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Criteria for Assessing Environmental, Economic, and Social Aspects of Biofuels in Developing Countries

Darmstadt, February 2005

Study commissioned by

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Note on This Report

The German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned a short study from the Öko-Institut (Institute for Applied Ecology) which was intended to provide give an overview of the followins isues:

- ecological, social, and economic impacts of the cultivation of energy crops for biofuels in Developing Countries (DCs) ;
- potential conflicts resulting from the cultivation of energy crops for biofuels in DCs;
- criteria for ensuring sustainable biofuel production in DCs;
- knowledge and research gaps.

The scientific work utilized existing studies, other research results, and information already available within Öko-Institut.

This report summarizes the results of the study. Open issues and questions which could not be adequately addressed are presented in section 6.

The German version of the study also has an appendix with key data for Brazil, and Indonesia, and consideration on biofuels in their national context. This appendix is not included in the English translation.

This brief report is meant to stimulate further discussion, and to act as a starting point for more in-depth analysis in the follow-up work proposed in section 6.

We sould like to thank the BMZ for sponsoring this study, and for giving helpful tips and feedback during the preparation of this report.

All responsibility for its contents remains with the authors.

Darmstadt, February 2005 The Authors

1 Introduction

The role of *bioenergy* within a sustainable energy system will be emphasized, both nationally and globally, more and more in the future (see renewables2004; WBGU 2003). Besides the biomass *wastes*[1] predominantly used up to now, dedicated *energy crops* are also a future option.

Because of the material characteristics of biogenic *wastes,* they will be used predominantly in regional systems while further processing into internationally tradable energy sources will remain the exception[2].

The dedicated *cultivation* of energy plants as renewable raw materials for the chemical and textile industry, or as biogenic energy carriers or biofuels is far more expensive than using biomass residues. Furthermore, dedicated biomass cultivation competes with other land-uses like food and fodder cultivation, and with nature protection. On the other hand, energy crops used as raw materials, energy carriers, or transport fuels could, for example, at least partially replace imports of mineral oil or natural gas in industrialized and developing countries. When used as *non*-energy raw materials, their energy content (heating value) is available for energy use at the end of their "material" life (use cascade).

For *industrialized counties* (ICs), some recent works analyze the sustainability of bioenergy strategies, including the potential role of biofuels (ÖKO 2005; EEA 2003). Results indicate that future developments in agriculture, forest, and waste management will allow for a significant amount of sustainably usable biogenic wastes (wood, sewage treatment gas, residual straw, and manure for biogas) in the near future. Furthermore, current trends in agriculture will "free" land presently used to grow fodder and food, so that dedicated cultivation of "energy crops" will become a relevant potential source of bioenergy, even if nature protection and biodiversity targets are factored in.

Preliminary work on the potential of energy crops in *developing countries* (DCs) indicates an order of magnitude similar to the total transport fuel use of the EU-25 *and* the USA.

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1 These are by-products of material use (e.g., residues and slash from forests and timber production, harvesting wastes, residues from animals and food processing) which could have significant potential. As long as medium-term development of BtL fuels (see footnote 2) and bioethanol from hemicellulose (esp. straw) results in marketable and competitive technologies, at least some of these wastes could be used to supply biofuel exports.

2 The relatively low energy density of residues like woodchips, straw, and manure only allows cost-effective transport distances of some 100 km. There are fully-developed technologies available for decentralizedized use of these local incidental residues. Still, there are conversion processes under development which could process biogenic residues to liquid bioenergy carriers (*Biomass-to-Liquids = BtL*, see section 2), thus overcoming the logistical restrictions. For BtL, residues are especially suitable due to their typically low costs. An exception from the transport constrains is already available today: pellets from wood wastes (e.g., saw dust), but their supply is rather restricted.

If and to what extent this potential for *sustainable* biofuel exports from DCs could be used is *not an academic issue*, but – given rising fossil fuel costs and the tendency of reduced revenues from food and fodder exports[3] – a question to be dealt with within the context of development cooperation.

Here, it must be recognized that the conditions for cultivating bioenergy in DCs are *very heterogeneous* – they are characterized (among other things) by population density and dynamics, natural factors, available infrastructure and capital, and logistical restrictions. One cannot consider "the" DC; instead, a *differentiated analysis* (potentially for clusters or groups of DCs) must be applied.

With regard to differentiation, one must take into account that the question of using endogenous biomass potentials to meet the *domestic demand* – instead of exporting processed biofuels – can only be addressed on a state-wide or regional scale.

In general, endogenous uses require less logistical demands, and, by replacing oil (product) imports, the costs of logistics also drop. With *decentralized conversion* and use, the utilization of *by-products* from biomass processing is usually easier (sites permitting) than for centralized conversion routes. A key argument against decentralized strategies is that the processing in export-oriented *central* plants often allows higher yields, and – due to the economics of scale – less cost (though also less employment).

The potential export value of biofuels must be weighed against the value of substituted imports. Here, the balance of payments of the respective country, its attraction to (foreign) direct investment in export-oriented biofuel supply, and the availability of capital for regionally oriented, decentralized alternatives must be considered.

A comprehensive treatment of these links cannot be given in the short study at hand.

In anticipation of work still to be done (see section 6), the appendix of this report gives a preliminary screening of two countries as examples[4].

3 Any analysis of the future attractiveness of bioenergy cultivation must take into consideration that *both* the global *demand* for food and fooder, and the *supply* of respective quantities are largely uncertain. The development of yields and harvest logistics alone in countries like Russia and China, as well as their nutrition habits significantly influence the world market and thus potential revenues from cultivating food and fodder. Recent price developments for crude oil, cooking coal, and steel clearly show this impact – though for different reasons.

4 The appendix is *not included* in English translation.

2 Bioenergy and Biofuels

Before the potential role of biofuels in DCs is discussed, this section gives a brief overview of the role of bioenergy in energy supply, and discusses the current state of biofuel processing.

