BUBE: Better Use of Biomass for Energy

Background Report to the Position Paper of IEA RETD and IEA Bioenergy

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Authors:

CE Delft:	Bettina Kampman
	Geert Bergsma
	Benno Schepers
	Harry Croezen
Öko-Institut	Uwe R. Fritsche
	Klaus Henneberg
	Katja Huenecke
AidEnvironment	Jan Willem Molenaar
	Jan Joost Kessler
CIEP	Stephan Slingerland
	Coby van der Linde

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Executive Summary

This report aims to provide a document that gives guidance on the issue of biomass energy policies in OECD countries. The main conclusions and messages from this project were published in a joint IEA RETD and IEA Bioenergy Position Paper and presented at the COP15 in December 2009. The following provides a brief summary of this report; for a more in-depth summary of the results of the study we refer the reader to the position paper (www.iea-retd.org).

Better use of biomass for energy: background

As the main contributor to renewable energy around the world (about 10% of total energy consumption), the term 'biomass for energy' covers a broad range of products, including traditional use of wood for cooking and heating, industrial process heat, co-firing of biomass in coal-based power plants, biogas and biofuels.

In many OECD countries, bioenergy is deployed to reduce fossil fuel use and improve security of supply, reduce greenhouse gas emissions and/or create new employment. Modern biomass can be more expensive than its fossil competitors, however, and there is evidence that biomass, unless produced sustainably, could have significant negative environmental and socio-economic impacts.

This report elaborates on how to improve the use of biomass for energy. It assesses and provides guidelines on how to make better use of sustainable biomass potential and how to increase the positive and reduce the negative impacts. This study was jointly commissioned by IEA RETD and IEA Bioenergy and carried out by a consortium consisting of CE Delft, Öko-Institut, Clingendael International Energy Programme (CIEP) and Aidenvironment.

Better supply and production

The first step in the biomass-to-energy chain is supply and production of the biomass. These processes can be improved by various means, the most important being:

- *Improving domestic supply and trade:* There is significant potential for increasing the supply of sustainable domestic biomass by improving the utilisation of forestry and agricultural residues. Increasing biomass cultivation sustainably typically requires a longer time period, but can provide additional feedstocks.
- *Reducing the environmental impact of biomass production:* If waste or residues are used, the environmental impact of biomass supply is typically low or even positive. There is also scope for sustainably growing biomass for energy on land which is underused or not used for other purposes. In addition, there is scope for increasing biomass supply accompanied by low environmental impact by shifting to perennial ('multi-year') plants, multiple cropping systems and agroforestry.

The use of land for bioenergy crop cultivation and any associated direct and indirect land use changes are key to the environmental performance of bioenergy, its socio-economic impacts and competition with food and feed.

Better conversion and use

There is a broad choice of technologies for converting biomass into usable energy and a variety of applications for the bioenergy. The key issues for improving these steps in the biomass-to-bioenergy chain are the following:

- *Improving the efficiency* of conversion and use will lead to greater replacement of fossil fuels and, in many cases, more greenhouse gas (GHG) savings and lower costs.
- *GHG savings* can also be improved by using low-carbon auxiliary energy sources in the processes concerned, through judicious use of co-products and by displacing fossil fuels with high carbon content. Some conversion processes provide good opportunities for *carbon capture and storage (CCS)*, which could help reduce atmospheric GHG concentrations in the future.
- The biomass can also be deployed in such a way that it contributes best to *energy security* or to *air quality improvements*. It may be worthwhile, moreover, to optimise biomass use to achieve the *best cost-effectiveness*, i.e. reduce the cost-benefit ratio to a minimum.

Better policies

Although a fair number of regional, national and international bioenergy policy instruments are already in place, few of them directly address sustainability and efficiency issues. Bioenergy is also a topic that is affected by policies extrinsic to it. Thus, policies on agriculture, forestry and waste are all highly relevant for the potential biomass supply as well as for performance. In addition, development aid can specifically improve biomass supply and use in developing countries.

The definition of 'better policies' may vary among countries, which may have different policy objectives and perspectives. Nevertheless, there is agreement on various issues. Quite a number of global and national initiatives are ongoing to improve the positive impacts and prevent the negative impacts of biomass-to-bioenergy routes by systematically including sustainability requirements.

Policy efforts to remove barriers to 'better' use can also lead to improvements. A number of such barriers can be identified, ranging from technological and trade issues to political and practical barriers.

