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Cellulosic Ethanol

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About Cellulosic Ethanol

What is it?

Cellulosic ethanol (sometimes referred to as *cellanol*) **is ethanol fuel produced from cellulose, a naturally occurring complex carbohydrate polymer commonly found in plant cell walls.**

Cellulosic ethanol is chemically identical to ethanol from other sources, such as corn, sugar or starch, and is available in a great diversity of biomass including waste from urban, agricultural, and forestry sources. However, it differs in that it requires an extra processing step called cellulolysis – breaking cellulose down into sugars.

Cellulosic ethanol production currently exists at "pilot" and "commercial demonstration" scale. The figure below shows how biomass is processed to transform it into cellulose ethanol.

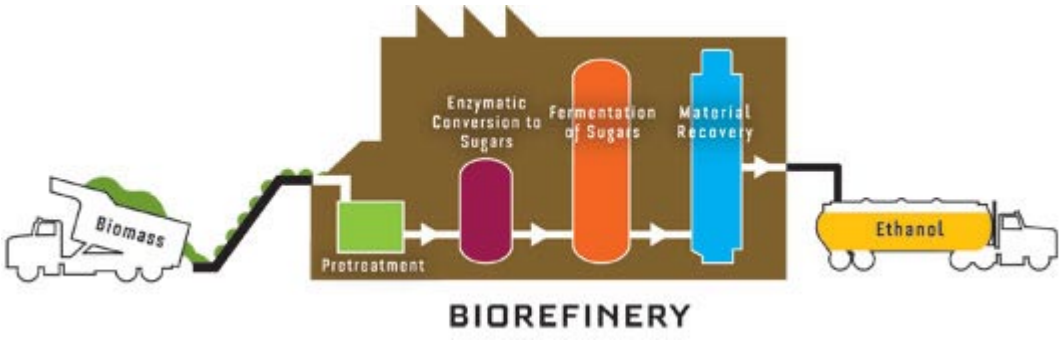

Figure 1 (Source: Verenium) – Technology which converts biomass into cellulose ethanol using a combination of thermal, chemical and biochemical techniques. Additionally the lignin in the plant fibre could be used to drive the process by generating steam and electricity, thus eliminating the need for fossil CO_2 sources such as coal or natural gas. [1]

Advantages of cellulosic ethanol

Renewable transportation fuel

About 40% of total energy consumption is dedicated to transportation and currently requires energy-dense liquid fuels such as gasoline, diesel fuel, or kerosene. Almost half of all gasoline sold today in the United States contains ethanol. Most of that gasoline is what is known as “E10” – a mixture that is 90 percent or more unleaded gasoline and 10 percent or less ethanol. The ethanol in E10 raises both the oxygen and the octane content of gasoline, allowing it to burn more efficiently and produce fewer toxic emissions.

Enough land space for the industry to grow

A joint study by the U.S. Departments of Agriculture and Energy has concluded that the land resources of the United States could produce a sustainable supply of biomass sufficient to displace 30% (60 billion gallons or 227 billion litres of renewable fuel per year) of the United States' present gasoline consumption. While these figures are somehow “theoretical”, they indicate that there is enough land space available for industrialisation and commercialisation of cellulose ethanol.

Substantial supply of raw material

The raw material for cellulose ethanol production is plentiful as cellulose is present in every plant. Most of these biomass products are currently discarded, but transforming them into ethanol might provide as much as 30% of the current fuel consumption in the US – and probably similar figures in other oil-importing regions like China or Europe.

Little or no impact on food prices

Since cellulose cannot be digested by humans, the production of cellulose does not compete with the production of food. The price per ton of the raw material is thus much cheaper than grains or fruits. Moreover, since cellulose is the main components of plants, the whole plant can be harvested. This results in much better yields per acre – up to 10 tons, instead of 4 or 5 tons for the best crops of grain.

Reduction of greenhouse gas emissions

According to U.S. Department of Energy studies conducted by the Argonne Laboratories of the University of Chicago, one of the benefits of cellulosic ethanol is that it reduces greenhouse gas emissions (GHG) by 85% over reformulated gasoline. By contrast, starch ethanol, which most frequently uses natural gas to provide energy for the process, reduces GHG emissions by 18% to 29% over gasoline.