In addition, the land-use aspect is touched upon, along with the role of biofuels in industrialized countries.

2.1 The Contribution of Biomass to Energy Supply

Today, all forms of biomass together supply more than 10% of the world energy demand, delivering some 45 EJ – this represents about 90% of the global contribution of *all* renewable energies (IEA 2003).

While bioenergy is decreasing in ICs energy supply [5], biomass is a rather important energy source in developing countries (DCs)[6], as shown in the following table.

Table 1 Primary Energy Demand, Renewables and Biomass in Selected Regions (Year 2000)

data in EJ/a	**total primary energy**	**total renewables**	**total biomass**	**biomass share of primary energy**
Africa	21.5	10.8	10.5	49%
Latin America	18.8	5.3	3.3	18%
Asia	48.2	16.1	15.0	31%
China	48.4	10.0	9.0	19%
Near East	16.3	0.1	0.0	0%
CIS + CEE	43.7	1.7	0.6	1%
OECD	223.3	12.7	6.8	3%
World	**420.3**	**56.7**	**45.2**	**11%**

Source: rounded figures from CIP (2004), based on IEA (2003), authors' computations

The major share of today's bioenergy use is supplied by *wastes,* and in a few (but relevant) regionals unstustainable use of forests, and bushlands, respectively.

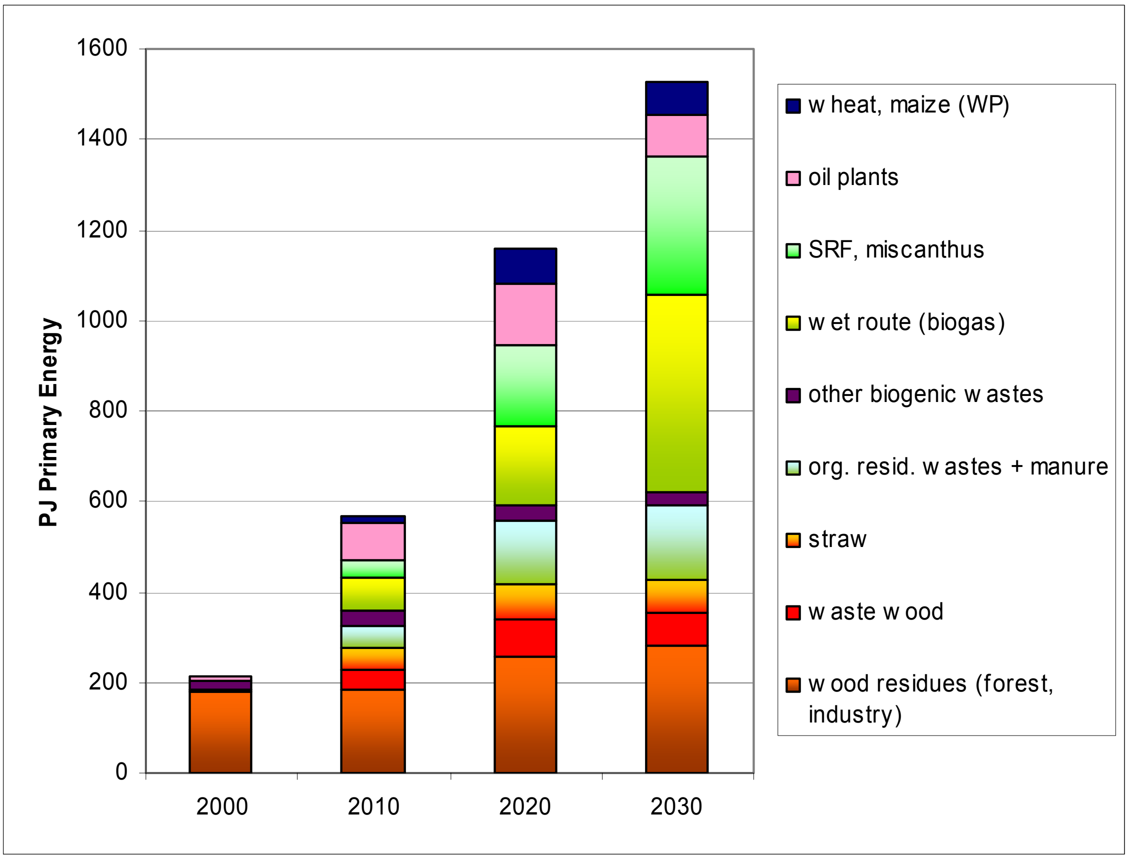
Due to material properties and available technologies, most bioenergy studies assume that, for the next 10 to 20 years, biogenic wastes will be used predominantly for *stationary* applications (i.e., for electricity and heat generation), as these areas offer the most attractive utilization, with respect to economic and ecological criteria (ÖKO 2004).

5 Exceptions to this trend are, e.g., Austria, Denmark, Finland, and Sweden. Also in Germany, drastically higher shares of bioenergy are expected in the near future (ÖKO 2004).

6 In DCs, some 35% of primary energy comes from biomass (on average); in some African countries, even up to 90%. The energy supply of approx. 2.4 billion people depends nearly exclusively on biomass. Here, "traditional" bioenergies (wood, manure) still play an important role for cooking (see Karekezi 2004).

For industrialized countries, "new" forms of bioenergy (biogas from energy crops, BtL and woodchips from short-rotation forestry etc.) will be especially important, as only they can offer sustainability and, given the required land, potential for increased supply use. This is shown in the following figure.

