THE 2010 - 2020 WORLD OUTLOOK FOR BIOFUELS

Case Studies for Biodiesel and Bioethanol

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Abstract

Biofuels now play a critical role in meeting global fuel demand. Experts think that prices of oil and gas would be about 15% higher in case of no world biofuel production. Global biofuel demand is expected to increase in the coming years. In the European Commission's view recommendation for the use of biofuels will: (1) improve energy supply security, (2) reduce greenhouse gas emissions, and (3) boost rural incomes and employment.

However the main traditional sources of feedstocks for biofuels may be dramatically affected in their economy depending on advances of biotechnology making commercially viable the second and third generation of biofuels, which will disregard food crops used by the first generation.

The worldwide claims against energy crops from sugar cane, soybean, sunflower, rapeseed, and palm are impressive as they impact on price of foods (sugar, grains, cooking oils, etc.). They were responsible for the researches for alternative sources for biofuels now been highlighted, especially the cellulosic ethanol and algae biofuel. Second generation biofuel technologies based on cellulosic materials or microalgae for conversion into diesel, gasoline or kerosene, are expected to become feasible in the next decade.

The international biofuel market is still at an early and very dynamic stage. Biodiesel and bioethanol produced from agricultural crops using existing methods cannot sustainably replace fossil-based transport fuels in large scale. There is no surface area of agricultural land for that in the planet. However either microalgae or cellulose biomass seems to be the only renewable biofuel sources having potential to replace fossil fuels in large scale. Most productive oil crops supporting the first generation of biofuels, such as jatropha and palm oil for biodiesel and sugarcane for bioethanol, seem not competitive to face these ongoing sources.

Vanguard biotechnology is expected to support well succeeded realizations on this field putting energy crops on a very odd situation in the next decades. Conversion technologies for producing biofuels from biomass resources such as algae ponds, forest materials, agricultural residues and urban wastes are under development and most have not yet been demonstrated commercially.

The fact that biofuels reduces lifecycle carbon dioxide emissions in a great extent make them part of the greenhouse gas emission (GHG) reduction policies being now worldwide discussed. Global emissions reduction legislation is setting progressively more stringent limits and transition to forthcoming Euro standards, and more recently trends to fix upper limits in the range of 120g/km drive greater use of biofuels.

Decisions on the type of biofuel and the degree of blending with gasoline or petro diesel also influence the extent to which automotive fuel systems require modification, and the type of materials required to contain these new fuels. It is currently accepted that most vehicles can operate with 15% to 20% ethanol blended in gasoline, and 10% biodiesel blended in petro diesel without requiring modifications in engines. Flex fuel engines are able to deal with different moistures of fuels. So, trends are to increase these limits depending on availability of future supply from biofuels which are connected to the advanced technologies of the second generation of biofuels under way.

Scenarios envisaged by OEDC and IEA forecast global biofuels output will reach 1.75 million barrels a day in 2012. The IEA projects increasing tightness in the market for petroleum and sees OPEC spare capacity decline to minimal levels by 2010.

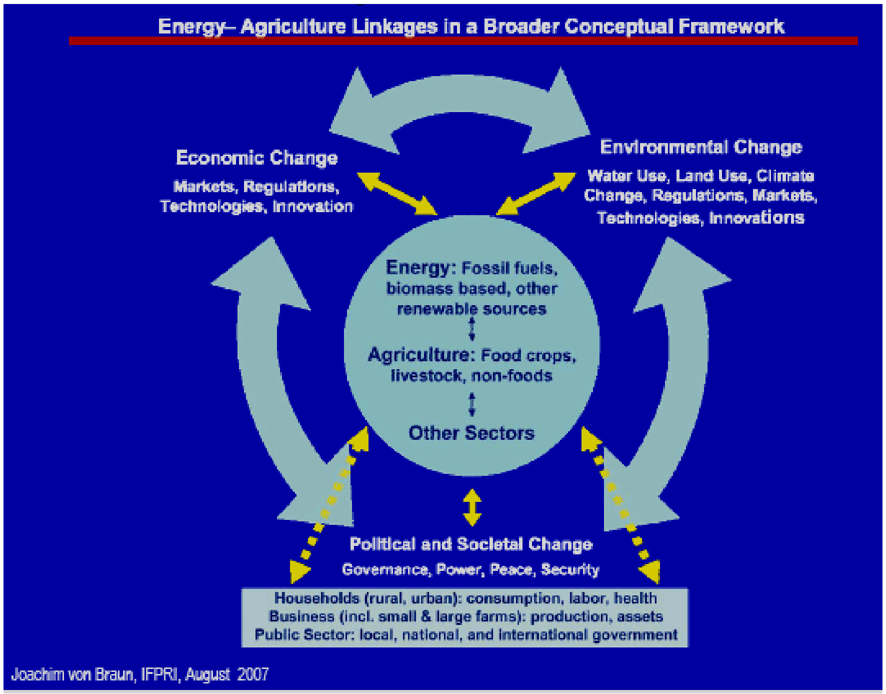
Nevertheless, in any case according to IEA (2009 report) the role of biofuels on the energy framework in the global strategy for a low carbon economy (GHG abatement to 450 ppm in 2030) will be relatively small as compared to other sources (renewable energy and improving efficiency on processes for instance).

1 – Background

The dilemma between energy and food crops is being intensified at a high speed. Whether to decide on food or biofuel crops for local or global trade is now a worldwide controversy. A full comprehension must be developed on the energy-agriculture linkages on a broader conceptual framework. As it has been outlined by the International Food Policy Research Institute (IFRPI) there are many things depending on each other in a complex system for food vs. energy, but the main components seem to be that:

- Biofuel feedstock should be grown on other soils than those used for food crops
- The huge potential for biofuel is not in the most sensitive famine areas
- The biofuel production can add value to the land use for poor farmers and attract capital to improve productivity in the food production

The linkages of energy-agriculture in a broader conceptual framework prepared by IFRPI in 2007 are shown below:

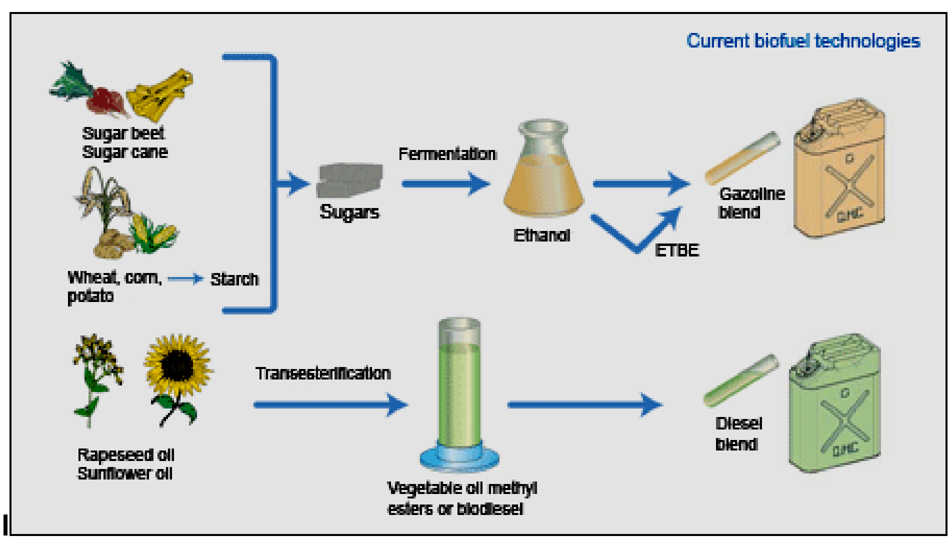


Linkage among economic sectors, political and societal change

There are two classic approaches for commercial production of biofuels with the current technologies of first generation:

- **Bioethanol** (from sugar cane, sugar beet, grains, etc.) essentially by fermentation and distillation
- **Biodiesel** (from vegetal oils) essentially through transesterification

Nevertheless, bioethanol has only 64% of the energy content of biodiesel. The scheme below illustrates these technologies. The feedstocks currently used for both are produced either in tropical or temperate climate extensive farming areas.



