Global Perspective on Production of Biotechnology-based Bioenergy and Major Trends

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Introduction

1. Bioenergy - electricity and any solid, liquid or gaseous fuel that is produced through the processing of biomass[1] - may provide an alternative to the expansion of fossil fuels consumption. With careful strategies and under appropriate regulatory frameworks, bioenergy, and in particular biofuels, may be instrumental to slowing down the process of global warming and enhancing energy security, as well as possibly providing opportunities for countries to diversify agriculture production and raise rural incomes.

2. New technologies, and more specifically genetic engineering, may play a role in enhancing bioenergy production and hence making it a viable component of the energy mix. Genetic engineering may be used to optimize the productivity of biomass of first generation and second generation energy crops, as well as to modify crops to enhance their conversion to fuels. There is also an opportunity to utilize genetic engineering to facilitate the downstream processing of biomass into fuels.

3. However, genetic engineering does not come without uncertainties. The use of this technology in products traded internationally may raise additional concerns.

4. The purpose of this paper is to provide an overview of recent developments in the production and trade of bioenergy, more specifically biofuels; analyze the role that genetic engineering may play to enhance bioenergy production and increase its competitiveness; and address some possible ramifications of utilizing genetic modification to produce bioenergy in the context of the multilateral trade regime and WTO rules.

The present energy scenario

5. The International Energy Agency (IEA)'s latest analysis[2] indicates that global primary energy demand is set to increase by 55% between 2005 and 2030, at an average annual rate of 1.8%. Fossil fuels will remain dominant, accounting for 84% of the projected increase in primary energy demand. In this scenario, the share of oil drops, though oil remains the largest single fuel in the global energy mix in 2030, followed by coal that sees the biggest increase in

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[1] The term "biomass" is used as defined by the U.S. Department of Energy: Biomass is "any plant derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes, and other waste materials.", http://www.energy.gov/energysources/bioenergy.htm

[2] IEA, *World Energy Outlook 2007*, Summary and Conclusions, OECD/IEA, 2007. http://www.iea.org/Textbase/npsum/WEO2007SUM.pdf

demand in absolute terms. Natural gas demand will also grow, but modestly. According to the analysis, rising global energy demand poses a real and growing threat to the world's energy security. Consuming countries' growing reliance on oil and gas imports from a small number of producing countries threatens to exacerbate short-term energy-security risks. The analysis also stresses that these trends lead to continued growth in energy-related emissions of carbon dioxide (CO2), which, in a "business as usual" scenario, will jump by 57% between 2005 and 2030. Considering the dramatic consequences that higher global temperatures and changes in climate may cause, especially in developing countries, alternative policies are urgently required.

6. Most agree that the energy challenge of this century – providing the affordable energy needed to achieve, expand, and sustain prosperity for all while avoiding intolerable environmental disruption – cannot be met without a huge increase in the global energy-innovation effort. While it would be unrealistic to think that alternative energy sources could solve all the energy problems that countries face at present, their development may contribute to alleviating climate change problems and lessening the dependence of energy-importing countries on increasingly expensive and scarce fossil fuels. Engaging in innovative energy technologies would thus be suitable in economic, environmental and geo-political terms.

Bioenergy and biofuels

7. The foundation of a bio-based industry depends on an abundant supply of biomass. Biofuels are fuels derived from biomass. The most widely used liquid biofuels are bioethanol and biodiesel. Ethanol is an alcohol that can be used directly in cars designed to run on pure ethanol, or blended with gasoline to make "gasohol". Ethanol can be used as an octane-boosting, pollution-reducing additive in unleaded gasoline, thereby substituting for chemical additives such as methyl tertiary-butyl ether (MTBE). Biodiesel is a synthetic diesel-like fuel. It can be used directly as fuel or blended with petroleum diesel. While there is much attention on biofuels for the transport sector, the use of biofuels for cooking is a potential application of great relevance globally, especially in rural areas of developing countries. Combustion of biofuels for cooking will yield far lower emissions of pollutants than emissions from cooking with solid fuels. Thus, biofuels could play a critical role in improving the health of billions of people.[3]

8. Biofuels are at present classified in two categories: “first-generation” and “second-generation” fuels. While there are no strict technical definitions for these terms, the main distinction between them is the feedstock used. A first-generation fuel is generally a fuel made from sugars, grains, or seeds; that uses only a specific (often edible) portion of the above-ground biomass produced by a plant; and that is the result of a rather simple manufacturing process. First-generation fuels are already being produced in significant commercial quantities in a number of countries. Second generation fuels are generally those made from non-edible lignocellulosic biomass,[4] either non-edible residues of food crop production (e.g., corn stalks or rice husks) or non-edible whole-plant biomass (e.g., grasses or trees grown specifically for energy). The process to covert the lignocellulosic biomass into a fuel is rather complex.[5]

[3] See Larson E. (2008), *Biofuel Production Technologies: Status, Prospect and Implications for Trade and Development*, UNCTAD/DITC/TED/2007/10, at 3, http://www.unctad.org/en/docs/ditcted200710_en.pdf
[4] Any whole-plant biomass consists of cellulose (typically about 50 per cent of the dry mass), hemicellulose (~25 per cent), and lignin (~25 per cent). The exact fractions of these components vary from one type of biomass to another. See: Larson (2008), op. cit., at 3.
[5] The description and analysis of first and second generation biofuels are based on Larson E. (2008), op. cit.

