

## **Second Generation Biofuels: An Unproven Future Technology with Unknown Risks**

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### **What are second generation biofuels?**

In this paper, we refer to second generation biofuels as meaning biomass-to-liquid technologies, namely cellulosic ethanol and Fischer-Tropsch gasification, which are intended to use lignocellulosic biomass. Those technologies are not yet commercially available. Some companies refer to certain agrofuel technologies which use existing feedstocks like palm oil or rapeseed oil as 'second generation' (for example Neste Oil's NExBTL diesel, which uses high-pressure hydrogenation of fatty acids).

### **Can second generation biofuels play a role in mitigating climate change?**

Any technology which can help to mitigate climate change must

- a) Have the potential to become commercially available on a large scale within the next 5-8 years: Unless we begin to reduce global emissions and introduce technologies and policy measures which can help us shift to a low-carbon society within that period, a mass extinction event may become unavoidable. [see: "Global temperature change", James Hansen et al, PNAS, 26<sup>th</sup> September 2006] ; AND
- b) Be proven to have the potential for large-scale emissions reductions, once life-cycle emissions of all greenhouse gases have been considered, not just at the micro-level, but at the global level. If a technology, directly or indirectly, destroys ecosystems which play an essential role in the Earth's carbon cycle, then it risks accelerating, not mitigating global warming.

As we show below, there is evidence that second generation biofuels satisfy neither of these criteria.

### **When will second-generation biofuels become commercially available?**

#### Cellulosic ethanol:

The only commercial cellulosic ethanol refinery is run by Iogen Corporation in Ottawa. It uses more energy than it produces, and, in terms of energy use and output, performs considerably worse than first-generation corn ethanol. The different processes needed to refine cellulosic ethanol, including pre-treatment and distillation, are extremely energy-intensive.

The United States Department of Environment are funding research into cellulosic ethanol, and they have identified significant 'biological barriers' which need to be overcome if cellulosic ethanol is to become a viable option. [Fuel Ethanol Production, DEO, Genomics:GTL, <http://genomicsgtl.energy.gov/biofuels/ethanolproduction.shtml#improve>] Enzymes can break down cellulose, but they cannot do so efficiently and they can only produce a very dilute mixture which is then distilled into ethanol. Making cellulosic ethanol viable is not a matter of scaling up existing technology and gradually improving efficiency gains: Firstly, scientists will have to better understand plant physiology and the mechanisms which prevent cellulose from being broken down by fungi and microbes. This will require some major scientific breakthroughs. Secondly, scientists will have to either find or, more likely, genetically engineer microbes or fungi which can produce enzymes that can efficiently break down cellulose and hemicellulose. Work is also being done on genetically engineering plants with lower lignin levels, because lignin helps to prevent cellulose from being broken down. There are other problems to be overcome, such as converting the sugars in hemicellulose into ethanol, or making it possible to recover and use the lignin.

Nobody can predict when or if all those scientific breakthroughs will happen. Billions of dollars are being spent on a technology which clearly will not be available in the crucial time left to avoid the worst impacts of global warming. The current situation is highly reminiscent of Gentech (biotech) industry promises for the second generation of GM crops such as drought and salt resistant crops, which still remain elusive even after many years of research. These Gentech “futures” have been very important to maintaining interest in Gentechnology. It is likely that second generation biofuels will suffer from similar delays but will in the meantime, be used to promote the Gentech agenda.

#### Fischer-Tropsch gasification:

Fischer-Tropsch gasification is used mainly to make diesel from coal, for example in South Africa. It is a highly energy-intensive process which is not currently commercially viable, despite 30 years of research, although it is about twice efficient at making biofuels from solid biomass as cellulosic ethanol is at present. We are concerned whether any technological break-through would primarily lead to a greater use of coal – even if the research had been financed with a view to using biomass. The technology is the same and there is nothing to prevent companies from switching from biomass to coal, or co-firing a small amount of biomass with a large amount of coal. We fear that a large-scale take-up of Fischer-Tropsch gasification could raise fossil fuel emissions beyond the ‘business as usual’ scenario given by the IPCC. [see: “Making it up as you go along”, Heidi Ledford, NATURE, Vol 444, 7 December 2006]

