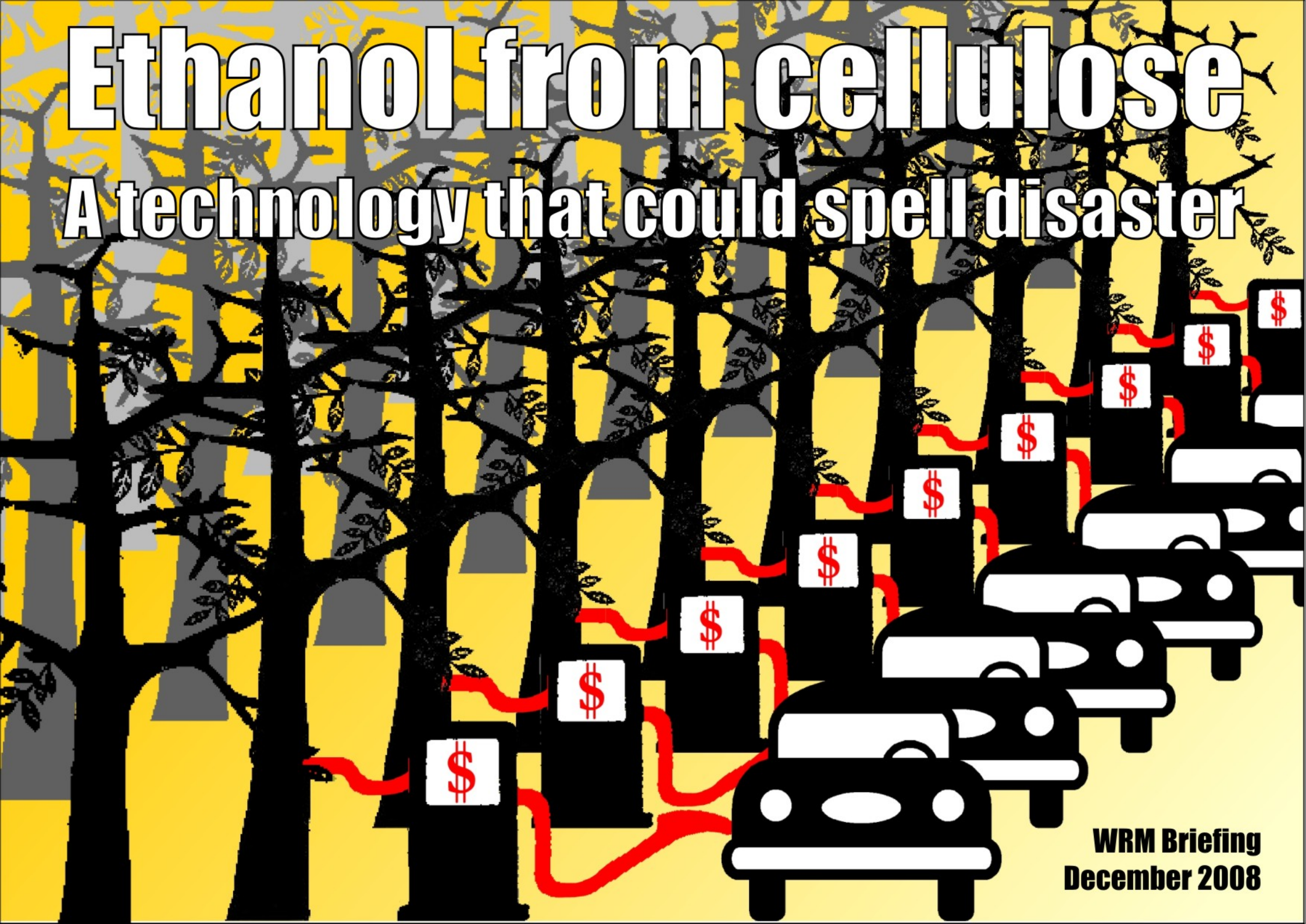
Ethanol from cellulose

A technology that could spell disaster



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Switching from fossil to alternative liquid fuels would appear to be a good idea, particularly in the context of climate change. Such is the case of converting the cellulose contained in plants into different types of fuels, among which liquid ethanol, that could be used in transport as an alternative to gasoline. However, current developments in this field show a number of threats that need to be highlighted.