Figure 1 Future Development of Bioenergy in Germany (Sustainable Scenario)



Source: ÖKO (2004); WP = whole plant, SRF = short-rotation forestry

Clearly, biogas from wastes, especially from "wet route" energy crops[7], and bioenergy from SRF offer the largest increases in the next decades. In comparison, oilseed plants (for biodiesel), and whole-plant use of wheat and maize (for bioethanol, biogas) will play a relatively small role. The reasons behind the varying importance of bioenergy forms are based on the following sustainability criteria for both cultivation and use:

- Yields – including full life-cycles (fertilizers, transport, etc.) – and nature protection potentials of *wet-route* energy crops, and SRF are higher than those of rapeseed or whole-plant maize, for example. The limited land available for bioenergy cultivation should primarily be used for the most sustainable bioenergy options.

[7] "Wet routes" for biogas are cultivation systems with multiple annual harvests of unripe plants, which brings high yields by extensive use of fertilizers and pesticides. Also, material/nutrient flows are nearly closed.

- Regarding energy use, biomass residues are usually ecologically and economically more attractive in stationary applications (electricity and heat supply); biofuels from residual straw (via hemicellulotic bioethanol), and residual wood (via BtL processes) won't be efficient as transport fuels until 2010.

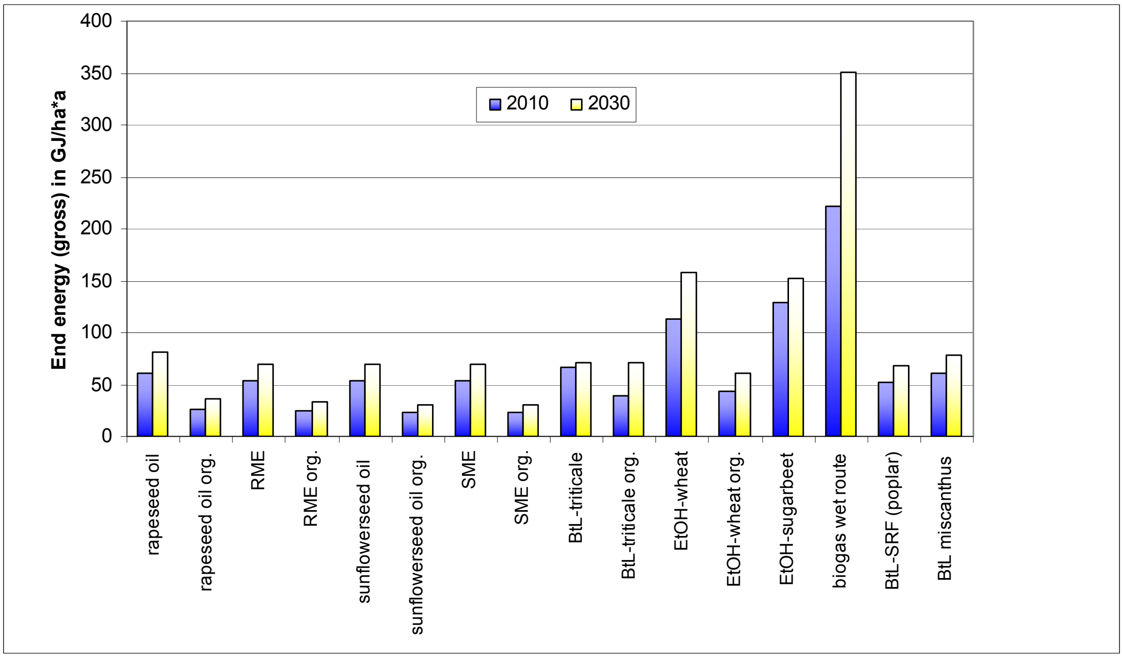
Cultivated biomass (*energy crops*), especially biogas from *wet-routes*, will correspondingly be used in decentralized cogeneration, while SRF wood will primarily be used as a source for BtL biofuels.

2.2 The Significance of Biofuels

Globally, *biofuels* represent only a niche; as seen in Brazilian bioethanol use, they can be found mostly in *blends* with conventional fuels (France, USA), and/or using oilseeds as biodiesel (Germany). Biogas is only used in a few local cases as transport fuel.

Until now, *mobile* uses of biofuels come mainly from oil seeds (e.g., rape, sunflower), plant oil methylesters (PME), and bioethanol (from sugar cane, sugar beets, wheat). The yields of these energy crops vary dramatically, when calculations include their path to the fuel tank, as shown in the following figure.

Figure 2 Gross Yields of Biofuels from Energy Crops in Germany



Source: authors' calculation based on ÖKO (2004); RME = rapeseed oil methylester; org = from organic farming; SME = sunflower seed oil methylester; SRF = short rotation forestry; BtL = Biomass-to-Liquid