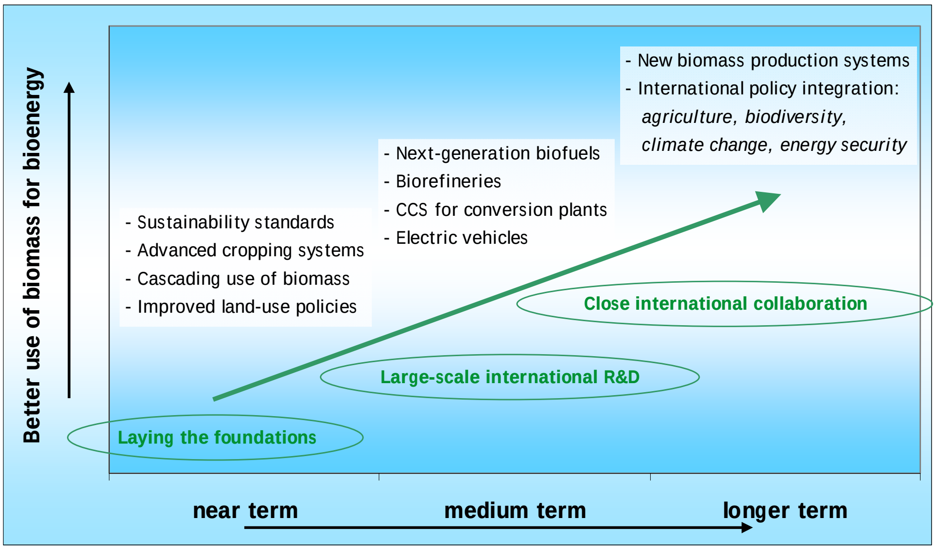
Conclusions: Roadmap for better use of biomass for bioenergy

The final chapter of this report provides a list of criteria for better use of biomass for energy, aiming to:

- Improve efficiency in the use of sustainable biomass resources.
- Maximise greenhouse gas reduction.
- Optimise biomass contribution to security of energy supply.
- Avoid competition with food, feed and fibre.
- Apply performance-based incentives for bioenergy proportional to the benefits delivered and demonstrated.

An overview of the key milestones that have been identified for better use of biomass for energy are illustrated in Figure 1.

Figure 1 Key milestones for better biomass use for bioenergy: timeline



1 Introduction

1.1 Background

Biomass for energy is the main contributor to renewable energy around the world, with almost 10% of total energy consumption in 2006 deriving from biomass. Biomass is in fact a term that covers a broad range of often very different products, although all are of organic origin. Many of these products can be used as a source of energy, either for electricity or heat production, or as a feedstock for biofuel production.

It is important to distinguish between 'traditional' and 'modern' use of biomass. Traditional use of biomass such as dung, charcoal and firewood for cooking and heating - mostly in open stoves - is still common practice for many people in developing countries. For 'modern' uses of biomass, a multitude of feedstock-to-end-use routes are feasible and indeed in use today. Modern biomass is used on a large scale for heating, power generation (e.g. co-firing in large-scale coal-based power plants or combined heat and power plants) and biogas and biofuels production. It is expected that in the future biomass could also provide an attractive feedstock for the chemical industry and that use of biogenic fibres will increase. In the oleo-chemistry sector, biomass has already served as an important raw material for decades (to produce soap, cosmetics, etc.). While many development policies seek to reduce 'traditional' uses of biomass (because of health and social issues and to prevent deforestation), the 'modern' uses of biomass are held to dovetail well with a future global low-carbon energy system.

For many of the modern applications of biomass, especially those in industrialised countries, government support is the main driver of the market - and it is expected that this will remain the case at least in the short and medium term (2020). In many countries biomass is considered an attractive option for reducing fossil fuel consumption for power and heat generation and transport fuels in order to improve security of supply, reduce greenhouse gas (GHG) emissions and create new employment. However, there is significant ongoing debate about the best way to design and implement policies relating to biomass use. Biomass can be scarce and often more expensive than its fossil competitors and there is evidence that biomass, unless produced sustainably, could result in significant negative environmental and socio-economic impacts, for example on GHG emissions, biodiversity, land use, water availability and food and feed prices.

Both directly and indirectly, biomass policies also play a role in international climate negotiations, for several reasons. Firstly, because modern uses of biomass provide promising GHG mitigation routes that might also contribute to rural development in developing countries and stimulate the agricultural and forestry sectors in industrialised countries – and if more sustainable trade is assumed, also in developing countries and emerging economies. However, increased use of biomass for energy can also lead to deforestation as a result of uncontrolled biomass production practices and may thus also have a negative impact on global and regional GHG mitigation capacities. While many countries using biomass thus see the benefits of biomass policies, in countries with underdeveloped sustainability governance, negative impacts may prevail.

In view of the complex nature of the issues, IEA RETD and IEA Bioenergy jointly commissioned a consortium comprising CE Delft, Öko-Institut, Clingendael International Energy Programme (CIEP) and Aidenvironment to carry out a project to further elaborate the notion of 'better use of biomass for energy'. The main aim of this project is to provide policy-makers and other stakeholders with concrete means of supporting sustainable bioenergy deployment and thereby contribute to the international debate on the use of biomass in global energy systems, *inter alia* in the context of global climate change mitigation (COP).

The main conclusions and messages from this project were published in a joint IEA RETD and IEA Bioenergy Position Paper and presented at the COP15 on December 15, 2009. To augment this position paper the present report provides background information and more in-depth analysis.

1.2 Aim and scope of the report

The objective of this report is to provide a document for policy-makers and negotiating parties that gives guidance on the issue of biomass energy policies, including those within the framework of the UNFCCC negotiation process.