What is cellulosic ethanol?

Cellulosic ethanol is a type of fuel produced from the cellulose contained in the biomass of plants – grasses, bushes, trees. Most of the mass of plants is composed of lignocellulose, which includes cellulose, hemicellulose and lignin. Converting cellulose to ethanol involves two fundamental steps: 1) breaking the long chains of cellulose molecules into glucose and other sugars, and 2) fermenting those sugars into ethanol. In nature, these processes are performed by different organisms: fungi and bacteria that use enzymes (cellulases) to "free" the sugar in cellulose, and other microbes, primarily yeasts, that ferment sugars into alcohol[1].

How is it produced?

There are many technical ways of converting biomass into ethanol, but most fall under two sets of approaches:

One approach involves the use of microorganisms as, for instance, a type of bacteria called *Moorella thermoacetica*, which can be found in a number of places in nature, including termite guts and the ruminant of cows. The bacteria convert sugars into acetic acid which is then converted into ethyl acetate. The final step – making ethanol – requires adding energy to the system in the form of hydrogen, which can be obtained using lignin, that can be converted into a hydrogen-rich mixture of gases by gasification. The hydrogen is combined with ethyl acetate to make ethanol.[2]

Another approach is to combine pulp for paper production with ethanol production within pulp mills in what has been termed as "biorefineries". While the major component of hardwood trees is cellulose, the second largest component is the polysaccharide xylan, which is the main component of hemicellulose. This component can be captured and fermented to produce ethanol. The process involves heat and pressurized water flows over a bed of wood chips to separate the cellulose. Then the water is forced through a membrane that removes the sugars and acetic acid, which are then fermented to produce ethanol.[3]

The actors involved

There are currently a number of actors actively involved in the development of cellulosic ethanol. The following are only a few examples for illustrating the range of those who stand to benefit.

The pulp and paper industry

According to Masood Akhtar, a council member of TAPPI, a technical association for the pulp and paper industry, biorefineries have "the potential for doubling profits to the industry by producing value-added

1 http://www.technologyreview.com/read_article.aspx?id=17052&ch=biztech&a=f

2 http://www.technologyreview.com/Energy/20151/

3 http://www.csmonitor.com/2005/0505/p17s01-sten.html

products from biomass on site, while the industry can continue making their conventional paper products."[4]

No wonder then that International Paper, the world's largest paper company has become involved in this business opportunity and is working together with the State University of New York and other actors for producing ethanol from wood.[5]

Stora Enso and Neste Oil are producing ethanol from gasifying biomass, in this case wood residues from Stora Enso's mill, which results in a carbon dioxide and hydrogen rich gas called syngas, which is then liquefied into ethanol via a Fischer-Tropsch process.[6]

Technology suppliers of the pulp industry

An organization called the Biorefinery Deployment Collaborative has been created and its membership shows the involvement of a number of big players both in pulp technology (Andritz, Metso Power, Pöyry, ThermoChem Recovery International, Voith Paper) and the pulp industry (International Papers, MeadWestvaco, Flambeau River Paper, Parsons and Whittemore).[7]

According to a representative of one of the above companies (ThermoChem Recovery International), "the focus on thermochemical or integrated biorefineries is rapidly becoming very big, like a snowball". The same source says that "the model is interesting to pulp and paper companies because it creates new value streams for mills that have struggled for more than a decade to stay globally competitive." This could be achieved by "using biotechnology to extract hemi-cellulose and convert what is seen today as a waste byproduct into a feedstock that can be used for ethanol and chemical production."[8]

On the other side of the Atlantic, Swedish company CHEMREC, which operates in the field of black liquor gasification technology affirms that "the technology has now matured into a proven concept which we offer on commercial terms to mills looking to expand their operations and enter the new pulp mill paradigm – the Biorefinery."[9] If this new "paradigm" is adopted, CHEMREC says that "the global production potential for biofuels is on the order of 225 million barrels oil equivalent per year" and that annual fuel revenues could represent more "than 1/3 of total pulp industry revenues."[10]

The oil and energy industries

Shell corporation "is already the biggest biofuel distributor in the world". Among other investments, Shell is involved in Iogen, a Canadian company that secured an $80 million grant from the US Government to build a plant in Idaho, which will produce cellulosic ethanol from plant waste and straw.[11]