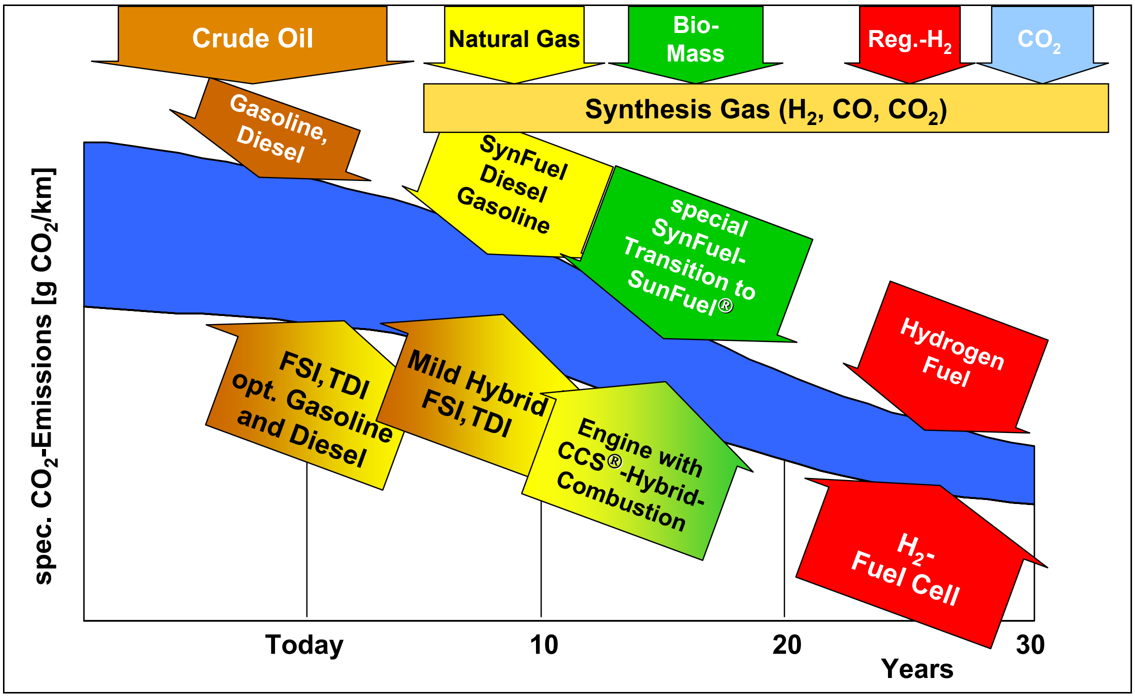
This comparison[8] shows that “biodiesel“ from rapeseed and sunflower seed oils have relatively low gross yields when compared to bioethanol from sugar beets or wheat, but a similar value to bioethanol from triticale. Synthetic fuels (Biomass-to-Liquids = BtL) from short-rotation forestry or energy grasses (e.g., miscanthus) promise similar yields, while “wet routes” offer higher outputs even without fertilizers, or pesticides.

Clearly visible is that, with organic farming, the yields are reduced by nearly half[9].

BtL from SRF offers high yields for biofuels from energy crops in the long run, and is of interest, as perennial plants can also contribute to nature protection and are thereby seen as ecologically advantageous[10].

Accordingly, car manufacturers now see synthetic biofuels as a “transition strategy“ until the implementation of a renewable hydrogen (H_2) system (see following figure).

Figure 3 VW’s Strategic Concept for Transport Fuels and Drives



Source: Steiger (2003)

8 This comparison refers to the *gross* yields of the entire production process of biofuels; included are: i.e., fertilizers, necessary auxiliary energy, transports, etc. - but potential *credits* for by-products (e.g., animal feed) are *not* taken into account. For a *net* comparison see ÖKO (2004).

9 Here, known yields from food cultivation were used. It can be expected that, for pure energy crops, organic farming could also achieve similar yield increases as conventional agriculture – at least in favorable locations.

10 This is especially true for SRF, utilizing domestic species like poplar and willow, which could contribute to erosion protection. For SRF, no problems worth mentioning are known in OECD countries (IEA 2002). From an ecological perspective, perennial, or multi-annual, species are advantageous compared to annual cultures, because they usually require less tillage and fertilizer, and fewer pesticides(see WBGU 2003).

This strategy reflects current opinion in the transport sector that new drive concepts for cars (like fuel cells) won't be able to claim significant market shares until 2020, and that natural gas and biofuels could build a "bridge" into a future, renewable hydrogen economy[11]. One positive aspect of a medium-term BtL strategy is that it doesn't require new infrastructure to distribute fuels, and is compatible with conventional car and truck drives. An unresolved issue is the state of development of BtL technologies, as only a few pilot production facilities exist today.

2.3 Biofuels and Land-Use

For today's yields of energy crops, *land requirements* are quite large if considerable shares of biofuels are assumed:

To reach the EU target of a 5.75% share of biofuels by 2010 (see EU 2003), some 10-15% of the current agricultural land of the EU would be needed, depending on the biofuel conversion route (Jensen 2003).

For Germany, the sustainable share of biofuels achievable until 2030 covers approx. 15% of today's fuel demand for cars[12]. This would represent some 10% of the *total* transport fuel demand in 2030, with the use of more efficient cars. This would take about 4 mio. ha of agricultural land.

For the EU, corresponding research for sustainable bioenergy potential, which takes nature protection into account, is under way; results are expected in mid-2005 (see EEA 2003; ÖKO 2005).

Research up to now indicates that, within the next 10 to 20 years, the potential for sustainable production of biofuels in the EU and – with careful comparison – also in the USA and Japan will meet approx. 10% of today's demand.

2.4 Biofuels and Greenhouse Gas Emission Targets in Industrialized Countries

Greenhouse gas emissions in OECD countries must be reduced by at least 20-40% in the near future. The domestic biofuel potential will not suffice to meet proportional reduction targets in the transport sector if increasing mobility demands are assumed. Besides increases in vehicle efficiency, use of public transportation, as well as rail and ship transport, importing biofuels could be another attractive option for climate and resource protection in OECD countries.

If, and under which conditions, the cultivation of bioenergy and export of biofuels from DCs can contribute to their sustainable development is discussed in the following.

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11 For details see DLR/IFEU/WI (2004); EUCAR/CONCAWE/JRC (2004); NRC (2004); ÖKO (2003a); WI (2003)

12 Included here were nature protection requirements and technological developments until 2030 have been included. Furthermore, a 30% share of organic farming for food was assumed, which entails a significant land use restriction (ÖKO 2004).

3 Assessing Exports of Biofuels from Energy Crops in Developing Countries

Until now, little research on cultivating energy crops in *developing countries* (DCs) for biofuel exports has been available. The few studies that do exist are mostly concerned with economic considerations and potentials.

Analyses for the potential of aquatic biomass resources (e.g., algae, seeweed, hyacinths) are completely absent, as well as *integrated* research on food demand and potential land use (see section 4).

3.1 Potentials for Energy Crops in DCs

Most existing studies on biomass potential often do not distinguish between individual bioenergy sources and reflect only rudimentarily the potential for energy crop cultivation, where, in the context of DCs, massive land-use conflicts are expected (see section 4.1). Also missing are differentiations between how biomasses are used.

