WBA fact sheet

ADVANCED BIOFUELS

SUMMARY

Biofuels are a green alternative to fossil fuels in the transportation sector. Along with satisfying basic energy needs, they reduce greenhouse gas emissions, provide energy security and support regional development. Conventional biofuels (also referred to as 1st generation biofuels) are being produced globally with a current production volume of more than 100 billion litres annually. To complement the conventional biofuels, recent advances are focused on the next generation of biofuels. Advanced biofuels – generally referred to as 2nd or 3rd generation biofuels – represent an important step forward as the world advances towards a sustainable bioeconomy. These fuels are produced from a broad spectrum of predominantly non-edible biomass feedstocks. These include lignocellulose based ethanol, hydrogenated vegetable oil – HVO, algae based biofuels and biogas. Some of these are “drop-in” biofuels that can be applied in existing distribution infrastructure and engine platforms. Byproducts of advanced biofuel production include bioelectricity, bioheat, biochemicals and protein based feed.

While commercial scale production of advanced biofuels has been limited compared to conventional biofuels, several facilities have begun operation in the past decade. Neste Oil started producing renewable diesel in Finland since 2007 while Beta Renewables plant in Italy started production of ethanol from cellulosic feedstock in October 2013 (1; 2). The production capacity of all advanced biofuels plants stood at 5.4 billion litres in 2013 (3). However, due to uncertainty in biofuel and fossil oil markets, and in policy domains, a number of large scale facilities are reportedly idle at the current time.

Although these technologies are developing rapidly despite the technical challenges associated with scale up from demonstration to commercial scale, the industry also faces substantial challenges. These include regulatory hurdles, inconsistent government policies, and a playing field tilted towards the incumbent fossil fuel producers, all of which continue to present challenges to develop commercial production facilities.

INTRODUCTION

This WBA factsheet aims to provide better understanding of the advanced biofuels sector. This document is a continuation of our presentation of biofuels in the transport sector that started with the factsheet on biofuels for transport in March 2013 (4). Details of technologies, feedstocks and products that make up the advanced biofuels sector are presented along with the current status of commercial production units.

The term, advanced biofuels has varied definitions. According to the International Energy Agency (IEA), advanced biofuels are conversion technologies that are still in the R & D, pilot or demonstration phase (3). This category includes: 1. hydrotreated vegetable oil, 2. biofuels based on lignocellulosic biomass, 3. algae based biofuels and 4. conversion of sugar to diesel type biofuels. In the European discussions the term advanced biofuels is not anymore technology-based but rather more and more used for biofuels produced from non-edible feedstock. According to Renewable Fuel Standards (RFS) in USA, advanced biofuels are fuels apart from corn ethanol which are produced from renewable biomass and achieve a minimum of 50% greenhouse gas emission reduction in comparison to fossil fuels (5). Cellulosic biofuels are categorized separately from advanced biofuels. In this factsheet, WBA follows the definitions based on IEA.