The debut of cellulosic ethanol

Iogen – Commercial mass production

In April 2004, Iogen Corporation – a Canadian biotechnology firm – became the first business to commercially sell cellulosic ethanol, though in very small quantities. The primary consumer thus far has been the Canadian government, which, along with the United States government, particularly the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), has invested millions of dollars into assisting the commercialization of cellulosic ethanol. [3]

Iogen aims to begin building a commercial plant in September 2007. If Iogen reaches this goal it will begin producing ethanol 18 to 20 months later, in the spring of 2009. [5]

Expanded use of cellulosic ethanol in the United States

President Bush, in his State of the Union address delivered January 31, 2006, proposed to expand the use of cellulosic ethanol and a mandate for 35 billion gallons of ethanol by 2017. It is widely recognized that the maximum production of ethanol from corn starch is 15 billion gallons per year, implying a mandated production of some 20 billion gallons per year of cellulosic ethanol by 2017. Bush's plan includes $2 billion funding for cellulosic ethanol plants, with an additional $1.6 billion announced by the USDA on January 27, 2007. [3]

Potential supply issues

As the industry is set to grow, we can expect some sort of issues around supply. For instance, only ethanol producers able to source biomass at a foreseeable cost will be a commercial success. Moreover, wood biomass is not sold on any organized market – possibly leading to a less efficient market for sellers.

Production methods

There are at least two methods of production of cellulosic ethanol (sometimes referred to as *Biomass-to-Liquid* conversion, abbreviated BtL). Neither production method generates toxic emissions.

Cellulolytic method (Biological approach)

There are five stages to produce ethanol using the cellulolytic method:

1. A pretreatment phase, to make the ligno-cellulosic material such as wood or straw amenable to hydrolysis;
2. Cellulose hydrolysis (cellulolysis), to break down the molecules into sugars;
3. Separation of the sugar solution from the residual materials, notably lignin;
4. Microbial fermentation of the sugar solution; and
5. Distillation to produce 99.5% pure alcohol.

Gasification (Thermochemical approach)

The gasification process does not rely on chemical decomposition of the cellulose chain (cellulolysis). Instead of breaking the cellulose into sugar molecules, the carbon in the raw material is converted into synthesis gas, using what amounts to partial combustion. The carbon monoxide, carbon dioxide and hydrogen may then be fed into a special kind of fermenter. Instead of sugar fermentation with yeast, this process uses a micro-organism named "*Clostridium ljungdahlii*". This microorganism will ingest carbon monoxide, carbon dioxide and hydrogen and produce ethanol and water.

The process can thus be broken into three steps:

1. Gasification, to break apart complex carbon based molecules to access the carbon as carbon monoxide, carbon dioxide and hydrogen are produced;
2. Fermentation, to convert the carbon monoxide, carbon dioxide and hydrogen into ethanol using the "*Clostridium ljungdahlii*" organism; and
3. Distillation, to separate ethanol from water.

Recent developments

Iogen and Goldman Sachs

According to a press release by Iogen in May 2006 – "*Goldman is the first major Wall Street firm to make a commitment to cellulose ethanol"*, says Iogen CEO Brian Foody. "*Renewable fuels like cellulose ethanol are one of the main options President Bush recently highlighted to reduce America's dependence on foreign oil.*" Goldman's investment gives it a minority stake in Iogen, the only company to be operating a demonstration facility that converts agriculture materials like straw, corn stalks, and switchgrass to ethanol. Goldman Sachs joins the Royal Dutch/Shell Group as a major investor. [3]

SunOpta and China Resources Alcohol

Cellulosic ethanol production currently exists at "pilot" and "commercial demonstration" scale, including a plant in China engineered by SunOpta Inc. and owned and operated by China Resources Alcohol Corporation that is currently producing cellulosic ethanol from corn stover (stalks and leaves) on a continuous, 24-hour per day basis.

SunOpta and GreenField Ethanol

In December 2006, SunOpta announced a joint venture with GreenField Ethanol, Canada's largest ethanol producer. The JV will build a series of large-scale plants that will make ethanol from wood chips – SunOpta and GreenField taking 50% ownership each. The first of these plants will be 10 million gallons per year, which appears to be the first true "commercial scale" cellulosic ethanol plant in the world.