9. There are two routes for producing second generation biofuels: enzymatic hydrolysis, which leads to so-called biological second generation biofuels; and gasification which leads to so-called thermochemical second generation biofuels. Cellulosic ethanol is an example of a biofuel obtained through a biological process. While cellulosic ethanol can be produced today, producing it competitively (i.e., without subsidies) from lignocellulosic biomass still requires significant successful research, development, and demonstration efforts. Key research and development goals include: developing biomass feedstocks with physical and chemical structures that facilitate processing to ethanol (e.g., lower lignin content, higher cellulose content etc); improving enzymes to achieve higher activities, higher substrate specificities, reduced inhibitor production, and other features to facilitate hydrolysis; developing new micro-organisms that are high-temperature tolerant, ethanol-tolerant, and able to ferment multiple types of sugars (six-carbon and five-carbon). Achieving these goals may be facilitated significantly by the application of genetic engineering.[6]

10. The kinds of biofuels that can be produced through gasification are fuels already being made commercially from fossil fuels using processing steps that in some cases are identical to those that would be used for biofuel production. These fuels include methanol, refined Fischer-Tropsch liquids (FTL), and dimethyl ether (DME). The conversion technologies are available today in the market, but they need to be adapted to use biomass, instead of fossil fuels, as input. Key characteristics distinguishing thermochemical from biochemical biofuels are the flexibility in feedstocks that can be accommodated with thermochemical processing and the diversity of finished fuels that can be produced. Second-generation fuels are not yet being produced commercially in any country.

10. First generation biofuels have several limitations. They compete with food uses and plants have been optimized for food, not energy use. Only part of the plant is converted into biofuel. They bring only modest greenhouse gas (GHG) emissions mitigation benefits, except for sugarcane ethanol. While first generation biofuels can be blended with existing fossil fuels and so require minimal infrastructure change, there is limited large-scale experience outside Brazil and the United States. Also, they bear relatively high costs - except for sugarcane ethanol in Brazil - due to high feedstock cost. Second generation biofuels have some clear advantages. Plants can be bred for energy characteristics, and not for food, and a larger fraction of the plant can be converted to fuel. Lignocellulosic crops can be grown on poor-quality land, requiring fewer fertilizers. There are substantial energy and environment benefits compared with most first generation biofuels due primarily to greater biomass usability per unit of land area. Second generation biofuels have greater capital-intensity than first generation biofuels, but lower feedstock costs. The projected costs are less scale-sensitive for biological biofuels than for thermochemical biofuels.

11. Global production of first-generation bioethanol in 2006 was about 51 billion litres, with the United States becoming the world's largest producer with 18.3 billion litres from corn and Brazil a close second with around 17 billion litres from sugarcane. China and India contributed with 3.8 and 1.9 billion litres respectively.[7] Production levels were much lower in other countries, with feedstocks that include sugarcane, corn, and several other sugar or starch crops (sugar beets, wheat, potatoes). Many countries are expanding or contemplating expansion of their ethanol production.

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[6] Houghton, J. S. Weatherwax, and J. Ferrell (2006), *Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda - A Research Roadmap Resulting from the Biomass to Biofuels Workshop*, December 7–9, 2005, Rockville, Maryland, US Department of Energy, June.
http://genomicsgtl.energy.gov/biofuels/b2bworkshop.shtml

[7] Renewable Fuels Association, Industry Statistics, found at: http://www.ethanolrfa.org/industry/statistics/

12. In December 2007, the US Congress passed the Energy Independence and Security Act (EISA).[8] The Act is designed to increase energy efficiency and the availability of renewable energy. Among many other provisions, the Act sets a modified Renewable Fuel Standard (RFS) which requires minimum annual levels of renewable fuel in U.S. transportation fuel. The new standard starts at 9 billion gallons in 2008 (approximately 34 litres) and rises to 36 billion gallons in 2022 (approximately 137 litres). The law distinguishes renewable fuels in four categories: (i) conventional biofuels, i.e., ethanol derived from corn starch that has lifecycle greenhouse gas emissions that are at least 20 percent less than baseline lifecycle GHG emissions[9]; (ii) advanced biofuels[10], i.e., renewable fuels, other than ethanol derived from corn starch, that have lifecycle greenhouse gas emissions that are at least 50 percent less than baseline lifecycle GHG emissions.; (iii) biomass-based diesel, i.e., renewable fuel that is biodiesel that has lifecycle greenhouse gas emissions that are at least 50 percent less than baseline lifecycle GHG emissions; and (iv) cellulosic biofuels, i.e., renewable fuels derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass, that have lifecycle greenhouse gas emissions that are at least 60 percent less than baseline lifecycle GHG emissions.[11]The law specifies a timetable beginning in 2009 for the mix of renewable fuels in transport fuels, including the annual escalating required volume of advanced biofuels: by 2022, 21 billion gallon (around 80 billion litres) of overall RFS goal must come from advanced biofuels, cellulosic biofuel and biomass-based diesel. Therefore, the law puts a cap on the use of corn-based ethanol, i.e. max 15 billion gallons (approximately 56.7 billion litres) by 2022.