The project aims to achieve the following objectives:
- *Issues*: Establish an overview of the key multidisciplinary and cross-sector issues facing the deployment of bioenergy technologies today. The key drivers for using biomass as an energy source should be addressed, taking into account regional circumstances.
- *Barriers*: Building on the findings of projects performed under the IEA Bioenergy Implementing Agreement, identify key questions and obstacles that need to be addressed to ensure the most rational use of biomass.
- *Opportunities*: Identify the specific opportunities and challenges for bioenergy in contributing to sustainable rural development and land use.
- *Solutions*: Provide recommendations for policies, including instruments and indicators that can guide policy- and decision makers in sustainable use of biomass for energy purposes.
- *Instruments*: Identify and evaluate appropriate tools for supporting bioenergy decision-making in the context of partially conflicting environmental, social, development and economic objectives.
- *Indicators*: Develop a set of indicators that can be used by policy-makers as guidelines for bioenergy deployment.

These issues and possible solutions will be illustrated with practical cases and examples of biomass supply chains in relation to current policies.

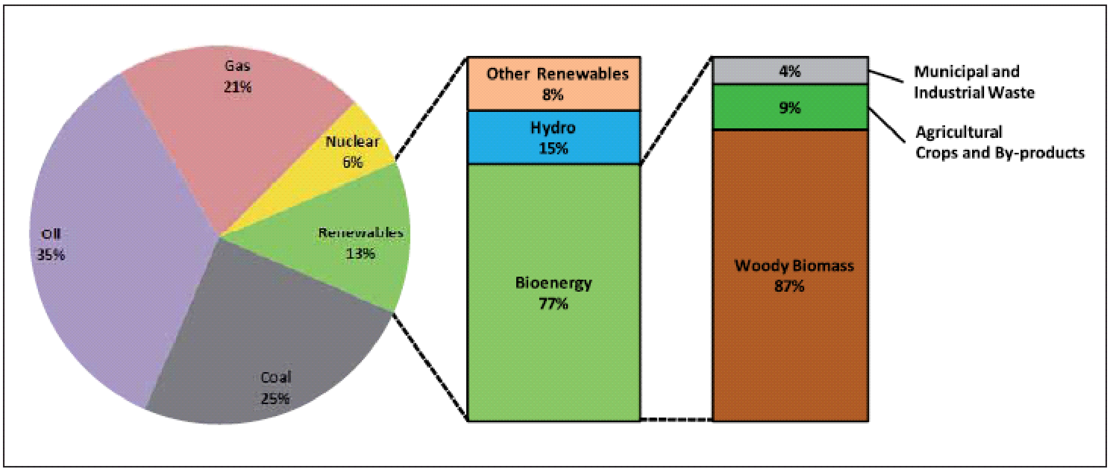
The scope of the project is mainly bioenergy use in OECD countries. However, as trade is increasing and biomass is becoming a global market, impacts on non-OECD countries are also included.

1.3 Biomass today and tomorrow: facts and prognoses

Use of biomass for energy

Around the world, biomass is the main contributor to renewable energy. According to a recent IEA Bioenergy report, renewables accounted for a share of 13% of total energy consumption in 2006 (IEA Bioenergy, 2009). Of this figure, 10% points are combustible renewables and waste (approximately 1.2 GtOE), with the remainder provided by hydropower (2.2% points), geothermal (0.4% points) and solar/wind/other (0.2% points).

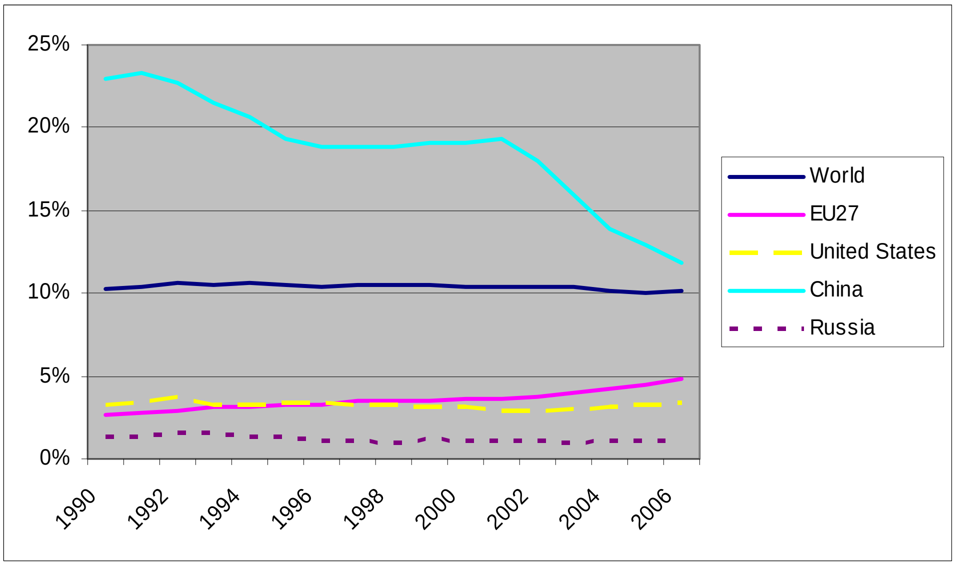
Figure 2 Share of bioenergy in world primary energy mix



Source: IEA Bioenergy, 2009.

