CONFERENCE HANDOUT

BIOFUELS FOR TRANSPORTATION

GLOBAL POTENTIAL AND IMPLICATIONS FOR SUSTAINABLE AGRICULTURE AND ENERGY IN THE 21ST CENTURY

Venue German Federal Ministry of Economics and Technology (BMWi)
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Conference Secretariat on behalf of BMELV:

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
Ms Ute Peters
Fax: +49 (0)30 726 14 130
Email: biofuels@gtz.de
Further information: www.gtz.de/biofuels-conference

Responsible for the Content of the Conference Handout:

1) Background information: BMELV
2) Excerpts from the Draft "Global Study ": Worldwatch Institute, Washington
3) Results of the regional studies: GTZ
4) Guiding questions for discussion fora: BMELV

DISCLAIMER: The content of the study does not necessarily reflect the view and opinion of the BMELV

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1 Background of the Conference

In view of the forecasted shortages and increasing prices of fossil fuels, climate change, and the need for new income and employment opportunities in rural areas, biofuels have taken centre stage in policy debates.

The use of biofuels is developing favourably worldwide. Brazil, the United States, many European countries and a growing number of countries in South-East Asia are now pinning their hopes on biofuels. Brazil and the United States are the largest producers of bioethanol in the world. China, too, has launched a programme with a view to using ethanol as a fuel.

The Federal Government welcomes and supports this development in the interest of global climate and resource protection and in order to seize the opportunities for rural development. However, the full potential of biofuels is only now becoming apparent.

What is now needed for targeted global action is a comprehensive account of the global options for the use of liquid bio-fuels. This does not only concern their technological potential, but also their sustainable economic potential. The Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) therefore commissioned the German Agency for Technical Cooperation (GTZ) to draw up a study on this global potential, involving the Worldwatch Institute (WWI).

The study aims at presenting the opportunities, but also the limits of global biofuel production and use in terms of energy, agricultural, environmental and developmental policy aspects, as well as in economic terms. The impact of the globally expanding biofuel production on Germany's biofuel sector will also be examined in the process. Finally, recommendations for action for decision-makers in politics and industry are to be derived from the results of the study.

Central elements of the study are:

- consolidation of previous German studies and experience,
- regional studies and workshops in China, India, Brazil, Tanzania as well as in the USA,
- the global analysis and derivation of recommendations for action and
- the incorporation of the results into the international debate.

The regional studies analyse the current market usage of liquid biofuels, new technologies, land availability, relevant trade issues, environmental risks and opportunities, social aspects and many other factors. The global study assesses the potential role of biofuels in the future global energy matrix and in sustainable development. This provides a basis for developing recommendations for policy-makers.

The outcomes of the studies are to be presented and discussed during the conference.

2. Excerpts from the Draft “Global Study”

2.1 Annotated[1] Executive Summary of the Draft “Global Study”

Biofuels: Current Status and Global Potential

The production and use of biofuels have entered a new era of global growth, with both the scale of the industry and the number of countries involved reaching unprecedented levels. Surging investment in biofuel production is being driven by a variety of factors, including the development of more efficient conversion technologies, the introduction of strong new government policies, and, of course, the rising price of oil. Underlying the growing commitment of governments to biofuel development is the desire to find new markets for farmers and their products and to reduce emissions of carbon dioxide and other gases that are contributing to global warming.

The two primary biofuels in use today are ethanol and biodiesel, which can both be used in existing vehicles. Ethanol is readily blended with gasoline, and biodiesel is blended with petroleum-based diesel for use in conventional diesel-fueled vehicles. Ethanol currently accounts for more than 90 percent of total biofuels production, with biodiesel making up the rest. Global ethanol production more than doubled between 2000 and 2005, while production of biodiesel, starting from a much smaller base, expanded nearly fourfold. By contrast, world [fossil] oil production increased by only 7 percent during the same period.

> Compared to petroleum refining, which is developed at a very large scale, biofuel production is lower volume and more decentralized. In the case of biodiesel in particular, where a wide range of plant and animal feedstock can be used, there has been a tendency for rather dispersed production facilities. Producers have the ability to extract raw vegetable oil at one site and send the oil to a different location for processing.
>
> Ethanol fuel production, which is ten times greater than current biodiesel production, has tended to be more geographically concentrated, but is broadly distributed among different facilities within a specific production region. In the United States, it is predominantly concentrated in Midwestern states that have abundant corn supplies, such as Iowa, Illinois, Minnesota, Nebraska, and South Dakota. In Brazil, sugar cane and ethanol production is concentrated in the center-south region, mainly in the state of São Paulo.
>
> Despite the two countries’ somewhat similar overall ethanol output, Brazil has three times more ethanol plants than the United States. Accordingly, the average capacity of plants in the U.S. is three times greater than the average capacity of those in Brazil. The largest plant in Brazil produces 328 million liters per year by crushing sugar cane, whereas in the U.S. the largest corn dry-milling ethanol plant produces 416 million liters per year. There are various reasons for the differences in plant capacities. One key reason corn-to-ethanol plants can be larger is because substantial amounts of harvested corn can be stored for long periods of time, whereas sugar cane must be processed shortly after it is harvested (preferably within 24–48 hours to avoid deterioration of the sugar).

[1] Indented text, tables and figures are taken from individual chapters of the draft “Global Study” submitted by WWI to GTZ on March 16, 2006. They are selected by BMELV in order to provide more details than found in the executive summary of the draft of that date.

A–3. Biofuels as a Percent of Gasoline and Diesel Consumption, by Country, p.296[2]

(Thousand Barrels per Day)

	Year 2004 PRODUCTION Biofuels		Year 2002 CONSUMPTION		Ethanol % of Gasoline & Ethanol Use	Biofuels % of Transport Fuel Use***
Country/Region:	Ethanol**	Biodiesel	Motor Gasoline	Diesel Fuel Oil		
Brazil	260,2		279,1	666,8	48,24%	21,57%
Mauritius	0,4		1,9	7,1	17,39%	4,26%
India	30,1		176,9	791,6	14,54%	3,01%
Cuba	1,1		8,1	26,7	12,01%	3,06%
Swaziland	0,2		1,6	1,4	11,11%	6,25%
Nicaragua	0,5		4,1	7,2	10,95%	4,24%
China	62,9		876,3	1.568,0	6,70%	2,51%
Pakistan	1,7		25,5	147,9	6,25%	0,97%
Guatemala	1,1		18,9	20,2	5,51%	2,74%
Zimbabwe	0,4		7,1	11,4	5,35%	2,12%
France	14,3	6,8	299,4	960,6	4,56%	1,65%
Argentina	2,7		62,1	176,4	4,17%	1,12%
South Africa	7,2		174,7	126,8	3,96%	2,33%
Ukraine	4,3		107,7	100,1	3,84%	2,03%
Thailand	4,8		126,2	277,2	3,66%	1,18%
Poland	3,5		97,8	151,5	3,45%	1,38%
Spain	5,2	0,3	190,0	587,1	2,66%	0,70%
United States	230,6	1,6	8.847,8	3.775,9	2,54%	1,81%
Kenya	0,2		9,0	12,9	2,19%	0,91%
Philippines	1,4		64,1	118,6	2,14%	0,76%
Russia	12,9		600,1	492,1	2,10%	1,17%
Saudi Arabia	5,2		256,2	402,1	1,99%	0,78%
Ecuador	0,8		40,6	45,7	1,93%	0,92%
Sweden	1,7		94,6	95,9	1,76%	0,88%
Indonesia	2,9		255,2	445,2	1,12%	0,41%
Korea, South	1,4		175,6	402,8	0,79%	0,24%
Germany	4,6	20,3	629,6	1.179,1	0,73%	1,36%
Australia	2,2		324,1	243,1	0,67%	0,39%
Italy	2,6	6,3	385,1	599,7	0,67%	0,90%
Canada	4,0		680,2	484,4	0,58%	0,34%
Japan	2,0		1.027,9	1.212,5	0,19%	0,09%
Mexico	0,6		550,6	282,0	0,11%	0,07%
Czech Republic		1,2	44,6	60,1	0,00%	1,13%
Denmark		1,4	45,2	85,8	0,00%	1,06%
Slovakia		0,3	17,0	21,4	0,00%	0,78%
Austria		1,1	49,6	141,5	0,00%	0,57%
Lithuania		0,1	16,9	36,6	0,00%	0,19%
United Kingdom		0,2	488,9	509,7	0,00%	0,02%

*Countries are ranked in this list based on the amount of ethanol produced as a percent of the gasoline demand plus ethanol produced.
** Ethanol production includes fuel, industrial, and beverage production
*** "Transport Fuel Use" includes gasoline & diesel use, plus ethanol and biodiesel production
References: Petroleum data: U.S. DOE - Energy Information Admin., International Petroleum Consumption,
http://www.eia.doe.gov/emeu/international/contents.html; Ethanol data: from F.O. Licht, cited in Renewable Fuels Association, Homegrown for the Homeland: Industry Outlook 2005 (Washington, DC: 2005), p. 14

[2] Indented text, tables and figures are taken from individual chapters of the draft "Global Study" submitted by WWI to GTZ on March 16, 2006. They are selected by BMELV in order to provide more details than found in the executive summary of the draft of that date. Page numbers refer to quoted draft.

Since the 1970s, Brazil has been at the forefront of efforts to produce ethanol from sugar cane, the leading feedstock to date. Three decades of government support and private investment have allowed Brazil to steadily improve the efficiency of its production processes and to make ethanol economical for consumers. During the same period, the United States has been the leader in turning grains (mainly corn) into ethanol fuel, improving efficiency and lowering costs. Germany has been a leader in the large-scale production of biodiesel fuel from rapeseed, a crop commonly used to produce vegetable oil for human consumption.

The recent pace of advancement in technology, policy, and investment suggest that the rapid growth of biofuel use could continue for decades in the future and that these fuels have the potential to displace a significant share of the oil now consumed in many countries. A recent study found that advanced biofuel technologies could allow biofuels to substitute for 37 percent of U.S. gasoline within the next 25 years, with the figure rising to 75 percent if vehicle fuel efficiency were doubled during the same period. The biofuel potential of EU countries is in the range of 20-25% if strong sustainability criteria for land use and crop choice are assumed, and bioenergy use in non-transport sectors is growing in parallel.

The potential for biofuels is particularly large in tropical countries, where high crop yields and lower costs for land and labor – which dominate the cost of these fuels—provide an economic advantage that is hard for countries in temperate regions to match. When petroleum prices are above €41 ($50) per barrel, as they were for most of 2005 and early 2006, ethanol from sugar cane is significantly less expensive than gasoline [see also excerpt Figure 2-1, p. 17 and Figure 2-2, p.18]. It has been estimated that worldwide sugar cane production could be expanded to a level such that this crop alone could displace about 10 percent of gasoline use worldwide. This would allow scores of low-income countries to become significant producers—and potentially exporters—of a valuable new commodity.

Figure 2–1. Cost Ranges for Ethanol Production, 2006

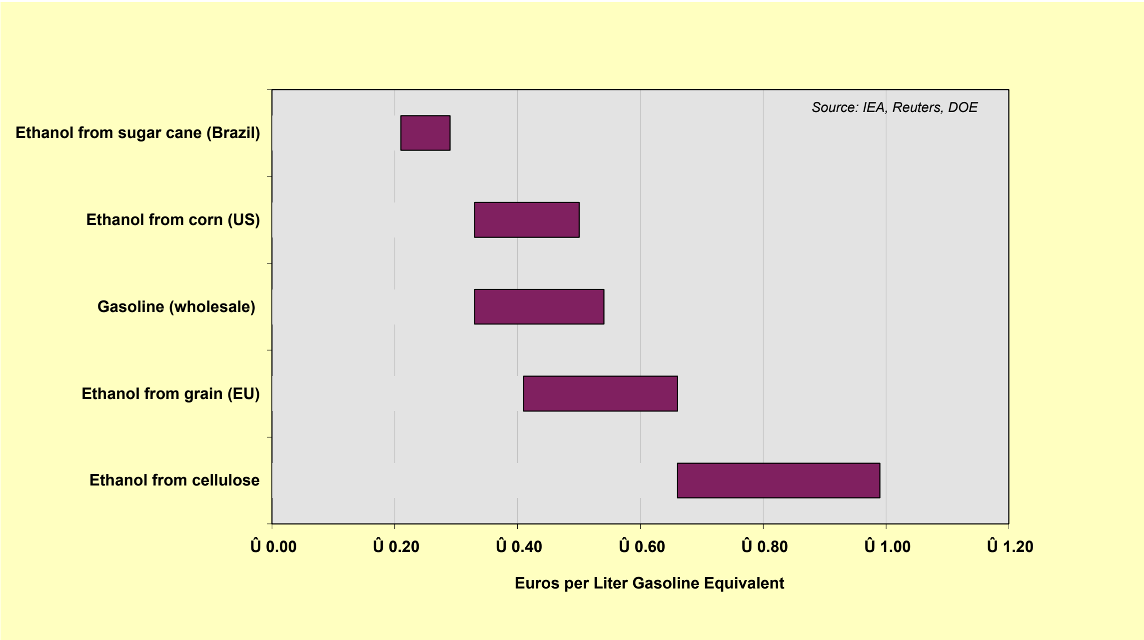
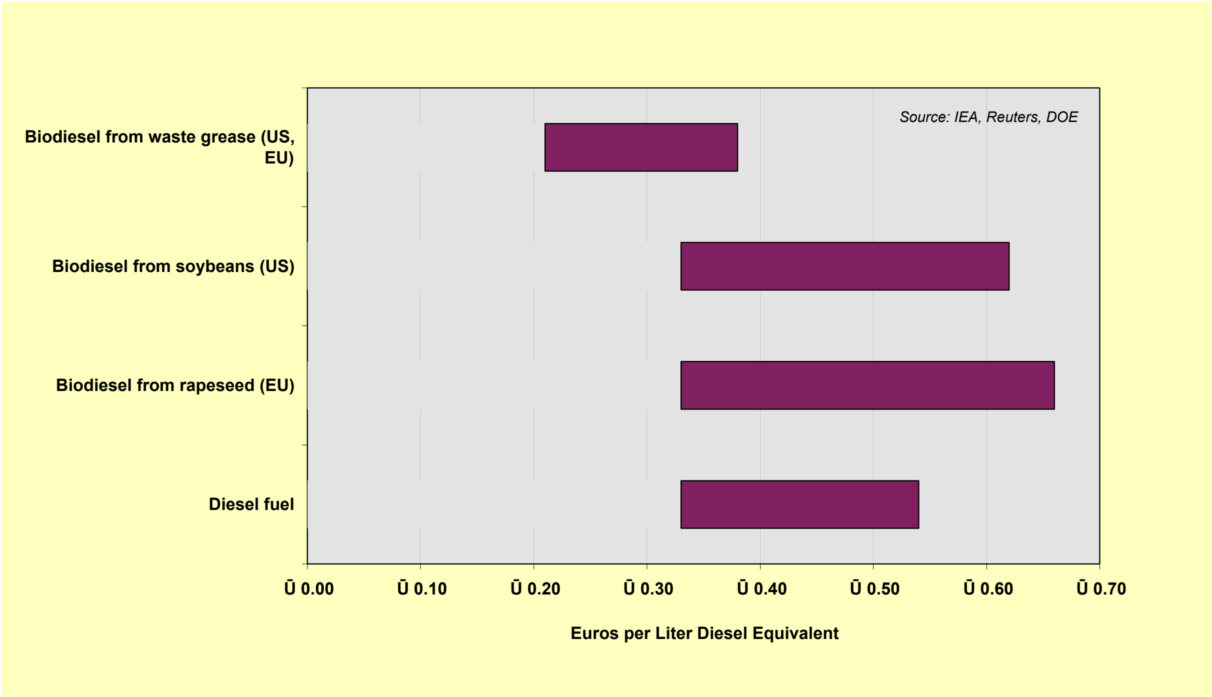


