a share of 3.5 percent in 2013 (2,3).

CONVENTIONAL BIOFUELS

The rapid growth of conventional biofuels such as ethanol and biodiesel initiated many discussions as they are closely related to land use and food production. Especially in Europe, in the last years an intensive debate on the future use of conventional biofuels took place with the result of political uncertainty and the reduction of the 10% blending target to probably 7%. In the United States recent policy reviews have brought uncertainty to the market, too. Also in Brazil the economic conditions are not favourable for the ethanol sector due to internal reasons. In other parts of the world, especially in Asia, the situation is better.

One reason for this debate is the misunderstanding of the interrelation between the biofuel production and the feed market.

Conventional biofuels and protein production

The production of conventional biofuels is in many cases connected with the production of protein. In this context we can distinguish between two types of crops for the biofuel production:

Crops A: deliver feedstock for biofuels and protein feed for the market

Crops B: deliver feedstock for biofuels without a protein production for the market such as sugar cane and oil palm (tropical crops).

Corn, cereals, rapeseed and soy beans used as a feedstock for biofuels also produce protein feed. These protein feeds like DDGS or rapeseed cake contain different quantities of protein per tonne. To make the yields better comparable they are expressed in table 3 for the fuel in energy units (toe) and for the protein in tons of soy cake equivalent with 44% protein.

As can be seen in table 3 the highest yields in terms of biofuels can be achieved with sugar cane for ethanol and oil palms for biodiesel. On the other hand corn and soybean, and to a lesser extent wheat and canola also deliver important quantities of protein feed. Table 3 gives an overview based on average yields in the main growing regions of the mentioned crops. In terms of total output – biofuels and protein feed – oil palm, corn and sugar cane are the highest yielding crops

Table 3: Comparable fuel and protein production for different crops per ha; unit toe for fuel and tons soybean equivalent for protein feed

Crop	Fuel toe/ha	Protein feed Soybean cake equiv. t/ha
Ethanol		
Corn,	1,9	1,9
wheat,	1.3	1.4
Sugar Cane,	3,1	-
Biodiesel		
Soybean,	0,4	2,1
rape,	0.9	1,4
Oil palm	4,3	--

Based on these data it is possible to calculate the total protein production related with the conventional biofuel production and the land requirements. WBA made such an analysis for the year 2010. In this year the production of biofuels based on corn, cereals, rape seed and soy bean reached 57.9 Mt biofuels and 79.1 Mt protein feed. Thus, these crops used for biofuels delivered more protein feed than biofuels expressed in tons. The biofuel production can be seen as a by-product of the protein production. This is in particular the case for soybeans and canola.

Land requirements for biofuels and protein in 2010

In 2010, the land need for the total biofuel and connected protein production was 39.5 million ha. The land needed for the ethanol production in 2010 is calculated with 20.3 Mha, comprising 13.2 Mha corn, 2.0Mha cereals, 4.6Mha for sugar cane and 0.5Mha other crops, hereof almost 0.3 Mha sugarbeets.

Biodiesel production was based on 19.2Mha, hereof 7.8Mha rapeseed,10.9 Mha soybeans and 0.5Mha oil palm and others. Together this makes 39.5Mha.

Table 4: global Land for biofuels and protein, Mha, 2010

crop	corn/ cereal	rape	soybean	sugar cane	oil palm /others	TOTAL
Mha	15,2	7.8	10,9	4.6	1.0	39.5

From the 39.5Mha land commonly attributed to the production of biofuels in reality only 19.8Mha served to produce the feedstock for biofuels and 19.7Mha to produce protein feed. There is a clear difference between non-tropical plants – group A – and tropical plants – group B. For group A plants as a whole the main output is protein and biofuels are a by-product, this is especially the case for soybeans and canola though not so much for corn. On the other hand tropical plants deliver a much higher output of biofuels per hectare than non-tropical plants.

Land requirements and the food/fuel issue

The land needed in 2010 for the simultaneous production of biofuels and protein has to be set in relation to the global land use pattern as an orientation for the further development.

Table 5: Available lands for energy crops [16,17]

	Billion hectares
Total global land mass without Antarctica	13.20
Forests	4.0 (30,3%)
Land for livestock	3.92 (29,7%)
Current crop land	1.56 (11,8%)
Additional potential for rain fed agric. (Includes partly land for livestock)	0.89 (6,8%)

At present only 11,8% of the total global land area is used as cropland and this with greatly varying yields from continent to continent. It is estimated that additional 893 million ha land can be used for rain-fed agriculture, part of this land is now not used, or is used as range grazing land for livestock.

