Value chain for liquid biofuels
the Cometha project

Stefano Capaccioli
ETA-Florence Renewable Energies

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
Overview on biofuels

Biofuels are liquid or gaseous transport fuels such as **biodiesel** and **bioethanol** which are made from biomass. [Directive 2009/28/EC of the European Parliament and of the Council]

They serve as a renewable alternative to fossil fuels in the EU's transport sector, helping to reduce greenhouse gas emissions and improve the EU's security of supply.

By 2020, the EU aims to have 10% of the transport fuel of every EU country come from renewable sources such as biofuels. Fuel suppliers are also required to reduce the greenhouse gas intensity of the EU fuel mix by 6% by 2020 in comparison to 2010.


**Biofuels of 1st generation** consist of three main types. The first type corresponds to petroleum-gasoline substitutes produced via biological fermentation of starch and sugar-rich crops (e.g. corn, sugar beet, sugarcane). The second type relates to petroleum-diesel substitutes, such as straight vegetable oil and biodiesel (e.g. FAME, FAEE, RME and SME) produced by transesterification of plant oils and fatty residues (e.g. soy, palm, jatropha, used cooking oil and animal fats). The third type corresponds to natural gas substitutes such as biogas, generally produced via anaerobic digestion of organic matter (Monreal, 2008; UNCTAD, 2008; International Energy Agency, 2010a).

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
A range of fuel blends can be produced from bioethanol, and BEST project demonstrated, tested and assessed several different blends, represented in the “bioethanol tree”.

http://www.anl.gov/energy-systems/project/biofuels

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
Biofuels have been around as long as cars have. At the start of the 20th century, Henry Ford planned to fuel his Model Ts with ethanol, and early diesel engines were shown to run on peanut oil.

Much of the gasoline in the United States is blended with a biofuel—ethanol. This is the same stuff as in alcoholic drinks, except that it's made from corn that has been heavily processed. There are various ways of making biofuels, but they generally use chemical reactions, fermentation, and heat to break down the starches, sugars, and other molecules in plants. The leftover products are then refined to produce a fuel that cars can use.

Countries around the world are using various kinds of biofuels. For decades, Brazil has turned sugarcane into ethanol, and some cars there can run on pure ethanol rather than as additive to fossil fuels. And biodiesel—a diesel-like fuel commonly made from palm oil—is generally available in Europe.

Biodiesel is a renewable fuel produced from vegetable oils such as rape seed oil, sunflower seed oil, soybean oil and also used frying oils (UFO) or animal fats. First generation (conventional) biodiesel is typically produced from oil crops (rape, palm, soy, etc.).

Fatty Acid Methyl Esters (FAME) are esters of fatty acids. The physical characteristics of fatty acid esters are closer to those of fossil diesel fuels than pure vegetable oils, but properties depend on the type of vegetable oil. A mixture of different fatty acid methyl esters is commonly referred to as biodiesel, which is a renewable alternative fuel. FAME has physical properties similar to those of conventional diesel. It is also non-toxic and biodegradable.

**Molecular Formula**

\[ \text{CH}_3(\text{CH}_2)_n\text{COOCH}_3 \]

FAME is produced from vegetable oils, animal fats or waste cooking oils by transesterification. In the transesterification process a glyceride reacts with an alcohol in the presence of a catalyst, forming a mixture of fatty acids esters and an alcohol.

"This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406"

http://www.biofuelstp.eu
Biodiesel has been produced on **an industrial scale in the European Union since 1992**, largely in response to **positive signals from the EU institutions**. Today, there are approximately 120 plants in the EU. These plants are mainly located in Germany, Italy, Austria, France and Sweden.

**Biodiesel production in cubic metres, 2012**

"This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406"
Ethanol, also known as ethyl alcohol, pure alcohol, grain alcohol, or drinking alcohol, is often abbreviated as EtOH. EtOH is a light alcohol and is a volatile, colourless, flammable liquid with a characteristic odour. EtOH burns with an almost invisible flame and is biodegradable. Without proper conditions, EtOH attracts water while stored. Another important feature of EtOH is the formation of an azeotropic mixture with water.