Figure 2–2. Cost Ranges for Biodiesel Production, 2006



This report concludes that biofuels have a large potential to substitute for petroleum fuels, which, together with a host of other strategies, including the development of far more efficient vehicles, can help the world achieve a more diversified and sustainable transportation system in the decades ahead. However, these promises will only be achieved if policies are enacted that steer biofuels in the right direction—policies that will need to be adjusted and refined as the state of knowledge advances and as the risks and opportunities of biofuel development become clearer.

In the coming years, the international development of biofuels and bio-based co-products has the potential to increase energy security for many nations; to create new economic opportunities for people in rural, agricultural areas the world over; to protect and enhance the environment on local, regional, and global scales; and to provide new and improved products to millions of consumers. Key to shaping such a future, in which biofuels are produced sustainably and used on a large scale, is defining clear goals and enacting the policies necessary to achieve them.

New Technologies, Crops, and Prospects

Biomass residues with potential energy uses are diverse. A distinction can be made between primary, secondary, and tertiary residues and wastes (which are available as a byproduct of other activities) and biomass that is specifically cultivated for energy purposes.

- *Primary residues* are produced during production of food crops and forest products (e.g., straw, corn stalks and leaves, or wood thinnings from commercial forestry). Such biomass streams are typically available "in the field" and must be collected to be available for further use.

- *Secondary residues* are generated during processing of biomass for production of food products or biomass materials. They include nut shells, sugar cane bagasse, and saw dust, and are typically available at food and beverage industries, saw and paper mills, etc.

- *Tertiary residues* become available after a biomass-derived commodity has been used. A diversity of waste streams is part of this category, from the organic fraction of municipal solid waste (MSW) to waste and demolition wood, sludges, etc.

Potential sources of biomass energy include energy crops grown on existing agricultural or marginal lands, agricultural residues, organic wastes, and forest residues. Table 6-1 provides an overview of the potential contribution of each of these biomass types to the global energy supply by the year 2050. [see also sidebar 6-1].

Sidebar 6–1. How Much Ethanol Could the Municipal Solid Waste from a City With One Million People Produce

In the United States, the average municipal solid waste (MSW) produced per person is around 1.8 kilograms [per day],which typically contains about 75 percent of mostly cellulosic organic material (waste paper, wood wastes, cardboard, waste paper, and waste food scraps). Thus, a city with 1 million people produces around 1,800 tonnes of MSW in total, or about 1,300 tonnes per day of organic material. With technology that could convert organic waste to ethanol, roughly 330 liters of ethanol could be produced per tonne of organic waste. Thus, 1,300 tonnes per day or organic waste from a city with 1 million people would be enough feedstock to produce about 430,000 liters of ethanol per day, or approximately 150 million liters per year. This is enough fuel to meet the needs of more than 58,000 people in the United States; 360,000 people in France; or nearly 2.6 million people in China at current rates of per capita fuel use.

Source: from Jim Easterly, Easterly Consulting, personal communication with Peter Stair, Worldwatch Institute, March 2006.

Yet bioenergy's potential is enormous. Studies suggest that biomass could potentially supply anywhere between 0 EJ to more than 1,000 EJ of energy by the year 2050. In the most optimistic scenarios, bioenergy could provide for more than two times the current global energy demand, without competing with food production, forest protection efforts, and biodiversity. In the least favorable scenarios however, bioenergy could supply only a fraction of current energy use by 2050, perhaps even less than it provides today.

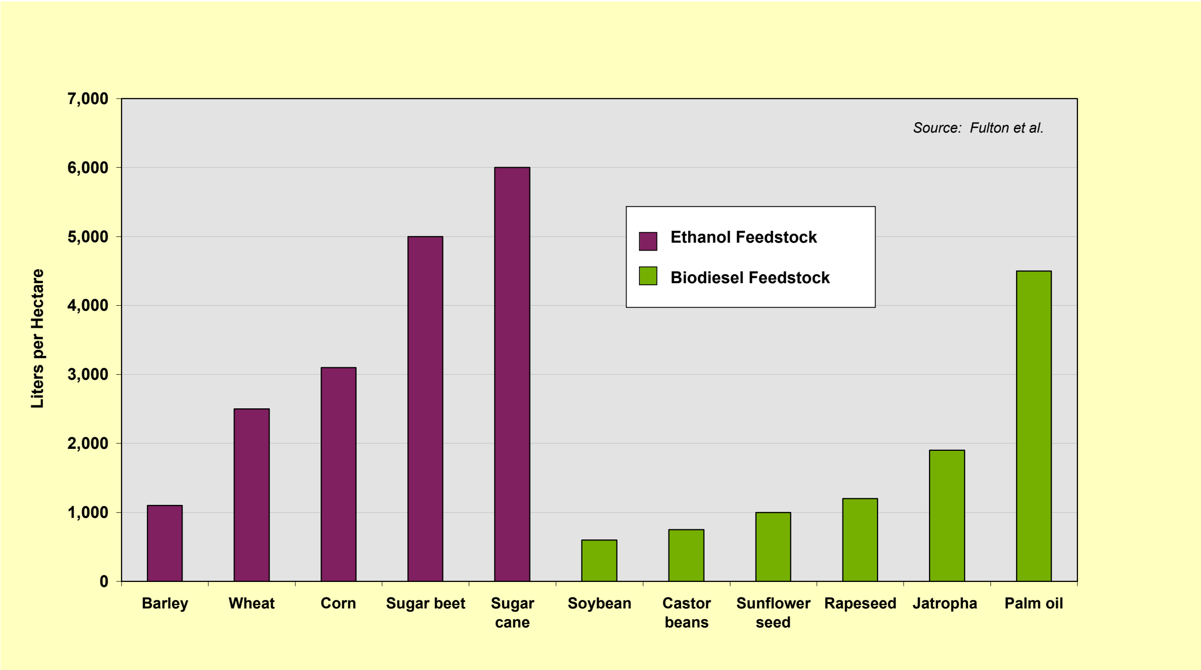
Table 6–1. Bioenergy Production Potentials for Selected Biomass Types, 2050

Biomass Type	Bioenergy Potential (exajoules)	Main Assumptions and Remarks
Agricultural Residues	15–70	• Based on estimates from various studies. • Potential depends on yield/product ratios, total agricultural land area, type of production system. Extensive production systems require leaving of residues to maintain soil fertility; intensive systems allow for higher rates of residue energy use.
Organic Wastes	5–50+[b]	• Based on estimates from various studies. • Includes the organic fraction of MSW and waste wood. • Strongly dependent on economic development and consumption, and as well as use for biomaterials. • Higher values possible by more intensive biomaterials use.
Dung	5–55 (or possibly 0)	• Use of dried dung. • Low range value based on current global use; high value reflects technical potential. • Utilization (collection) over longer term is uncertain.
Forest Residues	30–150 (or possibly 0)	• Figures include processing residues. • Part is natural forest (reserves). • The (sustainable) energy potential of world forests is unclear. • Low range value based on sustainable forest management; high value reflects technical potential.
Energy Crop Farming (current agricultural lands)	0–700 (100–300 is more average)	• Potential land availability of 0–4 global hectares (Gha), though 1–2 is more average. • Based on productivity of 8–12 dry tonne/ha/yr[a] (higher yields are likely with better soil quality). • If adaptation of intensive agricultural production systems is not feasible, bioenergy supply could be zero.
Energy Crop Farming (marginal lands)	60–150 (or possibly 0)	• Potential maximum land area of 1.7 Gha. • Low productivity is 2–5 dry tonne/ha/yr.[a] • Bioenergy supply could be low or zero due to poor economics or competition with food production.
Biomaterials	Minus 40–150 (or possibly 0)	• These provide an additional *claim* on biomass supplies. • Land area required to meet additional global demand is 0.2–0.8 Gha • Average productivity is 5 dry tonnes/ha/yr[a] • Supply would come from energy crop farming if forests are unable to meet this demand.
Total	**40–1,100 (250 –500 is more average)**	• Pessimistic scenario assumes no land for energy farming, only use of residues; optimistic scenario assumes intensive agriculture on better quality soils. • More average range = most realistic in a world aiming for large-scale bioenergy use.

Notes: (a) heating value: 19 GJ/tonne dry matter; (b) the energy supply of biomaterials ending up as waste can vary between 20–55 EJ (or 1,100-2,900 million tonnes of dry matter per year). Biomass lost during conversion, such as charcoal, is logically excluded from this range. This range excludes cascading and does not take into account the time delay between production of the material and its ‘release’ as (organic) waste.
Source: Andre Faaij, Copernicus Institute, Utrecht University, report submitted to Worldwatch Institute, 17 January 2005.

The various biomass feedstock used for producing biofuels can be grouped into two basic categories: the currently available "first-generation" feedstock [see Figure 3-1], which are harvested for their sugar, starch, and oil content that can be converted into liquid fuels using conventional technology; and the "next-generation" cellulosic biomass feedstock, which are harvested for their total biomass and whose fibers can be converted into liquid biofuels only by advanced technical processes.

Figure 3–1. Biofuel Yields of Selected Ethanol and Biodiesel Feedstock

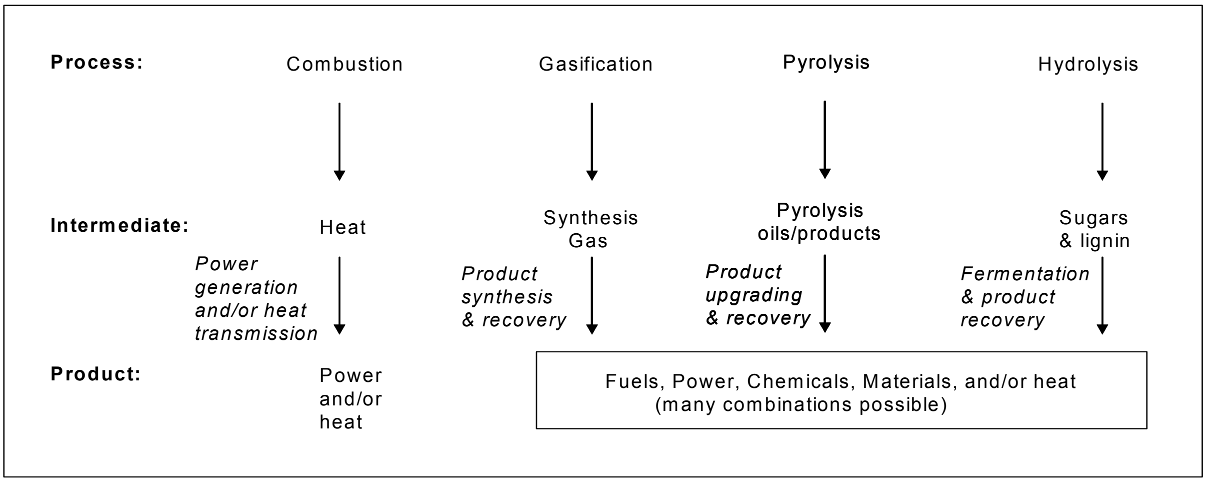


Cellulosic biomass such as wood, tall grasses, and crop residues are expected to significantly expand the quantities and types of feedstock available for biofuel production in the future, as new conversion technologies are developed that enable the production of fuels from these materials. Cellulosic biomass is much more abundant than food crops, and can be harvested with less interference in the food economy and potentially less strain on land, air, and water resources. Promising energy crops include fast-growing woody crops such as willow, hybrid poplar, and eucalyptus, as well as tall perennial grasses such as miscanthus and switchgrass.

The use of "next-generation" cellulosic biomass feedstock has the potential to dramatically expand the resource base for producing biofuels in the future. Technology development efforts to date have demonstrated that it is possible to produce a variety of liquid fuels from cellulosic biomass, for use in existing vehicles. So far, however, the costs of producing liquid fuels from cellulosic biomass are not competitive with petroleum-derived fuels, even with the recent rise in petroleum costs. Various government and industry-sponsored efforts are under way to lower the costs of making liquid fuel from cellulosic biomass by improving the conversion technologies.