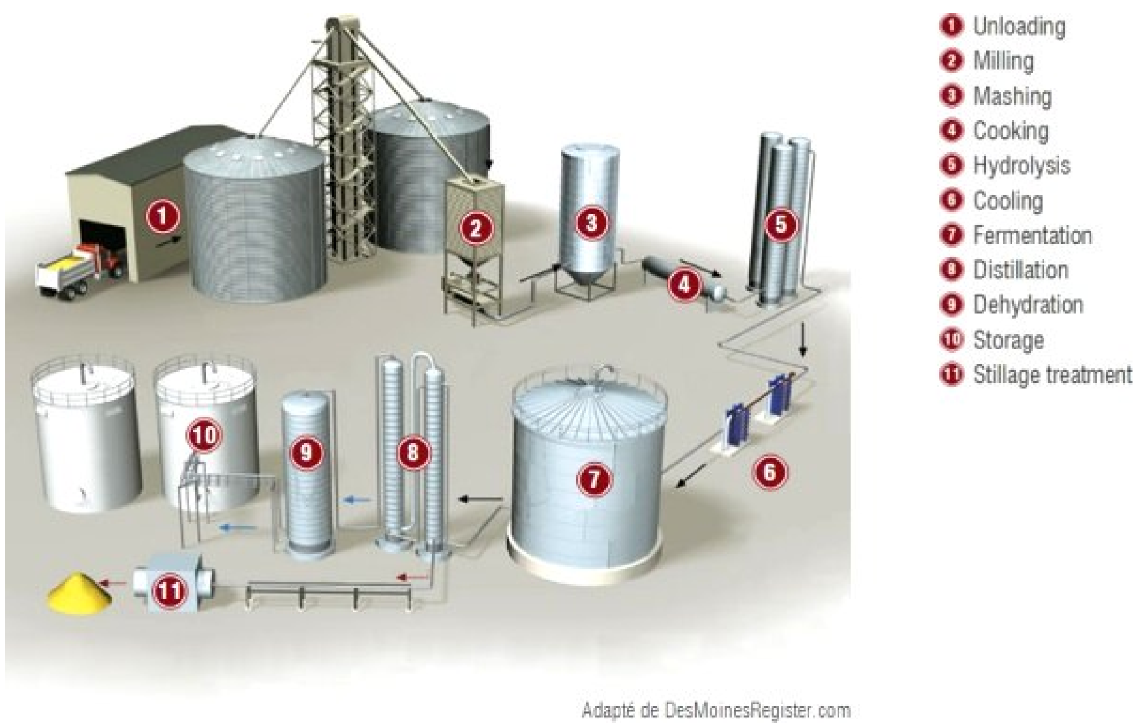
Schematic classical approaches to biofuel production

They form the so-called first generation of biofuels whose feedstocks are based on energy crops replacing partly previous food crops for sugar, cooking oil and grains.

Bio-fuels are made from biomass through thermo chemical processes such as pyrolysis, gasification, liquefaction and supercritical fluid extraction or biochemical. Biochemical conversion of biomass is completed through alcoholic fermentation to produce liquid fuels and anaerobic digestion or fermentation, resulting in biogas. In wood derived pyrolysis oil, specific oxygenated compounds are present in relatively large amounts.

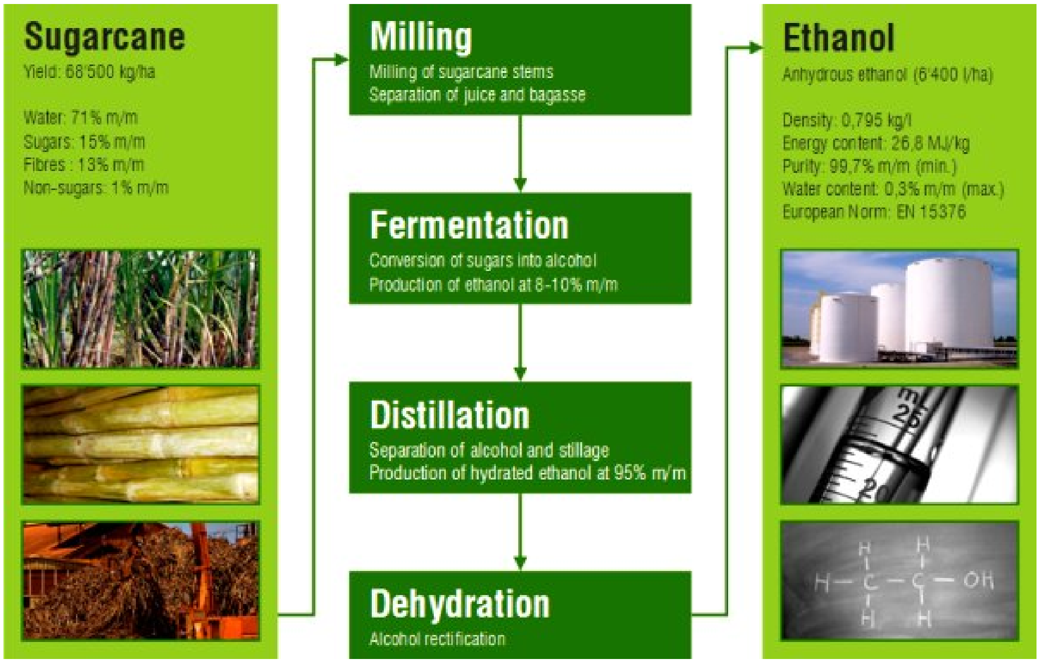
1.1- Bioethanol

Bioethanol show different technologies according to the feedstock used. Production pathways are referred to all fermentable sugars (i.e. glucose, sucrose, etc.) may be converted to ethanol by fermentation. Such sugars are present in a more or less polymerized state in many species of the plant world such as sugar beets, sugarcane, wheat, corn, potatoes, but also in grass or wood. Some waste products (e.g. cheese whey, waste paper, etc.) and various residues may also be converted into bioethanol. Depending on the state of polymerization, the sugars have to undergo one or several treatment steps, with the aim of transforming the various polymer chains in simple fermentable sugars. After fermentation by means of micro-organisms (yeasts, bacteria, etc.), ethanol is recovered by distillation (hydrous ethanol at 92-96% vol.) followed by dehydration (anhydrous ethanol at 99.7% vol.). The above figure shows the schematic process of bioethanol production from cereals (source: DesMoinesRegister.com). Figures which follow illustrate the main streamlines for sugar cane, corn and wood, showing the average values for efficiency on crop farming and industrial process.