13. In the European Union (EU), at the meeting of the European Council in Brussels in March 2007 it was decided to set a mandatory target of a 20% share of renewable energies in overall EU energy consumption by 2020, and a mandatory 10% minimum target for the share of biofuels in overall EU transport petrol and diesel consumption by 2020.[12]

14. Biodiesel production worldwide has been growing rapidly since 2005, with the EU producing 77% of the total in 2006. EU biodiesel production (primarily from rape seed oil and sunflower seed oil) has risen from 1.9 million tonnes (approximately equivalent to 2.2 billion

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[8] *Energy Independence and Security Act*, Public Law 110-140-Dec 19, 2007, found at: http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.pdf. See also: CRS Report for Congress, *Energy Independence and Security Act of 2007: A Summary of Major Provisions*, 21 December 2007, Order Code RL34294, found at: http://assets.opencrs.com/rpts/RL34294_20071221.pdf; and Beveridge & Diamond, P.C., *Renewable Fuel Standard Program Update*, 4 February 2008, http://www.bdlaw.com/news-270.html.

[9] The term 'baseline lifecycle greenhouse gas emissions' means the average lifecycle greenhouse gas emissions for gasoline or diesel (whichever is being replaced by the renewable fuel) sold or distributed as transportation fuel in 2005. Section 211 (1) (C). The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential. Section 211 (1) (H).

[10] More specifically, the types of fuels eligible for consideration as 'advanced biofuel' may include any of the following: (i) ethanol derived from cellulose, hemicellulose, or lignin; (ii) ethanol derived from sugar or starch (other than corn starch); (iii) ethanol derived from waste material, including crop residue, other vegetative waste material, animal waste, and food waste and yard waste; (iv) biomass-based diesel; (v) biogas (including landfill gas and sewage waste treatment gas) produced through the conversion of organic matter from renewable biomass; (vi) butanol or other alcohols produced through the conversion of organic matter from renewable biomass; (vii) other fuel derived from cellulosic biomass. Section 211 (1) (B) (ii).

[11] Section 211 (1) (E).

[12] Brussels European Council, 8/9 March 2007, Presidency Conclusions, 7221/1/07, Rev.1, Concl.1, Brussels, 2 May 2007. http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/93135.pdf

litres) in 2004 to 4.9 million tonnes (approximately 5.6 billion litres) in 2006, marking a further acceleration in the continuous expansion of this sector.[13] In the United States, biodiesel production (primarily from soy beans) rose from 2 million gallons (approximately 7.5 million litres) in 2000 to 250 million gallons (approximately 950 million litres) in 2006.[14] In Brazil, the government has mandated the addition of 2% biodiesel to conventional diesel starting in 2008, with the percentage increasing to 5% in 2013. Interest in palm biodiesel is growing, especially in Southeast Asia (Malaysia, Indonesia and Thailand) where the majority of the world's palm oil for food use is made today. Jatropha, a non-edible-oil tree, is drawing attention for its ability to produce oil seeds in semi-arid lands. In India, Jatropha biodiesel is being pursued as part of a waste-land reclamation strategy.[15]

15. Biofuels are increasingly traded internationally both because a number of developed countries which are transferring to biofuels do not have the land capacity to grow the required amount of biomass, and because several countries from the South enjoy the appropriate land and labor conditions for positioning themselves as efficient biomass and biofuels producers and exporters.

16. World ethanol exports grew from 3.2 billion litres in 2002 to 7.8 billion litres in 2006, with the Americas being by far the largest exporting region totalling 4.7 billion litres exports.[16]

The role of biotechnology, in particular genetic engineering

17. Karl Ereky, a Hungarian engineer, coined the term "biotechnology" in 1919 to refer to the science and the methods that permit products to be produced from raw materials with the aid of living organisms.[17] According to the Convention of Biological Diversity, biotechnology is "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use" (Article 2). According to the FAO's statement on biotechnology, "interpreted in a narrow sense,... [biotechnology] covers a range of different technologies such as gene manipulation and gene transfer, DNA typing and cloning of plants and animals."[18]

18. More specifically, genetic engineering (or recombinant DNA technology) is the technique that permits to change the genetic constitution of cells by introducing or eliminating specific genes through modern molecular biology techniques. This technology results in a genetically modified organism (GMO) i.e. an organism that has been transformed by the insertion of one or more transgenes, often but not always from a different species than that of the recipient.[19] In the first genetic modification experiments, which took place in the mid 1970s, synthetic human genes were combined with genes from a bacterium. Later that decade, researchers learned how to insert genes into fungi and yeast. In the 1980s, they found ways of

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[13] European Biodiesel Board, found at: http://www.ebb-eu.org/EBBpressreleases/EBB%20press%20release%202006%20stats%202007%20cap%20Final.pdf