Four primary pathways for bioenergy production are highlighted in the figure below. Whereas gasification (another thermochemical pathway) and hydrolysis (a biochemical pathway) can provide a variety of products, the production of liquid fuels for transportation uses is a primary focus of this report. Thus, the following pages and the full report focus mostly on these two pathways.

Figure 5-1 Lignocellulose Processing Pathways



[Source: Darmouth College and NRDC]

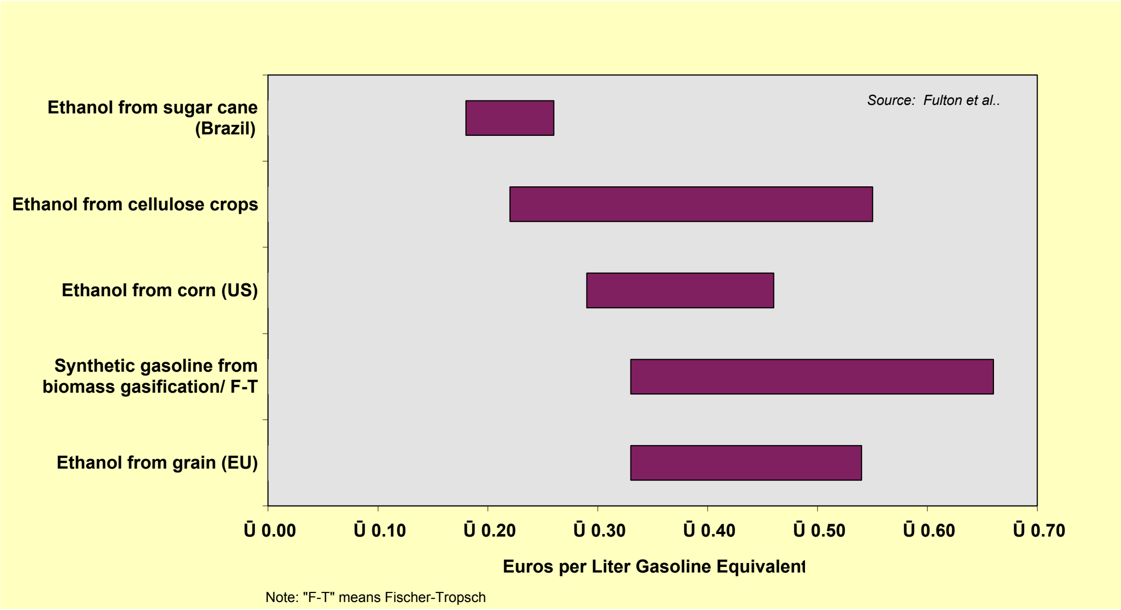
Over the next 10–15 years, it is expected that lower-cost sources of cellulosic biomass (e.g. the organic fraction of municipal waste, biomass processing residues, crop residues, and forest residues) will provide the first influx of next generation feedstock, with cellulosic energy crops expected to begin supplying feedstock for biofuel production toward the end of this period, then expanding rapidly in the years beyond.

For biofuels to reach their full potential in meeting future transportation needs, it is critical that economically competitive technologies that can convert abundant cellulosic biomass resources into liquid biofuels be developed and deployed.
The hydrolysis pathway relies on advanced enzymes that can catalyze cellulose and lignocellulose into sugars and then ethanol, while the gasification and F-T synthesis pathway uses high temperatures, controlled levels of oxygen, and chemical catalysts to convert biomass into liquid fuels, including synthetic diesel and DME. The gasification pathway, also called the BTL pathway, generally requires a larger sized facility and a larger capital investment, and improvements appear to be occurring more slowly than the advances in biotechnology that are propelling the hydrolysis pathway. However, the BTL pathway can also process lignin and can thus achieve higher liquid yields, displacing more petroleum. Accordingly, one detailed analysis of different conversion pathways concluded that a combination of the hydrolysis and BTL pathways was the most economical and energetically efficient.

It is expected that the combination of cellulosic biomass resources and next-generation biofuel conversion technologies will be able to fully compete with conventional gasoline and diesel fuel without subsidies within the coming decades.

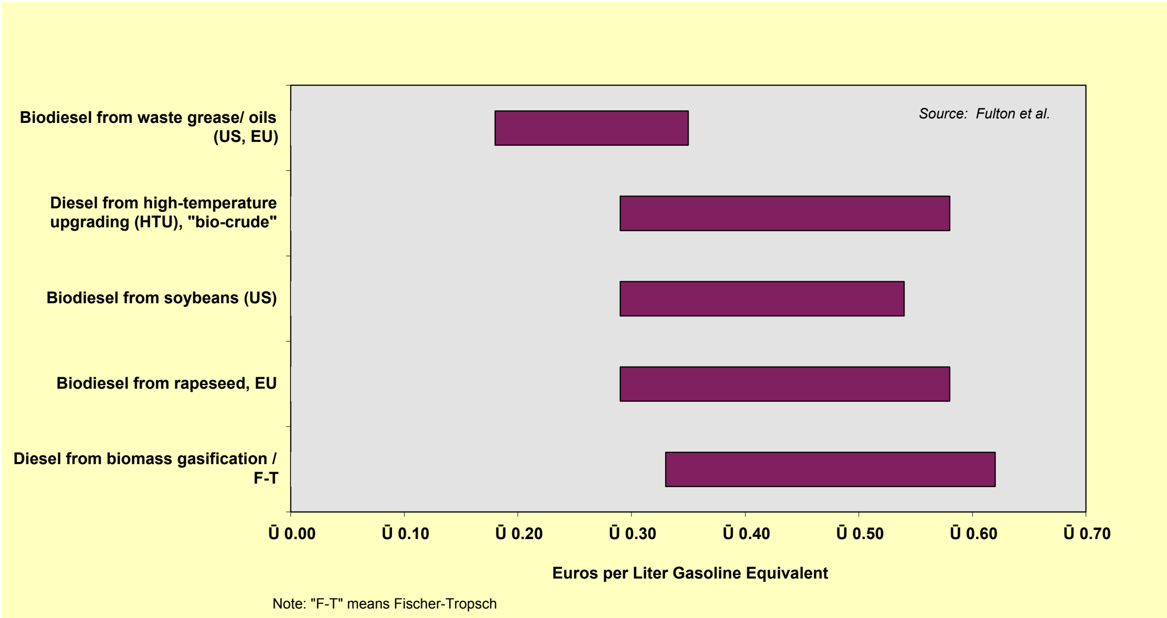
Various efforts are under way to estimate the anticipated costs for biofuels in the future as progress is made in reducing the costs of advanced “next-generation” biofuels. Figure 5-2 and Figure 5-3 summarize the results of an International Energy Agency study that estimated the costs of biofuels after the year 2010, comparing both first-generation and next-generation technologies for producing gasoline and diesel substitutes. The lowest cost biofuels are expected to continue to be ethanol produced from sugar cane and biodiesel produced from recycled cooking oil and waste grease. Beyond these two least cost options, the costs for producing next-generation biofuels are expected to be in a range that should make them generally competitive with first-generation technologies. The ability of next-generation technologies to use abundant cellulosic feedstock that do not rely on food crops offers the promise of dramatically expanding the amount of biofuels that could be produced for transportation needs in the future.

Figure 5–2. Cost Ranges for Ethanol Production after 2010



Estimates of the longer-term potential for harnessing biomass energy range widely and depend on factors such as the extent to which the yields of both food and energy crops can increase, the size of the human population, and the per capita human demand for food and land. Theoretically, biomass supplies could be huge, rivaling current oil supplies.

Figure 5–3. Cost Ranges for Biodiesel Production After 2010



The study concludes [3.8. Conclusion] that over the next two decades, existing starch, sugar, and oilseed crop varieties will continue to provide the bulk of the biomass supplies used for biofuel production. Biofuels grown in tropical areas are cheaper and can displace a larger share of petroleum than biofuels produced with more temperate feedstocks. European countries will likely find it preferable to import biofuels rather than attempt to grow all of their own. The United States may be able to produce more indigenous biofuel, but will ultimately face similar limitations.

Since the conversion technologies are on the verge of viability, continued research and development could be helpful, but extensive deployment is perhaps more important. This will allow operators to streamline new facilities while also reducing the risk perceived by investors looking at an “unproven” technology.[3]

Key Economic and Social Issues including Agriculture and Rural Development

Petroleum is a highly concentrated energy resource, and the world’s current transportation systems are almost completely dependent on it. As a result, the world economy is/could be at risk if oil supplies are disrupted in any of the relatively few countries that are significant oil exporters. Concentrated wealth, social tensions, and inadequate political institutions have left many of these countries as less than secure suppliers of the world’s most vital commodity. Biofuels will bring a much broader group of countries into the liquid fuel business, thereby diversifying supplies and reducing the risk of disruption. And because they can be produced in most regions of the globe, the risks inherent in transporting these fuels long distances will also be reduced. In the long run, this is likely to help stabilize fuel prices.

Large-scale production of biofuels will tend to increase the price of agricultural commodities. This can benefit farmers but will hurt those who can barely afford food. However, the situation is more nuanced than many have portrayed it to be: for example, the meat industry will benefit

[3] [Note: Alternatives like hydrogen or biogas have not been taken into account]

from the increased production of high-protein feeds that are the co-products of corn ethanol, soybean biodiesel, and other biofuel production. And many of the world's hungry are also farmers. The poorest people will benefit more from the cultivation of biofuels if they are involved in the "value-added" stages of their production, such as processing and refining. In remote areas, poor farmers could benefit by producing their own fuels.

Many of the countries that consume large quantities of transportation fuels have limited land available for producing biomass feedstock, which leaves them unable to produce more than a fraction of their transportation fuels from domestic biomass. This will likely encourage many industrial countries to consider importing biofuels and to push for elimination of the tariffs and other trade barriers that have so far limited biofuel trade. Ongoing WTO negotiations aimed at liberalizing trade in agricultural commodities are likely to spur the move to freer trade in biofuels, offering an opportunity for countries to provide new agricultural revenues as an offset to the loss of trade-distorting agricultural subsidies.

> The conclusion further elaborates that as the demand for non-fossil liquid fuels grows, countries will increasingly adopt and refine standards for biofuel quality and support advancements in compatible transportation infrastructure. However, careful policy planning will be needed to ensure opportunities for sustainable trading relationships that support socio-economic development in the world's rural and agricultural regions.

[With regard to impacts on Agriculture and Rural Development (Chapter 8 of the "Global Study"), the study concludes:]

> Continued expansion of biofuel production will increase global demand for agricultural products and result in the creation of new jobs at every stage of the production process, from harvesting, to processing, to distribution. As more countries become producers of biofuels, their rural economies will likely benefit as they harness a greater share of their domestic resources.
>
> But not everyone will benefit equally. Of all the participants in the biofuel economy, agribusinesses are most assured to profit, since mechanized harvesting and production chains are the easiest option for rapidly scaling up biofuel production. Large-scale agricultural processors and distributors will be responsible for supplying most of the refined fuels as well. The development of cellulosic conversion technologies will only further exaggerate the advantages of those interests with large pools of financial capital.
>
> As policy makers proceed with biofuel programs, they will need to decide to what extent they want to encourage small farmers or laborers to share in the profits. If this is a priority for governments, then policy options include well-enforced labor standards and profit-sharing agreements, possibly using existing models in the states of São Paulo in Brazil and Minnesota in the United States. On the processing side, governments can support smaller-scale producers and farmer cooperatives by requiring fuel blenders to purchase their fuel from them at fair prices.
>
> When considering biofuel programs for their capacity to promote rural development, decision makers in industrial countries must remain mindful of just how important agriculture is to the economies of the developing world. Advocates of rural development at home might consider to what extent they also care about development in other countries that face similar challenges in their agricultural sectors. Restrictive tariffs can benefit rural communities in industrialized countries while harming those in less wealthy countries.
>
> A biofuel industry that is locally oriented—in which farmer-owners produce fuel for their own use—is more likely to guarantee benefits to a rural community. In these situations,

farmers may risk bad seasons and poor harvests, but, by adding value to their own products and using these goods locally, they are also less vulnerable to external exploitation and disruptive market fluctuations. Although liquid fuels produced at home are often used for cooking or electricity, rather than transportation, it is worth noting that readily available technologies to convert “modern” biomass into energy promise to be a more directed way to alleviate poverty, especially in more remote, oil-dependent regions.

Environmental Issues

Petroleum fuels have exacted a heavy environmental toll on the planet, and their impact is likely to worsen as dirtier supplies are tapped. As an alternative, biofuels offer the opportunity to reduce the emissions of both greenhouse gases and urban air pollutants. Their cultivation could cause huge disruptions in land use, but, if managed properly, the cultivation of energy crops could also facilitate the sequestration of carbon in the soil and the protection and restoration of ecosystems otherwise degraded by human activities.

One of the largest questions raised about biofuels is their net energy balance, particularly the question of whether the bio-based fuels produced contain more useful energy than the (fossil) fuels required to make them. This was a greater concern a decade ago than it is today, since advances in technology have improved production efficiency, giving virtually all current commercial biofuels a positive fossil energy balance. Plants use photosynthesis to convert solar energy into chemical energy, and as technologies improve, the amount of fossil fuels used to produce the crops and convert them to biofuels will continue to decline.

There are two primary measures for evaluating the energy performance of biofuel production pathways. These are:

- *Energy balance*—the ratio of energy contained in the final biofuel to the energy used by human efforts to produce it. Typically, only fossil fuel inputs are counted in this equation, while biomass inputs, including the biomass feedstock itself, are not counted. A more accurate term for this concept is *fossil energy balance*, and it is one measure of a biofuel’s ability to slow the pace of climate change.
- *Energy efficiency*—the ratio of energy in the biofuel to the amount of energy input, counting all fossil and biomass inputs as well as other renewable energy inputs. This ratio adds an indication of how much biomass energy is lost in the process of converting it to a liquid fuel, and helps to measure more- and less-efficient conversions of biomass to biofuel.