Advanced biofuels are an important step in the biofuels sector. Conventional

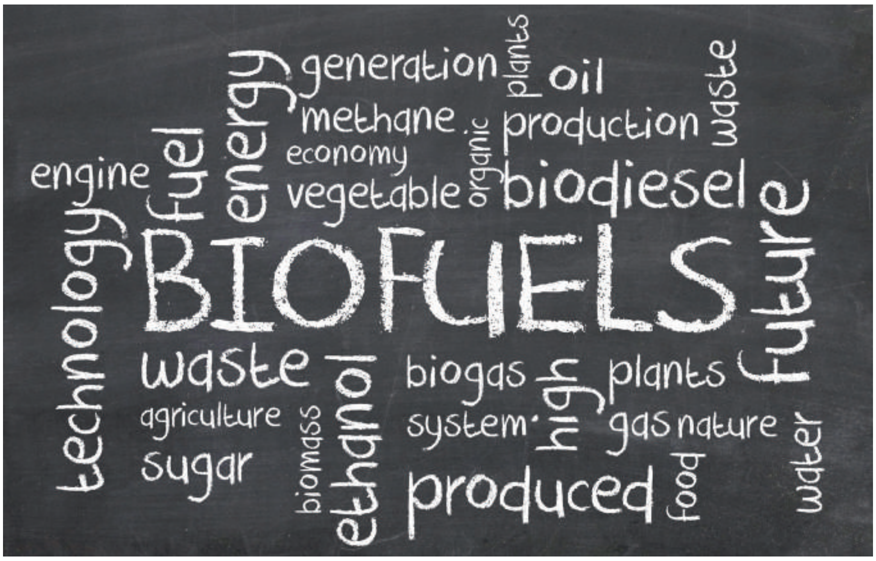

Photo:: iStock

Figure 1. Biofuels are produced from a variety of feedstock and via different pathways

BIOFUEL GENERATIONS

1G – Bioethanol from sugar crops via fermentation, biodiesel from vegetable oil and animal fats via transesterification etc.

2G – Cellulosic ethanol from residues, biodiesel from vegetable oils and animal fats via hydro treatment etc.

3G – Biofuels from algae etc.

biofuels production involves commercially mature processes, with annual global production exceeding 100 billion litres a year (6). Advanced biofuels open up a diverse range of biomass sources available for biofuel production. Some of these biofuels provide the benefit of complete compatibility with existing fossil fuels transport infrastructures, which will increase the efficiency of transporting to commercial markets. Although they present notable advantages, their production has been slower than originally anticipated by many policy makers due to technical, economic and logistical difficulties.


Photo: Advanced Biofuels Association

Figure 2: Advanced biofuels feedstock

PRODUCTION PATHWAYS

Numerous technological pathways are being developed and commercialized to produce advanced biofuels. These make use of chemical, biochemical and thermochemical methods.

Chemical

The chemical treatment of vegetable oil, animal based fats and byproducts such as used cooking oil, grease and sludge etc. with hydrogen yields a high quality bio-based substitute diesel. The final product is referred to as Hydrogenated Vegetable Oil (HVO) or as renewable diesel which can be used in all modern diesel engines or blended with fossil diesel. These can also be modified to produce jet fuels for the aviation industry.

Biofuels can also be chemically produced from algae. Microalgae consume CO_2, water, sunlight (only phototropic algae use sunlight) and nutrients. Once grown, algae is utilized to produce algal oil which has similar qualities to light sweet crude oil from hydrocarbons. It can be refined to diesel, jet fuel, and other products currently produced from crude oil.

Biochemical

Fermentation is a biochemical process by which ethanol is produced from crops such as corn/maize, sugarcane and sugar beet etc. In first generation processes, the sugars extracted from these crops are converted to ethanol in the presence of yeast. In contrast, advanced biofuels are produced from the lignocellulose part of the biomass feedstock. Cellulose structures must first be broken down to free sugars in a process that involves pre-treatment followed by either enzymatic or acid hydrolysis (see box). The sugars extracted after pre-treatment and hydrolysis are then converted to cellulosic ethanol.

It is also feasible for the microorganisms and process parameters to be modified to produce biobutanol as an alternative to bioethanol. Other biochemical pathways include:

- Biogas via anaerobic digestion of organic matter
- Cellulosic ethanol or butanol from lignocellulose part of algae
- Diesels from sugars extracted from energy crops

Thermochemical

Thermochemical conversion– either by pyrolysis or gasification – is another pathway to convert the energy stored in cellulosic biomass into more useful forms by direct reduction of the feedstock. Pyrolysis occurs in an oxygen starved environment leading to the production of bio char, bio liquids and non-condensable gases. The bio liquids can then be refined to be used as transport fuels, heating fuels, or for production of chemicals.

Gasification occurs in limited oxygen environment and yields synthesis gas or syngas (a combination of carbon monoxide and hydrogen). After conditioning and purification, the syngas can be converted to biomethane or liquid biofuels (like methanol, synthetic diesel etc.) at high temperature/pressure using various catalytic processes.

