biofuelwatch

Executive Summary

Dead End Road

The false promises of cellulosic biofuels

  

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Although the world's first commercial wood to ethanol plant opened in South Carolina one hundred and eight years ago, more than 99% of biofuels worldwide are still made from plant oils, animal fats and sugars in starch (mainly from cereals, including corn), and not from wood. Despite massive subsidies and other state support measures, the most abundant sources of sugar and energy in plants, found in the cell walls of plants, remain beyond the reach of fuel refiners.

This report looks at the history, the technologies and the experience of refineries where cellulosic ethanol production has been attempted. The technical challenges remain, suggesting that there is little likelihood that large new markets for wood and energy crops for biofuels will emerge any time soon. The illusion that cellulosic biofuel production has dramatically increased recently reflects a redefinition of "cellulosic" to include transport fuels made from landfill gas, biogas and corn kernel fibre. Even though large-scale production of cellulosic biofuels appears destined to fail, the development of risky genetically engineered (GE) trees, crops and microbes associated with this quest introduces imminent and serious risks.

Political context

First generation biofuels (those made from corn and other cereals, sugar and plant oils) have proven highly problematic. To date, they replace less than 3% of transportation fossil fuel use, but have already caused the displacement of peoples and communities, resulted in competition with food production which has exacerbated hunger, and biodiverse ecosystems have been lost. Furthermore, when full lifecycle accounting is undertaken, first generation biofuels are often worse for the climate than the oil-based fossil fuels they replace.

Cellulosic biofuels (liquid transportation fuels produced from wood, grasses or agricultural residues), have been touted as a solution to the problems of first generation biofuels, since they would be produced using "nonfood" feedstocks. Yet crops or trees grown for cellulosic biofuels would also require a very large land area, and hence compete with food production, and the energy and climate impacts remain questionable.

Subsidies and supports in the US and Europe

Policy supports and subsidies for the production of cellulosic biofuels abound. In the USA, the Renewable Fuel Standard and California Low Carbon Fuel Standard, and grants and loan guarantees from the US Department of Energy, Agriculture and Defense, all support cellulosic fuels. In Europe, incentives within the Renewable Energy Directive support cellulosic and other biofuels, along with supports under Research and Development programmes. Support has also come from individual states, yet none of this has led to any significant commercial breakthrough.

Cellulosic biofuel failures: is history repeating itself?

The first commercial-scale cellulosic ethanol refineries were built by Standard Alcohol and Classen Chemical Co. in the early 20th century, with one account claiming that production of up to 2.5 million gallons per year was achieved and another citing a far lower production rate. Differing claims made at the time about the production figures, or circumstances and timing of the closure of the facilities, makes it impossible to assess how much was produced and what yields were achieved. All that is certain is that the refineries shut down within a few years. The early history of cellulosic ethanol seems to have been marked by hyperbolic claims, obfuscations, unmet expectations and investment losses. Which, as this report shows, was a foretaste of what was to come many decades later.

Cellulosic ethanol made by fermenting sugars

Ethanol is conventionally made by fermenting sugars found inside plant cells (sugar cane and sugar beet for example) or converting starches such as maize or wheat into sugars, and then fermenting them. But most of the sugars found in plant biomass are locked up in cell walls as complex carbohydrates: cellulose and hemicelluloses. It has long been possible to access some of the sugars in cellulose and ferment them into cellulosic ethanol. But doing so consistently and efficiently has been problematic. Accessing enough of the “cellulosic” sugars in order to ferment them is difficult because of the complex chemical structure of plant cell walls. Furthermore, cell walls contain different types of sugars and no species of microorganism has been found in nature that can ferment all of them into ethanol.

Cellulosic ethanol production usually involves three stages: first, biomass is pretreated in some manner to break it down (often using heat). The carbohydrates are then broken down into the constituent sugars (called hydrolysis). Today, this usually involves adding enzymes produced by GE microorganisms to access sugars. The final stage is fermentation, now commonly by GE yeast and bacteria.

As is the case with all cellulosic biofuel technologies, few details are published as to why refineries have shut down or failed to achieve full production. Such information is commonly withheld as commercial secrets. However, based on a limited number of statements by companies, together with information from scientific studies, key challenges can be discerned.

It appears that problems with the first stage, i.e. pre-treatment, have been responsible for most of the recent failures and difficulties associated with cellulosic ethanol refineries. But this does not mean that the challenges associated with the other stages have been overcome.

Is anybody producing any cellulosic ethanol at present?

Raízen in Brazil, which produces cellulosic ethanol from sugarcane bagasse, announced the production of 1.58 million gallons in 2016. Operating far below capacity, it appears to be the most successful refinery of its type to date. GranBio, also in Brazil, claims to have achieved some recent production, but it has not announced any details other than that the plant is not running at full capacity. Both plants use sugar cane bagasse as the feedstock, which is far easier to refine than wood.