Table 10–1. Fossil Energy Balances of Selected Fuel Types

Fuel (feedstock)	Fossil Energy Balance (approx.)	Data and Source Information
Cellulosic ethanol	2–36	(2.62) Lorenz and Morris (5+) DOE (10.31) Wang (35.7) Elsayed et al.
Biodiesel (palm oil)	~9	(8.66) Azevedo (~9) Kaltner (9.66) Azevedo
Ethanol (sugar cane)	~8	(2.09) Gehua et al.

		(8.3) Macedo et al.
Biodiesel (waste vegetable oil)	5–6	(4.85–5.88) Elsayed et al.
Biodiesel (soybeans)	~3	(1.43–3.4); Azevedo et al. (3.2); Sheehan et al.
Biodiesel (rapeseed, EU)	~2.5	(1.2–1.9) Azevedo et al. (2.16–2.41) Elsayed et al. (2–3) Azevedo et al. (2.5–2.9) BABFO (1.82–3.71); depending on use of straw for energy and cake for fertilizer; Richards (2.7) NTB (2.99) ADEME/DIREM
Biodiesel (sunflower)	3	(3.16) ADEME/DIREM
Biodiesel (castor)	~2.5	(1.5); Kaltner (2.1–2.9) Azevedo
Ethanol (wheat)	~2	(1.2) Richards (2.05)ADEME/DIREM (2.02–2.31) Elsayad et al. (2.81–4.25) Gehua
Ethanol (sugar beets)	~2	(1.18) NTB (1.85–2.21) Elsayad et al. (2.05) ADEME/DIREM
Ethanol (corn)	~1.5	(1.34) Shapouri 1995 (1.38) Wang 2005 (1.38) Lorenz and Morris (1.3–1.8); Richards
Ethanol (sweet sorghum)	~1	(0.91–1.09) dos Santos
Diesel (crude oil)	0.8–0.9	(0.83) Sheehan et al. (0.83–0.85) Azevedo (0.88) ADEME/DIREM (0.92) ADEME/DIREM
Gasoline (crude oil)	0.80	(0.84) Elsayed et al. (0.8) Andress (0.81) Wang
Ultra low sulfur diesel	0.79	Elsayed et al.
Gasoline (tar sands)	~0.75	Larsen et al.

Note: These ratios do not count biomass inputs. Here, petroleum fuels cannot have a balance greater than 1 because crude oil is counted as an energy input, while biofuels processed entirely with non-fossil fuels could have a balance of infinity. The ratios for cellulosic biofuels are theoretical.[Source: as quoted in the table]

Ethanol feedstock such as sugar beets, wheat, and corn have been criticized because their fossil energy balance is close to 1, a threshold many consider the line between an energy sink and an energy source. But this view fails to account for two important nuances. First, ethanol is a liquid fuel that has qualities that make it useful in the existing transportation infrastructure. Since the natural gas and coal used to produce ethanol do not have this quality, it can be practical to lose energy in the process of converting these fuels into ethanol. Second, even crude petroleum must be refined into usable liquids.

Diesel and gasoline have fossil energy balances between about 0.8 and 0.9, numbers that are more relevant for comparison than 1.

Clearly, some biofuel production pathways are more efficient than others, with geography being the principle determinant of efficiency. Since transportation energy accounts for only a small share of a biofuel's overall energy use, this suggests that it would be more energetically efficient for countries with temperate climates to import biofuels (e.g. made from sugar cane or palm oil) than to produce them at home. It would be more efficient to transport the final fuels, rather than just the feedstock, because the fuels are more energetically dense.

It is generally acknowledged that biofuels produced from temperate oil seeds, sugar beets, wheat, and corn have limited ability to displace other fuels, because of either their low yields or high input requirements. However, this feedstock is still more energetically efficient than cellulosic biofuels, when considering all of the energy inputs including the biomass used to provide the energy needed for the conversion process. While cellulosic conversion technologies will improve over time, in the near term, cellulosic biomass has the greatest potential as a fuel to provide process energy for conventional (first-generation) biofuels, providing a means to significantly improve the overall fossil energy balance of these fuels. As cellulosic conversion becomes more viable, analysts should continue to evaluate the most efficient uses of cellulosic biomass, raising the importance of "energy efficiency" metrics as opposed to measures of fossil energy.

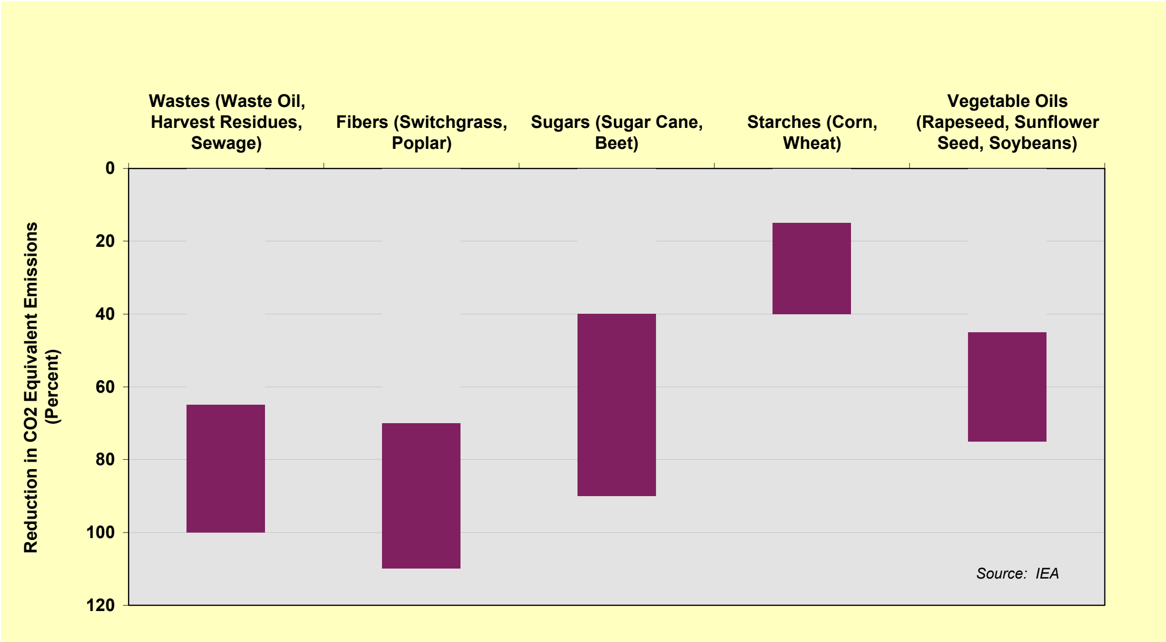
When considering strategies for slowing the pace of climate change, the fossil energy balance of different biofuel production pathways can be a useful measure of their relative effectiveness. It is worth emphasizing that the fossil energy balance of biofuels could theoretically approach infinity, but only if renewable energy alone is used to cultivate, harvest, refine, and deliver biofuels. However, fossil energy balance does not take into account other ways that biofuel production contributes to climate change, such as changes in land use.

Biofuels have great promise for reducing the transport sector's contribution to global climate change. Today, transportation is responsible for 25 percent of the world's greenhouse gas emissions, and that share is rising. A dramatic increase in the production and use of biofuels has the potential to significantly reduce those emissions, particularly with the development of advanced biomass technologies that rely on agricultural wastes and dedicated cellulosic crops such as switchgrass. However, if biofuels are produced from low-yielding crops and are grown with heavy inputs of fossil energy on previously wild grasslands or forests, they have the potential to generate as much or more greenhouse gas emissions than petroleum fuels do.

Figure 11-1 shows the range of estimated possible reductions in emissions from wastes and other next-generation feedstock relative to those from current-generation feedstock and technologies.

Figure 11–1.: Reductions in Greenhouse Gas Emissions per Vehicle-Kilometer, by Feedstock and Associated Refining Technology

[for biofuels from fibers and wastes, cellulose to ethanol through enzymatic hydrolysis provides the greatest potential for reductions, but gasification and conversion to diesel and DME provide similar reductions. Assumed for advanced technologies that biomass provides both the feedstock and much of the process energy.]]

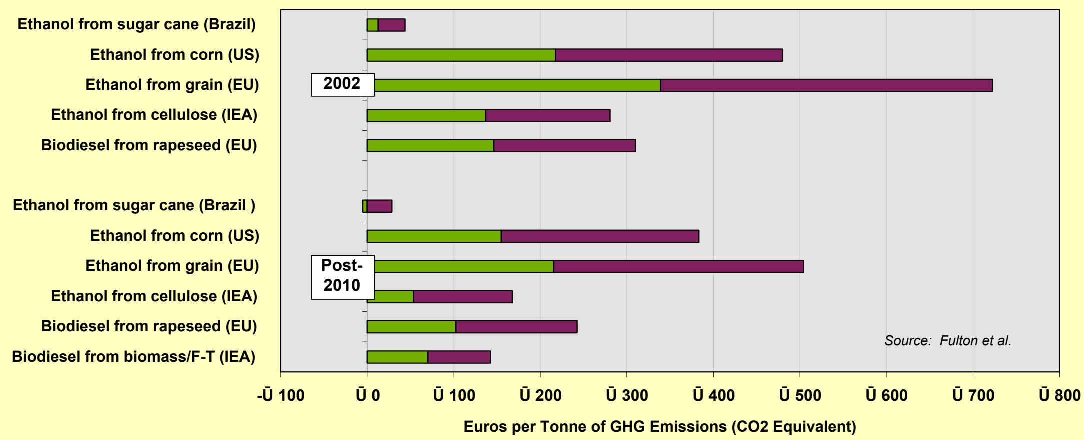


Biofuels are currently a relatively expensive means of reducing GHG emissions relative to other mitigation measures, according to analyses from many countries, with the cost of CO_2-equivalent emissions reductions exceeding €135 per tonne ($163/tonne), according to estimates analyzed by Fulton et al. (2004) (see Figure 11-2). The one exception is Brazil, where pure ethanol sold for nearly 40 percent less than the gasoline-ethanol blend in late 2005 (even accounting for the lower energy content in ethanol).

Biofuel production offers similar risks and opportunities with regard to the health of the world's ecosystems. Expanding the cultivation of biofuel crops has the potential to contribute to soil depletion and erosion, habitat loss, and reduced biodiversity. On the other hand, cellulosic biofuels could be produced from perennial grasses and trees that protect lands vulnerable to erosion and restore lands degraded by overuse. By diversifying monoculture ecosystems, such crops could also serve to increase local biodiversity. For these benefits to be realized, the expansion of biofuel production will need to be accompanied by a new generation of clear and strict land-use laws, particularly in countries with tropical forests that are at risk of destruction.

Replacing a portion of petroleum fuel with a biofuel generally brings a reduction in vehicle emissions of sulfur, particulates, and carbon monoxide. However, particularly in engines poorly calibrated to run on biofuels, nitrogen oxide emissions can increase, and in low-level blends with gasoline, ethanol can cause increased emissions of volatile organic compounds. Increasingly stringent standards for petroleum-based fuels will tend to reduce the emissions advantages offered by conventional biofuels, but the next generation of biofuels, including Fischer-Tropsch diesel and dimethyl ether (DME), can be tailored to meet certain emission specifications. Not only in developing countries, ethanol and biodiesel could play a significant role in improving urban air quality and helping to phase out lead-based and otherwise toxic fuel additives.

Figure 11–2.: Biofuel Cost per Tonne of Greenhouse Gas Reduction



Note: Ranges were developed using highest cost/ lowest GHG reduction estimate, and lowest cost/ highest GHG reduction estimate for each option, then taking the 25% and 75% percentile of this range to represent the low and high estimates in this figure. In some cases, ranges were developed around point estimates to reflect uncertainty.

Currently, tropical plants have more-favorable energy ratios because they grow in more ideal conditions for using sunlight and water and because they are often cultivated manually, with fewer fossil energy requirements and fewer inputs of fertilizer and pesticides. Temperate biofuel production pathways are usually less efficient, though they have become significantly more efficient in recent decades as agricultural practices have improved and fuel production mills have streamlined their operations. In the future, the energy cost of producing biofuels from lignocellulosic biomass will likely continue to exceed that of producing biofuels with conventional starch, sugar, and oil, but these lignocellulosic biofuels will bring with them greater quantities of residue bioenergy to use as processing energy.

The study further concludes that in general, any plan to promote the production and use of biofuels on a large scale must be part of a broader strategy to reduce total energy use in the transport sector. In addition to ending subsidies for conventional fuels (and for unconventional petroleum fuels), governments must encourage the development of lighter, more fuel-efficient vehicles, and promote and support smarter urban design and mass transit**.**

Market Introduction and Technology Strategies

The trend in biofuel production has been toward larger-scale conversion facilities. This is likely to continue, particularly since future facilities for converting lignocellulosic feedstock into biofuels are expected to be even larger (and more capital-intensive), and significant economy-of-scale advantages are expected to reduce the cost of production. However, the relatively dispersed nature of crops and the high cost of transporting solid biomass will put upper limits on the future scale of biofuel plants.

The development of biofuel facilities that deploy cellulosic biomass conversion will require substantial capital. Since investment in large new technologies is inherently risky, governments will need to play a key role in helping to reduce some of the risks involved, including assuring that the infrastructure is in place for transporting biofuels and integrating them into the transportation fuel market.

In order to be added to fuel tanks and combusted in vehicle engines, biofuels must be processed to consistent standards, though warmer temperatures tend to allow a larger margin for error. Vehicle manufacturers typically warrantee ethanol blends of 10 percent or less with gasoline in conventional spark-ignition engines. Specially designed flex-fuel vehicles can run on a range of ethanol-gasoline blends. Biodiesel blends of as high as 20 percent are authorized in the warrantees for most compression-ignition engines, and in a few instances warrantees allow 100 percent biodiesel. Other biofuels, such as straight vegetable oil, methanol, DME, and biogas require more extensive engine modifications.