FEEDSTOCK

A variety of feedstock (including wastes) can be used for the production of advanced biofuels. Some of the common feedstock include:

Vegetable oils and animal fats

The range of vegetable oils that are produced from oil seeds (for e.g. soybean, palm oil, rapeseed oil) and waste vegetable oil from restaurants, households and industrial processing, which is not fit for human consumption can be sources for renewable diesel. Animal fats are also used for production of renewable diesel/HVO. They are a relatively cheap by-product and are easily available. Tall oil – a residue of pulp and paper industry whose yield varies from 15 – 20 kg/ton pulp – is another feedstock (7).

Lignocellulosic biomass

Lignocellulose is plant/tree materials which can be converted to biofuels. This category principally includes woody biomass and crop residues. Feedstocks for lignocellulosic biofuel production systems often include discarded plant material – straw, corn stover and factory residues like sugarcane bagasse that are residues from food production.

Wood – directly harvested or from wood waste streams is also a lignocellu-

ENZYMES – A CRITICAL LINK IN CELLULOSIC ETHANOL

Enzymatic hydrolysis is one of the treatment methods (the other being acid hydrolysis) during the production of ethanol from lignocellulosic biomass. The hydrolysis releases fermentable sugars which are then converted to ethanol. This is essential because the cellulose is tightly bound. Some of advantages of using enzymes compared to acid hydrolysis include – mild operating conditions and high yield. Disadvantages include long operating time and high prices of enzymes. The major expense in the production costs of cellulosic ethanol are the costs of enzymes which have to be tailor made for type of feedstock. Current research is focused on reducing these costs.

losic feedstock. Grasses (including the giant grasses like maize and sorghum) are another lignocellulose source which have lignin content, grow quickly and can be converted to liquid biofuels. Finally, solid waste from household, industries, commerce, and food processing or production industries – which is usually sent to landfills in many countries – can be utilized for advanced biofuel production.

One of the energy source within the forest industry is black liquor – a byproduct of pulp and paper industry. It can be gasified to produce biomethanol, dimethyl ether and Fischer Tropsch (FT) diesel. An alternative route is to extract the energy rich lignin and convert it to biogasoline and a biodiesel via catalytic reactions (yield of 90 – 95%). The quantities of lignin is also large since ~30% of all trees content consists of lignin.

Algae

Algae is an alternative feedstock which uses sunlight, carbon dioxide, nutrients and water and produces oil which can be used as a feedstock for biofuels production. The advantages include rapid growth and flexibility with regard to water quality. The high growth of the algae and high energy density of algal oil means that more oil can be produced than from conventional crops per ton of feedstock and per unit area of cultivation. However, the technology is not yet cost competitive and the production is energy intensive. Research in scaling up technologies and in genetic engineering is important for success.

BIOFUELS AND PRODUCTS

Cellulosic ethanol is produced from fermentation of sugars derived from lignocellulose material. The ethanol can be blended with gasoline in automobiles in varying quantities or used as a pure fuel in dedicated flexi fuel engines. Already more than 80 billion litres of **conventional ethanol** every year is produced globally – predominantly from corn in USA and sugarcane in Brazil.

Photo: Abengoa

Figure 3: Lignocellulosic feedstock for Abengoa plant in Kansas.

Renewable diesel or HVO is diesel obtained from vegetable oil from various feedstock (oil seeds like palm oil, stearin, soybean, tall oil etc.) and animal fats produced by the food processing industry. The diesel produced after hydro treatment can be used in existing engines without modification. The lifecycle greenhouse gas reductions can be up to 90% in comparison to fossil diesel depending on factors such as: feedstock used, production efficiencies and use of byproducts etc. (8). Large scale production of renewable diesel according to this conversion route has been in operation since 2010.

BioSNG is produced via gasification of lignocellulose material. It can be directly burned or upgraded to biomethane and fed in to the national gas grid. Alternatively, it can be used in the transportation sector in pressurized form. For transporting it over long distances, BioSNG has to be liquefied.