In a recent study (1) referring to the period 2006 – 2009 Zeddies points out that globally 226 Mha land were set aside and not used at all. That is ten times as much as the net use of land for first generation biofuels!

The future availability of land will be determined

- By the growing population and changing eating habits
- By the ability to better use the available land and by
- By the technological progress in achieving higher yields

Over recent years global agricultural yields increased by 1% per year; this alone corresponds to 150Mha more cropland potentially available within ten years. Taking these different drivers into account Zeddies estimates additional 150.000 to 195.000 Mha will be available for energy crops, an average of 170 Mha, by 2020. This land can be used to produce more biomass for liquid, gaseous or solid biofuels.

It should be mentioned in this context that, assuming a production of 8t dry matter biomass per ha and year, an area of 100 Mha land planted with energy crops (short rotation forests, sweet sorghum, corn etc.) delivers 344Mtoe = 14,4 exajoule (EJ) of primary energy.

As a conclusion: there is enough land available to produce more food and more biomass for energy, but it has to be used more properly!

Global grain and oilseed production in relation to biofuels

The global grain production averaged 2250 Mt/year over the years 2007 – 2011. The annual variations of the grain harvest between 2007 and 2011, mainly due to changing weather conditions, amounted to 250Mt; the smallest harvest in this period was 2.100Mt, the biggest reached 2350Mt. How does this relate to the biofuel production? In 2010 a quantity of 137Mt grain (corn and cereal) was needed to produce 43.7 Mt biofuels and 42.0 Mt protein feed, hence a net share of 3.1% of the total grain production was used for biofuels, much less than the annual variations of the grain harvest. About 37% of the global grain production is used directly for food, almost 50% as feed for meat production, 6.1% for protein/biofuels and the rest as seed for new planting and for industrial purposes.

In an OECD/FAO outlook study the global oil seed production for the period 2009 -2011 is presented with 470 Mt and an increase until 2021 to 523 Mt is forecast. In 2010 around 53 Mt of oil seeds (canola, soybean) were used to produce 14.3Mt biodiesel and 37.1Mt protein feed, hence almost three quarters of this 53Mt oilseeds went to the protein feed and only 30% to the fuel production – about 3% of the total oilseed production(1).

Conventional biofuels and food security

Climate change is becoming more and more a threat to global food security, because extreme weather events are predicted to cause bad harvests more frequently. The difference in global crop harvests between good and bad years oscillates around 10 percent. In this context conventional biofuels can be seen as an insurance: in years with good or normal harvests the biofuel production capacity can be fully used whereas in years with bad global harvests the fuel production is reduced, the saved feedstock can be used for food and feed and more fossil fuels temporarily used instead for transport. Such a concept, including remuneration payments for plants shut down for a period of time, would better secure the food supply than set-aside programs. These set-aside programs imply no production on the concerned land and it might take one or two years to get a crop harvest from this land, whereas a global food shortage might be urgent immediately. Hence it makes sense to use several percent of the cropland for biofuels also from the standpoint of food security.

ADVANCED BIOFUELS

In the transformation of the transport sector conventional biofuels are not replaceable, they are one essential pillar of this transformation. The second pillar in the form of production of advanced biofuels has to be built up.

There are several chemical-based, biological and thermochemical technologies for producing advanced biofuels. They are under research and development (R&D) or in the pilot-plant phases or just entering the commercial phase.

Cellulosic ethanol
Cellulosic ethanol can be produced from lignocellulosic feedstocks through the biochemical conversion of the cellulose and hemicellulose components into fermentable sugar and then following the alcoholic fermentation. Agricultural and forest sources have great potential as cellulosic ethanol feedstock, for example: agricultural crop residues such as straw and corn-stover, energy crops, forestry residues and forest processing by-products such as pulping (black) liquor from paper mills and wood processing mill residues.

Hydrotreated vegetable oil (HVO) is a modern way to produce very high-quality bio based substitute diesel or aviation fuels. Feedstocks for the HVO process are the same as for biodiesel, vegetable oils or waste animal fats. HVO is known as Renewable Diesel (RD) in the United States. [4]

Biomass to Liquids (BtL) diesel is also referred to as a two-step process, in which any type of biomass is first gasified to produce a synthesis gas (Syngas). The syngas contains varying amounts of carbon monoxide and hydrogen. The gas produced is then treated further to clean it, remove tars, particulates and gaseous contaminants. After cleaning it is put through the Fischer- Tropsch (FT) or Mobil process [3] in which the syngas is catalytically converted into various hydrocarbon liquids, for example synthetic diesel.