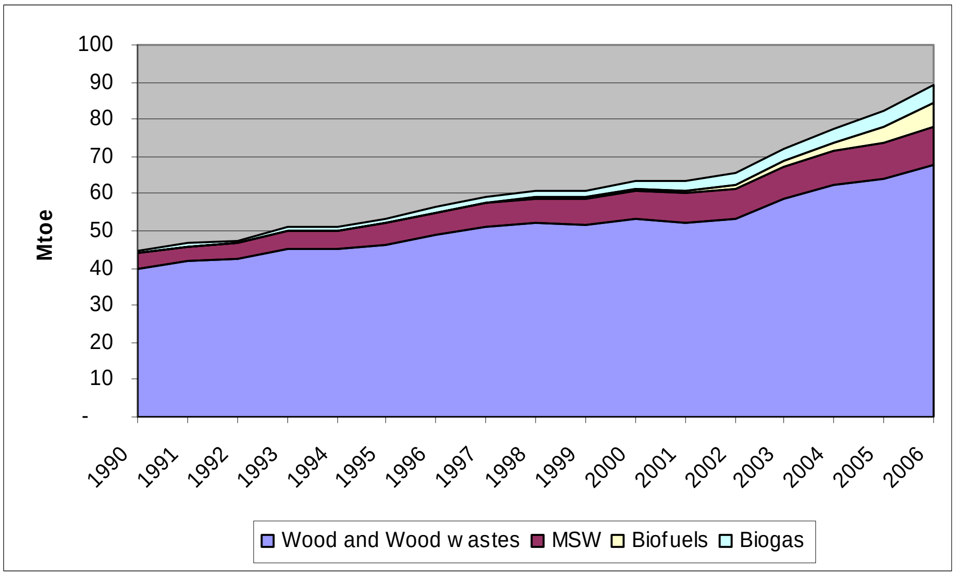
Figure 3 illustrates the dynamics of bioenergy use over the past two decades. Overall, the global share of biomass has remained stable, but in recent years a sharp decline in share can be observed in China and a steady increase in the EU. In China the amount of biomass used increased by 12.5% between 1990 and 2006, but in the same period total energy consumption rose by 117%, decreasing the share of biomass significantly. The increased share of biomass in the EU is the result of greater use of all types of biomass (for electricity, heat and biofuels), as shown in Figure 4.

Figure 3 **Share of combustible renewables and waste in total energy consumption**



Source: IEA, 2008a.

Figure 4 **Biomass use in the EU-27 (MSW = municipal solid waste)**



Source: Eurostat, 2008.

Around the world there are major differences in the use of biomass. In developing countries, biomass accounts for over 20% of the energy mix; this is mainly woody biomass and dung used for traditional domestic heating and cooking (mostly in simple, inefficient stoves). In industrialized (OECD) countries bioenergy on average only represents about 3% of the mix, but is used for electricity, heating and increasingly for transport fuels. Among the industrialized countries large differences can be observed: in 2006 Finland and Sweden had respective shares of 20.0% and 18.5%[1], for example, while for