Molecular Formula

Production process
EthOH is a naturally widespread chemical, produced by ripe fruits and by wild yeasts or bacteria through fermentation. Ethanol from biomass can be produced from any feedstock containing appreciable amounts of sugar or materials that can be converted into sugar. Fermentation (biotechnology) is the predominate pathway for EtOH production. Biomass can also be converted to EtOH via biotechnological and thermochemical pathways.

http://www.biofuelstp.eu
First generation bioethanol is produced by distillation from crops such as wheat, corn, sugar cane and sugar beet. In Europe, wheat is the main crop grown for bioethanol production - accounting for 0.7% of EU agricultural land and 2% of Europe's grain supply [Source: ePure].

Cellulosic ethanol (a second generation biofuel) can be produced from a wider range of feedstocks, including agricultural residues, woody raw materials or energy crops that do not compete directly with food crops for land use. 

[http://www.biofuelstp.eu](http://www.biofuelstp.eu)
Bioethanol, comparison of fuel properties

<table>
<thead>
<tr>
<th>Origin</th>
<th>Ethanol</th>
<th>Petrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 20 °C [kg/l]*</td>
<td>0.79</td>
<td>0.74</td>
</tr>
<tr>
<td>Lower heating value [MJ/kg]*</td>
<td>26.7</td>
<td>43.9</td>
</tr>
<tr>
<td>Octane number*</td>
<td>&gt;100</td>
<td>92</td>
</tr>
<tr>
<td>Fuel equivalence*</td>
<td>0.65</td>
<td>1</td>
</tr>
<tr>
<td>GHG [gCO₂eq/MJ]**</td>
<td>Sugar beet ethanol: 33&lt;br&gt;Farmed wood ethanol: 20&lt;br&gt;Wheat straw ethanol: 11</td>
<td></td>
</tr>
</tbody>
</table>

**Source: *FNR 2012. Median values are used for simplification. Please refer to standards for ranges.**

**Directive 2009/28/EC, total for cultivation, processing, transport and distribution.**

**Relevant fuel regulations**
EN 228, EN 15736

**Main feedstocks**
Sugar and starch from agricultural crops, (sugar cane, cereals, sugar beets); lignocellulosic biomass (forestry residues, agricultural residues, energy crops)

**Scale of Production**
Industrial production for first-generation ethanol and pilot-plant/demonstration scale for second generation (cellulosic) ethanol

Bioethanol is biodegradable and less toxic and explosive than petrol.

“*This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406*”
Bioethanol, production

Bioethanol production in cubic metres, 2012

Elaboration from: http://www.eia.gov

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
Bioethanol, production

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”

http://epure.org/media/1270/european-ethanol-installed-production-capacity.png
This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406
The CropEnergies Group has an annual capacity of over 1.2 million m³ for bioethanol and over 1 million tonnes for food and animal feed.

**Locations:** Four factories in four countries (Germany, Belgium, France and Great Britain), three branch sales offices in three countries (USA, Chile and Brasil)

**Raw materials:** Feed grain, sugar syrup, raw alcohol

**Products:** Bioethanol, protein-based food and animal feed, liquid CO₂

**Markets:** Europe

**Customers:** Oil companies and traders, food and animal feed producers, beverage and cosmetics producers, pharmaceutical companies

The CropEnergies Group includes:
- CropEnergies Bioethanol GmbH, Zeitz
- Biowanze SA, Brüssel
- Ensus UK Ltd., Yarm, Great Britain
- Ryssen Alcools SAS, Loon-Plage
- Joint venture CT Biocarbonic, Zeitz

Bioethanol production 2015/16: 0.8 million m³
Bioethanol sales 2015/16: 1.0 million m³ including 200,000 m³ trading goods

http://www.suedzucker.de/en/Unternehmen/Konzernstruktur/CropEnergies/

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
• The bioethanol plant in Klein Wanzleben/Sachsen-Anhalt, Germany, began its construction in September 2006
• The bioethanol plant will have a 130,000 m³ production
• It will be an annex to the sugar factory in Klein Wanzleben
• The factory will only process “surplus sugar beet”

Source: EXERGIA, Greece

Tereos built a 300.000 m³/annum (m³ of alcohol/ethanol) sugar beet distillery in Origny Sainte-Benoîte

The new unit is the largest one in the world for sugar beet alcohol

The raw materials are sugar beets from Origny region and low purity syrups from the sugar mills at Origny, Boiry, Escaudoeuvres and Chevrières

Estimation for processing of 3 million tons of beets yearly (40.000 hectares of land and 10.000 growers)

Source: EXERGIA, Greece


“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
• Located alongside the world's largest beet sugar factory at Wissington, Norfolk
• UK's first bioethanol plant
• It produces bioethanol from locally-grown sugar beet
• It has an annual production capacity of 70 million litres
• The raw material is about 110,000 tons of sugar

Source: EXERGIA, GREECE

http://www.britishsugar.co.uk/Bioethanol.aspx
European Associations

• EUBIA, the European Biomass Industry Association, was established in 1996 as an international non-profit association in Brussels, Belgium. It groups together market forces, technology providers, and knowledge centres, all of them active in the field of biomass.