#### **Second generation biofuels and genetic engineering:**

The genetic engineering industry is actively seeking ways of using genetic modification to simplify and streamline industrial processes to break down cellulose, hemicellulose and lignin, so as to produce biofuels more easily, cheaply and efficiently from plant biomass. The industry is looking at ways of modifying plants to:

- Produce less lignin
- Engineer the lignin and cellulose so that they break down more easily or in different ways
- Speed up the growth and yield of plants

At the same time they are experimenting with engineering microbes and enzymes to break down plant matter efficiently in an extreme industrial environment. They are also scanning recent discoveries of new microbes and enzymes that could perform these tasks more effectively than those they already know. For example Craig Venter has been collecting micro-organisms from sea water for investigation (including so-called extremophiles living in volcanic vents on the sea bed that could withstand extreme industrial conditions). Others are looking at the microbes in termite guts because these digest plant matter efficiently. Companies such as Genencor and Novozymes are working to reduce the costs of industrial enzyme production and Diversa Corporation is investigating enzymes to break down hemicellulose [see The Economist: Mar 8th 2007,

Could new techniques for producing ethanol make old-fashioned trees the biofuel of the future?  
[http://www.economist.com/science/tq/displayStory.cfm?story\\_id=8766061](http://www.economist.com/science/tq/displayStory.cfm?story_id=8766061) )

There is a great deal of interest in using tree biomass for second generation biofuels. As well as being an obvious source of supply if and when methods are developed of breaking down the plant matter cheaply and effectively, they are also lower maintenance and need fewer inputs than crops, so they promise a double advantage. Trees also contain more carbohydrates, the raw material for biofuels, than food crops. GM technology is being used to try to reduce the level of lignin in trees and change the structure of the hemicellulose. The general aim is to reduce the cost of ethanol production and increase the volume so that it can compete with fossil fuels on price without needing subsidy.

Willow, poplar and eucalyptus are major targets for research. For example, Purdue University, funded by the US Department of Energy is working on a poplar hybrid with the aim of producing a low-lignin, faster growing tree for mass production on “unused” and fallow land. [Fast-growing GM

trees could take root as future energy source, Friday, August 25 2006 @ 04:08 PM UTC  
[http://www.checkbiotech.org/root/index.cfm?fuseaction=news&doc\\_id=13382&start=1&control=177&page\\_start=1&page\\_nr=101&pg=1](http://www.checkbiotech.org/root/index.cfm?fuseaction=news&doc_id=13382&start=1&control=177&page_start=1&page_nr=101&pg=1)] Nothing is known about the potential impacts of releasing genetically engineered trees into ecosystems, but the risks to natural forest ecosystems could be very serious.

### **Synthetic biology for second generation biofuels**

'Synthetic biology' is the name given to a new area of work that combines GM technology with nanotechnology, computing and engineering. As ever more genomes of different organisms are mapped, providing the raw material, so researchers dream not only of redesigning existing organisms, but of building completely new organisms that are more precisely designed to do what is required, for example to break down plant matter, or thrive in conditions of mass industrial processing. For example, Craig Venter's new company, Synthetic Genomics, aims to study the genetic information from microbes collected from seawater (see above) to construct completely a new micro-organism designed to convert agricultural waste to ethanol. The US Government is putting massive resources into a program called Genomes to Life (GTL) which is supporting synthetic biology research to this end as part of the US aim to develop alternatives to its dependence on fossil fuels.

[see: An Introduction to Synthetic Biology, January 2007, ETC Group].

BP has offered 500 million US dollars to the University of Berkeley California for research into fuels. A major component of the work will be genetic engineering research into lignocellulosic fuels which will include the use of synthetic biology. BP has also joined the Bio-Industry Association. This demonstrates clearly one of the most disturbing aspects of the development of biofuels: it brings together powerful players from different sectors that have not previously collaborated so closely.

### **How will second generation biofuels impact on ecosystems, the carbon cycle and the global climate?**

Advocates of large-scale use of biomass for second generation biofuels (such as the US Department of Agriculture (USDA), the US Department of Energy (DOE), or the International Energy Authority) assume that large amounts of wood, grasses, and 'plant waste' can be sustainably used for biofuel production. If second-generation biofuels was to become viable, it would rely on large-scale refineries, which would need a constant supply of very large amounts of biomass. A 2005 DOE/USDA report , for example, speaks of using 1.3 billion tonnes of dry biomass every year, just from the US, and of removing most of the agricultural residues from soils, as well as planting 55 million hectares of land in the US under perennial crops for biofuels, using more manure than the Environmental Protection Agency currently allows, and putting all US cropland under no-till agriculture, which would require vast increases in the use of pesticides and fertilizers. [see: DOE/USDA report by Perlack et al. (2005), [http://feedstockreview.ornl.gov/pdf/billion\\_ton\\_vision.pdf](http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf)].