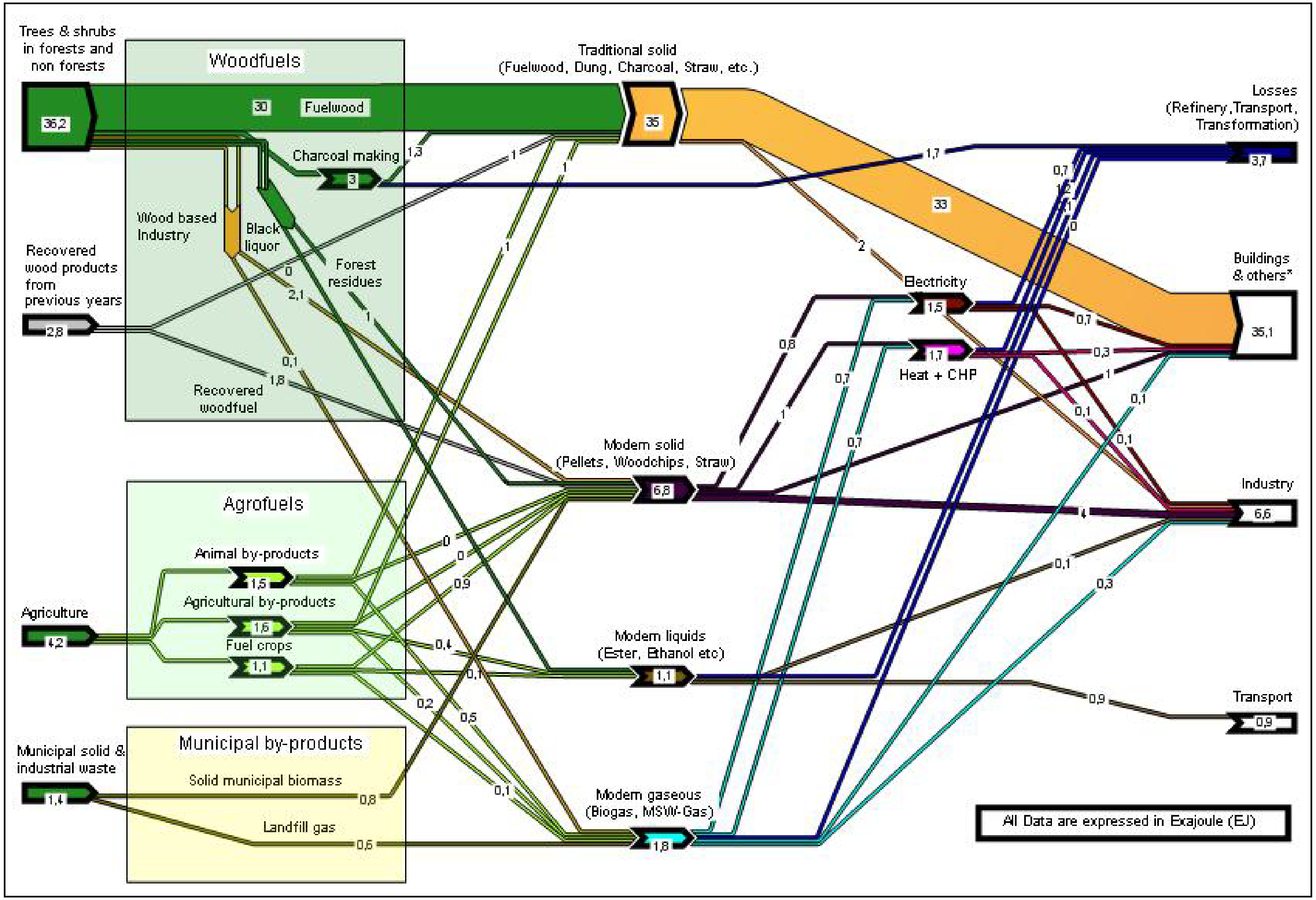
[1] Because of the large wood industries (pulp and paper) in both countries there is a large feedstock of black liquor (by-product from paper pulp production) which is used to produce industrial heat.

Ireland and the UK these figures were 1.3% and 1.5% respectively (Eurostat, 2008).

Over the past decades the use of biomass as an energy carrier for heat and power generation and for transport fuels diversified significantly and the development of new conversion techniques is expected to continue for many years to come, thus further broadening the range of applications for all biomass feedstocks. An overview of bioenergy routes is given in Figure 5.

The most significant (and by far the oldest) route is the use of wood for heat generation, as illustrated in Figure 4 and Figure 5. At present only a small fraction of biomass is used globally for biofuels production and power generation, but these shares are growing rapidly because of issues like energy security, rising fossil fuel prices and, last but not least, global warming concerns and greenhouse gas reduction policies. With demand for energy continuing to rise in absolute terms, the absolute use of biomass will increase even more.

Figure 5 **World biomass energy flows (EJ) in 2004 and their thermochemical and biochemical conversion routes to produce heat, electricity and biofuels**



Source: IPCC, 2007; Much of the data is very uncertain, although a useful indication of biomass resource flows and bioenergy outputs still results.

Biomass resources: current and potential

Figure 5 shows the current flow of global biomass, according to the IPCC (2007). Although much of the data is uncertain, it does provide a useful picture of the overall situation and the relative size of the flows. As can be seen, the largest flow of biomass is fuel wood for domestic use. Other routes are agricultural by-products and municipal waste, which are converted to gaseous, liquid or solid energy sources for various uses in buildings, industry and transport.

Besides diversification of biomass *conversion*, the past few decades has also seen a diversification of biomass *resources*. In the past, biomass was primarily limited to woody feedstocks, but today bioenergy resources range from residues from the food industry to dedicated energy crops and in the future may possibly extend to aquatic biomass, too. Globally, biomass currently provides around 50 EJ (1.2 GtOE) of bioenergy in the form of combustible biomass and wastes, liquid biofuels, municipal solid waste, solid biomass/charcoal, and gaseous fuels.

There is an intense debate about future biomass potentials, especially in the light of sustainability requirements. This is clearly illustrated in Table 1, which provides an overview of the global potential of land-based bioenergy supply over the long-term. The potentials shown here are the estimated technical potentials for a number of biomass categories, and the result of a synthesis of several global assessments. A more detailed analysis of the potential of biomass can be found in (IEA Bioenergy, 2009).