• ePURE, the European renewable ethanol association represents the interests of European renewable ethanol producers to the European institutions, industry stakeholders, the media, academia and the general public.

• EBB, the European Biodiesel Board is a non-profit organisation established in January 1997. EBB aims to promote the use of biodiesel in the European Union, at the same time, grouping the major EU biodiesel producers.

• EABA, the general objective of the European Algae Biomass Association is to promote mutual interchange and cooperation in the field of biomass production and use, including biofuels uses and all other utilizations.

• EBTP, The European Biofuels Technology Platform aims to contribute to the development of cost-competitive world-class biofuels value chains.

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
Concept of Sweet Sorghum Biorefinery

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”

Pictures: EUBIA, Bioethanol plant, Cogeneration plant, Pelletisation unit, D.D.G.s unit.
BEST project

City of Stockholm
Coordinator BEST project
Public tranpost of Stockholm
BSR Svenska AB
BFR Biofuels Region
BAFF Bioalchool Foundation
SEKAB
Saab Automobile AB
Umeå University
ETA-Florence Renewable Energies
Municipality of LaSpezia
Province of La Spezia
ATC S.p.A.
Rotterdam
Royal Nedalco
Somerset Country Council
Wessex Grain
Imperial College
EVE – Basque Country
City of Madrid
Cottbus / Brandenburg
WIP Munich
Ford Motor Company

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
**BEST project**

This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406

---

**Sweden**

A BioFuel Nation

Swedish shall be free from oil dependency by 2020!

Prime Minister Göran Persson
November 5, 2005
"This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n°322406"
Demonstrating large-scale bioethanol production from lignocellulosic feedstocks

The BIOLYFE project improved critical process steps and demonstrated the whole supply chain, from feedstock sourcing via fuel production to product utilisation. The main result is the constructed efficient 2nd generation industrial demonstration unit with an annual output of about 40,000 tons of lignocellulosic bioethanol, which is used for process optimization through extensive testing.

In October 2013 the world’s first plant for the production of second generation biofuels was opened in Crescentino, Northern Italy. It is the first commercial-scale plant in the world for the production of bioethanol from lignocellulosic biomass with a capacity to produce 75 million litres per year based on PROESA™ technology.

ETA locally supported the implementation of the first Italian E10 pump.

http://www.biolyfe.eu/

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
COMETHA (Industrial scale pre-commercial plant for second generation lignocellulosic ethanol) is a collaborative project started in 2014 and co-funded by the 7th Framework Programme of the European Union.

✓ The scope of COMETHA is the construction and operation of an integrated industrial facility for the production of second generation bioethanol and other co-products from lignocellulosic feedstock.

✓ The plant will be the first of its kind at pre-commercial scale and will be based on the innovative PROESA® technology, developed by Biochemtex and successfully demonstrated at the Crescentino plant, that is operational since 2013 with a capacity of 40,000 tons per year of bioethanol.

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
Project coordination construction and start-up of the biorefinery, management of the biomass supply chain.

Viscosity reduction, commercial-scale enzymatic hydrolysis processes development of enzyme cocktail.

Environmental assessment and policy-making component.

Communication and dissemination of results.

"This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406"
What progress beyond the state of the art will COMETHA achieve?

The Crescentino plant was designed with some operative margins, in order to allow for the further optimization and improvement of processes and layout. Relying on this technology validation phase, the COMETHA plant will then implement these improvements and will then represent an important milestone towards the real commercialization of cellulosic ethanol.
COMETHA will demonstrate the integration of second generation processes into a full industrial-scale biorefinery.