[14] Carriquiry M. (2007), "US biodiesel production: Recent developments and prospects", *Iowa Ag Review*, Spring 2007, Vol. 13, No.1., http://www.card.iastate.edu/iowa_ag_review/spring_07/article4.aspx

[15] Larson E. (2008), op.cit

[16] Schuetz G., *Overview of the global biofuels market*, Powerpoint presentation made at the UNCTAD conference "Biofuels: An option for a less carbon-intensive economy", 4-5 December 2007, Rio de Janeiro, Brazil. http://www.unctad.org/Templates/Page.asp?intItemID=4412&lang=1

[17] OECD Policy Brief, *Modern Biotechnology and the OECD*, June 1999. http://www.oecd.org/dataoecd/29/40/1890904.pdf

[18] http://www.fao.org/biotech/stat.asp

[19] FAO Biotechnology Glossary, http://www.fao.org/biotech/index_glossary.asp

putting foreign genes into the cells of plants and some animals. In the 1990s, the first experiments to insert new genes into human cells and tissues were developed.[20]

19. Within the bioenergy sector, biotechnology, and in particular genetic engineering, has the potential to be applied to agricultural production - to optimize the productivity of biomass of first and second generation energy crops; to raise the ceiling of potential yield per hectare; to modify crops to enhance their conversion to fuels - and to the biomass conversion process, for example by developing more effective enzymes for the downstream processing of biofuels. Whether genetic engineering will hold its promises, when the different technologies will become available and at which cost, remains, however, to be seen.

20. While conventional breeding methods continue to play an important role in developing new crops and cultivars, genetic engineering of existing crops may likely enhance the number and precision of such modifications and the variety of plant products available for industrial use. Genetic engineering permits the redesign of crops for easier processing and for creation of new types of raw materials. Plants could be modified or selected for characteristics that enhance their conversion to fuels. At present, for example, biomass from corn is converted to fermentable sugars for the production of bioethanol using pretreatment processes that disrupt the lignocellulose and remove the lignin, thus allowing the access of microbial enzymes for cellulose deconstruction. Both the pretreatments and the production of enzymes are expensive. Recent advances in plant genetic engineering could reduce biomass conversion costs by developing crop varieties with less lignin, crops that self-produce cellulase enzymes for cellulose degradation and ligninase enzymes for lignin degradation, or plants that have increased cellulose or an overall biomass yield.[21]

21. Genetic modification could be used to produce plants which have nitrogen fixing ability, consume relatively little water, are easy to harvest and can be grown extensively to produce protein, carbohydrates, and fibres which can all be processed through a bio-refinery into a range of industrial, edible and energy products.[22] Oilseed crops could also be bioengineered to become the source of bio-based lubricants and esterified fatty acids that are the main ingredient in biodiesel.

22. In parallel with trait modification, biotechnology could be used for yield increase purposes. The annual rate of increase in yield over the past 40 years has been significant. The major portion of yield increase has been accounted for by improved genetics via traditional gene recombination and recurrent selection, but the introduction of GM crops has also played a role during the last decade, though only for a limited number of crops and traits.

23. Genetic engineering is already being used to develop crops that are resistant to pests, weeds and diseases, and tolerant to stresses, such drought and salinity. Several doubts remain, however, on the environmental impact of modifying crops (see section below).

24. The second major potential application of genetic engineering in the energy sector is in the manufacturing process. Biologists are using genetic engineering to overcome two major difficulties that are hindering the conversion of lignocellulose into fuels: the high cost of cellulases, the enzymes that break down cellulose, and the limited ability of the microbes to ferment the breakdown products. Other researchers aim to overcome the limited diet of yeast. Yeast fermentation breaks down glucose and other hexoses but not the pentoses that result

[20] OECD Policy Brief, op.cit.

[21] Sticklen, M. (2006), "Plant genetic engineering to improve biomass characteristics for biofuels" *Current Opinion in Biotechnology*, 17(3): 315-319.

[22] Sims, R. E. H. (2004), "Biomass, Bioenergy and Biomaterials: Future Prospects" in *Biomass and Agriculture: Sustainability, Markets and Policies*, OECD, September, at 9. http://webdomino1.oecd.org/comnet/agr/BiomassAg.nsf.

from the breakdown of hemicellulose, which comprises 15–50% of lignocellulose, depending on the type of plant.[23]

25. The fermentable sugars in lignocellulose are derived from cellulose and hemicelluloses but these are not readily accessible to enzymatic hydrolysis and require a pretreatment, which causes an extensive modification of the lignocellulosic structure. A number of pretreatment technologies are under development and being tested on a pilot scale. Hydrolysis of lignocellulose carbohydrates into fermentable sugars requires a number of different cellulases and hemicellulases. Hydrolysis of cellulose is a sequential breakdown of the linear glucose chains, whereas hemicellulases must be capable of hydrolysing branched chains containing different sugars and functional groups. The technology for pretreatment and hydrolysis has been developed to an extent that it is close to a commercially viable level. It has become possible to process lignocellulose at high substrate levels and the enzyme performance has been improved. Also the cost of enzymes has been reduced. Still a number of technical and scientific issues within pretreatment and hydrolysis remain to be solved. However, significant improvements in yield and cost reductions are expected, thus making large-scale fermentation of lignocellulosic substrates possible.[24]