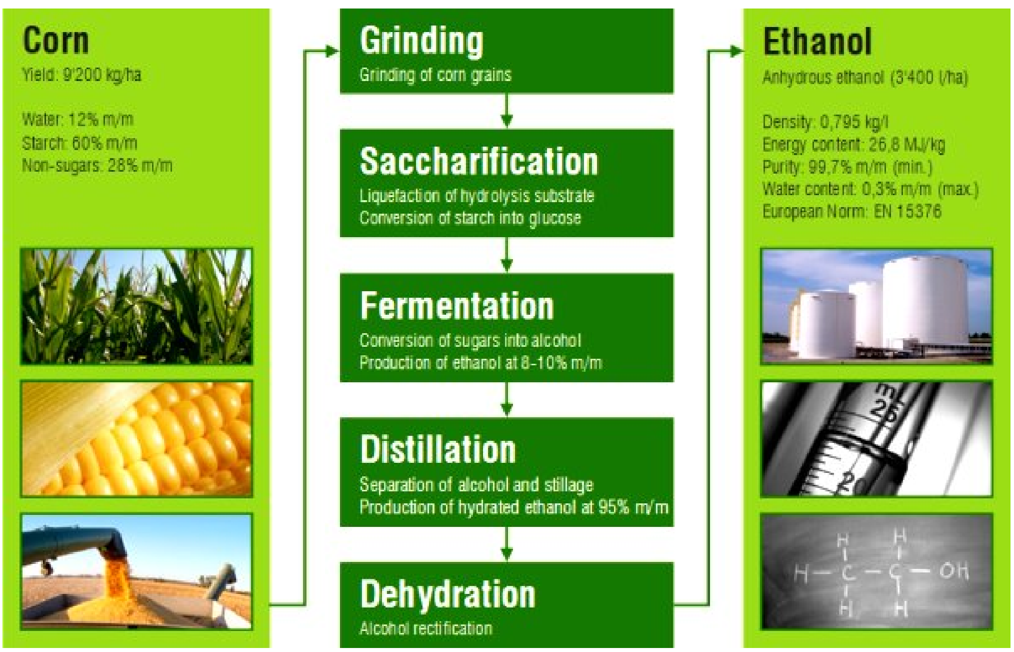


Production of bioethanol from sugarcane

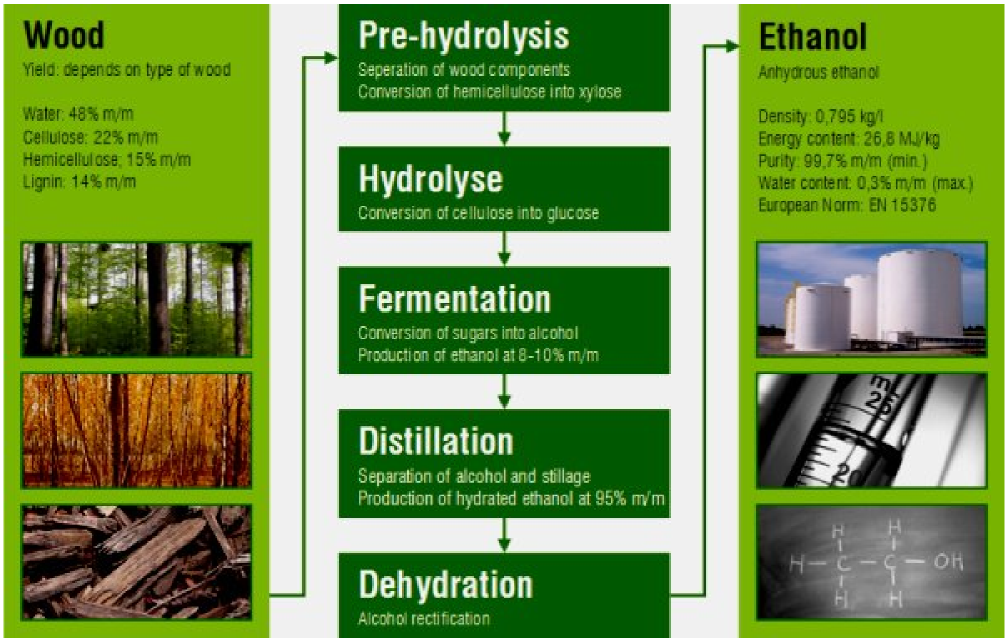
Following are presented some standard values for bioethanol production from different sources:



Production of bioethanol from corn



Production of bioethanol from corn



Production of bioethanol from wood

1.2 – Biodiesel

Biodiesel is the popular name of Fatty Acids Methyl Esters (FAME).used as fuels. Blends of biodiesel and conventional petro diesel are products most commonly distributed for use in the retail diesel fuel marketplace. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix:

100% biodiesel is referred to as B100, while

20% biodiesel is labeled B20

5% biodiesel is labeled B5

2% biodiesel is labeled B2

Production methods for biodiesel - The main process methods for producing the biodiesel are:

Batch process: This is the traditional method for producing biodiesel used in the nineties. It requires huge installation and large energy consumptions. Preparation: care must be taken to monitor the amount of water and free fatty acids in the incoming bio lipid (oil or fat). If the free fatty acid level or water level is too high it may cause problems with soap formation and the separation of the glycerin by-product downstream. Catalyst is dissolved in the alcohol using a standard agitator or mixer. The alcohol/catalyst mix is then charged into a closed reaction vessel and the bio lipid (vegetable or animal oil or fat) is added. The system from here on is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just above the boiling point of the alcohol (around 70 °C, 158 °F) to speed up the reaction though some systems recommend the reaction take place anywhere from room temperature to 55 °C (131 °F) for safety reasons. Recommended reaction time varies from 1 to 8 hours; under normal conditions the reaction rate will double with every 10 °C increase in reaction temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters.

The glycerin phase is much denser than biodiesel phase and the two can be gravity separated with glycerin simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster. Once the glycerin and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation. In other systems, the alcohol is removed and the mixture neutralized before the glycerin and esters have been separated. In either case, the alcohol is recovered using distillation equipment and is re-used. Care must be taken to ensure no water accumulates in the recovered alcohol stream.

The glycerin by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerin (water and alcohol are removed later, chiefly using evaporation, to produce 80-88% pure glycerin). Once separated from the glycerin, the biodiesel is sometimes purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage.

Supercritical process: An alternative, catalyst-free method for transesterification uses supercritical methanol at high temperatures and pressures in a continuous process. In the supercritical state, the oil and methanol are in a single phase, and reaction occurs spontaneously and rapidly. [6] The process can tolerate water in the feedstock; free fatty acids are converted to methyl esters instead of soap, so a wide variety of feedstock can be used. Also the catalyst removal step is eliminated. [7] High temperatures and pressures are required, but energy costs of production are similar or less than catalytic production routes.

Ultra- and high-shear in-line and batch reactors: It allows production of biodiesel continuously, semi- continuously, and in batch-mode. This drastically reduces production time and increases production volume. The reaction takes place in the high-energetic shear zone of the Ultra- and High Shear mixer by reducing the droplet size of the immiscible liquids such as oil or fats and methanol. Therefore, the smaller the droplet size the larger the surface area the faster the catalyst can react

Ultrasonic-reactor method: In this method, the ultrasonic waves cause the reaction mixture to produce and collapse bubbles constantly. This cavitations provide simultaneously the mixing and heating required to carry out the transesterification process. Thus using an ultrasonic reactor for biodiesel production drastically reduces the reaction time, reaction temperatures, and energy input. Hence the process of transesterification can run inline rather than using the time consuming batch processing. Industrial scale ultrasonic devices allow for the industrial scale processing of several thousand barrels per day. Ultrasonic reactors reduce the processing time from the conventional 1 to 4 hour batch processing to less than 30 seconds. More important, the ultrasonic effects reduces the separation time from 5 to 10 hours (using conventional agitation) to less than 60 minutes. The ultrasonic effects does also help to decrease to amount of catalyst required by up to 50% due to the increased chemical activity in the presence of cavitations. When using ultrasonic process the amount of excess methanol required is reduced, too. Another benefit is the resulting increase in the purity of the glycerin.

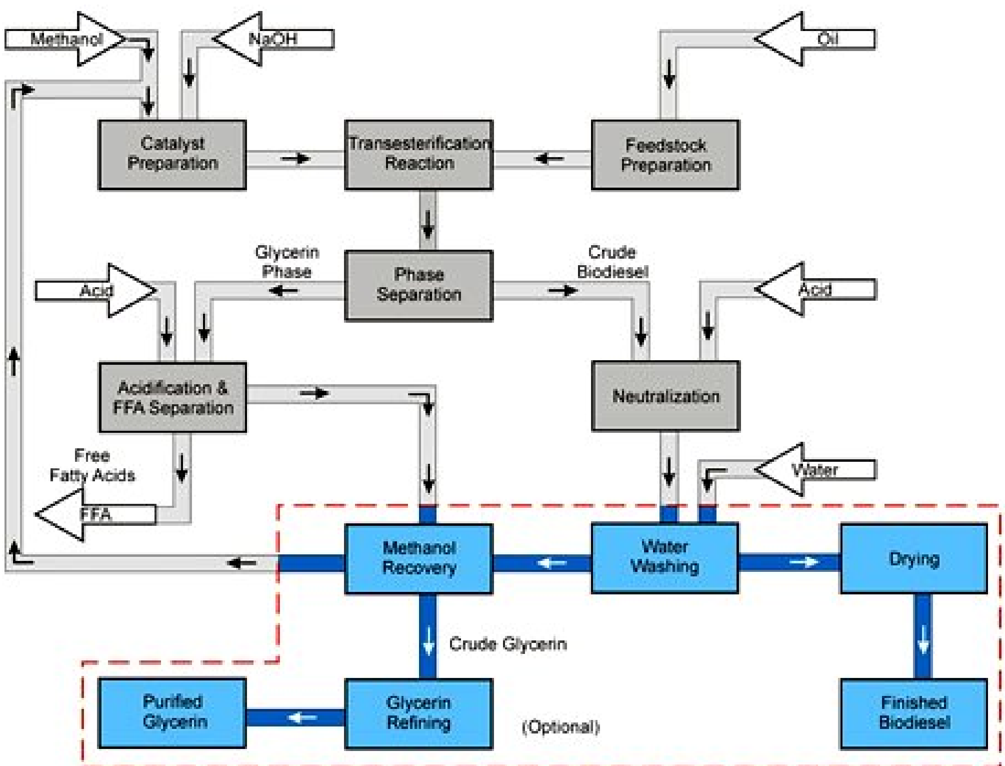
Biodiesel has been produced largely using batch reactors. Technology for continuous production of biodiesel came to market 10 years ago. The breadth of biodiesel production technologies has blown up with the expansive growth of the biofuel industry in the past years. The biodiesel process continues to evolve as producers and researchers determine ways to refine production techniques.