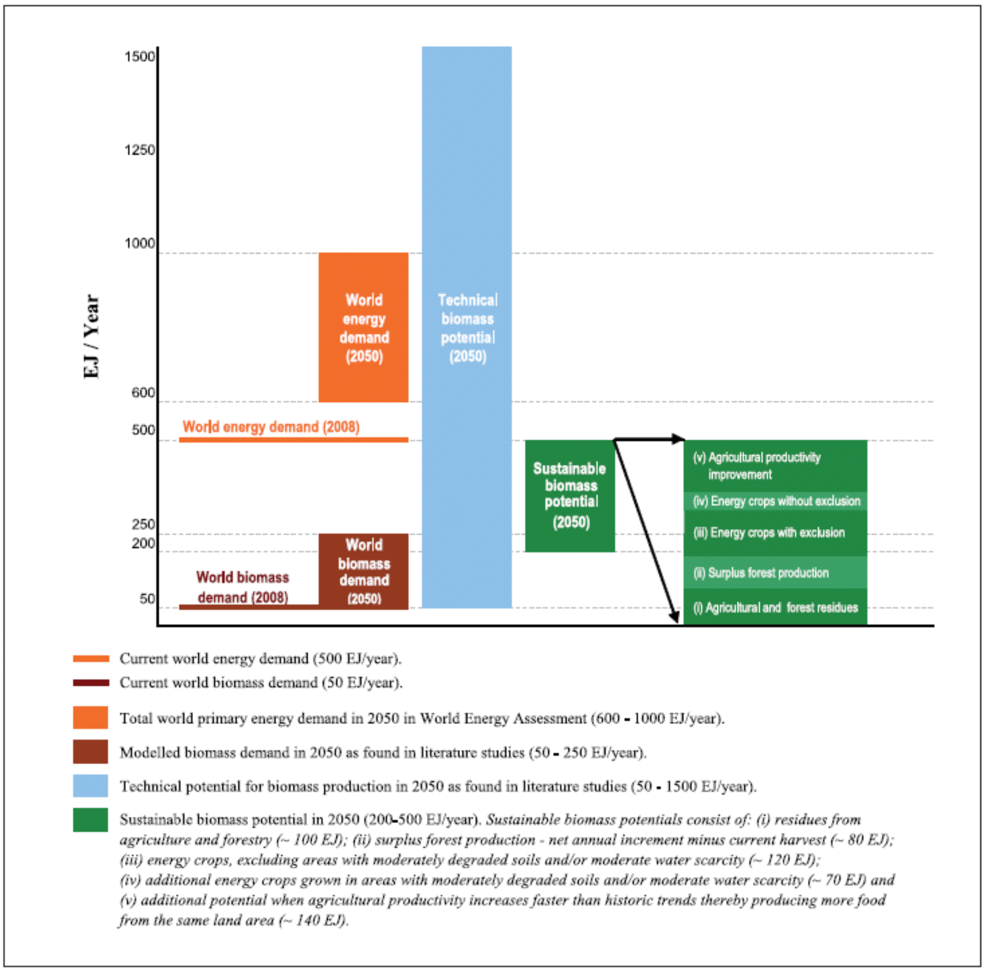
Table 1 **Overview of the global potential of bioenergy supply over the long-term for a number of categories (IEA Bioenergy, 2009)**

Biomass category	Technical potential in 2050 (EJ/yr)
Energy crop production on surplus agricultural land	0 – 700
Energy crop production on marginal land	<60 – 110
Agricultural residues	15 – 70
Forest residues	30 – 150
Dung	5 – 55
Organic wastes	5 – 50+
Total	<50 - >1,100

Note: For comparison, current global primary energy consumption is about 500 EJ.
Note also that bioenergy from macro- and micro-algae is not included owing to its early state of development.

Estimates of global biomass potentials vary widely, depending on the assumptions adopted (regarding agricultural yield improvements and trends in food demand, for example), modelling approaches and how sustainability is taken into account. According to IEA Bioenergy (2009), MNP (2008) and a recent German study (WBGU, 2009) biomass potentials are likely to be sufficient to allow biomass to play a significant role in the global energy supply system even if stringent sustainability requirements are to be met. There are, however, major uncertainties concerning multiple issues and effects such as water availability, soil quality and impacts on protected areas. Of the technical potential shown in Table 1, IEA Bioenergy estimates the sustainable potential to be around 500 EJ/yr (11.9 GtOE) when a number of uncertainties and sustainability issues have been taken into account (IEA Bioenergy, 2009).This potential is comprised of residues from agriculture and forestry (~100 EJ), surplus forest production (~80 EJ), energy crops (~190 EJ) and additional crops due to extra yield increases (~140 EJ). Figure 6 summarises the situation and explains the terms.