26. Genetic research into dedicated energy crops and manufacturing processes is still at an early stage. However, the biofuels blending targets put in place by many countries, including the United States and the EU, and, more generally, the policies and related measures that countries are implementing to address climate change, are spurring investments in the biofuel sector and research by private companies and public institutions. For example, in the United States alone in 2007 venture entities invested $2.9 billion in the biofuel industry. This amount is expected to increase significantly within the country and around the world in the coming years.[25] In addition, the U.S. federal government has allocated, for 2008 to 2015, $500 million in grants under the Energy Independence and Security Act of 2007 to promote the development of advanced biofuels.

27. A recent analysis[26] indicates that since 2002, a total of 2,796 biofuel related patents were published in the United States. In 2007, biofuel patents (1,045) dominated the renewable energy sector, followed by patents for solar power (555 patents) and wind power (282 patents). From the biofuel related patents published in the period 2006-2007 and within specific technologies (namely, agricultural biotechnology, biodiesel, biomass, ethanol and other alcohols, and enzymes) the following results were found: biodiesel-related patents came in first in the list of biofuel patents (299), followed by 110 for agricultural biotechnology; 42 for ethanol and other alcohols; 35 for enzymes and 41 for biomass. From the number of cellulosic-related patents published during the same period, the following distribution was found: one for biodiesel; one for agricultural biotechnology; four for ethanol and other alcohols; five for enzymes; and five for biomass. About 57% of patents in the selected technologies are owned by private companies, while 11% are owned by academic institutions. The remaining 32% are "undesignated" (patent owner not listed in application). An increase in "agriculture biotechnology biofuel patents" (particularly, transgenic bioenergy crops) is expected in the future, while traditional ethanol biofuel patents will continue to lag behind.

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[23] Schubert C. (2006), "Can biofuels finally take center stage?", *Nature Biotechnology*, vol. 24, No.7, July.

[24] Jorgensen H., J. Bach Kristensen, C. Felby (2007), "Enzymatic conversion of lignocellulose into fermentable sugars: challenges and opportunities", *Biofuels, bioproducts and biorefining*, Vol. 1. Issue 2, 119-134, http://www3.interscience.wiley.com/cgi-bin/abstract/114283520/ABSTRACT?CRETRY=1&SRETRY=0

[25] R. Kamis and M. Joshi, "Biofuel patents are booming", *Exchange Morning Post*, 22 January 2008, http://www.exchangemagazine.com/morningpost/2008/week4/Tuesday/0121220.html

[26] Ibid.

Clearly, forthcoming biofuel technology will be proprietary. The interaction of strong intellectual property rights (IPR) regimes with access to technology, especially in developing countries, may be problematic, as well as developing country ability to adapt complex and sophisticated technologies to local needs and capacities.

The trade and development implications

28. Biotechnology applied to the energy sector may offer opportunities for developed and developing countries alike, if an appropriate regulatory framework is in place and if careful strategies are developed. For the former, it presents the opportunity to use their technological capabilities for national energy security and to avoid major social and economic disruptions due to fluctuations in the availability and price of fossil fuels. For a number of developing countries, it may provide the potential to reduce dependency on oil imports, become less exposed to oil price fluctuations and diminish the environmental shortcomings related to fossil fuel burning.[27] For both developed and developing countries alike, the bio-based economy may boost employment and revenues in rural areas and revitalize them. It may offer new end-markets for agricultural products and therefore add value to them. All these goals are crucially important for all countries, but particularly for developing countries. People in developing countries suffer the most from limited access to commercial energy[28], from air pollution[29], and from the decline of their agricultural sector.

29. Despite the potential of contributing to the development of bioenergy, biotechnology does not come without risks and uncertainty. Genetic modification of energy-dedicated crops - aimed both at yield increase and at developing suitable traits - may raise fears linked to perceived threats to plant life and health, to the conservation of biodiversity and to the environment at large. Although there is not yet any definite scientific evidence of environmental harm, it is submitted by many that adverse effects of genetic engineering in the agricultural sector may be revealed in the future by more extensive research.

30. While fuel-dedicated crops would not be used as food or feed, and this would downsize the human and animal health-related fears, a major concern relates to potential consequences of gene flow from GM to non-GM individuals of the same species and to the possibility of unpredictable crosses with other species. Gene flow would trigger the risk of contamination of crops meant as food or feed and bring back the human and animal health concerns.

31. People's resistance to GM crops, for whatever purpose they may be grown, can also represent a problem that needs to be addressed. The overall environmental impact, sustainability and people's acceptance of GM energy crop production should be carefully evaluated before widespread production could start.

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[27] OECD (2002), *The Application of Biotechnology to Industrial Sustainability - A Primer*, July, at 18-19, http://www.oecd.org/dataoecd/61/13/1947629.pdf.