Biomass to liquids or BtL fuels refer to liquid fuels produced from biomass sources via thermochemical conversion. The fuels are produced from syngas in catalytic conversion processes after gas cleaning and conditioning. The fuels include biomethanol, DME (gas), FT diesel, as well as poly-alcohols and aviation fuels. Bioliquids produced via pyrolysis also come under the category of BtL. Raw pyrolysis oil cannot be used in engines but after upgrading steps the products can be blended into bunker oils and potentially into diesel fuels.

Biogas is produced from anaerobic digestion of organic matter like wet organic wastes, putrescible wastes and algae and consists predominantly of methane and carbon dioxide. The gas can be upgraded to increase the methane content to over 97% and injected into the fossil gas grid to be used for direct heating or as biomethane in the transportation sector.

Biobutanol can be produced biochemically or by thermochemical conversion. Butanol is a more energy dense alcohol in comparison to ethanol as it contains two carbon atoms more than ethanol. It has energy content closer to gasoline than ethanol and can be combusted in existing gasoline engines without any modifications.

Biochemicals. Many advanced biofuel producers are looking to the high value biobased product markets to help grow their businesses as they scale up. Up to

Photo: POET DSM Advanced Biofuels

Figure 4: POET DSM cellulosic ethanol plant in Emmetsburg, USA.

20% of all crude oil extracted is used to produce a range of products including plastics, synthetic fibres, detergents, cosmetics, paints, pesticides, fertilizers, and electronics. These biofuels can be refined into substitutes for these products.

ENVIRONMENT AND ENERGY SECURITY BENEFITS

In addition to reducing lifecycle greenhouse gas emissions by up to 97% – in comparison to fossil fuels – the use of advanced biofuels will reduce emissions of other air pollutants such as particulates, sulphur oxides, nitrous oxides and carbon monoxide. Some companies are developing and deploying technologies to utilize industrial waste gases like carbon dioxide (CO_2) and carbon monoxide (CO) as the feedstocks to produce a wide range of transportation fuels.

In addition to the environmental and economic benefits associated with replacing fossil fuels, the development of advanced biofuels has important global security implications. Instability in the major oil producing regions, as well as recent threats regarding Europe's fossil gas supply, are indicative of security issues related to reliance on geographically constrained fossil fuel sources. By contrast, advanced biofuels that can be produced with locally produced feedstocks have the potential to increase global stability by limiting the need to secure and maintain access to fossil fuel resources. Military officials have recognized the potential benefits of distributed domestic fuel production, and are actively engaged in this area. For instance, the United States Navy has purchased large quantities of advanced biofuels for research and development, and, in partnership with other government agencies, awarded $210 million to three companies in 2014 to build integrated biorefineries that will produce drop-in renewable fuels for military use (9).

POLICY UNCERTAINTY

In spite of the benefits of advanced biofuels, current government policies in many countries limit the valuing of their environment benefits. For example, some of the waste industrial gases are not considered eligible feedstocks for the production of biofuels. As a specific example, the restrictive nature of the woody biomass definition in the United States' Renewable Fuel Standards (RFS) limits the use of many resources, resulting in their use in an inefficient manner. Other policy imbalances still exist which are detrimental to the development of a balanced marketplace, and are indicative of the need of technologically-neutral government policies that support the commercialization of a broad range of advanced biofuels. In this regard, to ensure the sustainability of biomass feedstock, WBA released the Sustainable Biomass Verification Scheme (10). This manual aims to guide various stakeholders to use the criteria for verifying the sustainability of biomass.

Photo: Abengoa

Figure 5: Abengoa advanced biofuels plant, Hugoton, Kansas, USA.