Figure 6 **Global energy sources (EJ)**

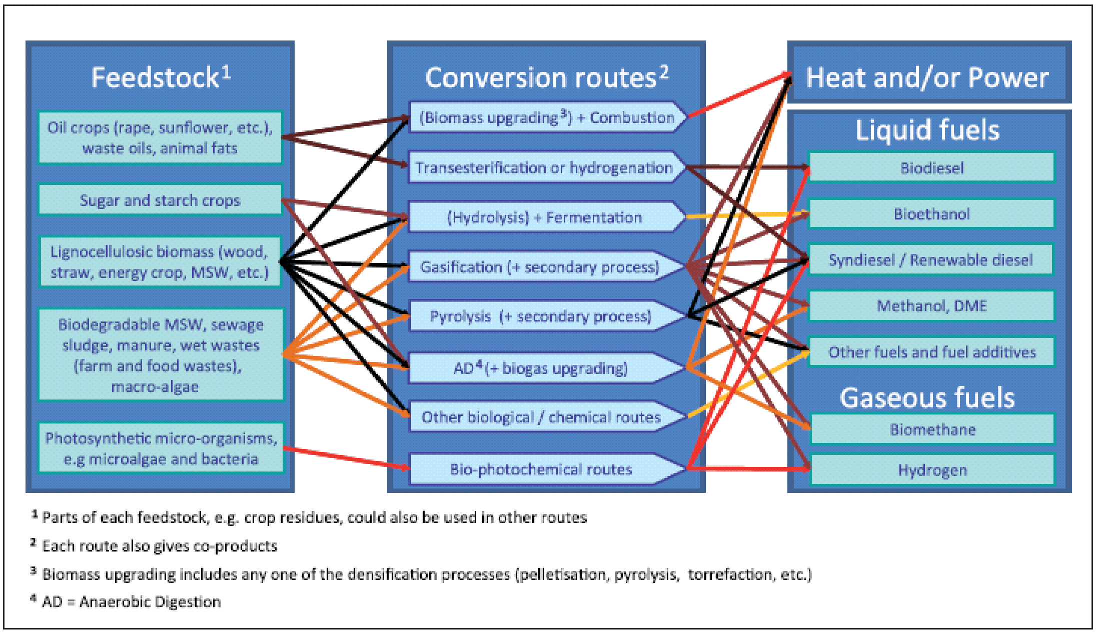


Source: IEA Bioenergy, 2009.

Bioenergy routes: a wide range of options

There are numerous routes available for converting biomass to various forms of bioenergy. A schematic overview is provided in Figure 7 (IEA Bioenergy, 2009). While many of these routes are already mature and commercially available, some are still in the research and development stage, as with conversion of lignocellulosic biomass to synthetic diesel via gasification, for example.

Figure 7 Schematic view of the wide range of bioenergy routes



Source: IEA Bioenergy, 2009.

This schematic illustrates the variety of options that exist in this field, with each route possibly resulting in different economic, environmental and social impacts. In addition, each of these feedstocks, conversion processes and bioenergy applications will have its own potential for improving environmental and economical performance, for example. Many of these feedstocks will also have other useful applications: they may also be used for food or feed, chemicals or products, paper, construction material, etc. Even though this report focuses on energy applications, in an overall assessment of best use of biomass these other uses should also be considered.

1.4 Drivers for bioenergy

Considering the various countries and regions of the world, several main drivers or objectives for the increasing use and development of bioenergy can be identified. Especially in the industrialized countries, climate change is an important driver, together with energy security concerns and rural development interests. These three issues are the key drivers of sustainable energy policies in the EU and its member states, for example. Policy support schemes in these countries are often used to drive modern bioenergy, especially bioelectricity and liquid biofuels, but also biomethane, into the energy markets. In the US, energy security, job creation in 'green' industries and GHG mitigation are the key drivers of bioenergy development. In developing countries, governmental influence on biomass use features less prominently and biomass is generally used because it is the cheapest energy source available for heating and cooking[2]. In general, the aim of policies is to increase modern uses of biomass, thus reducing traditional uses of biomass in developing countries.

2 The exception is the growing governmental influence on transport fuel markets also in developing countries, where quota systems or biofuel 'mandates' are used to increase domestic use of biofuels. In this case it is generally security of supply concerns, hard currency restrictions for oil imports and rural development interests that are the drivers.

The main drivers of an increase of traditional biomass use are population growth and poverty. It is expected that with the growing world population and remaining poverty these types of biomass applications will grow as well, since fossil alternatives (e.g. diesel, LPG, kerosene) are more expensive. Presently, 2.5 billion people - a third of the world's population - rely on traditional forms of biomass. In the absence of new policies this figure may rise to 2.7 billion people in 2030. Because traditional biomass use is very inefficient and causes adverse health effects (IEA, 2006), there is major potential for improving the technical and environmental aspects[3]. Such improvements in efficiency could, if implemented, offset expected growth.

In OECD countries the main drivers of bioenergy deployment are the following:
1. Climate change.
2. Energy security (including concern about energy prices).
3. Air quality.
4. Rural development (e.g. local economic improvements).
5. Agricultural development (e.g. improvement of degraded land, soil protection).
6. Technological progress/innovation.

An overview the main drivers in a number of countries is provided in Table 2. Although these drivers are all interconnected, their weight and implications for policy differ at local and regional levels.

Table 2 Drivers and main objectives for the development of bioenergy in G8 + 5 countries

Country	Climate change	Air quality	Energy security	Rural development (economic)	Agricultural development (remediation)	Technological progress
EU	X		X	X	X	X
US		X	X	X	X	X
Canada	X	X	X			X
Japan	X	X			X	X
Russia	X	X	X	X	X	X
China	X	X	X	X	X	
India			X	X		X
Mexico	X	X	X	X		X
Brazil	X	X	X	X	X	X
South Africa	X		X	X		

Source: GBEP, 2007.
Note: As stated in country summaries and key policy documents.