Basic raw materials for production of FAME are:

- Vegetable oil (new, used, non-edible, etc.)
- Methanol
- Catalysts such as, KOH, NaOH, MeONa (sodium methanolate)
- Side products such as, glycerol and fatty acids.

The variety of technologies involves continuous (new ones) and discontinuous (old) processes.

The general flow diagram of the process is shown below:



General flow diagram of biodiesel production

2 - Critical analysis

Besides the security of energy supplies, climate change is the major driver of the EU's efforts to promote renewable fuels. The transport sector is currently responsible for one third of the EU's carbon dioxide emissions, and growth in the sector is negating reductions made in other economic sectors (industrial and domestic). Without alternatives to oil, growth in the EU's greenhouse gas (GHG) emissions will be dominated by the transport sector, which will contribute up to 60% of all new emissions.

There are only two options to change this situation: increasing the efficiency of transport and utilizing more biofuels. Biofuels offer advantages in that they bring rural development, new markets and jobs, as well as opportunities for scientific work and technological development which will result in newer generations of cleaner fuels. But their potential to reduce GHG emissions remains the main reason for their support.

Intergovernmental and international efforts are needed to streamline and help the convergence of biofuel standards. Several initiatives on international standardization are currently underway, which will improve the tradability of the fuels.

The EU is fully committed to creating an international market for biofuels - it *does not want to* rely on domestic production alone because this would require new land (set-aside land) to be taken in production, which is not desirable as it impacts biodiversity. But closing off the market is not desirable for another reason: biofuels offer a unique lever for global solidarity. Countries in the South have competitive advantages (land, sun, climate, crops) but often lack the technological and financial means to create biofuel industries. The EU can help transfer technologies, encourage investors to go South, and learn from countries like Brazil. Moreover, the sector will boost international cooperation in a range of fields - from biotech and agronomy, to bioconversion technologies and cooperation in the field of infrastructures. In the era of climate change and growing oil scarcity biofuels trigger a world-wide sense of responsibility; successful policies and the use of biofuels in one country, positively impact all citizens of the globe.

Some highlights of the recent conferences (The Future of Biodiesel in Uncertain Times Outlook Biodiesel & Vegetable Oils for 2010 & Beyond) are presented as follows:(many other references were published on Biofuels Digest):

a) Market will continue to look for ways to grow especially bioethanol. Energy security politics will be the key drivers behind this effort.

b) For new sources on feedstocks algae is the main interesting area, jatropha still get some attention and could be viable for a while for not being a food crop and could be cultivated in marginal lands. Interest in algae biofuels peaked in the summer of 2008, but afterwards declined almost half by the summer of 2009. Jatropha peaked in the summer of 2008, after steady growth 2004-2008, and has declined about 60 percent from that high point, including a steady decline throughout 2009.

c) Attention is to be concentrated on algae farms and related bio-refinery for biodiesel production and cellulosic ethanol for not impacting to food crops. A Danish company has announced that its productivity increases bringing enzyme costs down to allow biofuel industry to produce cellulosic ethanol at a price below USD 0.50 per liter for the initial commercial-scale plants that are scheduled to be in operation in 2011. This cost is on par with gasoline and conventional ethanol at the current US market prices.

3 - Worldwide outlook for biofuels

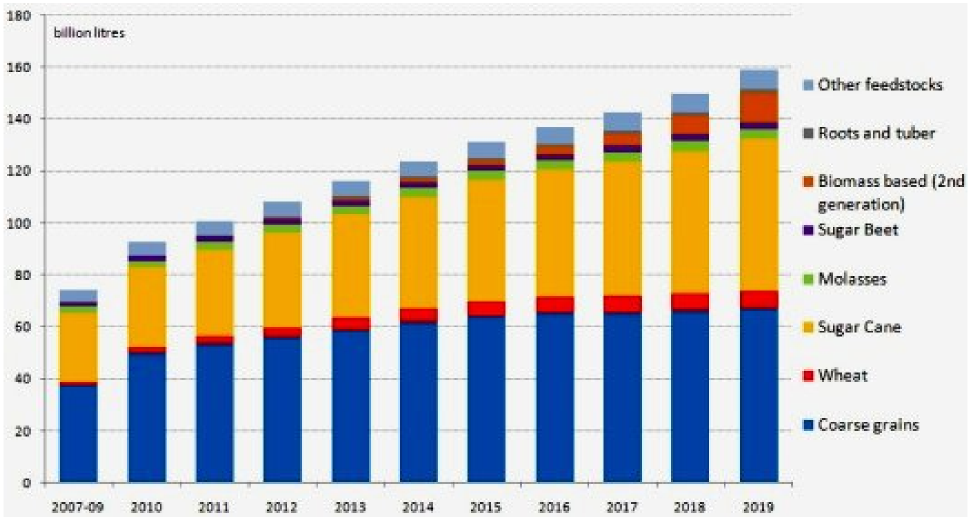
Pressed by energy security, environmental quality, and economic development issues, some nations are following Brazil in developing domestic biofuels markets. National governments are envisaging the biofuels market opportunity estimated at $100 billion-plus per year — but it is still in its infancy. The United States, Brazil, and the European Union are the big three biofuels markets in terms of volume. Biofuels now provide more than 50% of the fuel by volume that powers Brazil's road transportation vehicles with gasoline engines. While currently only a small fraction of the U.S. and EU total transportation fuels markets, these regions dominate Brazil in absolute numbers in their respective biodiesel and ethanol markets. The figure below illustrates the situation in 2004 and the forecasted one by 2030.

According to OECD (Agricultural Outlook 2010-2019) the evolution of ethanol production by feedstock over the projection period shows that the major feedstock for ethanol production should remain coarse grains. The use of coarse grains for ethanol production should grow relatively less after 2015 when the mandate for Conventional Renewable Fuels reaches its maximum in the US. Following is a table showing the demand of biofuel for road transport by region.

Biofuels Demand in Road Transport, by Region

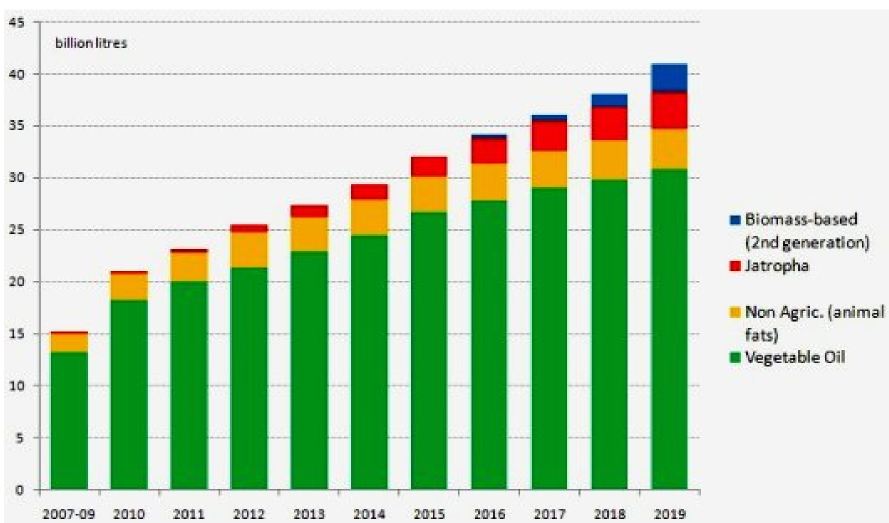
	2004		2030	
	Demand (Mtoe)	% in Road Transport	Demand (Mtoe)	% in Road Transport
OECD	8.9	0.9%	84.2	7.2%
North America	7.0	1.1%	45.7	6.4%
United States	6.8	1.3%	42.9	7.3%
Europe	2.0	0.7%	35.6	11.8%
Pacific	0.0	0.0%	2.9	1.9%
Transition economies	0.0	0.0%	0.5	0.6%
Developing countries	6.5	1.5%	62.0	6.9%
China	0.0	0.0%	13.0	4.5%
India	0.0	0.0%	4.5	8.0%
Other developing Asia	0.1	0.0%	21.5	4.6%
Brazil	6.4	13.7%	23.0	30.2%
World	15.5	1.0%	146.7	6.8%
European Union	2.0	0.7%	35.6	11.8%

Almost 40% of the increase in global ethanol production should be due to the increase in the production of ethanol based on sugar cane, mainly from Brazil, to meet both domestic and US demands. Biomass based second generation ethanol is only expected to develop in the latter years of the projection period, representing about 7% of total ethanol production. Roots and tubers and molasses are expected to be used as feedstocks for ethanol production in developing countries. Wheat, coarse grains and sugar beet should be used in the European Union to produce ethanol.