Photo: Beta Renewables

Figure 6: Novozymes/Beta Renewables advanced biofuels plant, Crescentino, Italy

ACHIEVING COMMERCIAL SCALE PRODUCTION

The advanced biofuels industry continues to face technical hurdles in scaling up from laboratory to demonstration to commercial scale production. Further, the costs for some of the technologies remain too high to be competitive with fossil fuels that do not carry the environmental costs. Perhaps more importantly, uncertainty regarding incentives, including impermanent tax credits and varying and delayed fuel use obligations, has created an unstable market that inhibits private investment.

Even though financing for first-of-a-kind facilities is difficult to obtain, a number of projects have been able to start. The first commercial scale cellulosic ethanol plant came on stream in 2013 in Crescentino close to Milano in Italy. The technology is supplied by Beta Renewables who is also involved in one of the first cellulosic ethanol plants in Brazil built by GranBio. Italy became the first EU member to mandate the use of 1.2% advanced biofuels from January 2018

TABLE 1: ADVANCED BIOFUEL PLANTS GLOBALLY (NEARING COMPLETION OR OPERATIONAL IN 2014)						
Company	**Location**	**Production**	**Product, Capacity (Million litres)**	**Capital costs ($ Million)**	**Feedstock (1000 tons per year)**	**Feedstock**
Poet DSM	Emmetsburg, Iowa, USA	Sep - 14	Ethanol, 95	275	285	Corn cobs, leaves, husk and stalk
Abengoa	Hugoton, Kansas, USA	Oct - 14	Ethanol, 95	500	365	Corn stover, wheat straw, milo stubble and switchgrass
Göteborg Energi	Gothenburg, Sweden	Dec - 14	Biomethane, 20 MW	170	50	Wood pellets
Granbio	Sao Miguel Dos Campos, Brazil	Sep - 14	Ethanol, 82	265	400	Sugarcane straw and bagasse
Dupont	Nevada, Iowa	Dec - 14	Ethanol, 113	225	700	Corn stover
Enerkem	Edmonton, Canada	June - 14	Ethanol, 38	75	100	Municipal solid waste
UPM	Lappeenranta, Finland	Dec - 14	Biodiesel, 120	210	Not disclosed	Tall oil

(11). Enerkem's first full-scale commercial facility on waste to biofuels is currently in commissioning and a similar project is under development in Pontotoc, Mississippi. In the HVO market, the current production capacity is close to 3 million tonnes/year (12). According to IEA, there will be 22 billion litres of advanced biofuels produced in 2020 (3).

CONCLUSION

In order to increase their overall market share, advanced biofuels must overcome remaining technical hurdles. Doing so will require stable regulatory regimes that promote investor backed financing of commercial – scale biorefinery capacity. Such a regime would provide incentives for production on a technologically – neutral basis over the extended period of time necessary to build and operate a large-scale refining facility to cover capital costs and depreciation of the investment. Further, such a regime must promote innovation by providing ready access to market based incentives for newly developed advanced biofuels and associated biobased products, while limiting the advantage of incumbent fossil fuel interests. If properly implemented, such a regulatory regime would level the playing field to allow advanced biofuels to provide cost-competitive fuels in a manner that results in immense environmental, economic, and national security advantages.

POSITION OF WBA

WBA is of the position that advanced biofuels are vital in meeting the climate targets. They have huge potential but are hindered by high production costs. Moreover, there is a need for stable government policies for the technological advancement of advanced biofuels. Recently, the advanced biofuels plant capacity has crossed 4 billion litres but with lower production volumes. However, the outlook is that there will be 22 billion litres of advanced biofuels produced in 2020.

The production of advanced biofuels has already started couple of years back in Sweden, Finland, Canada, Italy, and USA etc. With the start-up of the cellulosic ethanol plants by POET – DSM and Abengoa in autumn 2014, the sector now appears to be crossing an important threshold towards mainstream markets. The success/failure of these cellulosic ethanol plants will play a significant role in future investments.