Biofuels can generally be distributed via the petroleum distribution infrastructure, though in some cases special measures must be taken. Ethanol has a high affinity for water, which can cause it to separate from gasoline. For this reason, colder climates may require dedicated ethanol pipelines, which are the cheapest means of fuel distribution. And because of the relatively high solvency of ethanol and biodiesel, their introduction into tanks and facilities previously used only for petroleum-based fuels may initially cause a release of deposits left by gasoline and diesel.

With its success in commercializing sugar cane ethanol, Brazil has accumulated a reservoir of experience that will prove valuable for countries developing new biofuel programs. As other countries develop expertise in cultivating new crops and utilizing new technologies for converting these into fuels, they can expedite both the displacement of petroleum and global economic development by sharing their knowledge. This interchange of technology and ideas offers an opportunity to promote the sustainable use of biofuels. As the next generation of these fuels is developed, it will be important to develop efficient systems for harvesting, pre-processing, and delivering new types of feedstock to processing facilities.

Policy Recommendations

> In 2006, the increased demand for oil worldwide has kept prices high, and the situation is not expected to change anytime soon. The rapidly industrializing economies of China and India in particular are projected to increase their consumption of petroleum fuels dramatically in the coming decades, as levels of consumer spending and car ownership rise. These and other developing countries are projected to account for more than two-thirds of global energy demand by 2030.

To achieve a rapid scaling-up in biofuel production that can be sustained over the long term, governments must enact a coordinated set of policies that are consistent, long-range, and informed by broad stakeholder participation.

Supportive government policies have been essential to the development of modern biofuels over the past two decades. Blending mandates, tax incentives, government purchasing policies, and support for biofuel-compatible infrastructure and technologies have been the most successful in fostering biofuel production. Countries seeking to develop domestic biofuel industries will be able to draw important lessons—both positive and negative—from the industry pioneers: Brazil, the United States, and the European Union.

Efforts to commercialize new energy crops will require particular attention from governments, many of which already possess national agricultural policies that have a significant impact on the choice of which crops to grow. Government policies can help assure that particular crops are grown on lands that are appropriate for them. For example, perennial grasses for biofuel production may be grown on erosion-prone land that would be inappropriate for annual row crops. The environmental benefits of energy crop production can be “monetized” with the help of government programs, such as payments or tradable credits for benefits such as reduced runoff of soil and agro-chemicals into streams, and greenhouse gas benefits related to increased storage of carbon in soils.

In the future, biofuel promotion policies should be tied to criteria that ensure sustainable production methods and equitable distribution of production revenues. They should also be crafted in the context of larger transportation goals: reducing petroleum subsidies and increasing the taxes on petroleum are indirect ways to promote biofuels while also helping to lessen the use of oil. Measures to increase efficiency remain the cheapest way to alleviate the pollution and security risks associated with petroleum use.

As biofuels are increasingly traded across international boundaries, biofuel standards can help ensure that the industry develops without exploiting laborers or degrading the resource base. Initially, these standards can be based on existing certification schemes for forestry and farming practices. It is important that such ecological and social standards not be unduly burdensome on infant biofuel industries, nor should they be surreptitious trade barriers.

The emerging biofuel industry also faces challenges in obtaining financing for the first risky, commercial-scale systems for producing biofuels from cellulosic biomass. Governments and international financial institutions can play a critical role in providing financing and taking other actions to help reduce financial risks, in order to help the industry move quickly through early commercialization barriers for these technologies.

The large variety of vegetable oils and animal fats that can be used for biodiesel production, and the variability in fuel characteristics that can occur with biodiesel produced from this feedstock, means that fuel quality specifications require particularly close attention for biodiesel. The European Union and the United States have developed their own unique biodiesel standards and are continuing to work to improve these standards. With worldwide demand for biodiesel escalating rapidly, there is a growing need for international collaboration on biodiesel standards and fuel quality in order to facilitate trade.

Collaboration between industry and government will be essential to ensuring that sustainable feedstock supplies are developed. In addition, some form of certification will be needed to verify the sustainability of feedstock production. This is particularly true with regard to greenhouse gas impacts, where countries are working to achieve measurable, verifiable reductions in carbon emissions. Based on lessons learned from organizations such as the Forest Stewardship Council, the approach used to establish policies and standards for feedstock sustainability should be transparent, independent, and participatory—and it should not be used as a Trojan horse for introducing trade barriers.

It is also essential that governments promote biofuels within the context of a broader transition to a more efficient, less polluting and more diversified global transport sector. These fuels must be part of a portfolio of options that includes dramatic improvements in vehicle fuel economy, investments in public transportation, better urban planning, and smarter and more creative means of moving around a village or across the globe. In combination with improved vehicle efficiency, smart growth, and other new fuel sources such as biogas—and eventually even renewable hydrogen or electricity—biofuels can drive the world towards a far less vulnerable and less polluting transport system.

Key overarching recommendations for accelerating the development of biofuels, while maximizing the benefits and minimizing the risks, include:

- **Strengthen the Market**. Biofuel policies should focus on market development. An enabling environment for renewable fuel industry development must be created in order to draw in entrepreneurial creativity, private capital, and technical capacity.
- **Speed the Transition to Next-Generation Technologies.** Policies are needed to expedite the transition to the next generation of feedstock and technologies that will enable dramatically increased production at lower cost, combined with the real potential for significant reductions in environmental impacts.
- **Protect the Resource Base.** Maintenance of soil productivity, water quality, and myriad other ecosystem services is essential. The establishment of national and international environmental sustainability principles and certification is important for protecting resources as well as maintaining public trust in the merits of biofuels.
- **Facilitate Sustainable International Biofuel Trade.** The geographical disparity in production potential and demand for biofuels will necessitate the reduction in barriers to biofuel trade. Freer movement of biofuels around the world should be coupled with social and environmental standards and a credible system to certify compliance.
- **Distribute Benefits Equitably.** This is necessary in order to gain the potential development benefits of biofuels. Enabling farmers to share ownership throughout the production chain is central to this objective.

[The recommendations are further elaborated in the next Chapter which is an excerpt of the Recommendations of the draft “Global Study”.]

2.2. Recommendations for Decision Makers (Shortened[4] Version of Chapter 21, Draft "Global Study")

21.1 Introduction

[…] Some governments have already enacted policies to support biofuels production, use, and increasingly, trade. While specific policy decisions will have to be made on a country (or regional) basis, according to unique natural resource and economic contexts, this chapter elaborates overarching recommendations to policy makers and describes a number of policy options that governments should consider enacting in order to advance sustainable biofuel development. These recommendations are drawn from experiences to date with biofuels, with other fuels, and with other renewable energy technologies, and are also based on the challenges that biofuels face today.

21.2 Developing the Biofuel Market

The most efficient way to hasten a rapid expansion of biofuel production is for governments to create a policy environment that is conducive to private sector investment in the development of these fuels. Policy makers should focus on creating a predictable and growing market for biofuels. In turn, this market will draw in the substantial capital, entrepreneurial creativity, and competitive spirit required to advance technologies, build production infrastructure, and achieve the learning and the economies of scale that are necessary to drive down costs.

Policy actions that governments can take right away, at no- or low-net cost, to help develop the market include:

- **Enact Tax Incentives.** Tax incentives have been used effectively in Brazil, Germany, the United States and other countries to spur biofuel production and reduce biofuel prices at the pump. They can also be used to encourage certain types of biofuels development (i.e. small-scale, community oriented), and to speed the adoption of biofuel-compatible vehicles and other infrastructure. (Tax incentives for biofuels can be made revenue-neutral in a number of ways, for example, by increasing taxes on petroleum-based fuels. Governments that subsidize fossil fuels can save revenues and reduce the need to subsidize alternative fuels by reducing direct and indirect subsidies for the petroleum sector.)

- **Establish Mandates and Enforcement Mechanisms**. Blending mandates create consistent and expanding markets which, in turn, attract private sector investment in technology advancement, infrastructure development, etc. Voluntary targets have been somewhat effective, but have not achieved the level of success provided by mandatory schemes coupled with credible enforcement mechanisms. Enforcement is important to ensure that targets are met. Mandates can be designed to steadily increase requirements for the share that must come from next-generation fuels. Mandates should also be tied to environmental and social standards (see below).

- **Use Government Purchasing Power**. The enormous purchasing power of governments has been used successfully in a number of countries to expand the market for various products. Government purchasing of vehicles and fuels that are certified under sustainability schemes (which could eventually involve a GHG component), could provide a powerful market driver. Local governments can switch entire fleets to vehicles that run on biofuels, as

[4] The Chapter 21 of the Draft 'Global Study' submitted 16.3.2006 was shortened in the introduction only.

many have already done. National governments could gradually increase the share of their fleets that are fueled by biofuels and ramp up to 100 percent; the one exception might be tactical military vehicles.

- **Collaborate to Set International Fuel Quality Standards.** While many nations have developed or adopted biofuel quality standards, others still need to take this step. In order to develop a significant international biofuel market, fuel quality standards need to be agreed upon and enforced on the international level. This is necessary for consumer confidence and will gain increased importance as international trade in biofuels expands. Automakers need assurances of consistent fuel characteristics so they can honor vehicle warranties.

- **Account for Externalities**. Although it is extremely difficult, decision makers should find ways to assign monetary values to currently uncounted externalities, including local and regional pollution, health problems, climate change, and other environmental costs, as well as potential benefits, such as job creation and rural revitalization. This can be done through tax increases or incentives. For example, in the case of climate change, this could be done through a carbon cap and trade system.

- **Facilitate Public-Private Partnerships.** Public-private partnerships have resulted in important technological breakthroughs that have led to dramatic cost reductions (for example, in the enzymes needed for the breakdown of cellulose via enzymatic hydrolysis), and will continue to play an important role in advancing next-generation technologies.

- **Increase Public Awareness.** Consumer demand could be a powerful driver of the renewable fuels market. Strategies to increase the public's awareness and comfort level with biofuels include various forms of public education, such as formal awareness campaigns, public announcements, university research, and signage along highways. Typically outside the government sphere, but also potentially effective, informal methods include discussions on radio, blogs, podcasts, and the use of biofuels in movies and television shows.

Mandates paired with subsidies have also proven to be an effective combination for biofuels industry promotion; however, subsidies should be phased-out once a domestic industry has been established. Subsidies are often difficult to discontinue once created, so phase-outs should be strategically designed into the enabling legislation. For instance, subsidies for current-generation biofuels can be phased out first, while those for next-generation feedstock and refineries continue.

Mandates and subsidies can be used together, or as in the case of Germany, mandates can follow subsidies. As of early 2006, the German government was in the process of replacing subsidies for first-generation biofuels with a fuel blending mandate, but intended to maintain the subsidy for next-generation biofuels to further their development. In the near term, the promotion of biomass generally for various bioenergy and materials uses will help develop the biomass feedstock production sector while the next-generation liquid fuel conversion technologies are developed.

Public concerns regarding possible environmental impacts of biofuel feedstock cultivation must also be addressed if biofuels are to gain broad public acceptance. (See section 21.8 for a discussion of certification and other proposed schemes to assure the sustainable production of biofuels.)

21.3 National and International Research, Development, and Demonstration

To date, the world's engineering and scientific skills have not been focused coherently on the challenges associated with large-scale biofuel development and use. Thus, there is enormous potential for dramatic breakthroughs in feedstock and technologies that could allow biofuels to play a major role in enhancing energy security, reducing greenhouse gas emissions, and providing much of the world community with economical transport.

There has been a tremendous surge in private-sector investment in biofuels in recent years, but this investment tends to be oriented towards short-term and high payoff research. There are many long-term research needs that governments are best-suited to address; governments and international organizations should help coordinate public and private efforts by bringing together the best minds and resources in national research facilities, universities, civil society, and industry. Because intermittent funding seriously hampers research efforts, funding for research, development, and demonstration must be consistent as well as long term. It is worth noting that much of this research will likely have applications across the broader agricultural sector.

Research is needed to develop feedstocks and sustainable management practices, as well as technologies for harvesting, processing, transporting, and storing feedstock and fuels. Research is also required to better understand the potential environmental and societal impacts of biofuels throughout the entire supply chain. Some of the key areas for further research are provided below.

21.3.1 Feedstock Production

- **Improve Conventional Feedstock**. Improve energy yields of conventional biofuel feedstock, while developing sustainable management systems that include minimizing the use of chemical inputs and water. This includes research into the potential for modifying food crops to maximize both food and cellulose (for energy) production.

- **Develop Next-Generation Feedstock**. Improve management techniques and develop high-yield perennial crops suited for biofuel applications that require low inputs, are location-appropriate, and can improve soil and habitat quality while sequestering carbon. (See Chapters 4 and 12.)

- **Advance Alternatives to Chemical Inputs**. Research the potential for integrated pest management and organic fertilizer development and use, including the use of mixed-crops, rotations, and other management techniques.

- **Assess the Risks of Genetic Modification**. Potential risks and costs and the chances of developing and using GM crops must be fully assessed to determine if benefits outweigh costs. It is also important to research and develop appropriate safeguards for the use of genetically modified industrial organisms required [for] biological conversion of cellulosic biomass to ethanol.

- **Supplement Environmental Life-Cycle Studies**. Research is needed to fill in gaps in the existing body of analyses, with regard to global climate impacts and effects on local and regional air, soil, water quality, and habitat, including a better understanding of the impacts of land-use changes, and of the scale of N_2O emissions from feedstock production, and their potential impact on the global climate. (See Chapters 11, 12 and 13.)

- **Develop Methodology for Measuring Life-Cycle GHG Emissions**. There is need for consistent, internationally used, methodology and assumptions for measuring GHG emissions associated with the production and use of biofuels from various feedstocks, associated land-use changes, management strategies, and processing practices. (See Chapter 11.)