The following table gives a brief summary of available data on bioenergy potentials for different regions.

Table 2 Global Biomass Potentials by Category and Region

Potential (EJ/a)	North America	Latin America, Caribbean	Asia	Africa	Europe	CIS + Near East	Total
- wood	12.8	5.9	7.7	5.4	4	5.8	41.6
- grasses & straw	2.2	1.7	9.9	0.9	1.6	0.9	17.2
- manure	0.8	1.8	2.7	1.2	0.7	0.4	7.6
Sum of biogenic wastes/residues	**15.8**	**9.4**	**20.3**	**7.5**	**6.3**	**7.1**	**66.4**
Energy crops	**4.1**	**12.1**	**1.1**	**13.9**	**2.6**	**3.6**	**37.4**
Grand total	**19.9**	**21.5**	**21.4**	**21.4**	**8.9**	**10.7**	**103.8**
Share of energy crops	21%	56%	5%	65%	29%	34%	36%

Source: authors' computations based on IE (2003); assumes technical potentials *without* ecological restrictions.

Energy crops have a *global* technical potential of about 37 EJ, but the relatively small contributions from Asia seem questionable, from a current perspective.

In WBGU (2003), the potential supply of sustainable energy crops was estimated using "ecological guardrails" (see section 5.1), which assumed a somewhat different regional distribution, and a slightly higher total potential:

Table 3 WBGU Potentials for Energy Crops by Continent

	potential land		WBGU-„guard rail“		
Region	**[mio.ha]**	**[%]**	**[mio.ha]**	**[%]**	**[EJ/a]**
Europe	22	4.5	22	4.5	2.5
Asia + Australia	37	0.7	26	0.5	3
Africa	111	3.8	111	3.8	12.7
Latin America	323	16	165	8	18.8
North America	101	5.9	67	3.6	7.7
World	**595**	**4.6**	**391**	**3**	**44.7**

Source: WBGU (2003)

According to WBGU, the potential supply from sustainable energy crop cultivation world wide of about 45 EJ per year approximately represents *total current* bioenergy use, based primarily on biogenic wastes and residues[13].

The potential for energy crops in *all DCs* can be estimated as some two thirds of the world potential, i.e. some 30 EJ/a. This equals the *total sum* of fuel consumption in the EU-25 *and* the USA in the year 2000.

3.2 Technologies for Biofuels in DCs

The supply of biofuels in DCs can *use principally the same* cultivation options and process routes as ICs, but differences in cultivation technologies and energy crops must be considered, as well as the status of technical infrastructures for energy and transport.

Furthermore, the technological base and its “soft“ infrastructure[14] in DCs are typically less developed than in ICs.

Within the study at hand, no detailed consideration of these aspects could be carried out, so that supply options for biofuels in DCs are only summarily treated.

3.2.1 Cultivation Forms and Types of Biomass in DCs

The form of high-tech industrialized agriculture used in ICs is also being applied more and more in DCs, and is the main route to exporting *cash crops* (maize, soybeans, wheat, sugar).

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13 The specific yield figures used by WBGU appear rather conservative when the forseeable “energy-only” cultivation schemes for biomass are taken into account. In the near future, net yields of some 450 GJ/ha*a are possible for “wet route“ cultivation with ecological constraints, and this without fertilizer or pesticides. Short-rotation forestry currently supplies some 150 GJ/ha*a. Therefore, even a cautious estimate of globally sustainable potentials of energy crops could be about 100 EJ/a.

14 This includes human capital, research (R&D) and learning organizations (schools, universities, etc.), as well as financial and legal frameworks.

Beside this industrialized agriculture, various forms of traditional land use exist in small, often family-run businesses. These are usually organized in cooperations on a village or tribal level, supplying local demands and markets. Here, as well, integrated management, including animals (e.g. pigs, chicken), as well as combinations with forestry or fishing, can be found.

On a limited basis, but with strong growth rates and highly oriented toward export, different forms of organic (or biological/ecological/integrated) agricultural methods (in general: *organic farming*) are also practiced in DCs, often with certification. Traditional forms of agriculture often comply with the formal requirements of organic farming, even without certification.

In examining energy crops *for export*, one can refer to other cash crops. Evidence suggests that energy crops could be similarly cultivated with high-tech, industrialized production methods on rather large farms to keep delivery costs as low as possible, and to ease the logistical links to transports and further processing. Based on this logic, *high-yield species* with corresponding specifications for irrigation, fertilization, and pesticide application could be grown on relatively good soils.

As to species, various C_4 grasses like miscanthus, and short-rotation types of bamboo, eucalyptus, etc., would be used for new processes like BtL (with its rather high irrigation requirements), parallel to sugarcane and oil plants traditionally used for bioethanol, and RME. Theoretically, "wet routes" for biogas could be used as sources for BtL or GtL, but these schemes are in the early stages of development. Additionally, the demands for irrigation varies, depending upon the cultivation scheme.

3.2.2 Supply Technologies for Biofuels in DCs

With the restricted availability of high technologies in mind, along with corresponding infrastructure requirements in most DCs, supply routes for biofuels will be primarily based on *existing* agricultural practices, and will consist of rather few conversion steps.

Therefore, especially *bioethanol* and related products like ETBE and (hydrated) bioethanol blends with conventional gasoline and diesel, as well as oil seeds and PME (*biodiesel*) are the biofuels most probably available for export from DCs.

In the *longer term,* DCs could also implement technologies currently under development in ICs like BtL routes (assuming a transfer of technology occurs), so that the potential resource base for biofuels could be significantly expanded[15].

[15] Besides BtL, blends with Gas-to-Liquids (GtL) are also possible as biofuels, if cleaned and processed biogas is used. In the short term, the processing costs seem prohibitive, though in the near future, biogenic GtL – especially from biogas generated from wet routes – might play a larger role.