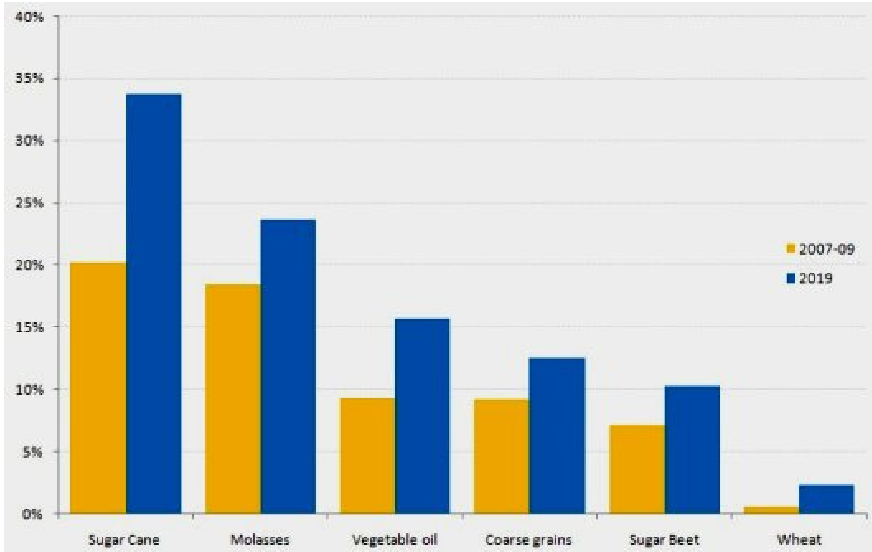
Global ethanol production by feedstock

Edible vegetable oil is expected to remain the major feedstock used to produce biodiesel. However, its share in total biodiesel production should decrease from almost 90% over the base to about 75% by 2019. This is due to the development of the production of biodiesel based on jatropha mainly in India, to the increasing use of animal fats to produce biodiesel in the US and to the availability of biomass based second generation biodiesel in the latter years of the projection period. Biomass based biodiesel should represent almost 6.5% of total biodiesel production by 2019.



Global biodiesel production by feedstock

Biofuel use represents an important share of global cereal, sugar and vegetable oil production. By 2019, about 13% of the global production of coarse grains will be used to produce ethanol compared to 9% in 2007/2009. And about 16% of the global production of vegetable oil will be used to produce biodiesel compared to 9% in 2007/2009. The share of sugar cane to be used for ethanol production at the worldwide level is expected to reach almost 35% in 2019.



Share of feedstocks used for biofuel production in global production

The report “Global Biodiesel Market Analysis and Forecasts to 2020” produced by GlobalData makes an analysis of the global biodiesel market and provides forecasts up to 2020. It provides a detailed qualitative analysis of the market scenario from 2001 to 2009, and forecast forward 11 years to 2020 and also involves:

- Data on historic and forecast production, by region and country
- Analysis of key countries such as the US, China, India, Brazil, Germany, France and Italy
- Analysis of the key drivers, restraints & challenges of the global biodiesel market
- GlobalData is a UK-based company, and an industry analysis specialist, providing business information products and services. To access this report one shall go to http://www.oilgae.com/ref/report/others/global_data/

According to this report the biodiesel production increased from 0.96 billion liters in 2001 to 15.760 billion liters in 2009, at a an average annual growth rate of 41.9%. Supported by governments to increase energy independence and meet the rising energy demand, the biodiesel market is expected to produce 45.3 billion liters of biodiesel in 2020, representing a average annual growth rate of 10.1% during 2009 to 2020.

Europe was the leading biodiesel market in 2009 with a production share of 49.8%, followed by the Americas with a production share of 32.8% and the Asia Pacific with a share of 4.4%. The European share in biodiesel production has been declining since 2001, while the share of the Americas and the Asia Pacific increased. The top five biodiesel producers in the world are the Germany, the US, France, Argentina and Brazil. All of these countries together produce 68.4% of the world’s total biodiesel. Australia is the largest producer of biodiesel in the Asia Pacific, followed by China and India.

The European Union has been stimulating the expansion of the use of the two major biofuels (biodiesel and bioethanol) as it seeks to cut emissions of the greenhouse gases which contribute to climate change. But political reactions partly due to the alleged growth of energy crops for biofuels causing detriment to food crops (increasing prices of food) have hit this growing business. There has been having problems for biofuel business in Europe in the last two years

For instance the Germany's biodiesel industry, Europe's largest, expects to operate at only around 50 percent of capacity in 2010. The industry is facing a poor outlook. According to expertise sources about half of the 49 German biodiesel plants were not working at all and many of the operational plants were producing well under capacity.

European Union expects to raise the ratio of renewable energy sources in transport fuel to 10 percent by 2020 as part of the trading bloc's climate change goals and many countries have set interim targets. This seems to be very hard as biofuels have been suffering a political backlash following claims they may have contributed to a rise in food prices in 2007/08 while some scientists doubt about their environmental benefits.

However in 2010 biofuel industry found a political review on this subject and again the EU´s targets by 2020 are now being reconsidered. That includes both bioethanol from sugar cane and beet as well as from grain crops, as a substitute for gasoline, and biodiesel from vegetable oil, tallow and recycled cooking oil, after transesterification as a substitute for petro diesel.

4 - The new biotechnology for biofuels

The oil industry currently still views the emerging bio-fuels industry with fear, rather than acceptance. Eco-defenders have long waited for a way to drive around without contributing to global warming, but the slow pace of progress in alternative fuel technologies has kept that vision far away. New technologies are needed to make this vision economically and environmentally feasible. There are many efforts being done throughout the world to consolidate new technology either for bioethanol or biodiesel to be used in transportation, defining 2nd and 3rd generation biofuels. However some relevant comments herein made are restricted to those related to ongoing processes involving algae, biomass and celluloses for producing biofuel which present signs for commercial success in the early future.

Algae biofuel (biodiesel but also bioethanol): It is the 3rd generation biofuel. It is said that algae can produce up to 300 times more oil per acre than conventional crops, such as grape seed, palms, soybeans, or jatropha. As Algae has a harvesting cycle of 1–10 days, it permits several harvests in a very short time frame, a differing strategy to yearly crops. Algae can also be grown on land that is not suitable for other established crops, for instance, arid land, land with excessively saline soil, and drought-stricken land. This minimizes the issue of taking away pieces of land from the cultivation of food crops (Schenk et al. 2008). Algae can grow 20 to 30 times faster than food crops.