Key innovative elements:
• a proprietary **biomass pre-treatment** unit;
• SSCF (simultaneous saccharification and co-fermentation) technology;
• use of novel high-performance **enzymes**;
• high-efficiency integrated distillation and dehydration system;
• valorisation of **secondary streams** and process integration.

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
Large-scale efficient and sustainable biomass supply

**Dual feedstock:** Dedicated energy crops and agricultural residues.

Different biomass sources with non contemporary harvesting times to ensure constant supply and regular functioning of the plant.

The biorefinery will be fed with fresh biomass from *Arundo donax* and agricultural residues in the seasons when they will be readily available from the fields.

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
COMETHA will develop a detailed life cycle assessment of the bioethanol flagship plant in order to demonstrate the actual GHG emission savings of second generation ethanol and the overall sustainability of the Biochemtex PROESA® technology and of the supply chain.

"This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406"
Industrial scale pre-commercial plant for second generation lignocellulosic ethanol

Please visit www.cometha.eu for more information and news updates

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
From: The state of the biofuels market: regulatory, trade and development perspectives, United Nations

In 2001, the European Commission (EC) launched a policy to promote the use of biofuels for transport in order to reduce GHG emissions and environmental impacts as well as to increase security of supply, technological innovation and agricultural diversification. The basis of such a policy was a “regulated market-based approach”, in which market forces play a role and market interventions are regarded as necessary to achieve the stated goals.

In May 2003, Directive 2003/30/EC (Biofuels Directive) entered into force. The Directive required that Member States (MS) introduce legislation and take the necessary measures to ensure that, beginning in 2005, biofuels account for a minimum proportion of the fuel sold on their territory. Meaning, 2 percent by December 2005 and 5.75 percent by December 2010, compared with 0.6 percent in 2002. These were indicative targets. Since the 2005 target was not achieved - biofuel use attained only 1.4 percent of transport fuel at region level, the EC established mandatory targets.
In parallel, legislation was developed on taxation of energy sources. According to Directive 2003/96/EC, MS may apply total or partial exemptions or eductions in the level of taxation to, inter alia, forms of energy derived from solar, wind, tidal or geothermal energy, or from biomass or waste. These tax concessions are considered as state aids, which may not be implemented without prior authorization by the Commission in order to avoid undue distortion of competition and over-compensation (European Union, 2003a).

The EU production of biofuels amounted to around 14.3 bnl in 2012, with bioethanol totaling 4.6 bnl and biodiesel the remaining 9.7 bnl. It was 7 percent lower than previous year due to a decrease in biodiesel volumes. The region is by far the world’s biggest producer of biodiesel. In 2006, the top three producing MS were Germany, France, and Italy and they together accounted for 75 percent of the EU’s biodiesel. By 2012, the share of the top three producing members Germany, France, and the Benelux (Belgium, The Netherlands, and Luxemburg) dropped to 64 percent.
Double counting measures in some member states, and reduced mandates since 2013 in Spain, are having a negative impact on EU demand and production. The growth of bioethanol production flattened somewhat from an annual average increase of about 700 million liters in 2008, 2009 and 2010 to only around 176 million liters in 2011 and 2012. Since 2010, producer margins deteriorated in the region due to low domestic bioethanol prices versus high feedstock prices.

Some European producers were only able to make a profit due to the returns on selling distillers dried grains (Flach, et al., 2013). Regarding consumption, the bioethanol consumption in the region increased from 1.7 to 5.6 bnl in the period between 2006 and 2012. In the same period, the EU biodiesel consumption increased from 5.5 up to about 12 bnl. Figure presents the biofuel production and consumption in the EU from 2006 to 2012.
Figure: EU biofuel production and consumption in billion liters

“This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 322406”
The feedstocks used for bioethanol production are cereals and sugar beet, while biodiesel is manufactured mainly from rapeseeds. The use of soybean and palm oil is limited by the EU standard for pure biodiesel (EN 14214). However, it is possible to meet this standard by using a feedstock mix of rapeseed oil, soybean oil, and palm oil. Recycled vegetable oils and animal fat are not as popular feedstock as vegetable oils, however, their use is steadily increasing as they form a cheaper alternative feedstock and in some MS - such as Austria, Denmark, Finland, France, Germany, Ireland, the Netherlands, and the United Kingdom - they count double against the use mandates. Not conventional feedstocks include cottonseed oil used in Greece as well as pine oil and wood in Sweden (Flach, et al., 2013).