Abengoa Bioenergy

Another company which appears to be nearing commercialization of cellulosic ethanol is Spain's Abengoa Bioenergy. Abengoa continues to invest heavily in the necessary technology for bringing cellulosic ethanol to market.

Choren Industries and Royal Dutch Shell

Carbo-V is a patented biomass gasification method process of Choren Industries that is used to produce Biodiesel. Shell Deutschland GmbH in 2005 purchased an equity interest in Choren. The combination of Shell's SMDS (Shell Middle Distillate Synthesis) *Fischer-Tropsch* synthesis process with the Carbo-V gasification process may be a winning combination in BtL processes.

Range Fuels (formerly Kergy)

In July 2007 Range Fuels announced that it has received a permit to build an ethanol production plant that uses wood chips as its feedstock. By 2008 the company intends to have a facility capable of creating 20 million gallons of ethanol per year.

BioEthanol Japan

BioEthanol Japan became the world's first company to produce cellulosic ethanol from wood construction waste on a commercial basis in January 2007. The plant in Osaka Prefecture has an annual capacity of 1.4 million liters (about 370,000 gallons). In 2008, it plans to boost production to 4 million liters (1 million gallons). BioEthanol Japan was established in 2004 by five companies, including construction firm Taisei Corp., major trading house Marubeni Corp., Daiei Inter Nature System, and beer-maker Sapporo Breweries Ltd. [6]

Boeing and Virgin Atlantic

Boeing and Virgin Atlantic announced in April 2007 a new environmental partnership. The environmental work between the two companies will focus on developing biofuels that can be used as commercial jet fuel. The first demonstration is scheduled for next year using one of Virgin's Boeing 747-400s and also includes engine supplier General Electric. [9]

Brazil's Dedini

Brazil's Dedini, a leading manufacturer of sugar and biofuel equipment, has announced in June 2007 that it has demonstrated a cellulosic ethanol process on an industrial scale, a development that could revolutionize the industry by boosting the competitiveness and energy balance of biofuels. Dedini's São Luiz Mill in São Paulo state began producing cellulose ethanol at about US$ 40 cents a liter in 2002. Production costs have now fallen, due to improvements in processing technologies, to below €20/US$ 27 cents a liter (US$ 1.02 per gallon). [11]

List of potential global players

Cellulosic ethanol producers and developers

- Australia, Farmacule, www.farmacule.com
- Brazil, Dedini, www.dedini.com.br/en/index.html
- Canada, Iogen Corp, www.iogen.ca
- China, China Resources Alcohol Corporation, *no website*
- Germany, Choren Industries, www.choren.com/en/
- Japan, BioEthanol Japan, www.bio-ethanol.co.jp *(Japanese only)*
- Spain, Abengoa Bioenergy, www.abengoabioenergy.com
- United States, Dyadic International, www.dyadic-group.com
- United States, Mascoma, www.mascoma.com
- United States, NovaFuels, www.novafuels.com
- United States, RangeFuels, www.rangefuels.com
- United States, Verenium Corporation (subsidiary Celunol), www.verenium.com
- United States, Xethanol, www.xethanol.com

Apart from pure ethanol players, there seems to be a tendency of major oil corporations to diversify away from fossil fuels like oil and natural gas and to build up stakes in renewable energy companies – mostly in the biodiesel and cellulosic ethanol business, but also solar and wind energy (e.g. BP Solar, Shell Solar).

Diversifying oil companies (mostly European ones)

- Finland, Neste Oil, www.nesteoil.com
- Netherlands, Royal Dutch Shell, www.shell.com
- United Kingdom, British Petroleum (BP), www.bp.com

Interested in cellulosic ethanol and Biomass-to-Liquid conversion processes are also vertically integrated food conglomerates.

Vertically integrated food companies

- Canada, SunOpta, www.sunopta.com
- Denmark, Danisco, www.danisco.com

Other active players in the cellulosic ethanol sector include biotech companies as well as chemical companies doing in R&D in the domain of gasification, fermentation and so forth.

Chemical and biotechnology companies

- Denmark, Genencor (owned by Danisco), www.genencor.com
- Denmark, Novozymes (owned by Danisco), www.novonymes.com
- United States, Dow Chemical, www.dow.com
- United States, DuPont de Nemours, www.dupont.com – *joint venture with BP and ABF*
- United States, Monsanto, www.monsanto.com

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