3.3 Preliminary Assessment of Biofuels in DCs

From the *societal* point of view, the "domestic," often local use of endogeneous bio-energy in DCs is typically more attractive than export, as direct domestic use can replace expensive imports of oil or natural gas and create regional value chains.

Furthermore, "modern" biomass use is an important contribution to rural development, especially regarding access to energy (Karekezi 2004; Fritsche 2004).

The preliminary estimates of sustainable biomass potentials for biofuels or blends from energy plant cultivation in DCs, even considering ecological restrictions, are of the magnitude of the current *total* transport fuel demand of both the EU-25 *and* the USA.

From today's perspective, near-term revenues for (unsubsidized) bioenergy exports to the energy markets of EU and OECD countries, which are characterized by oil price developments and national taxation, are far from attractive for the majority of DCs[16].

Still, there are some DCs which have favorable conditions for cultivating biomass, so that energy crops and their subsequent conversion to biofuels for export could be an economically interesting option[17].

From these "spotlights," the following general conclusions for the assessment of biofuel exports from DCs can be drawn.

- Short and medium-term potential for biofuel exports from DCs can be seen mainly in bioethanol, and to a lesser extent, in plant oil, and PME.
- For bioethanol from sugar cane, conversion in hybrid plants is most likely. These plants can vary their output between BioEtOH and sugar, but require more centralized production.
- For plant oil and PME, a broader range of species could be used for cultivation, and a more decentralized production and conversion is possible, which also facilitates the use of by-products and residues. The conversion to PME can be done in more centralized plants, possibly close to the export harbours.
- Plant oil and PME used as biofuels directly compete with their use as "raw materials" (e.g., chemical base, detergents, lubricants).
- Plant oil and PME exports could be possible for a broader range of countries than BioEtOH, as plant oil and PME feed is more diverse, and infrastructure requirements are fewer.
- Bioethanol supply seems less attractive regarding employment effects than PME.

16 Exceptions are possible. If, for example, the EU would accept imported biofuels as a means for Member States to fullfil their biofuel quota by 2010, and subsequently also allow for respective tax excemptions, the potential value of biofuel exports could be high enough for exporting countries. The example of palm oil in Indonesia clearly shows that (assuming adequate and secure revenues), international trade of biomass could be an attractive option for DCs (WWF 1998).

17 For impacts of the ProAlcol bioethanol program in Brazil, see, e.g., FIAN (2002).

- In the near future, biofuel exports will be economically attractive only if adequate infrastructures for processing and transport exist, or can be expanded at a low cost.
- In the longer term, BtL routes could also be employed in DCs, significantly broadening the resource base for biofuels. Here, domestic use of biogenic wastes in stationary applications seems to be more competitive.

Regarding land use competition (see section 4.1) and social questions related to land ownership (see section 4.2) one can conclude that, in the absence of *massive regulatory frameworks*, biofuel supply in DCs would face conflicts similar to *cash crops* already cultivated and marketed today.

The WBGU concludes in its global energy study that, acknowledging land use problems, biofuels are not a "solution," and that current support for them should be reduced (WBGU 2003). However, this is *not explicitely stated* for DCs.

From today's point of view, biofuel exports from DCs seem to be a generally reasonable option *only if*:

- security of food supply is assured in the potential export countries as far as possible *and*
- total biofuel cultivation and production has a positive sustainability balance when compared to alternate land uses, whereas environmental and nature protection issues, as well as economic and social aspects, are to be considered.

For the second condition, no sufficient analysis is available for DCs, and there are a lack of operational and quantified concepts to assess sustainability in DCs.

Within the context of bilateral and multilateral economic cooperation, such analyses should be initiated and carried out *with active participation of DCs*.

In an *open process* with partners from DCs, the criteria developed here (see section 5) should be discussed, reviewed, further developed, and, if need be, modified or supplemented.

4 Conflict Potentials of Energy Crops for Biofuel Exports from DCs

The cultivation of energy crops in DCs alongside the cultivation of crops for other uses leads to some potential and real conflicts, described in the following section.

4.1 Land Requirements

The central conflict in the cultivation of energy crops in DCs is land requirement, which varies depending on the kind of cultivation, soil and climatic conditions, as well as crop- and processing methods.

Biomass supply is already especially scarce in arid environments like the Sahel in Africa, or in the steppes of Asia, because more is extracted than grows back. Two EJ of unsustainably forested wood are harvested in Asia every year: approximately 20% of the biomass energy used there. In Africa and in Latin America, the share of biomass energy from unsustainable forestry is around 30% and 10%, respectively (WBGU 2003). If these presently unsustainable forms of biomass use are converted to sustainable patterns, land requirements increase accordingly, reducing the available area for additional bioenergy production.

In terms of quantity, land use for *other (non-energy) purposes* is more important, though:

In industrialized nations, where a reliable food supply is a given, a medium to long-term *decrease* in agricultural land use is expected, due to population developments, an expected opening of agricultural markets, and increased harvest yields. In contrast, an *increase* in agricultural land use is to be expected in DCs, due to population growth, changes in diet, increasing export options for food and animal feedstocks, as well as degradation and salination of currently cultivated land, increasingly limited irrigation, and ongoing desertification.

At the same time, demand for wood products (timber, cellulose for paper manufacturing, etc.) will increase not only in DCs, but also worldwide, parallel to economic development which will also cause new demand for land devoted to housing and transport in DCs as well.

Because of varying local conditions, a detailed consideration of individual countries is indispensable, if conflict is to be avoided[18].

[18] Dependent upon the bigness of the country are regional differentiations necessary.

4.2 Land Ownership

Besides quantitative questions of land requirement, there is the fundamental issue of land ownership structures, i.e. of property to be used for future energy plant cultivation. If an "industrialized" form of energy plant cultivation takes place (chapter 3.2.1.), then the land required will, in all probability, be controlled by larger national or transnational companies and/or large property owners in DCs.