Boston-based Mascoma Corporation "is a leader in advanced low-carbon biofuels technology" and is currently "deploying advanced technologies that enable the creation of fuel from a range of non-food biomass feedstocks. Mascoma is developing demonstration and commercial scale

4 http://republicans.resourcescommittee.house.gov/archives/ii00/archives/108/testimony/2004/masoodakhtar.pdf

5 http://www.csmonitor.com/2005/0505/p17s01-sten.html

6 http://news.mongabay.com/bioenergy/2007/03/stora-enso-and-nesto-oil-partner-on.html

7 http://www.biorefinerydc.org/Members.html

8 http://www.tri-inc.net/common/New%20Biorefinery%20Model%20Would%20Link%20Chemical,%20Forestry%20Companies.pdf

9 http://www.chemrec.se/Page78.aspx

10 http://www.chemrec.se/Technology.aspx

11 http://business.timesonline.co.uk/tol/business/industry_sectors/natural_resources/article1459141.ece

production facilities globally." General Motors Corp. and Marathon Oil have made equity investments in Mascoma.[12]

In 2008, oil corporation Chevron Corp and forestry company Weyerhaeuser launched a joint venture, Catchlight Energy, to develop renewable fuels from wood. Catchlight Energy will research and develop technology for converting cellulose-based biomass into "economical and low-carbon biofuels." According to a news report, "the venture will focus on developing technology to transform wood and other cellulose sources into clean-burning fuels for cars and trucks."[13]

The biotechnology industry

The production of cellulosic ethanol has attracted major biotechnology players at two different levels: the raw material (trees) and the transformation of biomass to ethanol (enzymes and microorganisms).

Part of the research on genetic manipulation of trees is focused on modifying wood to make it easier to convert into ethanol. The four main countries where this research is being carried out are Belgium, France, Sweden and the USA. However, much research is also being carried out in those and other countries for increasing the level of cellulose in wood and decreasing lignin as a means of lowering the costs of production and bleaching of pulp. Though aimed at a different purpose, such research could also be beneficial for the production of wood-based ethanol.[14]

12 - http://www.mascoma.com/news/pdf/Mascoma%20DOE-Michigan%20funding%20announcement%20joint%20release%20FINAL%2010%207%2008.pdf

- http://www.tennesseeanytime.org/energy/node/491

- http://www.autobloggreen.com/2008/05/01/gm-to-invest-in-mascoma-cellulosic-ethanol-project/

13 http://www.eleconomista.es/noticias/noticias/386718/02/08/Weyerhaeuser-and-Chevron-form-biofuels-joint-venture.html

14 http://www.wrm.org.uy/subjects/GMTrees/Briefing_GM_Trees_by_country.pdf

Regarding conversion of biomass into ethanol, a number of companies are either selecting or genetically manipulating different organisms for producing ethanol.

Already, the field has attracted players representing Big Chemical (DuPont), Big Oil (Royal Dutch Shell) and Big Agriculture (Syngenta). Each of them has aligned with small companies like Verenium Corp, Codexis Inc. and Novozymes A/S catering to the growing market for "enzyme cocktails" that can produce ethanol faster and cheaper.[15]

The prevailing scenario

It is clear from the above that the prevailing scenario is not focused on small scale production of ethanol from a number of locally available biomass sources but on large-scale centralized production and commercialization involving big corporations and genetic manipulation.

Within such a scenario, wood from trees becomes the main candidate as raw material, to be extracted from both forests and industrial tree plantations. Thomas Amidon, a professor at State University of New York's College of Environmental Science and Forestry, a research center working in partnership with International Paper and Lyonsdale Biomass, explains why: "Wood is a perennial crop that can be harvested every month of the year. It is relatively dense and slow to decay, which facilitates transportation and storage. Large-scale manufacturing operations need to function year-round to be economic and using wood as the raw material base allows that."[16] This explains why cellulosic ethanol has been also termed as "treethanol".

