Plants designed for deconstruction? The use of wood cellulose for fuels

Globally, many people rely on wood as fuel for cooking and heating, but increasingly, commercial and industrial interests are also turning to wood for producing so-called ‘bioenergy’. Massive coal plants in the EU and the USA are co-firing large amounts of wood alongside coal. Some coal power plants are even converting entirely to wood pellets, for which, in several countries, they can be rewarded with 'renewable energy' subsidies. Those energy facilities require vast amounts of wood, creating a new international trade in wood chips and pellets, and further threatening forests, ecosystems, human rights and climate (1).

Meanwhile, it is more challenging to convert wood into liquid fuel for transportation. Most liquid fuels currently used for transport –and, to a lesser extent, for electricity generation – are made from corn, sugarcane and oilseed crops, but industry and proponents of a ‘bio-based economy’ heavily rely on wood-based and other so-called second-generation liquid fuels in their scenarios for future use of liquid fuels. Large amounts of money have been deployed on research and development over many years, and yet, there remains no significant commercial production of wood based liquid fuels.

Indeed, to convert wood into liquid fuel requires energy. Depending on the process, the energy inputs may outweigh the energy derived from using the fuel. Making liquid fuels from wood also expensive. Several projects, including Choren in Germany and Range Fuels in the US state of Georgia, which were to produce wood based liquid fuel, have ended in bankruptcy. Yet, great interest (and public grants) remains, not least on the part of the USA military and the aviation industry, both of which see liquid fuels from biomass as essential to their future since there are no other options for fueling military equipment and airplanes.

There are two approaches to turning solid biomass, like wood, into liquid fuel: One relies on heat and pressure – and, unfortunately for the industry, on far too much heat and pressure to make the process worthwhile economically as well as energetically.

The other relies on biotechnology – i.e. on engineering microbes and enzymes to break down cell walls. Thus, by engineering the wood from the trees, their cell walls can be broken down more easily. That means that the cellulose from the wood can be used more easily to obtain ethanol. The challenges are many, but one of the biggest stumbling blocks is lignin. Lignin is the material that lends strong structure to the cell walls in wood, allowing trees to grow upright and reach for the sky. But, in trying to turn wood into ethanol and other liquid fuels, lignin gets in the way, making it difficult to access the sugars in the cellulose, and creating large amounts of a low-quality by-products (i.e. residues).

Altering and engineering trees to have less, or modified, lignin is therefore one of the primary aims of tree biotechnology research. Another complementary approach is to use new synthetic biology techniques to engineer microbes that can produce enzymes that break down lignin (and then, perhaps also convert sugars to fuels and other chemicals).

To grasp what research is underway and the mindset behind it, it is worthwhile taking a glimpse into academic publications. In one recent paper entitled “Lignin Bioengineering”, the authors state: “Lignin is the primary material responsible for biomass recalcitrance [resistance to breakdown], has almost no industrial utility, and cannot be simply removed from growing plants without causing serious developmental defects. Fortunately, recent studies report that lignin composition and distribution can be manipulated to a certain extent by using tissue-specific promoters to reduce its recalcitrance [resistance to breakdown], change its biophysical properties and increase its commercial value. Moreover, the emergence of novel synthetic biology tools to achieve biological control […] opens new doors for engineering.” (2)

Synthetic biology techniques are sometimes referred to as “extreme genetic engineering”. They make use of new computer assisted capabilities that allow researchers to analyze and synthesize genetic codes on a computer, working not just with one or two genes, but with sequences of hundreds of genes. These approaches essentially permit the construction of novel life forms (microbes, including yeast, e-coli bacteria and microalgae) programmed as ‘living chemical factories’ to produce chemicals and compounds considered ‘useful’ to people. The risks are high and many, especially because containment and control of microbes is virtually impossible. Yet, synthetic biology is proceeding rapidly. Many of the industry’s ‘top’ rated 'biofuel' companies, like the giant agribusiness Syngenta and the German chemical company BASF, use synthetic biology (3). Meanwhile, a number of (non-biofuel) products, that is, products derived from synthetic biology that are not fuels including fragrances, pharmaceuticals and more, are already on commercial markets, without oversight or regulation (4).

Another recent academic paper states: “Redesigning lignin, […] is a promising way to produce plants that are designed for deconstruction.” (5)

Engineering deforestation

An international campaign to halt the commercial release of genetically engineered trees, requests for which are currently pending in Brazil and the USA, is growing in momentum and we can hope that this movement will be as ‘recalcitrant’ as lignin itself (6).

The campaign points out the potential risks of contaminating wild tree species with traits for ‘deconstruction’ as well as the virtually inevitable escape of lignin munching microbes from laboratories and refineries. Campaigners are calling for a ban on commercial release of GE trees. There is also growing momentum calling for a moratorium on commercial release of synthetic biology derived products.

The destructive impacts of industrial tree plantations on communities where they exist are well known. Genetically engineered trees are intended to be grown in plantations and will only contribute further to those problems. The impacts of synthetic biology remain unclear but there is growing awareness that some products under development are poised to undermine livelihoods (for example, vanilla growers may lose their market to synthetic producers). Further, the impacts of any release of synthetic microbes that digest plant cellulose into the environment have the potential to be disastrous. Finally, the very large scale of wood that is required to make liquid fuels on commercial scale has the potential to dramatically escalate deforestation and conversion (to plantations) of native forests and ecosystems.

The entire concept of manipulating and engineering trees, microbes and other life forms to meet an insatiable demand for fuels, chemicals and materials, is ethically and morally bankrupt. The arrogant and reductionist mentality that approaches nature as something to engineer for commercial purposes entirely ignores any understanding of the profound, intricate and beautiful interconnectedness of all life forms, achieved as a product of our shared evolutionary heritage.

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(1) For more info see: http://www.biofuelwatch.org.uk/2013/chain-of-destruction/ and

http://www.pfpi.net/trees-trash-and-toxics-how-biomass-energy-has-become-the-new-coal

(2) Aymerick, Eudes, Liang, Y., Mitra, P. and Loque, D. 2014. Lignin Bioengineering. *Current Opinion in Biotechnology* 26: 189-198

(3) See: http://www.biofuelsdigest.com/bdigest/2014/05/04/the-complete-2014-5-minute-guides/

(4) For more info: http://www.etcgroup.org/issues/synthetic-biology

(5) Wilkerson et al, 2014. *Monolignol Ferulate Transferase Introduces Chemically Labile Linkages Into the Lignin Backbone*. Science 344 (90)

(6) More information here: http://stopgetrees.org