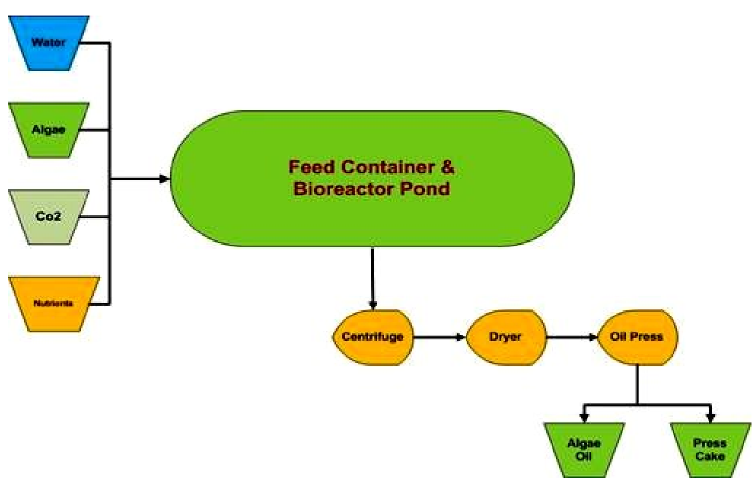
Most companies pursuing algae as a source of biofuels are pumping nutrient-laden water through plastic tubes (called "bioreactors") that are exposed to sunlight (and so called photo bioreactors or PBR). Running a PBR is more difficult than an open pond, and more costly. Algae can also grow on marginal lands, such as in desert areas where the groundwater is saline, rather than utilize fresh water.

As algae strains with lower lipid content may grow as much as 30 times faster than those with high lipid content, the difficulties in efficient biodiesel production from algae lie in finding an algal strain with a combination of high lipid content and fast growth rate, that isn't too difficult to harvest; and a cost-effective cultivation system (photo bioreactors) that is best suited to that strain. There is also a need to provide concentrated CO2 to increase the rate of production.

There are four important steps in the production of algal biofuels: growing the algae, harvesting the crop, separating the oil, and refining the oil to useful fuels. In any algae oil production system the algae is harvested from the growing process as algae paste. It is then de-watered either by heat drying or de-watering presses. Centrifuges are also another way in which the algae past can be de-watered. The Biofuel is then separated from the paste wither by a chemical process or by pressing in a high pressure device such as a screw press. The finished product is algae oil in a form that is then suitable for use in the transesterification process to make biodiesel fuel.

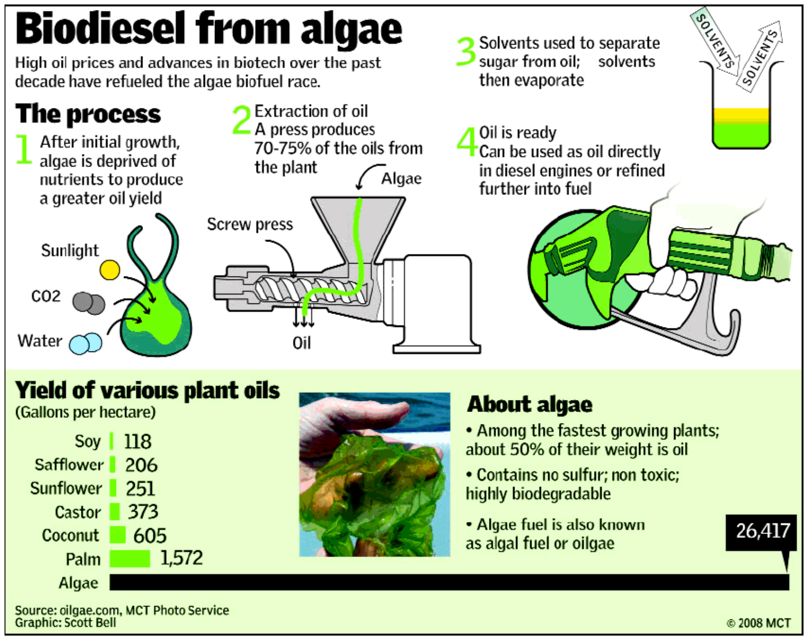
Each step in the process is the focus of intense study by scientists, engineers, and technologists across the developed world. Progress are reported for the use of a solid catalyst instead of liquid catalysts. The solid catalyst can be used over and over and allows the continuously flowing production of biodiesel, compared to the method using a liquid catalyst. Continuous process using solid catalyst is potentially more efficient and productive, compared to batch processing.

Currently, producing biodiesel from algal oil costs about $20 a gallon. But with all the attention being given each of the multiple steps in the fuel production process, some producers are projecting production costs as low as $1.50 a gallon. If costs drop that low within the next 10 years, algal biodiesel will begin to place an effective ceiling on the costs of petrol diesel. It will take time to scale up production, of course. (see http://pmittal.files.wordpress.com/2008/09/biodiesel-from-algae.png). The simplified diagram below from EWBifuel illustrates the process.



Simplified flow diagram for biofuel production from algae

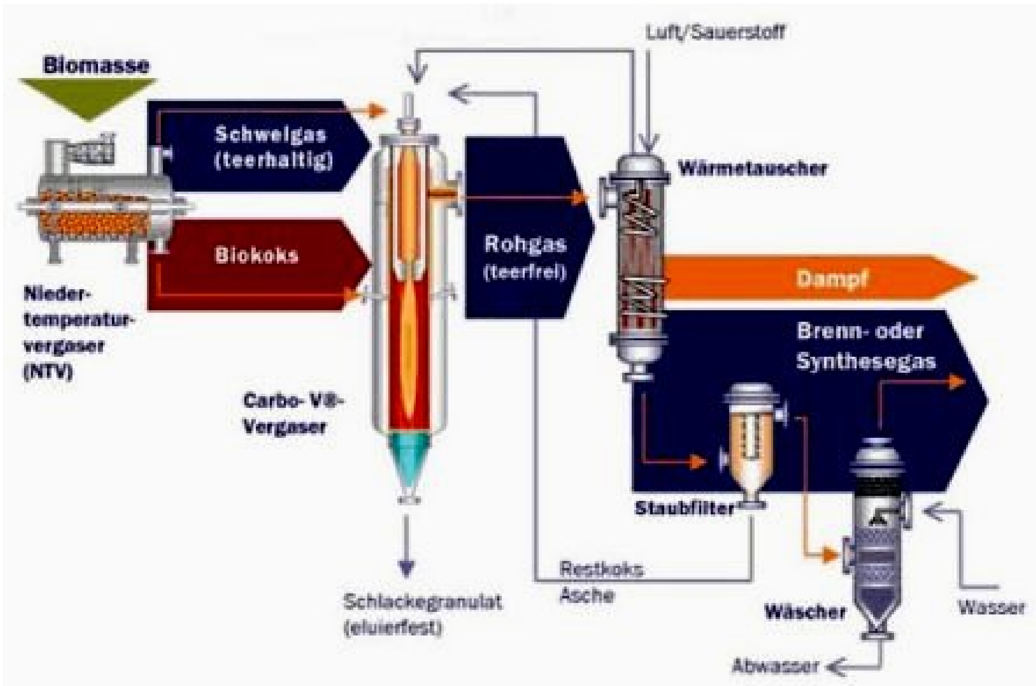
The next figure informs about some preliminary efficiency for the process made by Oilgae.



In EU the firm AlgaeLink NV, a European leader in alternative energy production, announced in August 2007 they will be giving professional Algae production courses at their production facility in the Netherlands. AlgaeLink is a developer of scalable AlgaeLink photo-bioreactors for the production of biodiesel, which have been developed with patented technology. They also produce other valuable bio-commodities produced from algae oil. This technology has the potential to dramatically improve biodiesel yields from algae oil. AlgaeLink is engaging in research and development of algae cultivation as an energy source for the production of biodiesel, which is an economically feasible and eco-friendly alternative to petroleum-based fuels.

BTL biofuel (biodiesel): Biodiesel from biomass, also a 2nd generation biofuel, has it as feedstock (Biomass-to-Liquid, or BTL) may replace up to 13% of Germany's current diesel use. Biodiesel from vegetal oils is the most popular biofuel in Germany, and government has been very supportive in promoting biodiesel as a fuel alternative, but recent changes are now opening the door to other sources for biofuels in Germany.

It has been inaugurated the "first refinery of second generation" biofuels in Freiberg. The plant, owned by Choren, which partners with car companies VW and Daimler and the Shell oil company, produces BTL (biomass-to-liquid) fuel from any kind of biomass, such as wood chips, straw, weeds or leftover milk rejected by the agro-food industry. The resulting biodiesel is like a fuel ready to be used in diesel vehicles without further modification. The plans is to have the plant produce 18 million liters through a sophisticated 3-step process (gasification, gas treatment and hydro cracking) which transforms any kind of biomass into a biodiesel. If successful, entrepreneurs will spend 1 billion Euros in a bigger plant to produce 200,000 million liters of BTL / year.