[28] Almost 1.6 billion people do not have access to electricity today. Most of the electricity-deprived are in South Asia and sub-Saharan Africa. Because of continuing population growth, if no new policies are put in place, there will be 1.4 billion people lacking access to electricity in 2030. See: IEA, *World Energy Outlook 2006*, at 157, http://www.worldenergyoutlook.org/2006.asp.

[29] Air pollution causes premature deaths and chronic illnesses, which have a strong negative impact on the human and economic resources of the countries affected. Air pollution has been a steadily growing problem in developing countries, where urban expansion and rapid industrialization are accompanied by increasing road traffic and growing energy consumption. See: *The Economist*, "Power to the poor, A survey of energy", 10 February 2000, pp 17-19.

Biofuels certification

32. In parallel with fast-growing biofuel use and trade, concerns are being voiced about the sustainability of biofuels and feedstock production and interest in mechanisms to ensure sustainability are intensifying. Discussions are ongoing on the development of certification schemes that encourage sustainable production. Four stakeholder groups are involved in developing biofuels certification schemes: 1) national governments, and regional groupings (the European Union in particular), 2) companies, 3) non-governmental organizations and 4) international organizations and initiatives.[30] The numerous public and private certification initiatives being undertaken are in various stages of development ranging from the discussion phase to full implementation.

33. Increased production and use of biofuels raise indeed a number of concerns. Some shortcomings refer to the danger that rapid growth in demand for energy crops would divert too much cropland to fuel feedstock production, jeopardising food security and resulting in socially detrimental increases in the prices of agricultural commodities. Concerns refer also to the risk that increasing biofuel demand will lead to the cultivation of previously uncultivated lands, including land having high biodiversity value or high carbon stock. Large use of water and pesticides for feedstock production could jeopardise the environmental advantages of biofuels. The process of transforming feedstocks into biofuels may also be environmentally unfriendly and possibly eclipse the greenhouse benefits of biofuels.[31]

34. Certification is a form of communication along the supply chain that permits the buyer to be ensured that the supplier complies with certain requirements. Certification allows product differentiation and provides information about certain characteristics of a product, in this case its sustainability. Depending on how sensitive a market is to certain product attributes, certification may have a significant market impact, affecting both domestic and imported products. Moreover, certification may be linked to tax breaks and other fiscal incentives or it may be the precondition for products to be counted towards national biofuels targets or renewable energy obligations. Indeed, several of the certification schemes under discussion establish such a link. All this makes certification a crucial product attribute.

35. The development of a certification scheme is a rather complex process. Principles are usually established as general starting points that describe the objective of certification. These objectives are then translated into measurable requirements by criteria. Testing utilizes indicators or verifiers which serve as quantitative or qualitative minimum requirements for certification.[32] An independent third party assesses conformity with the requirements.

36. Most biofuels and biomass certification schemes under discussion put emphasis on greenhouse gas emissions reduction. A few others tackle also issues such as biodiversity preservation; environmental protection; land use changes; food security and social well-being. The use of genetic engineering in biomass production may become a concern and an obstacle to obtaining a sustainability certificate.

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[30] Van Dam J, M. Junginger, A. Faaij, I. Jürgens, G. Best, and U. Fritsche (2007). "Overview of recent developments in sustainable biomass certification", paper accepted for publication in a Special Issue on International Bio-energy Trade - *Biomass and Bioenergy*.

[31] This section is based on: Zarrilli S. (2008), *Making Certification Work for Sustainable Development: The case of biofuels*, UNCTAD/DITC/TED/2008/1, forthcoming.

[32] Lewandowski and A. Faaij (2006). "Steps towards the development of a certification system for sustainable bio-energy trade." *Biomass and Bioenergy* 30: 83-104; and *Testing framework for sustainable biomass*. Final report from the project group "Sustainable production of biomass." March 2007, http://www.lowcvp.org.uk/assets/reports/070427-Cramer-FinalReport_EN.pdf

37. Ongoing biofuels certification initiatives try to avoid re-inventing the wheel in that there are plenty of standards ready in use or under development that address the sustainability of biomass production and can be applied to biomass used for bioenergy. Several of these standards do not allow the use of GMOs. For example, the Forest Stewardship Council includes within its Principles and Criteria for Forest Stewardship that "Use of genetically modified organisms shall be prohibited"(Principle 6 - Environmental Impact. 6.8).[33] Similarly, all certification systems for organic agriculture do not permit GMOs.

38. The draft principles for sustainable biofuel production developed by the Roundtable on Sustainable Biofuels (RSB) - an international initiative that aims to bring together farmers, companies, non-governmental organization, experts, governments, and intergovernmental agencies concerned with ensuring the sustainability of biofuels production and processing[34] - include the following: "If biotechnologies are used in biofuels production, they shall improve the social and/or environmental performance of biofuels, and always be consistent with national and international biosafety and transparency protocols." (Principle 11 - Biotechnology).