This contrasts the right to democratically regulated land access, and the implementation of human rights guaranteeing sufficient food. Depending upon the social situation and historical developments, the requirements of industrial-style cultivation of energy plants could come into conflict with the requirements of diversified agriculture driven by family businesses and cooperatives, aiming at supplying food and income for the local population.

4.3 Environment and Health

Conventional cultivation of energy plants could cause not only land use conflicts, but also direct impacts regarding the environment and health, depending on the type of energy crop being cultivated, and its downstream processing.

Apart from possible loss of biodiversity, potential conflicts include the availability of water, as well as the impact on ground and surface water supplies of agrochemicals (fertilizers, pesticides) from industrial methods of cultivation.[19] Agrochemicals are also the primary cause of possible health risks for agricultural workers.

Especially with the cultivation of sugar cane, air pollutants caused by field burn-off can cause effects injurious to health.

4.4 Nature Conservation

Conflicts between conservation and energy plant cultivation are also possible, depending upon cultivation form and harvest procedure. These conflicts could include: erosion, soil compaction and degradation, as well as loss of biodiversity by mono-cropping.

These conflicts can be minimized by more extensive forms of cultivation[20], variation of the assigned kinds of crops and crop rotations, small-scale structuring of the cultivation and (partial) integration into, for example, forestry use.

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19 Access to drinking water will be, for some regions, one of the central environmental problems in the years and decades to come (WBGU 1997).

20 However, this would have the negative effect of increased area requirements.

4.5 Economic Development– Endogenic vs. Global

Another area of conflict is the increasing orientation of energy plant cultivation in DCs towards product *export*.

This contradicts the idea, increasingly recommended by NGOs, of an agricultural economy emphasizing nations' needs for a reliable food supply and the development of *internal* markets.

The distribution of revenues between local/regional and national/international players, and between sub-national groups and nations can vary, depending on the potential source of bioenergy and the degree of centralization of the pre-manufacturing process,.

This balance depends on biomass availability, and whether it is used in decentralized (as with local/regional use) or centralized systems (bio ethanol/sugar-hybrid factories, large "bio-refineries" for PME or BtL).

In the case of centralized use, slightly more favourable values per economic unit can obtained, but usually, fewer jobs are created. Furthermore, revenue creation in rural areas beyond "raw material procurement" is possible only if a considerable part of the processing also takes place there.

This seems questionable, in terms of the present, export-oriented practises where processing is often located close to the international harbors, or other transport nodes.

5 Criteria for Sustainable Biofuels from DCs

Scientific literature from the last few years provides plenty of sustainability criteria for the energy sector, but only recently have there been studies on sustainable biomass use for energy production.

None of these works focuses *directly* on sustainable biofuel production in DCs. In order to design a *first set* of criteria, this study puts together results from studies on the sustainability of energy systems, especially those utilizing bioenergy.

Preventing (environmental) degradation is the *absolute basic criterion* for sustainability in export DCs[21]. Furthermore, a process oriented development of criteria involving relevant players is of central importance.

5.1 Environmental "Guardrails"

Widespread agreement exists among various research groups and studies on the "guardrails" concept for the *environmental dimension* of sustainability, as it applies to: air pollutants, climate protection, land use, and conservation of biodiversity.

Essential environmental criteria for *biofuels from DCs* are

- conservation of natural ecosystems - excluding destruction, e.g., clearing of old-growth forests for cultivation of energy crops;
- reserving at least 10% of the land for nature conservation with regard to biotope networks and protection corridors;
- preserving genetic diversity, including a minimum number of species, as well as structural diversity within energy crop plantations;
- sufficient recirculation of nutrients into cultivated soils and woodlands;
- avoiding negative impacts of fertilizer and pesticide use, as well as of air pollutants;
- avoiding water pollution and critical irrigation needs in semi-dry and dry regions;
- avoiding soil erosion.

It should be noted that adequately selected and managed bioenergy cultivation could also positively affect (i.e. enhance) soil quality, habitats, and biodiversity, and modern biomass use could help to reduce air pollution e.g. from coal, or heavy fuel oil.

21 e.g., no cultivation of energy crops to the disadvantage of food crops, no negative processes of concentration in animal husbandry.

5.2 Social Criteria

In general the sustainability discussion lacks a systematic analysis and development of social criteria. The multitude of possible social conflicts tied to the cultivation of energy crops (see chapter 4) precludes the development of a detailed set of criteria within the limited scope of this study. Above all, such a task would only be reasonable if it involved a specific country and the relevant players, respectively.

Besides environmental terms, some other basic criteria should be mentioned, if only for the sake of consideration:

- priority for food supply and food security for the export country's people;
- avoiding health impacts from energy crop cultivation;
- instead of displacement, integration of landless persons in energy cropping systems and subsequent local processing of the crops;
- preservation and development of jobs in rural areas;
- inclusion of local people in the distribution of economic revenues from bioenergy;
- participation of local people in decision-making.

5.3 Economic Criteria

The German Advisory Council on Global Change (WBGU) has also developed a set of criteria and "guardrails" for economic questions, which are generally referred to here (WBGU 2003).

In our opinion, the following criteria relating to the cultivation of energy plants in DCs are of top priority:

- access to modern energy for all people, and covering of each individual's minimum needs for modern energy;
- balancing possible export revenues with potential losses of endogenous (domestic) value;
- contribution of possible export revenues to economic and social development of the exporting country;
- costs of expansion and development of infrastructure and logistics for energy crop cultivation, processing , and exports.

6 Knowledge and Research Gaps

The study at hand summarizes the knowledge about biofuels in DCs. The findings clearly indicate that systematic analyses of *integrated* effects (interaction between agriculture, forestry, and bioenergy cultivation; export revenues vs. endogeneous development; environmental and social impacts of energy cultivation in DCs) *are missing*.