21.3.2 Feedstock Collection and Handling

- **Improve Equipment and Harvesting Practices.** Agricultural equipment and harvesting practices must be optimized for both crop and residue harvesting, to maximize economic benefits for farmers while minimizing soil compaction, and minimizing interruption of primary food crop harvests.

- **Ascertain Sustainable Residue Removal Rates.** Conduct research to determine sustainable extraction levels of agriculture and forestry residues to maintain soil quality under varying conditions.

- **Improve Waste Handling Practices**. Develop optimal means for safe handling and collection of various municipal waste resources (e.g. waste grease, cardboard).

- **Optimize Feedstock Storage and Transport Methods**. For example, improved methods are needed to prepare feedstock for transport by reducing bulkiness and water content.

21.3.3 Processing

- **Maximize Efficiency of Input Use**. Technologies and practices should be optimized to make the most efficient use possible of water, energy, chemicals, and other inputs, and to minimize waste through recycling of wastewater, waste heat, etc.
- **Advance Biorefinery Concept**. Continue support for the integration of a variety of related operations, including use of animal and crop residues as fuel feedstock and/or for process energy, and co-products (such as wet-distillers grain) as animal feed, bio-plastics, etc.

21.3.4 Fuel Distribution and End Use

- **Advance Fuel and Power Train Development**. Combine research and design needs to optimize engine designs/performance to take full advantage of the unique properties of biofuels (e.g., higher oxygen content, higher octane, etc.), and evaluate fuel specification criteria to identify potential fuel changes that could improve engine performance.

- **Optimize Vehicles** (including fine tuning control systems and engine designs) to run on varying blends for maximum fuel efficiency and minimum emissions across the full range of potential blend mixes.

- **Develop Materials**. Research materials for higher-quality tubes, hoses, and other connectors to reduce evaporative emissions.

- **Develop Fuel Additives**. Additives are needed to reduce emissions of NO_x and other harmful emissions from blends of fossil and biofuels.

21.3.5 Demonstration and Field Trials

In addition to resource assessments, policy analyses, and applied crop and processing research, it will be critical to advance experience on the ground, in varied settings. This will include field trials of new energy crops in different climate and soil conditions. Pilot conversion facilities, using cutting-edge technologies, should be funded and constructed in a wide range of settings in order to work out any related problems or challenges and to develop and make use of in situ ingenuity and local adaptation of technologies, crops and crop management, and handling systems. This should involve well-organized and well-monitored efforts in several countries (with varying climates, soil conditions, social structures, etc., including heavily degraded and desert lands), to build a body of practical experience over the next decade.

21.3.6 Outreach/Extension

On the national level, findings need to be disseminated to producers through demonstration projects, extension services (where they exist), and other farmer education mechanisms, including feedstock demonstration projects. In addition, farmers will need the appropriate know-how, capital, and incentives to risk planting new crops and to follow best practices; sustainable management and good crop choices should be tied to existing or newly created government incentives.

21.3.7 Information Clearinghouse

On the international level, a clearinghouse is needed to gather and make available to the global community, information regarding relevant findings and experiences with biofuel research and policies from around the world.

21.4 Incentives for Rapid Deployment of Advanced, Low-Impact Biofuels and Technologies

Policies are needed to expedite the transition to the next generation of feedstock and technologies that will enable dramatically increased production at lower cost, combined with the real potential for significant reductions in environmental impacts. To date, high costs and risks associated with construction of new conversion facilities have hampered the development of next-generation fuels. Governments and international financial institutions can play a critical role in reducing financial risks and providing low-cost capital, helping industry to move quickly through early commercialization barriers.

Specific actions that governments can take to expedite the transition include:

- **Provide Incentives**. Create tax structures and other incentives that favor next-generation biofuels and integrated “biorefineries” and bioprocessing.

- **Enact Mandates**. Mandates could require that an increasing share of total fuel come from advanced feedstock and technologies.

- **Fund RD&D**. More sustainable feedstock and technologies are needed, including those that provide enhanced net reductions in GHG emissions and in fossil inputs.

- **Support Farmers**. Farmers will need information, crop and equipment assistance, market access, and other help to make the transition to producing new feedstock.

- **Facilitate Conversion of Existing Plants**. Retraining and retooling are important for converting existing plants to next-generation facilities.

- **Provide Capital**. Low-interest, long-term loans and risk guarantees are required to facilitate the development of commercial cellulosic refineries and "biorefineries."

- **Encourage the Development of New Uses and Demand for Co-products.**

- **Encourage Technology Transfer.** Transfer of technology and capacity building to countries with nascent industries (particularly those with great potential for producing sustainable feedstock and fuels) will be of utmost importance.

21.5 Infrastructure Development

Ethanol use can increase to 10 percent of non-diesel fuel, possibly more, with minimal changes to current car fleet or infrastructure; biodiesel blends can be higher. To go beyond this, however, governments need to address the 'chicken or the egg' dilemma: vehicles are needed that can run on high-blends of biofuels, but consumers will not buy them without a distribution system that assures access to these fuels; such a distribution system is not likely to develop without the vehicles to demand/use it. This dilemma can be resolved with technologies like flex-fuel vehicles.

To enable the expansion of biofuels, infrastructure changes will also be required on the production side (especially for next-generation biofuel production). New crops and production methods, as well as associated distribution requirements, will necessitate substantial infrastructure planning and development. The existing infrastructure available for the use of agricultural and forestry resources should be evaluated to determine what expansion and refinements are required for renewable biomass resources to play an expanding role in providing sustainable transportation fuel supplies.

To *encourage the necessary infrastructure transition*, governments should:

- **Advance Flexible-Fuel Vehicle Technology**. Governments could advance the development and availability of flex-fuel vehicles, including those appropriate for high-blends, through legislative mandates or softer incentives (like targets—for example, governments could call for 100 percent of new cars available in the domestic marketplace to be biofuel-compatible within 10 years). In promoting FFV's, governments should not allow trade-offs in fuel economy or air quality standards.

- **Promote Use of Flex-Fuel Vehicles**. In addition or instead, governments could establish incentives for consumers who buy such vehicles and use them with biofuels. Governments should also commit to transitioning to flex-fuel vehicles for non-diesel, non-strategic fleets.

- **Require Fuel Companies to Provide Biofuels**. Because of the control the fossil fuel companies hold over fuel distribution and sale in most countries, most governments will have to require that these companies distribute and sell biofuels. Governments could, for example, require that all fueling stations over a certain size convert at least one pump to biofuels (this would have to be phased in as fuel becomes available).

21.6 Optimizing Ecological Impacts

While many perceive biofuels as environmentally beneficial because they are “renewable,” these fuels have the potential to positively or negatively affect the natural world—everything from local soil and water quality, to biodiversity, to the global climate—and human health, depending on factors such as feedstock selection and management practices used. Whether the impacts are largely positive or negative will be determined, in great part, by policy.

As described in detail in Chapters 11 and 12, the most significant potential impacts associated with biofuel production result from changes in land use, including natural habitat conversion. With regard to climate change, land use changes (from razing of tropical forests to replacement of grasslands) for the production of biofuel feedstock can result in large releases of carbon from soil and existing biomass, negating any benefits of biofuels for decades. Therefore, governments must prioritize the protection of virgin ecosystems and should adopt policies that compel the biofuel industry to maintain or improve current management practices of land, water, and other resources.

Next-generation feedstocks and technologies offer the potential to improve soil and water quality, enhance local species diversity, and sequester carbon if lands are managed sustainably. This provides governments with yet another reason to speed the transition.

In addition, national and international standards and certification schemes will be necessary to safeguard the resource base (see Chapter 18 and below). Standards and best management practices take time to develop properly, so it is critical to initiate practical, step-by-step processes that entail consistent progress towards increased sustainability. Work on this has begun but should be supported with more substantial resources and greater international coordination.

Some specific actions that governments should take to help safeguard the environment and human health, while ramping up biofuels production, are provided below.

21.6.1 Feedstock Production

- **Conserve Natural Resources.** Local, national, and regional policies and regulations should be enacted to ensure that impacts on wildlife, and on water, air, and soil quality are minimized. For example, payment systems for irrigation and processing water could be adopted to encourage more-efficient use, and nutrient and water recycling should be encouraged.

- **Protect Virgin and Other High-Value Habitats**. Governments must find ways to protect natural forests, wetlands, and other ecosystems that provide air and water purification, soil stabilization, climate regulation, and other vital services. Options include: enforcing bans on wild land conversion for biofuel feedstock production including strong penalties for noncompliance; using satellite and global imaging technology to track land use changes; tying tax incentives, carbon credits, qualification for government purchase, sustainable production certification, etc. to the maintenance of natural ecosystems; and requiring land preserves. Large-scale feedstock producers can be required to set aside a share of their land as natural reserve, as the Brazilian state of São Paulo has done.

- **Encourage Sustainable Crops and Management Practices.** Extension services for farmers should provide them with the proper resources and incentives to select sustainable crops (particularly native species that reduce need for water, fertilizers, and pesticides), reduce the frequency of tilling and replanting, and provide habitat for wildlife. They should encourage sustainable management practices, including minimal use of inputs, buffer zones between waterways or wildlands and crops, intercropping, crop rotation, and adjusting harvest schedules to minimize conflicts with wildlife, etc. Subsidies can be linked to meeting specific criteria.

- **Improve Degraded Lands**. Encourage the rehabilitation of degraded lands through appropriate perennial feedstock production.

- **Maximize GHG Benefits.** Feedstock should be selected to maximize GHG reductions (see Chapters 4 and 11).

21.6.2 Processing, Distribution, and End Use

- **Develop Licensing Procedures**. Require that refineries meet strict environmental standards that include efficiency of water use and recycling, air and water pollution controls, etc.

- **Promote Use of Renewable Process Energy**. Provide incentives to use biomass as process energy and guarantee fair access to the grid for sale of excess electricity.

- **Establish Emissions Standards for Biofuels**. Just as regulations exist for conventional fuels, they are necessary for transport and combustion of biofuels. Regulations are needed to minimize spills and hydrocarbon emissions during transport and fueling, and to minimize evaporative and combustion emissions from storage, handling, and combustion stages of the supply chain.

- **Encourage Rapid Transition to High-Blend Fuels**. High blends with properly optimized vehicles can minimize a variety of harmful emissions. High biodiesel blends, particularly in urban areas of developing countries (where there may be weak emissions standards), can reduce public health risks, especially from particulate emissions. Cities can commit to shifting public buses and other government vehicles to 100 percent biodiesel over a few years.

- **Encourage Biofuels for a Range of Uses**. In developing countries where lead is still used as a transport fuel oxygenate (particularly in Africa), ethanol should be phased in rapidly to replace it. Biofuel (especially pure biodiesel) use for marine applications is particularly beneficial and should also be encouraged. Biofuel use for agricultural machinery (as in Germany), and construction and other heavy equipment (that is generally far more polluting and has much slower turnover rate) should be encouraged as well.

21.7 Promote Rural Economic Development

21.7.1 Maximizing Rural Development Benefits

If biofuels continue their rapid growth around the globe, the impact on the agricultural sector will be dramatic. Increased jobs and economic development for rural areas in both industrialized and developing countries is possible if governments put the appropriate policies in place and enforce them. The more involved farmers are in the production, processing, and use of biofuels, the more likely they are to benefit from them. Enabling farmer (and forest material producer) ownership over more of the value-added chain will improve rural livelihoods. This not only helps improve the well-being of farm families, it increases the positive effects as greater farm income is circulated in local economies and jobs are created in other sectors. As biofuel industries grow, this multiplier effect will have impacts on the regional, national, and international levels.

In regions where access to modern forms of energy is limited or absent, government and development agency support for small-scale biofuel production can help provide clean, accessible energy that is vital for rural development and poverty alleviation.

Specific options for decision makers include:

- **Support Cooperatives and Small-Scale Ventures.** Governments can provide support for cooperatives and small-scale biofuel production facilities—for example through tax structures that give preference to small-scale feedstock and fuel production, or preferential government purchasing from farmer/cooperative-owned facilities. Cooperatives allow small- and medium-size producers to share more in the economic gains of the biofuel industry and to negotiate on more equal footing.

- **Require Purchasing from Small Producers.** Governments can require fuel purchasers and distributors to buy a minimum share from farmer or cooperatively owned facilities.

- **International Development Funding.** National and international development institutions can provide financial and technical support for small-scale biofuel initiatives for rural energy provision and poverty alleviation.

- **Technical and Materials Assistance.** Governments, civil society, and others can provide assistance to small landholders in obtaining materials (energy crops seeds and seedlings), know-how, and market access.

Government action to assure markets for biofuels and for energy crops (e.g. mandates, preferential purchasing, etc.) helps give producers the confidence to adopt new crops and crop management systems. In addition to providing markets for their products, ensuring fair prices for farmers is also essential to improving rural livelihoods.

21.7.2 Social Responsibility

Biofuel industries should be developed in a socially responsible way, advancing human rights and encouraging equitable distribution of benefits. This will entail the protection of small landowners, assurance of workplace safety, workers' rights, child labor laws, and other basic tenets of sustainable development. Policies and actions that can help achieve these goals include:

- **Enact and Enforce Anti-Oligopoly Laws.**
- **Include Social Criteria in Certification Definitions**
- **Enact or Strengthen Land Titling and Ownership Laws**.

Within nations, strong environmental and social protections, rule of law, public accountability, and other aspects of good governance will be key to the overall success of biofuels. Transparency of government funding, taxation, and other revenue streams will be essential to assure that the money is actually reaching the intended beneficiaries and used for the intended purposes. Among nations, the degree to which many developing nations will play a role in the emerging energy economy will depend largely on trade rules and technology transfer.