An additional argument for the promotion of cellulosic ethanol is that cellulose "is contained in nearly every natural, free-growing plant, tree,

15 http://bioenergy.checkbiotech.org/news/2007-07-10/Big_business_bets_on_bio-refineries_for_nations_fuel_needs/

16 http://www.csmonitor.com/2005/0505/p17s01-sten.html

and bush, in meadows, forests, and fields all over the world without agricultural effort or cost needed to make it grow."[17]

The main threats

Ethanol production thus clearly involves a number of threats:

More and intensified deforestation

According to the FAO, "the potential for large-scale commercial production of cellulosic biofuel will have unprecedented impacts on the forest sector."[18] In many regions of the world, wood is still plentiful within forests. For logging corporations ethanol could be an additional business opportunity by which they would increase their profits through intensifying logging, "without agricultural effort or cost needed to make it grow."[19] All the trees that today have no market value as wood and are currently left standing after logging, could become valuable as raw material for ethanol. The same would be applicable to much of the wood that is currently left to rot in the forest after logging operations, that could be profitably removed for conversion into ethanol. Deforestation would thus intensify, as well as soil nutrient loss. Other forests, that for different reasons are now economically unsuitable for commercial logging, could become a source of raw material for cellulosic ethanol, thereby increasing deforestation.

Further expansion of monoculture tree plantations

Large-scale monoculture tree plantations are obviously the more strategic candidate for supplying large volumes of raw material. As the FAO explains, "wood will be increasingly demanded as a source of energy, especially if cellulosic biofuel production becomes commercially viable; this development would likely result in much larger investments in [sic] planted forests." (FAO's terminology for tree plantations) [20]

The trees to be planted would be selected as the most suitable for ethanol production, the raw material would be homogeneous to facilitate the industrial processes, chemical fertilization, pesticide use and weed control would ensure survival and fast growth, while mechanisation would facilitate management and harvesting operations. As a result, wood raw material would be abundant, homogenous and cheap. From a social and environmental perspective, however, these plantations would occupy vast areas of land, displace local communities, impact heavily on people's livelihoods as well as on water, soils and biodiversity. Those impacts are well documented in all the countries where such plantations have been established and information can be accessed at www.wrm.org.uy under the sections "by country" and "by subject" ("Pulpwood and Timber Plantations") as well as in "WRM Publications".

Genetically engineered trees

A further step in making the raw material and the industrial processes for conversion into ethanol even cheaper would be the use of genetically engineered trees. Research with this aim, including field trials, is already being carried out. It is important to note that plantations of transgenic trees would not only pose the threat of polluting forest trees with pollen from genetically engineered trees, but would also exacerbate all of the impacts of current industrial tree monocultures. Essentially, trees that grow more rapidly will exhaust water supplies more rapidly; there will be greater destruction of biodiversity in the biological deserts of trees genetically modified to be resistant to insects and to not produce blossoms, fruits or seeds; the soil will be destroyed at a faster pace by the increased extraction of biomass; intensive mechanisation will eliminate even more jobs; the

17 http://www.csmonitor.com/2005/0505/p17s01-sten.html

18 ftp://ftp.fao.org/docrep/fao/011/i0350e/i0350e00c.pdf

19 http://en.wikipedia.org/wiki/Cellulosic_ethanol

20 ftp://ftp.fao.org/docrep/fao/011/i0350e/i0350e00c.pdf

increased use of agrotoxic substances will affect the health of humans and ecosystems; and sources of livelihood will be taken away from more communities displaced to make room for even more "green deserts".[21]

Genetically modified enzymes and microorganisms

The danger of the use of genetically modified enzymes and microorganisms for converting cellulose into sugars is even more daunting. Alan Shaw, CEO of "enzyme developer" Codexis, is reported to have said that if the earth had created enzymes that could easily break down cellulose, "Our forests would all be lakes of goo." In spite of that, his company "literally designs enzymes from scratch." It follows that if an accident were to occur, those enzymes would have the potential to convent forests into "lakes of goo."[22]

One good example of what researchers are doing is illustrated in an article under the title "Redesigning Life to Make Ethanol." After having interviewed several people involved in ethanol research, the journalist summarises what they are aiming at: "The ideal organism would do it all – break down cellulose like a bacterium, ferment sugar like a yeast, tolerate high concentrations of ethanol, and devote most of its metabolic resources to producing just ethanol. There are two strategies for creating such an all-purpose bug. One is to modify an existing microbe by adding desired genetic pathways from other organisms and 'knocking out' undesirable ones; the other is to start with the clean slate of a stripped-down synthetic cell and build a custom genome almost from scratch."[23]