The benefits for development of advanced biofuels are immense: (1) reduction of fossil fuel use, (2) expansion of available biomass source base, (3) job creation and (4) possibility of integrating with existing fossil infrastructure. However, there are still regulatory, technical and economic hurdles that hinder the growth of this sector. WBA opines that advanced biofuels technology is on track to satisfy more than 5 – 15% of the global transport sector needs by 2035, depending on the implementation of reliable economic policies and incentives to support the innovation and development of advanced biofuels.

SOURCES

1. Neste Oil. Singapore renewable diesel refinery. Plants. [Online] Neste Oil, 2015. http://www.nesteoil.com/default.asp?path=1,41,537,2397,14090.

2. Beta Renewables. Worlds first advanced biofuels facility opens. News archive. [Online] Beta Renewables, 2015. http://www.novozymes.com/en/news/news-archive/Pages/World%E2%80%99s-first-advanced-biofuels-facility-opens.aspx.

3. IEA. Tracking Clean Energy Progress. Paris : IEA, 2014.

4. World Bioenergy Association. Biofuels for transport. Stockholm : WBA, 2013.

5. Schnepf, Randy and Yacobucci, Brent D. Renewable Fuel Standard (RFS): Overview and Issues. s.l. : Congressional Research Service, 2013.

6. REN21. Global Status Report 2014. s.l. : REN21, 2014.

7. Wansbrough, Heather. Tall oil production and processing.

8. NESTE OIL. NEXBTL renewable diesel. Renewable Products. [Online] NESTE OIL, 2014. http://www.nesteoil.com/default.asp?path=1,41,11991,22708,22709,22710.

9. US Department of Energy. Energy Department Joins Navy and Agriculture Departments to Invest in Drop In Biofuel for Military. [Online] September 25, 2014. http://www.energy.gov/eere/bioenergy/articles/energy-department-joins-navy-and-agriculture-departments-invest-drop-biofuel.

10. World Bioenergy Association. Introduction of a sustainable biomass verification scheme. Stockholm : WBA, 2010.

11. Downing, Louise. Italy to requre advanced biofuels in gasoline and diesel. s.l. : Bloomberg, 2014.

12. Square Commodities. Global - Summary of HVO production capacity. Square Commodities. [Online] November 25, 2014. http://www.squarecommodities.com/content/global-%E2%80%93-summary-hvo-production-capacity.

13. POET DSM. First commercial scale cellulosic ethanol plant in US opens for business. News. [Online] POET DSM, September 3, 2014. http://poetdsm.com/pr/first-commercial-scale-cellulosic-plant.

14. Abengoa. Abengoa celebrates grand opening of its first commercial scale next generation biofuels plant. News. [Online] Abengoa, October 17, 2014. http://www.abengoa.com/web/en/noticias_y_publicaciones/noticias/historico/2014/10_octubre/abg_20141017.html.

15. GoBiGas. [Online] 2015. www.gobigas.se.

16. GranBio. GranBio begins producing second generation ethanol. Press releases. [Online] GranBio, September 24, 2014. http://www.granbio.com.br/en/wp-content/uploads/sites/2/2014/09/partida_english.pdf.

17. DuPont. Dupont: Cellulosic ethanol: commercializing advanced renewable fuel in Iowa. Nevada Site CE facility. [Online] DUPONT, 2014. http://biofuels.dupont.com/cellulosic-ethanol/nevada-site-ce-facility/.

18. Enerkem. Waste-to-Biofuels and Chemicals Facility. News. [Online] Enerkem, June 4, 2014. http://edmonton.ca/for_residents/PDF/News_release_waste_to_biofuels_opening_2014_for_web.pdf.

19. UPM. [Online] http://www.upmbiofuels.com/whats-new/news/Pages/UPM-Lappeenranta-Biorefinery-is-in-commercial-production.aspx.

20. Buckley, Tera;. From 1st to 2nd generation biofuel technologies. Paris : IEA Bioenergy, 2008.

21. Solecki, Mary, Scodel, Anna and Epstein , Bob. Advanced biofuel market report 2013. San Francisco : Environmental Entrepreneurs, 2013.

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