21.8 Encourage Sustainable Trade in Biofuels

For the dozens of nations that are just beginning to develop biofuel industries, many decisions will have to be made, including the type, scale, and orientation (i.e. for domestic consumption, for export, or both) of production. Policies will need to be designed appropriately based on domestic economic and resource situations. Decision makers will also need to factor in the impacts that the policies of other nations (e.g. the EU biofuels initiative) and international trade policies (e.g. continuing trade liberalization negotiations) will have on their own biofuel and biofuel feedstock markets. In general biofuels trade restrictions should be removed over time, respecting the fact the countries with nascent industries will want to protect them.

Integrated planning is necessary at the national level so that short-term or sectoral interests do not take precedence over strategic national priorities. For instance, market incentives at the microeconomic level might encourage biofuel exports. But when other factors—such as national employment needs, domestic energy needs, trade balance, food security and land use concerns, the condition of domestic transport and export infrastructure, and GHG reduction obligations—are taken into consideration, exports might not make sense at that point in time. In many nations **where displacing a modest amount of petroleum could make a significant difference, production for domestic use should take precedence over export**. Alternatively the value of biofuels as an export commodity to earn foreign exchange may be preferable in other instances. National leaders will need to weigh these factors for their countries.

Well-established markets such as the United States and the EU have enormous fuel needs and growing energy security concerns. Due to policy initiatives actively promoting the use of biofuels, **markets in these countries are large enough to accommodate both domestic production and imports** (and the more rapidly biofuel-compatible transport infrastructure is phased in, the faster their biofuels markets will grow). International trade may help to ease fuel supply issues, linking a larger number of producers in order to minimize the risk of supply disruption. Also as renewable fuel use becomes more widespread, opportunities for countries with more developed biofuel industries to export their technologies will expand.

Some agriculture incentive programs in wealthy countries have been blamed for supporting food production in a way that harms competitors in developing countries. These could be transformed into programs that instead support biofuel production, a process that has begun in Europe and is being discussed in the United States. While this is a step in the right direction, **replacing highly subsidized and protected commodity food production in rich countries with highly subsidized and protected biofuel production is not the aim**. Biofuel support strategies must be planned with gradual phase-outs, or other means of moving beyond the subsidies once they are no longer necessary.

Trade and the Environment
Energy crops and biofuels may be categorized as agricultural goods under the WTO Agreement on Agriculture. Industry proponents may seek an exemption from the Agreement's restrictions on domestic price supports by including biofuels subsidies in the so-called "Green Box." To qualify for Green Box status the incentives must be "non-trade distorting," meaning they do not affect global market prices. This will be a difficult test to meet if financial incentives for biofuels are tied to production levels, especially if the trade grows to a significant size. The more that incentives are clearly tied to producing public goods, such as clean water and air, wildlife habitat preservation, carbon sequestration and soil erosion control, unconnected to crop yields and refinery production levels, the more likely they are to pass muster.

Alternatively, if biofuels are categorized as industrial goods, they may qualify for treatment as "environmental goods." To be included in such a category they should be required to meet strict environmental standards for their production.

Developing countries have traditionally fought attempts to differentiate among traded goods based on Process and Production Methods (PPMs). However, some biofuels producers in developing countries could rank quite well in a scheme based on production standards. For example, the ethanol industry in Brazil has generally achieved very low net GHG emissions. (For more information on trade and biofuels, see Chapter 9.)

Standards and Certification
There are increasing calls in Europe and elsewhere for traded biofuels to be certified based in social and environmental standards. This could provide a means of ensuring that the production of these fuels provides net positive impacts for the planet and for society. However, if not developed in a participatory, transparent way, such a certification scheme could be viewed as a means for industrialized countries to erect new trade barriers to protect their domestic biofuel producers.

A certification framework based on sound standards could become a critical driver to facilitating development of sustainable trade in biofuels. A compromise must be reached between developing complicated certification schemes to ensure long-term sustainable biomass trade on the one hand and putting safeguards in place quickly to direct the rapidly growing market on the other. The *incremental* development of such a certification scheme is probably the most feasible option, allowing for gradual learning and expansion over time. Existing certification schemes provide useful models. While not all biomass types may fulfil the entire set of sustainability criteria initially, the emphasis should be on the continuous improvement of sustainability benchmarks.

While a certification scheme should be thorough, comprehensive, and reliable, it should also not create a significant hurdle for nascent biofuel industries. Criteria and indicators should be adaptable to the requirements of different regions, and be mindful of the implementation costs. It will be important to pair any certification scheme with technical assistance, incentives, and financing, so that small- and medium-scale producers can qualify as readily as large-scale producers. Furthermore, it is important to ensure that any standards and certification schemes for biofuels address the issue of possible leakage effects, through which benefits gained in one location could “leak away” to another. (For a more information see Chapter 18.)

Moving forward, additional research will be needed to determine whether an independent international certification body for sustainable biomass is feasible. This should be done in collaboration with a consortium of all stakeholders in the biomass-for-energy production chain. At this stage, and at later steps in the development process, public information dissemination and support will be critical.

3. Results of the Regional Studies

3.1 Biofuels for Transportation in China

China was selected as a pilot country for one of the four regional studies because energy consumption in China is expected to increase considerably over the next few years. The Chinese Government started promoting biofuels several years ago. For German industry, investment opportunities will arise in plant engineering and other areas. In addition, there is a need to appraise China's role as importer in terms of its impacts upon global markets.

Current situation

Current **biodiesel production in China is 50,000 t/a**, mainly from **used edible oil**. Production costs currently range between **0.17 and 0.35 €/l** and are therefore still relatively high compared with costs in other regions (in Germany, substantially higher production costs of 0.68 €/l are assumed). Existing biodiesel facilities and facilities currently under construction will provide a total annual capacity of approx. **2 million tonnes by 2010,** corresponding to about **3% of** predicted **diesel consumption.**

Parameter	***China (now)***	***China (2020)***
Acreage for oil seed plants (million ha)	40	up to 67
Cooking oil (million t/a)	18	70
Biodiesel production (t/a)	50,000-60,000 (2004)	1.5 – 2.0 million (2010) 10.6 – 12 million (2020)
Biodiesel plant capacity (t/a)	82,000 (2004) 241,500 (2006)	1.5 – 2.2 million (2010)
Biodiesel production costs (EUR/l)	0.17 – 0.35 Depending on feedstock	
Biodiesel energy GJ/ha	120	130

In 2004, **1.3 million tonnes** of **bioethanol** were produced (for use as fuel). The Chinese Government provides a subsidy of 137 € per barrel of bioethanol. Five provinces currently operate an admixture obligation of 10% (E10) bioethanol in petrol. The corresponding regulations are currently handled at province level, although the Chinese Government intends to create a national statutory framework for a **nationwide E10** admixture obligation **by 2020**. This would translate into a **demand of approx. 8.5 million t** of bioethanol.
Production costs for bioethanol currently range between 0.23 and 0.38 €/l, depending on a raw material price between 0.16 and 0.32 €/l. In future, bioethanol production will mainly be based on sweet sorghum and manioc (cassava). In the past, production was based on surplus wheat, which is no longer available.

Potential

The Chinese Ministry of Science and Technology (MOST) aims to produce 12 million tonnes of biodiesel by 2020. The **acreage for oil plants** (40 million hectares, 2004) can be expanded to a **maximum of 67 million hectares** (optimistic estimate). Jatropha and a pistachio species are currently under discussion as crop species.

Based on a 10% admixture, even with a conservative estimate there will be a 7-million tonne biodiesel shortage in 2020.

The bioethanol production target for 2020 is between 8 and 20 million tonnes, based on an expansion of the current **acreage from 2.7 million hectares to 7.6 million hectares in 2020.** According to the National Development and Reform Commission (NDRC), based on a 10% admixture domestic production will be sufficient in 2020 (even with a conservative assessment). This assessment assumes that 25% of the required biomass will be covered by foodstuffs.

Parameter	***China (now)***	***China (2020)***
Fuel ethanol output (million t)	1	8 – 28
Total ethanol (million t)	> 3	
Fuel ethanol area (million ha)	2.7	4.3 (2010) 7.6 min. (2020)
Subsidies for ethanol (€/t)	137	0
Mandatory blending (%)	10% in 5 Provinces	10%
Production costs for ethanol (EUR /l)	0.23 – 0.38	
- of which feedstock price	0.16 – 0.32	
Ethanol net energy balance (I/O)	1:1.1 (corn) 1:2.1 (cane) 1:0.7 (cassava)	

According to forecasts, **about 9 million jobs can be created in agriculture and industry** through the production of biodiesel and bioethanol.

Outlook

In order to enable decentralised production of biofuels in China, improvements in the conversion technologies for liquid biofuels are required. Decentralised processing of biomass and suitable wastes into liquid biofuels would enable savings in energy expenditure and avoid transportation costs. China is very interested in the development of biomass-to-liquid (BTL) technologies, particularly in view of the large quantities of agricultural and forestry waste products generated in rural regions of China. Yet despite the fact that the first BTL conference was held in China in 2001, not a single BTL pilot plant is in operation today.
As concerns biodiesel, the market would develop much more quickly if the government were to introduce standards for cultivation, processing technologies and distribution networks. However, instead of national biodiesel standards, **inadequately defined diesel standards are currently applied** in China. For **bioethanol,** the Chinese regulations follow **American standards,** which differ from European standards. In practical terms this will be reflected in higher blending ratios, thereby increasing Chinese demand for bioethanol even further.
Although **the prospects for the international bioethanol trade are good and production costs in China are below the world market price, it cannot be assumed that China will become a global bioethanol supplier. The reasons are limited production capacities and** high domestic demand. In future, China will thus continue to struggle to meet increasing demand for fuels through domestic production of biofuels. China is therefore likely to emerge as a buyer, both regionally and internationally. This will lead to corresponding to prices increases on the biofuel markets. In order to facilitate international biofuel trade, ports with suitable import and export capacities and associated investments are required.

The full regional study entitled "Biofuels for Transportation in China" is available from http://www.gtz.de/en/themen/laendliche-entwicklung/natuerliche-ressourcen/14071.htm

3.2 Biofuels for Transportation in India

India was selected as a pilot country because energy consumption is expected to increase over the next few years. The Indian Government actively promotes the production of biofuels. India offers German industry investment opportunities in the areas of cultivation and processing.

Current situation

India has been operating a **bioethanol programme** for several years, although the programme has been severely hampered since 2002 by crop failures due to drought. Current bioethanol output (for fuel) is **665 million litres**. **Molasses from sugar production** is used as feedstock. Subsidies for sweet sorghum are currently under discussion. The current sugar cane acreage is 4.4 million hectares. The aim is a slight expansion to 5 million hectares by 2007. Nine provinces currently operate an official admixture obligation of 5%. **Production costs** are currently around **0.36 €/l,** which is an average value from an international perspective.

Parameter	***India (now)***	***India (2006/7)***
Fuel ethanol output (million l)	665	823
Total ethanol (million l)	2,000	
Total sugar area (ha)	4,361,000	5,000,000
Mandatory blending (%)	5% in 9 states	
Production costs for ethanol (EUR/l)	0.36	

Biodiesel is a relatively new fuel in India and not yet commercially available at present, although it is already being produced in pilot projects (e.g. Public Private Partnerships involving Daimler Chrysler, Hohenheim University and DEG, and Lurgi, SBT and GTZ). Several states (Andhra Pradesh, Tamil Nadu, Chhattisgarh, Uttaranchal, Rajasthan) have established a policy framework in support of biodiesel.

Potential

Over the medium term, the ethanol programme aims to achieve a **5% admixture in petrol nationwide**. Based on close links with the sugar industry, this is regarded as ambitious but achievable.
The targets for biodiesel production are less clearly defined, since production has only just started. According to information contained in the “Wasteland Atlas”, **68 million hectares of wasteland are available in India** alone. The Indian Government is very hopeful that this degraded land can be cultivated with **jatropha and pongamia**. Based on an assumption of a 20% admixture by 2020, 38 million hectares of wasteland would have to be cultivated, and the current yield of 1-2 t/ha would have to increase to 5 t/ha. Availability of degraded land is limited to some extent due to unresolved ownership issues. In addition, the long-term economic viability of jatropha plantations on degraded soils has not yet been established.

Outlook

Due to high domestic fuel demand, India is likely to emerge as a biofuel importer, rather than an exporter. This is based on attempts to diversify the sources for increasing fuel demand (in 2003 90.4 million tonnes of crude oil were imported, for 2019 crude oil imports are projected at 166 million tonnes). In order to be able to achieve the admixture targets set by the Indian government, significant investments in national production and processing facilities are required. Technology transfer options (e.g. in the field of plant engineering) are of particular interest for German industry.
The regional study is available from http://www.gtz.de/en/themen/laendliche-entwicklung/natuerliche-ressourcen/14071.htm.

3.3 Biofuels for Transportation in Tanzania

Tanzania was chosen as one of the four regional pilot countries as it is a country with great agricultural potential in Africa and is impacted by the changing sugar trade regulations. Currently it does not have a policy framework for biofuels.

Current Situation

Tanzania is totally dependent on the import of petroleum products. The import of petroleum products (1.2 million tons in 2003) accounts for about 40% of all imports to Tanzania, and is thus responsible for a significant fraction of the country's foreign exchange spending. The transport sector consumes more than 40% of the imported refined petroleum products. In 2002, the consumption of petrol and diesel in Tanzania was about 134,000 and 390,000 metric tons, respectively, and for projections of fuel demand to 2010 the Tanzania Petroleum Development Corporation (TPDC) forecasts an annual growth of 5% for both petrol and diesel.

In summer 2005, fuel prices of unleaded petrol ranged between Tshs 1120 and 1195 per litre (i.e. 0.77-0.83 €/L) and diesel prices between Tshs 1075 and 1095 per litre (0.75-0.76 €/l). Tanzania has a complex taxation system for petroleum products consisting of three main taxes (i.e. excise duty, road toll, and Value Added Tax), which together comprise about 40% of the final fuel price charged to the consumers.