Synthetic Natural Gas (BioSNG)
Bio-SNG is produced by gasification of cellulosic materials (e.g. forestry residues, energy crops) followed by gas conditioning, SNG synthesis and gas upgrading. Bio-SNG can be used in a similar way to biomethane upgraded from biogas.

Bio-based dimethylether (BioDME)
BioDME or bio-based dimethyl ether is a fuel with similar energy content and handling requirements to LPG (liquified petroleum gas), which is produced in two steps. The first step is methanol production from gasified biomass feedstock and the second step is conversion of methanol to BioDME. DME is a gas at room temperature and pressure and burned like natural gas. BioDME production from black liquor has been demonstrated in a trial.

Biobutanol
Butanol is an energy dense pure alcohol formed by fermentation from biomass by using specific microorganisms. It has a greater energy density with four carbon atoms per molecule by comparison with ethanol with two carbon atoms. Biobutanol can be burned without modifications in an existing gasoline engine and has been demonstrated to be less corrosive than ethanol.

The volumes of possible feedstock for the production of advanced biofuels are vast: by-products from agriculture like straw, bagasse, rice husks, oil palm empty fruit bunches, MSW, by-products of the forest-and-wood industry, woody harvest residues, dedicated cellulosic energy crops like grasses, short rotation woody coppices and algal biomass.

One big advantage of these fuels is that there is no direct competition with the food market. There can be a competition with other energy outlets like biomass for heat, or potentially for land use in case of growing dedicated crops. But there is definitively no competition as long as waste or unutilized cellulosic by-products serve as biofuels feedstock and there are plenty of these residues worldwide.

In general the conversion of cellulose to liquids is complex and rather expensive as is the production of algae for producing biofuels. Intensive research is required to improve the technologies. This research has been going on now for years. As a result different technologies are under development and several pilot- and demonstration plants are increasingly in operation or under construction.

Now the time is ripe to start commercial plants to gain experience in large-scale operation. The production cost will be high due to the lack of experience, the complexity of the conversion technology, the high capital investment and the difficulty to get sufficient feed stock volumes for large-capacity plants at reasonable costs. But only commercial plants can bring the needed experience for further development and a quantity of fuel production that counts. A first commercial plant just started production. Let me give a brief description of this important initiative.

TWO EXAMPLES

Project ADDAX Bioenergy, Makeni, Sierra Leone, Africa
In spring 2014 a commercial ethanol plant has started producing sugar cane ethanol and electricity in Makeni, Sierra Leone. This project realized by the company ADDAX Bioenergy is a good example for the growing biofuel production in Africa (5).

Some key facts of the project:

- The sugar cane estate covers an area of approximately 10,000 hectares.
- It will produce about 85,000m3 of ethanol per annum and approximately 100,000 MWh of renewable power per annum.
- The refinery and the irrigation system for the sugarcane estates will be powered by the biomass plant, fuelled with sugarcane fibre residues.
- A capacity of up to 15 MW of power will be supplied to the national grid of Sierra Leone, significantly adding to the country’s overall electric power capacity.

- Construction of the distillery and power plant began in 2011 with production becoming fully operational in 2016.
- At May 2014, the project employed 2,750 people.

The Project demonstrates how agriculture and biomass from agriculture can become the source of social improvement, economic growth and better use of the available land for food and energy production.

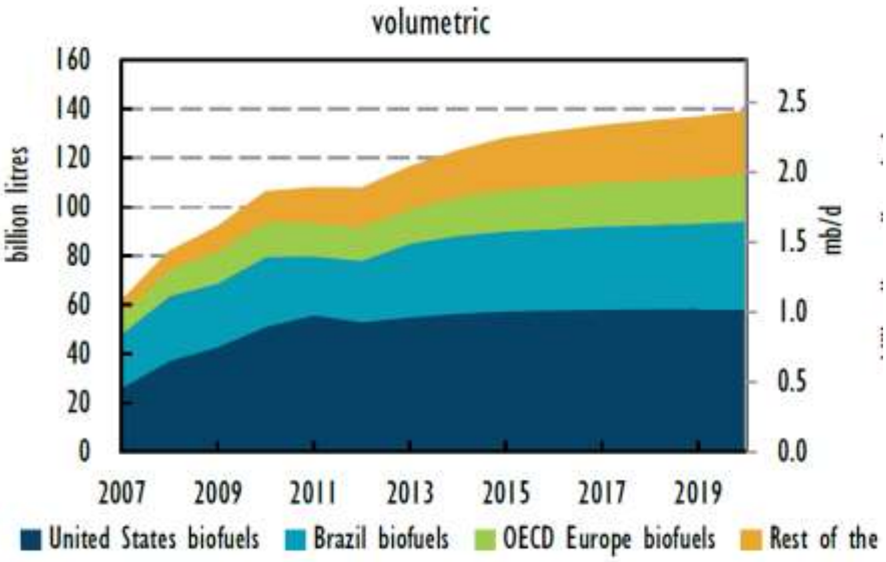
Project Liberty, Emmetsburg, Iowa, USA:
In September 2014 the first Commercial-scale Cellulosic Ethanol Plant started production in Emmetsburg, Iowa, USA. The plant is a joint venture of the Dutch Company DSM, a biochemical company strong in enzyme production, nutrition and health and the US company POET, a big producer of corn ethanol. The plant converts baled corn cobs, leaves and stalk into renewable fuel. At full capacity it will convert 770 tons of biomass per day.