Flow diagram for BTL production

The key to Choren's system is its patented Carbo-V gasification process—the means by which it converts biomass into a synthetic gas. (Diagram above.). The raw gas produced in this process can be used as a combustion gas to produce electricity and heat or as a synthesis gas for producing synthetic renewable automotive fuels, methanol and paraffin through a Fischer-Tropsch reaction.

The combined process of energy conversion and Fischer-Tropsch synthesis, however, is energy intensive—and more so when using biomass as a feedstock than natural gas. On a Well-to-Wheels basis, BTL diesel is far better from a greenhouse gas emissions perspective than any other variant of synthetic or conventional petroleum fuel (except for DME from biomass) or conventional biofuel, but the worst in terms of energy requirement.

Cellulosic biofuel (Bioethanol): Cellulosic ethanol is referred as to 2nd generation biofuel produced from wood, grasses, or the non-edible parts of plants. It is a type of biofuel produced from lignocellulose, a structural material that comprises much of the mass of plants. Lignocellulose is composed mainly of cellulose, hemicellulose and lignin. Corn stover, switchgrass, miscanthus, woodchips and the byproducts of lawn and tree maintenance are some of the more popular cellulosic materials for ethanol production. Production of ethanol from lignocellulose has the advantage of abundant and diverse raw material compared to sources like corn and cane sugars, but requires a greater amount of processing to make the sugar monomers available to the microorganisms that are typically used to produce ethanol by fermentation.

This is a much larger source of biomass that can be used for bioethanol production in more areas of the world, not competing for crop lands.. Sustainably managed forests, crop residues and a sort of several biomasses can provide a substantial source for the cellulosic bioethanol. The main processes: involves biomass feedstock, pre-treatment, hydrolysis, and finally fermentation to ethanol.

Cellulosic ethanol is chemically identical to first generation bioethanol (i.e. CH3CH2OH).

There are two ways of producing ethanol from cellulose:

- Cellulosic processes which consist of hydrolysis on pretreated lignocellulosic materials, using enzymes to break complex cellulose into simple sugars such as glucose and followed by fermentation and distillation.
- Gasification that transforms the lignocellulosic raw material into gaseous carbon monoxide and hydrogen. These gases can be converted to ethanol by fermentation or chemical catalysis.

They both include distillation as the final step to isolate the pure ethanol.

Significant investment in R&D&D have been made in Europe and the United States. Both will lead to production of cellulosic ethanol on the commercial scale within the next decade.

In 2007 the US Department of Energy (DOE) announced an investment of up to $385 million for six bio-refinery projects over the next four years. When fully operational, the biorefineries are expected to produce more than 520 million liters of cellulosic ethanol per year. The goal in the US is to make cellulosic ethanol cost-competitive with gasoline by 2012. The summary of the ideas for this project are presented below.

In Europe a number of companies are developing enzymes for cellulose hydrolysis including *Novozyme*, Denmark, which produces cellulose and hemicellulose. In 2009, *Syngenta* entered into a collaboration agreement with Proteus, France to develop CE enzymes.

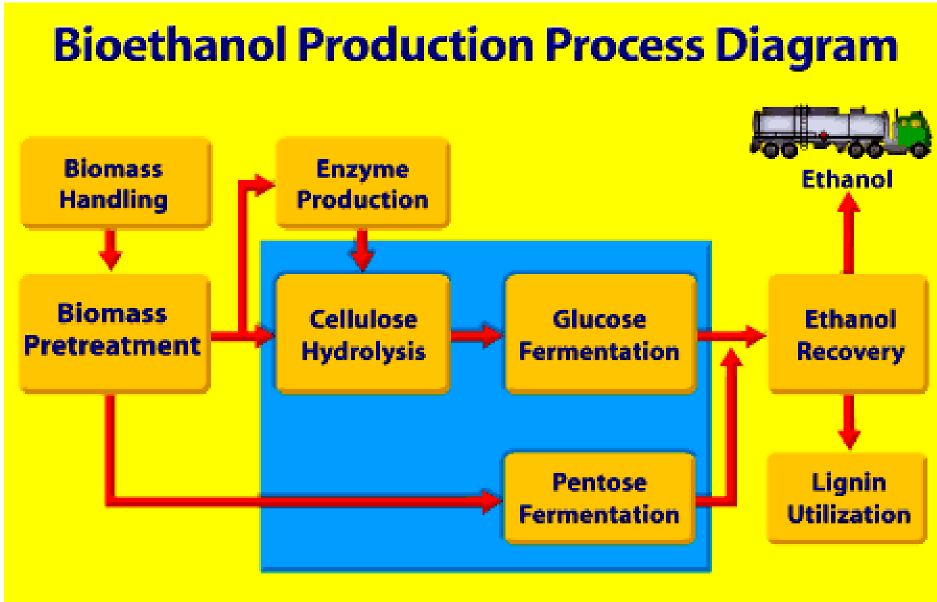
Codexis works closely with *Shell* and *Logen* on enhancing the efficiency of enzymes for cellulosic ethanol production.

Dyadic optimizes C1 Platform Technology for the development of novel enzymes to convert biomass into fermentable sugars to produce cellulosic ethanol and butanol as well as chemicals, polymers and plastics. Dyadic is currently a party to non-exclusive license agreements with *Abengoa Bioenergy New Technologies*, Inc. and *Codexis*, Inc.

Biométhodes has developed proprietary technologies within pretreatment and a unique enzyme solution for maximum cost reduction of ethanol production and valuation of all biomass compounds. The company also aims to develop value-added applications for lignin.

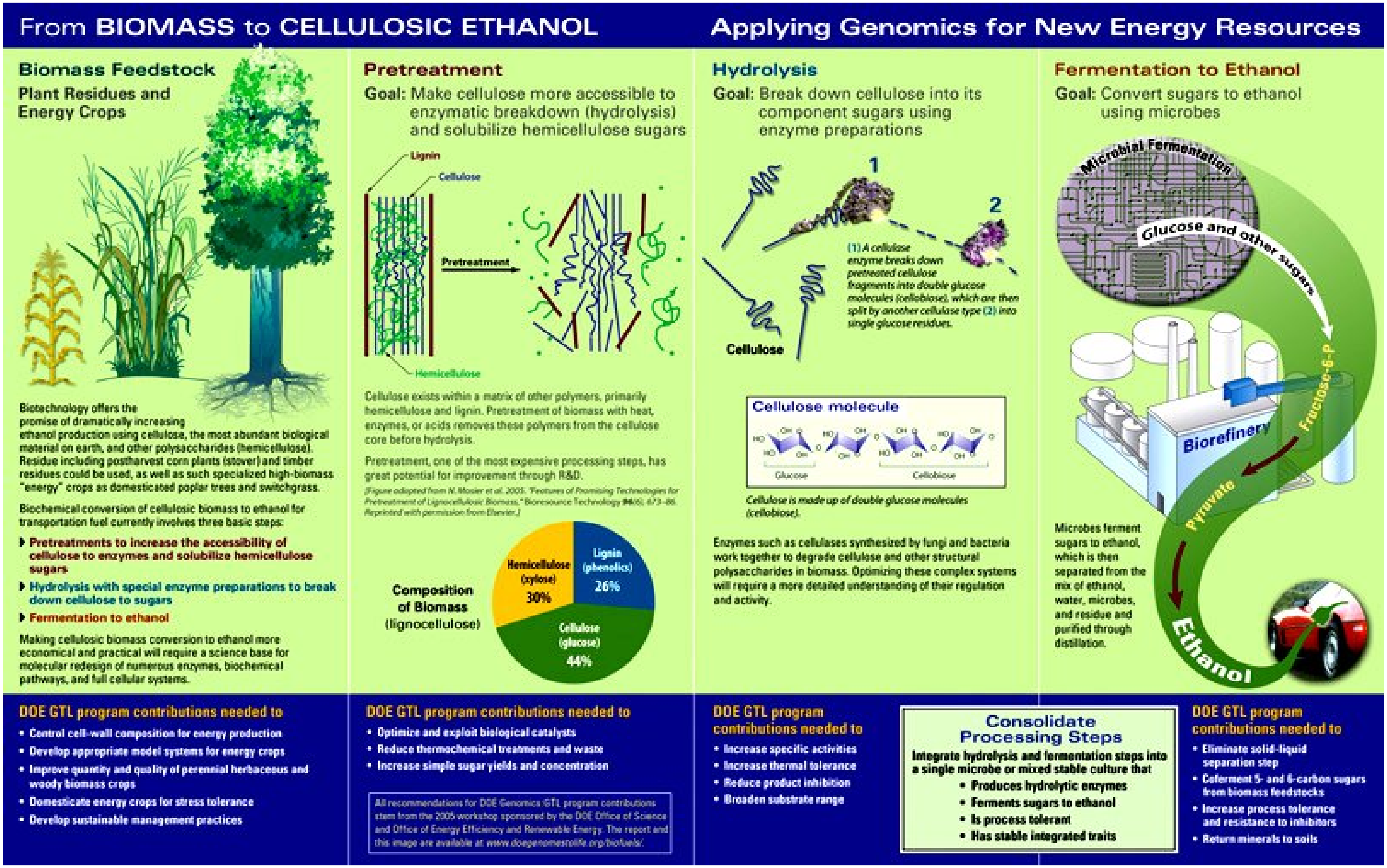
Other efforts (but not exhausting the topic) are related to; *Chemopolis biorefinery* for cellulosic ethanol (Finland); *Abengoa* Commercial Demonstration Plant in Salamanca (Spain); *BioGasol* Demonstration Plant - *BornBioFuel2* (Finland); *Inbicon* Biomass Refinery for production of Cellulosic Ethanol (Denmark), and *TMO Process Demonstration Unit* (PDU) for Cellulosic Ethanol (UK).