Currently, there is **no commercial biofuels production** in Tanzania. However, several stakeholders are engaged in the development of biofuels, such as FELISA (palm oil), KAKUTE, Diligent, PROKON and D1 Oils (jatropha oil) in the field of commercial biodiesel production as well as the 4 main sugar companies (Kilombero Sugar Company, Mtibwa Sugar Estates, Kagera Sugar Limited, Tanganyika Planting Company) in the field of sugarcane-based bioethanol production.

Roughly, the current biofuels activities and opportunities in Tanzania can be divided into large-scale and small-scale approaches. Thereby, **large-scale biofuels production**, such as the production of ethanol from **sugarcane** promoted by the sugar industry, will have a prime focus on biofuels for transportation and will require supportive policies and regulations in place for start-up in order to secure the rather large investment required.

On the other hand, **smaller-scale activities** by organisations such as FELISA and KAKUTE are currently mainly concerned with the creation of rural income and revenue opportunities from **oil seed crops**, either through the production of plant oils (for food and/or fuel) or other commodities such as soap production from jatropha oil.

Potential

A recent assessment by the FAO found that in Tanzania **44.4 million ha of land** is potentially available for (food and non-food) crop production. While these figures present only a broad picture of land use in what is a very large and diverse country, they do suggest that land availability is not likely to be a barrier to bioenergy production in Tanzania.

The following estimate of the potential for bioenergy production from the "potentially available land" (44.4 million ha) can be used to gauge the limits of any real production.

Using a range of biomass production of **75-300 GJ (gigajoules) per hectare per annum**, the limits of bioenergy production in Tanzania would be in the range **3.3 to 13.3 EJ (exajoules) per annum**. This compares with total annual primary **energy consumption in Tanzania of 0.602 EJ**.

	Potential (estimation)
Land area	44.4 million ha (30 very suitable)
Sugar crops	570,000 ha
cereals	24 million ha
Root crops	14 million ha
Energy	3.3 EJ (exajoules)
Palm oil	186 GJ /ha
Jartopha oil	59 GJ/ha
EtOH sugar cane juice	173 GJ/ha
EtOH C-molasses	20 GJ/ha

For an introduction of a biofuels industry in Tanzania, the following expected energy yields for the production of different transport fuels in Tanzania are important, namely biodiesel from palm oil (186 GJ/ha), ethanol from cane juice (173 GJ/ha), biodiesel from jatropha oil (59 GJ/ha) and ethanol from C-molasses (20 GJ/ha).

Sugar crops provide the simplest and most cost-effective feedstock options for bioethanol production, and with the area under sugarcane growing from 23,000 to 39,000 hectares in the last five years alone, increasing availability of suitable feedstock for ethanol production is expected. Current (**2004/2005) production of C-molasses** by the cane sugar industry in Tanzania (about 90,000 tons) could be converted into more than 20 million litres of ethanol per year, or **enough for** a 10 % blend of bioethanol into petrol (**an E10 blend) - or equivalent to nearly 7% of national petrol consumption on an energy basis**. In August 2005, the retail price of petrol in Dar es Salaam was Tshs 1120/litre. At that price, ethanol would be competitive at a retail price of Tshs 729/litre, or about US$ 0.64/litre. Therefore, at **current petroleum prices**, production of ethanol in Tanzania is likely **to be competitive with petrol**.

Current production of oil crops is much lower than even current demand, and a **biodiesel programme** of any real impact would **require considerably more land planted with oil crops** than is currently the case. Oil palm and Jatropha curcas are the two oil crops most likely to be used as feedstock for biodiesel production in Tanzania. Of the oil crops available, oil palm has the highest potential yield of oil per hectare of land harvested. However, there is currently great demand for palm oil for food and other uses, and local production meets less than 5% of this.

There is a current proposal for a ***palm oil*** biodiesel project in the Kigoma region. The proposed project would involve cultivation of 8,000 hectares of oil palm, firstly to produce palm oil to meet local food and soap production demands, and then eventually to produce biodiesel. If the project achieves the target oil yield of **5000 litres/ha**, palm oil production could approach 40 million litres per year. This production would itself not be enough to displace current imports (about 172 million litres of palm oil were imported into Tanzania in 2002). Alternatively, 40 million litres of palm oil could be converted into about 39 million litres of biodiesel. Diesel fuel consumption in Tanzania is projected to be about 700 million litres in 2010. Thus, if all the projected palm oil production in the Kigoma project were to be converted to biodiesel, a 5.7% national blend would be possible (equivalent to 5.2% on an energy basis).

The other crop most favoured as a feedstock for biodiesel production is ***Jatropha curcas***. There is experience in Tanzania of cultivation of jatropha for small-scale oil production, and this has been particularly promising in its demonstration of the potential for aiding rural poverty alleviation and empowerment of women. Cultivation of jatropha around the world has tended to be small scale, and production and yield data for plantation-scale cultivation is limited. The oil yield from jatropha plantations is reported to be about 1600 kg oil per hectare from the fifth year onwards, although some local experience in Tanzania suggests that actual yields in Tanzania may be significantly less than this. On the basis of a yield of 1600 kg oil per hectare, 19,700 hectares of jatropha would have to be harvested to produce enough biodiesel for a 5% national blend with petroleum diesel in 2010.

Outlook

The exploitation of the large resource potential for the production of biofuels in Tanzania is mainly hampered by lack of information. The lack of policies and regulations make investment in the biofuels sector difficult in Tanzania, as the prospective return-on-investment remains largely unclear. In the meantime the Tanzanian Government is well aware of the benefits offered by the introduction of biofuels for transport applications and it is seriously assessing the different options for the development of policies and strategies for an increased use of biofuels.
Activities towards an implementation of biofuels policies are currently mainly driven by the Tanzanian Ministry of Energy and Minerals (MoE). At the expert workshop and policy discussion in Dar es Salaam, which was organised in the framework of this regional study, the representatives of the MoE strongly supported the proposed establishment of a ***high-level Tanzanian Biofuels Task Force*** which shall provide advice and recommendations for the elaboration of biofuels policies and regulations suitable for the Tanzanian framework conditions.

It can be stated, that certainly the production and use of biofuels in Tanzania has the potential to offer **large opportunities for investors**. For the time being, these opportunities have to be carefully identified on a case-by-case basis (in close co-operation with local partners), until the Tanzanian Government has committed itself to actively promote the national biofuels sector development and biofuels market.

The complete regional study "Biofuels for Transportation in Tanzania" is available under: http://www.gtz.de/en/themen/laendliche-entwicklung/natuerliche-ressourcen/14071.htm

3.4 Biofuels for Transportation in Brazil

Brazil was chosen, because it is the biggest producer of biofuels in the world. Brazil has a long history in establishing a biofuel programme. Nowadays, Brazil is also the leading exporter of biofuels worldwide. The study was written by FBDS, a Brazilian private industry foundation, with GTZ professional guidance.

Current Situation

Over the last 30 years Brazil has implemented a very successful renewable energy programme – the **Proalcool**. This was the first large-scale biofuel programme in the world. As a response to the international oil crisis, the programme was installed in 1975 to reduce the country's imports of oil and to promote the production of **bioethanol** using sugarcane as feedstock. In a transition period from the middle of the 90's to 2002, government control of prices and subsidy concession to production and logistics were eliminated for sugar and ethanol. In 2003, the first **"flex-fuel" vehicles** (running on either bioethanol or petrol) were introduced to the Brazilian market and since then, their number has increased steadily. In 2005, sales of flex-fuel cars totalled 855,000.

Brazil's Proalcool has resulted in a number of positive effects, such as the creation of about **625,000 direct jobs** in harvesting and processing, the development of a national technology and a completely mature industry. Besides contributing to better climate protection –namely **46.6 million t reductions of CO_2 emissions** per year - the replacement of gasoline by ethanol provided important savings of foreign currency for Brazil. The avoided fuel imports between 1976 and 2004 represented **savings of US$ 60.7 billion** (Dec 2004 US$).

Today, ethanol from sugarcane grown in the Center-South region of Brazil is by far the cheapest biofuel, thus making the ethanol industry competitive. The financial costs are estimated to be around **US$ 0.18 per litre**. The costs of ethanol production in other countries are significantly higher than those from sugarcane in Brazil. Sugarcane is presently cultivated in about **5.5 million ha**. In 2004 52% of the area was cultivated for the production of ethanol and 48% for the production of sugar. Nowadays, 48% of total gasoline is made from ethanol. Moreover, biofuels for transportation correspond to **22% of total fuel consumption** (incl. gasoline, diesel, biodiesel and ethanol) in Brazil.

Currently, the Brazilian Government is again following a similar strategy through its **Biodiesel Production & Use Programme** in order to mitigate its dependency on fossil fuels and to push socio-economic development in rural areas by graduated tax exemption depending on region and scale of production (**"combustível social"**). However, biodiesel is just in the initial phase, with a chain of production being structured to provide an overall sustainable development of the sector. Currently the acreage for oil seed plants, primarily soybean, totals approximately 23 million ha.

Parameter	Brazil (2004)	Brazil (future)
Fuel ethanol output	12.88 billion litres for fuel	20,5 billion litre of alcohol plus exportations of 5.5 billion litre
Fuel ethanol area (ha)	Sugar in general 5.5 million: 52% for ethanol 48% for sugar	-
Production costs for ethanol	US$ 0.18/litre	US$ 0.107litres
Ethanol net energy balance	1:8.3 (in/out)	1:10.2 (in/out)
Acreage for oil seed plants (ha)	Soy Oil total area: 22 million Palm Oil: Almost 60,000 Castor Oil: 134,000 Sunflower: 52,800	Soy Oil: 100 million Palm Oil: 66 million Castor Oil: 4 million
Biodiesel production	production still in experimental phase	Governments ambition: 2 million t/a (2013+)

Regarding international trade, export market opportunities for ethanol do exist either to countries which use biofuel either directly, in blends more than 70%, or in blends up to 10%.

Potential

According to projections of the sugar/ethanol sector in Brazil, increasing internal and export market demands for sugar and ethanol can easily be met. It is assumed that the industry should be able to produce 33.7 million t of sugar (12.8 M t for internal consumption and 20.9 M t for export) and **26.4 million m^3 of ethanol (of which 4.4 million m^3 for export)** by the year 2015. This will mean an increase of about 230 million t of sugarcane in ten years - a doubling in the ethanol production and an increase of 44% in sugar production.

Considering the potential for biodiesel, soybean oil can have an important role in the first years of implementation of the Brazilian biodiesel programme, as the country is already one of the major world producers of soybean oil. However, for soybean production its low oil content as well as the poor energy balance and the low employment generation impact will have to be taken into account. Furthermore, the expansion of soybean production could expand into sensitive ecosystems if not guided otherwise. Similar problems may occur with other crops relevant for biodiesel production, such as castor oil and palm oil.

Outlook

Bioethanol trade is likely to further extend internationally. Worldwide, sugar production has increased by 50 % from 2004/5 to 2005/6 harvest alone, with biofuels seen as a major reason. Bioethanol trade has increased even more steeply. **More than 50 % of the future international trade is likely to be provided by Brazil.**

In case of biodiesel, Brazil is a potential exporter. Due to limitations for production increase in Europe, Brazilian biodiesel enjoys an unprecedented opportunity to build up market share in the European continent. However, because of the restrictive specifications and national policies for biofuels around the world, the market for biodiesel exports is rather dispersed, inhomogeneous, and faces various trade barriers.

Regarding the biodiesel programme, which has set a 2% biodiesel blending target in January 2006, there is a potential market of about 800 Million litres of biodiesel (B2) per year. From 2013 onwards, a further mandatory increase to 5% biodiesel blend (B5) will be considered, that would create a firm market of 2.4 Billion litres per year. Gains in the Brazilian foreign currency reserves resulting from the prospective reduction of fossil oil and oil product imports, amount to about US$ 160 Millions per year by substituting 2% of petroleum diesel by biodiesel.

Furthermore, the substitution of 1% of the Brazilian diesel consumption by harvesting a virtual selection of different oil crops could result in approx. 190.000 jobs created in rural areas. The option for employment creation emphasises the importance of combining the Biodiesel production programme to the national land use reform.

Concerning the bioethanol sector alone, around US$ 10 Billion of private investment is needed until 2015 in order to meet the national and export market demands for sugar and ethanol as mentioned above.

To expand the biofuel sector, foreign investments will certainly be necessary. Germany has a long tradition of investment in Brazil. Germany could provide processing technology and equipment, as well as know-how on planning and capacity building in addition to providing direct investments. Besides, a major factor in the development of the Brazilian biodiesel programme will be the definition of biodiesel standards (technical, environmental and social) and the formulation of a sustainable global trade strategy.

The complete regional study on Brazil is available for conference participants under: http://www.gtz.de/en/themen/laendliche-entwicklung/natuerliche-ressourcen/14071.htm

4. Guiding Questions for Discussion Fora

Forum 1: Biofuels in developing countries and rapidly emerging economies - Socio-economic and political aspects

- To what extent can and could developing countries benefit from production of biofuels (land availability, volume of output, impact on employment)?
- To what extent will the biofuels value-chain be aimed at meeting national demand and how important will be the regional and international trade in biofuels?
- What agreements (standards) are necessary along the value-chain? How can decentralization of benefits merge with requirements for economic efficiency?

Forum 2: Development of technologies and innovations

- What will be the role of biofuels within a strategy for sustainable transport in the future?
- What is the role of technical standards in supporting biofuels utilization and what is the most appropriate technical standard?
- How can the transfer of technology and expertise be promoted?

Forum 3: Environmental aspects of biofuels

- What is the future development of the energy balances in biofuel production?
- Given that the CO_2-abatement costs for biofuels are comparatively high, how can we rate the contribution of biofuels to climate protection?
- What has to be done to secure a sustainable biofuel-production?

Forum 4: Biofuels in industrialised countries, e.g. Germany

- What is the impact of an arising global biofuel-sector on the European und German biofuels production?
- What is the role of biofuel imports into the European Union in relation to domestic biofuel production?
- What are the next steps required in European and German biofuels politics in order to facilitate the development of biofuel production and use?