The removal of organic residues from fields will require greater use of nitrate fertilisers, thus increasing nitrous oxide emissions, nitrate overloading and it's devastating impacts on biodiversity, on land, in freshwater and in the oceans. It is also likely to accelerate topsoil losses.

The removal of dead and dying trees from managed forests is already leading to large-scale biodiversity losses, and also to lower carbon sequestration in forests. According to a recent study, less than 5% of the biomass in managed forests in Germany is made up from dead or dying trees, or fallen down branches, whereas in natural forests it would be around 40%. 20-25% of all woodland species depend on so-called 'forestry waste' being left in woodlands – including 1500 types of fungi and 1350 types of beetles in Germany alone, as well as many other species of insects, of lichens, and of birds and mammals [see: "Totholz - Bedeutung, Situation, Dynamik" Steffen Herrmann und Prof. Dr. Jürgen Bauhus Waldbau-Institut, Albert Ludwigs Universität Freiburg, March 2007,

[http://www.waldundklima.net/wald/totholz\\_bauhus\\_herrmann\\_01.php](http://www.waldundklima.net/wald/totholz_bauhus_herrmann_01.php)]. Removing even more 'wood residues' for biofuels would almost certainly accelerate biodiversity losses, and reduce carbon storage in forests.

Growing millions of hectares of land under perennial crops for bioenergy will put intense pressure on land both for food production and communities, and for natural ecosystems. Both in the United States and in the EU, set-asides (called Conservation Reserve Programme in the US), already risk being sacrificed for bioenergy expansion. Those programmes play a major role in reducing soil erosion and depletion and halting biodiversity declines. There have been suggestions that biodiverse prairie or meadow grasses could offer the most productive feedstock for second generation biofuels. [see: Tilman, D., Reich, P. B. & Knops, J. M. H. *Nature* 441, 629–632 (2006).], and Tilman, D., Reich, P. B., Knops, J., Wedin, D., Mielke, T. & Lehman, C. *Science* 294, 843–845 (2001)] . There is no doubt that such healthy biodiverse ecosystems contain more biomass than intensively farmed monocultures. However, the technical hurdles for using such multiple feedstocks are considerably greater than for using monoculture feedstocks – a mix of different enzymes will be required to break down the different plant materials effectively, which will be far more complicated than breaking down one particular feedstock. R&D investment is very clearly biased in favour of genetically modified monocultures, rather than native, biodiverse grass mixes, and it seems unlikely that companies would delay commercializing second generation biofuels in order to wait for more environmentally-friendly sources of feedstock. Furthermore, most projections for land-requirements assume that per hectare yields will go up when, global grain yields have been falling for the past two years and European oilseed rape yields have been falling for three years now. A recent study by the Carnegie Institute has found that global grain yields have already been reduced by global warming – a trend which can only become worse. Falling per-hectare yields will result in more pressure on land to produce the same amount of agrofuels.

Many plants which have been identified as preferred choices for second generation agrofuels already cause serious environmental harm as invasive species, such as miscanthus, switch grass, or reed canary grass. [see: 'Adding Biofuels to the Invasive Species, Fire, S. Rathu, et al., DOI: 10.1126/science.1129313, *Science* 313, 1742 (2006)] .

### **Conclusion:**

Cellulosic ethanol is not close to becoming commercially available, and faces technical barriers which may not be overcome in the foreseeable future. Much of the cellulosic ethanol R&D investment is going into genetic engineering, without any risk assessment having been done. Fischer-Tropsch biodiesel faces different serious technological hurdles, and R&D in that technology might inadvertently aid greater consumption of coal. There has been no assessment of the consequences of using large amounts of biomass from so-called 'plant waste', from tree plantations, or from perennial crop plantations on food production, on ecosystems, global greenhouse gas emissions, soil fertility or water supplies. This means that there is no evidence that large-scale second-generation biofuels would be either sustainable or climate-friendly.