The simplified cellulosic bioethanol flow diagram for production is presented below:



Source: US Department of Energy

In the following page it is presented a summary chart of cellulosic ethanol from biomass.



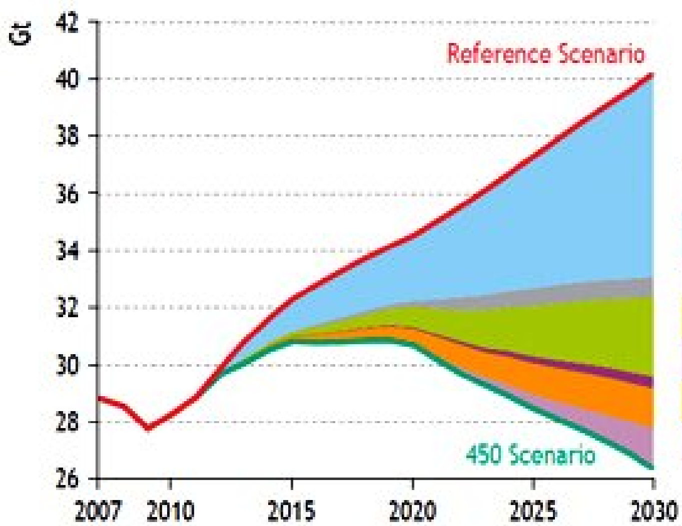
Source: US Department of Energy

5 - The role of biofuels on CO2 abatement - The IEA position

A recent report from the International Energy Agency suggests a strategy for stabilizing carbon atmospheric concentrations.. For the IEA, keeping carbon concentrations at 450 ppm is the key, since that's the level they believe will minimize the effects of global warming. Hence they call getting to that goal the "450 scenario." Achieving the 450 scenario, according to IEA, requires pursuing a variety of different carbon abatement measures. These measures include pursuing greater energy efficiencies, renewable energy, biofuels, nuclear power and carbon capture and storage (see figure below).

Based on the IEA's handy graph and table, we can see that they believe end-use energy efficiency to be the greatest slice of the carbon-abatement pie. And within that category fall lots of measures that we each can take to boost our personal energy efficiency – better insulation, building sealing, replacing incandescent light bulbs, driving a car with better mileage, etc.

World energy-related CO_2 emissions abatement



	Abatement ($Mt\ CO_2$) 2020	Abatement ($Mt\ CO_2$) 2030	Investment ($2008 billion) 2010-2020	Investment ($2008 billion) 2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	2 284	7 145	1 933	5 551
Power plants	233	735	66	35
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

6 - Conclusions

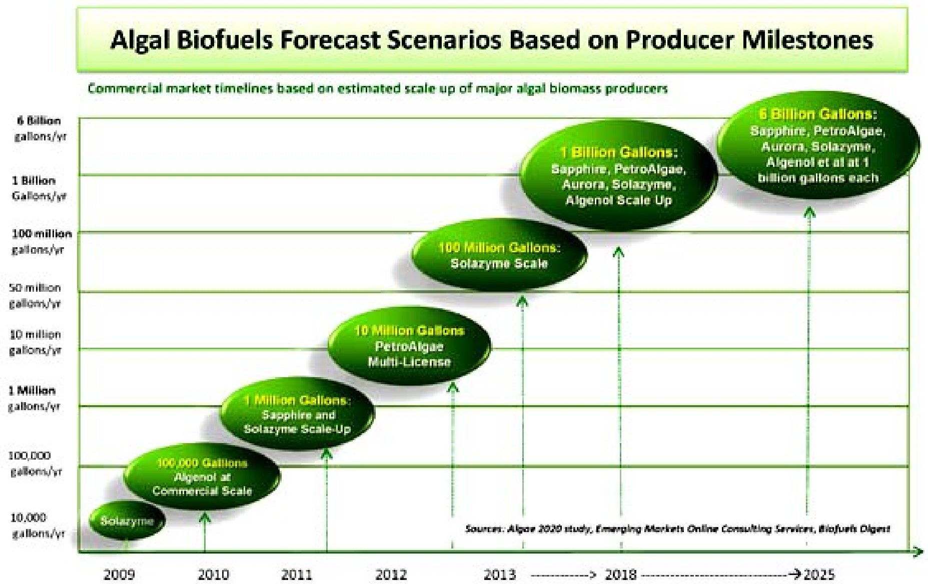
The worldwide effort on biofuels to replace fossil fuels will be impressive in the next decades, but will depend on advances of technology in processes to reduce production costs and avoid conflict to food crops and environmental impacts.

The second and third generation of biofuels are to gradually replace the first generation as their commercial success become effective. The transition to this new era of biofuels may take 15 to 20 years till achieving a sustainable business alternative worldwide.

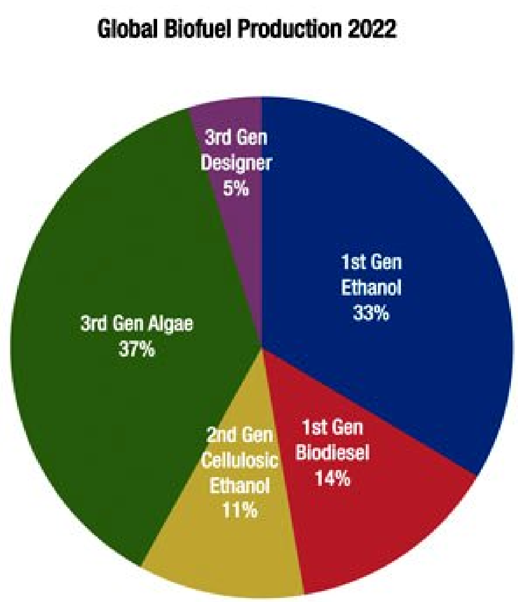
Collaboration to the world effort of CO2 abatement by biofuels will be small till 2030 as there are many other sources in which abatement could be more effective as compared to the investment to be made.

The first generation of biofuels based on feedstocks from crops tend to be restricted in the future to those few countries still having large agricultural areas for energy crops, despite claims from environmental and sustainability entities. Most countries have to compulsorily adopt new advanced biofuels to derive a national policy for replacing fossil fuels.

Special attention is assigned to the algal biofuels forecast which can determine the future of biofuels economy dictating or not living space for other biofuel sources and processes. The graphic below figures out the expectation for the evolution of algal biofuels (reference: Emerging Markets Online Consulting Services - Algae2020 study).



The global biofuel production by 2022 is expected to be share among first, second and third generation of biofuels as below. There one can see that by 2022 only about 48% of global biofuel production would be in the first generation level.



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