A closer look at the six recently opened commercial-scale cellulosic ethanol plants which ferment sugars from biomass

Six facilities claim to have been “operational” since 2010. In spite of much hype at the time of commissioning, not a single one has been operating continuously at capacity with economically viable yields. These six plants are:

1) Beta Renewables in Italy: Closed 15 months after opening, with the company admitting technical difficulties and filing for bankruptcy in 2017;

2) GranBio in Brazil: Was to use the same technology as Beta Renewables, but 21 months after opening remained plagued with difficulties, had to replace the pretreatment facility altogether and hadn't released any production figures;

3) Project Liberty in Iowa, USA (a joint venture between DSM and POET): Opened in September 2014, admitted ongoing technical problems in November 2017, and has not pulished production figures since;

4) Abengoa refinery in Kansas, USA: Successful production was never achieved, and the plant was sold to a company with no cellulosic ethanol ambitions, due to Abengoa’s wider financial difficulties;

5) DuPont refinery in Iowa, USA: Opened in October 2015, but shut down in November 2017 without having produced any cellulosic ethanol;

6) Raizen Energia refinery in Brazil: As stated above, the only cellulosic ethanol refinery which has achieved regular production. However, early 20th century cellulosic ethanol plants may have achieved higher volumes from wood, a more challenging feedstock.

Cellulosic biofuels made by gasification

A second approach to making cellulosic biofuels involves gasification: exposing biomass to high temperatures and controlled oxygen delivery. This results in a gas (syngas) which must then be cleaned and further processed using either chemical catalysts (Fischer-Tropsch synthesis) or syngas fermentation. Most biomass gasification facilities worldwide have failed. Furthermore, cleaning of the syngas is especially challenging as it must be free of impurities for successful processing to fuel. Two refineries using gasification and syngas processing have been opened this decade: Indian River Bioenergy Center in Florida, USA, which has since closed, and Enerkem, in Alberta, Canada, which has produced limited quantities of methanol from waste, and no ethanol, despite being open for 6 years.

Cellulosic fuels made via pyrolysis and cracking

The third approach involves pyrolysis and “cracking”. Pyrolysis refers to exposing biomass for a short time to high temperatures in the absence of oxygen, resulting in formation of “bio-oil”. Bio-oil can – in theory – be processed into transport fuels through ”cracking”, as is achieved in oil refineries using heat and chemical catalysts. However, the energy balances associated with this approach are particularly bad and there are no credible proposals for improving them. One company, KiOR, opened a refinery based on this technology in 2006, and subsequently filed for bankruptcy and remains embroiled in legal action for fraud. In Canada, Ensyn has been producing bio-oil through pyrolysis since 2006 but, despite publicly speaking about upgrading it to transport fuels, has never done so (apart from minor experiments involving collaboration with oil refiners), nor has it invested in the technology that would be needed.

Legislating “cellulosic ethanol” into existence: corn kernel fibre ethanol and fuels from landfill gas

The Renewable Fuel Standard was enacted in the USA in 2007 and requires the addition of 16 million gallons of cellulosic fuels by 2022. Given that such fuels remain essentially nonexistent, the Environmental Protection Agency (EPA), responsible for implementation, responded by redefining the term “cellulosic biofuels” to include fuels made from biogas, landfill gas and corn kernel fiber. This allowed the EPA to claim that “cellulosic biofuel” production had risen from near zero to over 250 million gallons in 2017.

Ironically, while cellulosic fuels were touted as an alternative to using corn, thus avoiding competition with food production, the redefinition of corn kernel fibre ethanol as a cellulosic fuel means that most of the fuel defined as “cellulosic” is in fact now made from corn. Compared to other cellulosic ethanol production approaches, corn kernel fibre processing is relatively straightforward, but undermines the intent of the cellulosic mandate. Furthermore, an unknown proportion of the so-called “cellulosic” fuel from corn kernel fibre is likely to be nothing other than ordinary corn starch ethanol.

Cellulosic biofuels as a false pretext for developing GE trees

The desire to develop cellulosic biofuels is widely promoted as one of the key drivers behind the development of GE trees, including eucalyptus and poplar, among others. In particular, reducing lignin content would in theory enable better access to the sugars in cellulose. Producing healthy low-lignin GE trees remains elusive. In order to access public funding, biotech companies trying to develop such trees routinely cite cellulosic biofuels as their purpose, but there is strong evidence that cheaper pulp and paper production has been the primary motivation. GE trees involve serious but only partially known risks, because forest trees are long-lived, disperse through different methods and across large distances, and because their functions and interactions within ecosystems are not fully understood.

Manipulating microbes for cellulosic biofuels

Most cellulosic biofuel research and development involves genetically engineering microbes, mainly for enzyme production and fermentation. Yeasts, fungi and bacteria are subjected to very drastic manipulations to force them to adopt entirely different metabolic pathways and to synthesize and/or degrade molecules they would not normally be capable of. Risks from any deliberate or accidental release of GE microbes are especially worrisome given that bacteria and yeast reproduce, proliferate and evolve very rapidly, and can exchange genes with other species. Once released, they would be impossible to track, much less recall. Microbes are the basis for all life on earth and play a fundamental role in virtually all life processes. As this report shows, accidental releases of GE microbes from biofuel refineries are all but guaranteed.

Conclusions

Despite huge public subsidies, there is little evidence that commercial cellulosic biofuel production today is any more successful than the first, short-lived wood-to-ethanol refineries built more than a century ago. There is little public awareness of this, and little to no regulatory oversight or review. The taxpayer funds that continue to flow into research and development could be put to far better use, for example to improve public transportation systems. Furthermore, while it appears highly unlikely that cellulosic biofuels will ever become commercially viable, they are spurring the development of GE microbes, trees and crops, which introduces serious biosafety risks. Finally, the ongoing hype that cellulosic biofuels will “soon be available” and will alleviate competition with food production has only served to perpetuate the policies and supports that underpin problematic first generation biofuels.