39. Turning to the certification initiatives initiated by governments or regional groupings, the certification scheme of the Netherlands - the so-called Cramer Report - does not include any indicator for GMOs. The project group reached the conclusions that "Although contacts with various parties involved have proved that many respondents attach importance to an indicator aimed at Genetically Modified Organisms (GMOs), no indicator has eventually been included for this. The views with regard to GMOs are divided, also in the project group, and the discussion about this lies beyond the field of activity of the project group. In the future the results of the discussion held around the subject of food may help to clarify the views on biomass production. In the future hallmarks could be used, as is the case with food."[35]

40. The recent European Commission proposal for a Directive on the promotion of the use of energy from renewable sources[36] contains, among many other provisions, environmental sustainability criteria for biofuels. The draft text does not include reference to genetic modification, implying that biofuels produced from GM raw agricultural materials can get certification, provided that they comply with the requirements spelled out in the Directive.

41. The German Biomass Sustainability Ordinance, which includes biofuels sustainability criteria, does not refer to genetic modification either. However, it refers to the need for biomass to be produced in accordance with the principles of good practice pursuant to the laws and regulations governing agriculture, forestry and fisheries. Similarly, the proposed EC Directive refers to the need for biomass to be produced in accordance with the minimum requirements for good agricultural and environmental condition as spelled out in EC legislation, *inter alia*, on the protection of groundwater against pollution caused by certain dangerous substances, and on the conservation of natural habitats and of wild flora and fauna.

42. Most certification initiatives include among the requirements that biomass and biofuels should satisfy in order to be certified, the need to comply with domestic legislation, including laws and regulations aiming at environmental protection (e.g. biodiversity protection; soil, water and air quality; conservation of natural resources). This may imply that, should such legislation change as far as genetic engineering in the agricultural sector is at

[33] *FSC Principles and Criteria for Forest Stewardship*, http://www.fsc.org/en/about/policy_standards/princ_criteria.
[34] Ecole Polytechnique Fédérale de Lausanne Web site: http://cgse.epfl.ch/page65660-en.html
[35] *Testing Framework for Sustainable Biomass*, op.cit., at 2.2.
[36] Found at: http://ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf

stake, the requirements for obtaining biofuels sustainability certificates would change accordingly.

Product differentiation under the WTO

43. Distinguishing biofuels and feedstocks on the basis of sustainability remains a complex legal issue.[37] There seem to be two questions to address, namely whether biofuels which involve genetic modification and those which don't may or may not be regarded as "like" products; and whether certified biofuels and non-certified biofuels may or may not be regarded as "like" products.

44. The national treatment principle incorporated into Article III of the GATT (General Agreement on Tariffs and Trade of the World Trade Organization - WTO) implies non-discrimination between domestic and imported goods. This means that the importing country is not allowed to apply to foreign products measures more onerous than those applied to “like” domestic products. Hence, the question is under which circumstances two products can be considered as "like" products.

45. According to WTO law and practice, there are four general criteria that would be relevant for analyzing the “likeness” of particular products on a case-by-case basis: (i) the products’ properties, nature and quality; (ii) the products’ end-uses in a given market; (iii) consumers’ tastes and habits, which change from country to country; and (iv) tariff classification. In the case of GM biofuels, two of the above-mentioned criteria (i.e. end-use and tariff classification) would point to "likeness", one (i.e. consumers' perception) may point (especially in environment-sensitive markets) to "non-likeness", and one (i.e. product characteristics) would point to "likeness" or "non-likeness" depending on whether the genetic modification is still detectable in the ultimate product. WTO jurisprudence may provide some overall guidance when addressing this controversial issue. In the *Asbestos* case[38], the Appellate Body reached the conclusion that the competitive relationship between products in the market place is of paramount importance for assessing "likeness". Applying this reasoning to biofuels, it may be said that if consumers view GM biofuels and their non-GM counterparts in a different way (for example because of the perceived negative environmental impacts) and consumers' perceptions and behaviours in respect of the two sets of items ultimately affect the degree of competitiveness or substitutability of GM biofuels and their counterparts in the marketplace, then the two sets of products may not be regarded as "like" and different rules may apply to them.

46. In assessing whether products are “like”, the product/process distinction has often been raised and the legitimacy of distinguishing products according to the way they have been produced has been questioned, especially if the production methods are not reflected in the final characteristics of the products (non-product related process and production methods - npr PPMs). The main concern about those measures is that, by establishing requirements on the way products should be manufactured, they limit the freedom of foreign producers to produce according to the technologies they have available and following the priorities and strategies set up by their government. They would then represent an undue interference of one country into the sphere of discretion of another. Moreover, npr PPMs could rather easily be used for protectionist purposes, creating barriers to international trade.

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[37] Zarrilli S. (2008), op. cit.

[38] *European Communities - Measures Affecting Asbestos and Asbestos-Containing Products*, Report of the Appellate Body, WT/DS135/AB/R, 12 March 2001.

47. The product/process distinction remains an open issue in WTO law. Jurisprudence related to GATT Article XX (General Exceptions)[39], on the other hand, has evolved to interpret Article XX as covering measures that distinguish products on the basis of the production processes.[40]

48. Assuming that GM and non GM biofuels, as well as certified and uncertified biofuels are found to be “like” products, there is a second element that must be established before a measure can be held to be inconsistent with GATT Article III and then the importing country found in violation of its obligation of non-discrimination: “like” imported products are accorded less favourable treatment than “like” domestic products. Only if a “less favourable treatment” is detected - meaning a certain asymmetry which affects the competitive relationship between the group of imports as opposed to the group of domestics - can the measure be considered to be in violation of Article III.