This first set of criteria suggested here needs further scientific foundation and backing by concrete measurement (indicators), and assessment by s*hare- and stakeholders*, including local ones. For this to happen, differentiation between the nations and/or regions involved is necessary.

Knowledge gaps exist, in general, regarding if, and under which conditions, bioenergy cultivation in DCs could be more environmentally benign and less intrusive for nature than today's agroindustrial production of *cash crops*.

Here, it must be recognized that existing experience with plants and techniques from the cultivation of fodder and food *cannot be directly translated* to energy crop cultivation.

Typical food and fodder cultivation:

- optimizes maintenance and harvesting for qualities like starch or oil content,
- restrains biological competition by applying pesticides,
- supplies nitrogen (mostly) though fertilizers.

The cultivation of biomass-for-energy *could*:

- optimize *total* yields,
- make use of a broad variety of species and rotation schemes (depending on the respective biomass "routes").

This holds true especially for mixed-cultivation schemes, agroforestry approaches, and so-called "wet routes," as well as short-rotation forestry and multi-year cultivation of, e.g., miscanthus and bamboo.

Here, there is a great need for research on extensive cultivation schemes which combine high yields with soil/erosion protection and positive biodiversity impacts, so that a sustainable bioenergy supply is possible in DCs[22].

[22] Some examples which do not refer to exports, though, are given in TAB (2002).

Furthermore, the assessment of the sustainability of biomass-for-energy cultivation is meaningful only within a *participatory process* including partners from DCs. Here, Germany soybean exports from Brazil provides a first example. This could act as a basis for examination of the broader issue of bioenergy strategies in DCs [23].

The following open questions should be dealt with in a participatory process, factoring in national or regional conditions in the prospective export countries:

- Do national and local stakeholders see the possibility of assessing sustainability (at least qualitatively), are they ready to participate in such a process, and are sufficient resources available to do so?
- Does biofuel processing offer a chance for regional or industrial development, and can biofuel exports contribute meaningfully to the economic and social development of the countries under consideration?
- Are there local and regional options for higher income from re-orienting biomass production?

Studies and other work completed in the last few years – and some ongoing ones – which concern the integrated analysis of sustainable biomass use in ICs should be adjusted to the conditions in DCs, and supplemented with *local knowledge and cooperation with local partners*.

Accordingly, the cultivation schemes that should be investigated are those which:

- allow, to a great extent, closed material and nutrient flows (e.g., "wet routes");
- are adjusted to the special climatic and soil conditions in many DCs (dry periods, strong rains, low-humus soils);
- promise contributions to erosion protection and containment of desertification (example: Daimler-Chrysler biodiesel project with Jatropha in India[24]).

These kinds of projects could be initiated in, e.g., Brazil[25], desertification-endangered areas of Africa, or Southeast Asia.

A collaboration of several research institutions regarding cultivation in DCs, as well as countries like Germany, seems sensible, and one in which (German) enterprises from the strongly growing bioenergy sector should participate.

Only on the basis of such exemplary projects and their subsequent evaluation, is it possible to derive solid conclusions regarding the "sustainability of biofuel export from developing countries."

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23 See Bickel (2002); Hees (2001); Lanje (2004); Osorio-Peters (2003); Peisker (2001).

24 This project, supported by DaimlerChrysler, started in 2003, and is based on previous work of GTZ (see GTZ 1986) and the University of Hohenheim (Sauerborn 2000).

25 In Brazil, great interest exists to go "beyond bioethanol," and to integrate other (indigenous) energy crops in sustainable use schemes. Here one finds potential starting points for a bilateral project, taking into account the experiences from the "Soybean Material-Flow" project.

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8 List of Abbreviations

a	year
BioEtOH	bioethanol
BtL	biomass-to-liquid
CEE	Central and Eastern Europe
CIP	Conference Issue Paper (for the renewables2004 conference)
CIS	Commonwealth of Independent States (former USSR)
CONCAWE	The Oil Companies' European Association for Environment, Health and Safety in Refining and Distribution
DC	Developing Country
DLR	German Center for Air and Space (Deutsches Zentrum für Luft und Raumfahrt - www.dlr.de)
EEA	European Environment Agency (www.eea.eu.int)
EJ	exajoule = 1000 petajoule (PJ) = 1 mil. terajoule (TJ) = 1 bil. gigajoule (GJ)
ETBE	ethyl-tertiary-butylether
EU-25	EU after enlargement (as of May, 2004)
EUCAR	European Council for Automotive R&D
FIAN	FoodFirst Information & Action Network
GES	Global Energy Strategy
GtL	gas-to-liquids
GTZ	German Agency for Technical Assistance (Deutsche Gesellschaft für technische Zusammenarbeit GmbH – www.gtz.de)
h	hectare
IC	industrialized country
IE	Institute for Energy and Environment (Institut für Energetik und Umwelt, Leipzig - www.ie-leipzig.de)
IEA	International Energy Agency (www.iea.org)
IFEU	Institute for Energy and Environment Research (Institut für Energie- und Umweltforschung - www.ifeu.de)
JRC	Joint Research Centre of the EU Commission
MTBE	methyl-tertiary-butylether

NRC	National Research Council (USA)
OECD	Organization for Economic Cooperation and Development (www.oecd.org)
org	organic farming
ÖKO	Institute for Applied Ecology (Öko-Institut - www.oeko.de)
PME	plant oil methylester
RME	rapeseed oil methylester
SRF	short-rotation forestry
SRU	The German Advisory Council on the Environment (Der Rat von Sachverständigen für Umweltfragen - www.umweltrat.de)
TAB	Office of Technology Assessment at the German Parliament (Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag)
TUB	Technical University of Berlin (Technische Universität Berlin)
WBGU	Scientific Council of the Federal Government on Global Environmental Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen)
WI	Wuppertal-Institute for Climate, Environment, Energy (Wuppertal-Institut für Klima, Umwelt, Energie GmbH)
WP	whole plant
WWF	World Wildlife Fund