A few facts about this project:
Biomass consumption 285 000 tons biomass annually sourced from 140 000 ha in an area with a 65 km radius of the plant
Ethanol output: up to 90 million litres (0.1 billion litres) per year
Investment cost: 275 million Dollar,
Financial support: about 40% grants by the federal and state government
It is intended to remove 1 ton of residue per acre (25%) which will bring an additional income to the farmers in the size of 20 million Dollars (4).

In several other parts of the world, especially in North and South America new investments in advanced biofuels take place and will change the supply of biofuels in the next ten years. In its last publication IWA estimates an advanced biofuel capacity of 4 billion litres by 2020. 2020, corresponding to a volume of 20 plants like the one in Iowa.

OUTLOOK AND CONCLUSIONS

The fast growth of the biofuel production, experienced in the first decade of this century will not continue. IEA published recently an outlook expecting 140 billion biofuels in 2020, mainly as conventional biofuels. This equals an annual growth of 3-4percent



Source: 3, IEA

The World Bioenergy Association(WBA) sees the future position of biofuels within the broader scope of the global transformation of the energy system from fossil-based to renewable energy-based sources. A main driver for an accelerated transformation is the struggle for a better fuel security. A second driver is the threat of climate change.

According to WBA calculations the CO_2 emissions from fossil fuels should be reduced by 50% until 2035 to keep on track towards the 2℃ target. Based on this background and on the presented facts in this paper WBA's position on biofuels can be summarized as follows-

Improved fuel security: WBA reminds the public that 41 years ago, during the winter 1973/74 an oil crisis hampered severely the supply with transport fuels. Especially the transport sector and the agriculture were concerned. In some regions even the planting of new crops in spring 1974 was endangered. Nobody can exclude a similar situation within the next two decades. Therefore, WBA supports the consequent, far sighted further deployment of biofuels for transport as an important strategy to improve the fuel security worldwide.

Conventional biofuels should further grow to cover 5-7% of the global transport demand by 2035. The public perception of these fuels produced from corn, cereals, canola, and soybean should be improved in the sense that these crops are recognized as being an important basis for the global protein supply. Biofuels should be seen as a by-product of the protein production and as an important contribution to the global supply of protein.

Advanced biofuels should enter the market on the basis of commercial production units. As production costs are higher than the market price this can only happen if government set up reliable long lasting framework conditions for investors to offset the higher cost. This should be done soon otherwise advanced biofuels will not gain momentum within the next ten years. A quadruple counting of advanced biofuels as proposed in Europe serves nothing. It reduces the market demand for these fuels and offers no security for investors. If these commercial plants develop successfully advanced biofuels could cover 4 - 9% of the transport sector by 2035, with biomethane for transport included. The deployment should be intensified especially on the basis of waste materials and by-products such as straw, bagasse, and organic waste.

On agriculture Much more emphasis is needed to improve the agriculture productivity world-wide by a set of measures such as education, training, supply with modern inputs, improved facilities for the storage of the harvests to avoid losses, access to markets, better extension services, more research to increase the production per hectare and also to increase surface of arable land by a new land policy such as fighting desertification, regaining degraded land for production.

On land availability: WBA emphasizes there is enough land available to feed a growing population and advocates use of several percent of the agricultural land for the production of biomass for fuels. A better use of the available land is needed -this will help to improve the security of food supply of the local population, stimulate endogenous economic growth, reduce poverty and by integrating biofuel production also reduce emissions and dependancy from imports.

On CO_2 emission and biofuels: There is an urgent pressure to reduce the CO_2 emissions also in the transportation sector. Conventional biofuels such as ethanol, biodiesel, biogas are needed as well as advanced biofuels. Also, other renewable technologies for transport have to be pushed as well.

Finally, the use of land for energy is nothing new. Before entering the fossil age mankind used 20 – 30% of the land to produce feed for animals used for traction and transport. Leaving the fossil age means that again a few percent of the land will be needed to produce energy for transport and traction!

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