49. In the *EC-Biotech* case[41], the WTO Panel reached an interesting conclusion in this regard. It stated that, to hold a violation of Article III, the "less favourable treatment" of imported products should be explained by their foreign origin, rather than by other reasons, such as a perceived difference between products in terms of their safety or other characteristics. More specifically, the Panel held that the fact that GM products and non-GM products were treated differently in the EC market was not the central issue; what was more relevant was that the different sets of rules which applied to them were not linked to their origin. Indeed, imported and domestic GM products were treated equally, as well as imported and domestic non-GM products. Though different rules applied to these two categories of products, they were not justified by the origin of the products. It is noteworthy that the Panel decided to analyse the "no less favourable treatment" obligation before the "like products" element. Having reached the conclusion that the complaining country at stake - Argentina - had not been able to prove that its products had been treated "less favourably" than domestic EC products, it did not need to address the issue of likeness between GM and non-GM products.

50. Applying the Panel's reasoning to biofuels might lead to the conclusion that a country could apply different sets of rules to GM and to non-GM biofuels, as well as to certified as opposed to non-certified biofuels and this product differentiation would be consistent with WTO law. Nevertheless, this conclusion would hold only if the measures at stake would not be aimed at *de facto* discriminating foreign products under the disguise of distinguishing them on the basis of some differences unrelated to origin. For example, the way biofuel certification schemes are developed and the opportunities which are given to foreign producers to be part of the process and to get their products certified without incurring prohibitive and unjustified costs and delays would probably be highly relevant to assess whether a "less favourable treatment" is taking place.

[39] GATT Article XX gives countries the legal means to balance their trade obligations with important non-trade objectives - such as health protection, the preservation of the environment or the protection of natural resources - which form part of their overall national policies.
[40] In the *US - Shrimp* case (*United States-Import Prohibition of Certain Shrimp and Shrimp Products,* Appellate Body Report adopted on 12 October 1998, WT/DS58/AB/R), the Appellate Body stated that "It appears to us, however, that conditioning access to a Member's domestic market on whether exporting Members comply with, or adopt, a policy or policies unilaterally prescribed by the importing Member may, to some degree, be a common aspect of measures falling within the scope of one or another of the exceptions (a) to (j) of Article XX.(para 121).
[41] Panel Report, *European Communities – Measures Affecting the Approval and Marketing of Biotech Products (EC–Biotech)*, WT/DS291/R, WT/DS292/R, WT/DS293/R, 29 September 2006, at paragraphs 7.2511 to 7.2516.

Conclusions

51. Under sound strategies and appropriate regulatory frameworks, increased use of bioenergy may represent a way to alleviate the serious problems that most countries face at present with high prices and possible supply disruptions in international petroleum markets, and may facilitate access to energy, especially for poor people in developing countries. Bioenergy may contribute to environmental preservation, by reducing greenhouse gas emissions; provide new opportunities to rural communities, especially in developing countries; and add new value to agricultural commodities. If it keeps up to its promise, genetic engineering may play a role in enhancing bioenergy production and hence making it an increasingly important component of the global energy mix.

52. The use of genetic engineering in the agricultural sector is, however, a controversial issue. While GM coverage worldwide is expanding - the estimated global area of GM crops reached 114 million hectares in 2007 - many concerns exist about the health and environmental impacts of using GM technology in agriculture. As a result, GMOs are highly regulated in many countries and traceability, certification and labelling are instruments used to differentiate GM products from conventional products.

53. The use of GMOs in energy crops production will likely trigger the same concerns. Not only will the existing regulatory frameworks on the use of GMOs and international trade of GMOs apply to GM energy crops, but some specific measures may also be developed. Conversely, it seems that the use of genetic modification during the manufacturing process, i.e. during the conversion of the plant biomass into biofuel, is more acceptable and less prone to criticism.

54. The biofuels certification programmes that a number of countries, companies and NGOs are developing are examples of specific instruments meant to encourage sustainable production of biofuels and biomass.

55. Some doubts have been expressed about the suitability of granting sustainability certification to biofuels produced from GM biomass. The biofuels certification initiatives that rely on existing standards for sustainable biomass production may prohibit the use of GM biomass. On the other hand, biofuels certification will become an important product attribute, since it will be linked to tax benefits, and to the ability to count biofuels towards national targets of fuel blending or renewable energy use. Certification may also become a precondition for consumer acceptability of the product.

56. From a WTO point of view, distinguishing biofuels and feedstocks on the basis of how they have been produced, including their sustainability, remains a complex issue. WTO jurisprudence, however, has proved increasingly flexible to accept the differentiation of products based on their environmental and health impacts through life cycle.

57. Regulatory frameworks, private sector and civil society initiatives, and consumer perceptions will all play a role in the global perspective of producing GMO-based bioenergy.