21 http://www.wrm.org.uy/subjects/GMTrees/briefing_GMT.pdf

22 http://bioenergy.checkbiotech.org/news/2007-07-10/Big_business_bets_on_bio-refineries_for_nations_fuel_needs/

23 http://www.technologyreview.com/read_article.aspx?id=17052&ch=biztech&pg=1

Other types of threats

New life to the pulp and paper industry

It is important to underscore that the pulp and paper industry already has access to or owns large areas of forests and/or plantations. Production of ethanol could be a by-product helping to make pulp production cheaper, thus enabling it to expand further. This would result in either an increase in forest logging or in the expansion of monoculture tree plantations or in both.

More power to large corporations

Energy is not solely a technological but also a power issue. For corporations such as Shell, for instance, it doesn't matter whether its products are environmentally friendly or not. What matters is profitability which at a global scale is only possible through power. Such power is achieved, among other things, through centralization and concentration. The same can be said about other large corporations now involved in biomass ethanol such as International Paper, General Motors, Dupont, Syngenta.

More powerful conglomerates

Not only corporations involved aim at becoming stronger, but they are also making strategic alliances that will make them even stronger. For instance, the marriage between the oil, car, pulp and paper, biotech industries will undoubtedly increase their power.

Larger scale and concentration

The way this is being designed, the raw material will be obtained through large scale logging of forests and from large scale tree plantations, mostly based in the South. As a result, both forest resources and lands would be

either directly or indirectly concentrated in the hands of large corporations. At the same time, production and distribution of cellulosic ethanol will be concentrated in the hands of few large corporations having the necessary technical and financial capacity for large-scale production and distribution, as well as access to the profitable energy market of the industrialized North.

Less investment in better technologies

As Scot Quaranda from the U.S. Dogwood Alliance puts it: "cellulosic ethanol [is] a false solution. It should be set aside in favor of more positive solutions. Biofuel has served as a distraction and diverted funding which could have been utilized for more proven or promising technologies in the area of conservation and efficiency, solar, wind and hydrogen technology, and more."[24]

Manipulating the public

As usual corporations that aim to profit from this new development are using a number of arguments for manipulating the uninformed public.

One of the main arguments is that, unlike other agrofuels such as corn or sugar cane, cellulosic ethanol is "not competing for food or agricultural land."[25]

Another argument is that it helps to avert climate change, because "Burning a gallon of ethanol … adds little to the total carbon in the atmosphere, since the carbon dioxide given off in the process is roughly equal to the amount absorbed by the plants used to produce the next gallon.[26]

24 http://pressroomda.greenmediatoolshed.org/sites/default/files/Forest4Fuel08.pdf

25 http://www.chemrec.se/Technology.aspx

26 http://www.technologyreview.com/read_article.aspx?id=17052&ch=biztech&pg=1

Both arguments could be convincing were it not because:

- most of the corporations involved are already occupying or degrading agricultural lands for producing non-food products all over the world
- much of the ethanol would be produced from industrial tree plantations, resulting in the occupation and degradation of agricultural lands
- logging for ethanol production in forests would result in vast emissions of carbon dioxide
- replacement of native ecosystems by plantations, whether forests or grasslands, would also result in huge emissions of carbon dioxide

A place for cellulosic ethanol?

At least in theory, cellulosic ethanol can be a good idea. However, good ideas in the wrong hands can spell disaster and it is clear that this one has in fact fallen into some of the worst possible hands.

For cellulosic ethanol to play a positive role it needs to meet some simple conditions, the main ones being:

- That it is locally produced and used
- That its operations are small scale
- That it is based on locally available resources
- That the main raw material used is waste
- That its production and commercialization are decentralized
- That it is part of a diverse set of locally available energy sources
- That it does not involve genetic manipulation of living organisms

Those conditions are basically impossible to meet in the current scenario dominated by global corporations. Within such context, cellulosic ethanol must therefore be exposed as a false solution that must be set aside in favour of more positive alternatives.

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