Although there is currently far less 'modern' than 'traditional' biomass use, it typically involves the processing of larger quantities at single sites and conversion plants. Only 6% of the total volume of biomass used for energy purposes is presently converted in biomass-based power and heat plants. Modern biomass is used primarily for power generation and less for heat and transport. Its main applications are co-firing in coal plants, CHP for district heating, large process heat boilers in pulp and paper or food industries, and municipal solid waste (MSW) incineration plants. Over the past few years the use of biomass for transport biofuels has grown significantly in many countries

3 The main reasons to reduce both growth and level of traditional biomass use are to halt deterioration of existing forests, and to reduce health impacts from indoor air pollution. Approx. 80% of all natural forests in Africa are already been used to harvest feedstock for biomass, and some 1.3 million people per year die from indoor air pollution (IEA WEO, 2006).

worldwide, but it still accounts for 2% of the final bioenergy mix (IEA Bioenergy, 2009).

The technologies used to convert biomass to energy are largely dependent on the type of biomass resources available. For example, anaerobic fermentation (biogas) plants exist where an abundance of dung or manure can be found, and stand-alone power plants are built near high-volume sources of agricultural or forest residues. Over the past decade the import of biomass has become increasingly popular for co-firing in coal plants (especially palm oil and wood pellets) because of its promising cost-effectiveness and flexibility. This development gave a huge impulse to the global market for biomass.

1.5 Environmental impact: positive effects can be significant, but not for all routes

In many OECD countries, GHG reduction is one of the main drivers, or at least a prerequisite, for bioenergy use and policies. The amount of GHG reduction achieved by the bioenergy will thus be an important criterion in any assessment of how bioenergy use can be improved. Other environmental impacts may be significant, too, especially in the case of biomass cultivation for bioenergy. In some cases there may be major impacts on local and regional water use and pollution, on soil quality (nutrients, erosion, etc.) and on biodiversity. These issues are typically very location-specific and also depend on the type of crop under cultivation and on local agricultural practices.

1.5.1 Greenhouse gas emissions and reductions

Most bioenergy routes will indeed reduce greenhouse gas emissions, in many cases significantly, but there also examples where the opposite holds: if the bioenergy is based on biomass cultivation that leads to land use change (either directly or indirectly), GHG emissions may rise when bioenergy is used to replace fossil fuels. These effects can be reduced, though, by controlling land use change in non-bioenergy sectors (especially forestry) and by using more productive non-agricultural feedstocks and more efficient conversion routes.

Various bioenergy routes will also have other environmental impacts, mainly on local and regional air quality, water quality and availability, and biodiversity. These effects may sometimes be positive, often be negligible, especially when organic waste or residues are being used as the energy source, but in other cases they may also be significant – either positively or negatively. Large-scale biomass cultivation may, for example, lead to reduced water availability and biodiversity loss if it leads to land use change or agricultural intensification. However, bioenergy may also lead to significant air quality improvements – where biogas replaces traditional biomass for cooking and heating, for example, or through a decline in airborne particulates in urban areas due to the low sulphur content of biodiesel.

Focusing here on the impact on GHG emissions, it can be concluded that biomass contributes most effectively to GHG mitigation if biomass routes are used which:

a Yield the lowest GHG emissions down the chain from feedstock cultivation to end use. And
b Replace a (fossil) fuel with high GHG emissions.

This implies that an important aspect of better bioenergy policy is to ensure that only bioenergy is used that actually achieves GHG reduction when the entire supply chain is considered, as calculated using life cycle assessment (LCA) methodology.

The literature indicates that both GHG emissions and energy balances may vary significantly across the various applications - power, heat and transport - and across the various specific feedstock-to-end-use routes. The precise situation depends very much on a wide range of factors, including:

1. The type of biomass feedstock and its source (e.g. region of cultivation).
2. The agricultural practices employed (in the case of cultivated biomass).
3. Whether or not biomass production leads to land use change (either direct or indirect) and, if it does, what previous vegetation is replaced and what soil type is converted.
4. Process conversion efficiencies and auxiliary energy supply (e.g. coal or gas).
5. The quantity, quality and use of by-products.
6. The fossil fuel being replaced (e.g. coal, gas or oil).
7. In some cases (notably biogas) the GHG emissions of the biomass in the reference case (i.e. if the biomass were not used for bioenergy).

There may also be differences in the LCA results themselves, owing to methodological differences, for example regarding how by-products of processes are accounted for (especially relevant in the case of biofuels, but also for biomass CHP), and how land use change is factored in.

In addition, it is worth noting that even if the LCA is carried out comprehensively and accurately, there may still be fairly large uncertainties in the results (UNEP, 2009)[4].

Research has indicated a further source of emissions from increased biomass for energy production: if bioenergy crops are grown on land **previously used** for food, feed or fibre production, it **displaces** this prior production of food, feed or fibre.
As demand for this displaced production remains, it will be produced somewhere else, which may result in the conversion of other land (with the associated carbon emissions) to produce the respective volumes of food, feed or fibre. These emissions from **indirect** land use changes (iLUC) due to the displacing action of bioenergy production can, on balance, do away with any positive effects of fossil fuel substitution.
The extent to which iLUC may occur and the GHG emissions to which it may give rise are issues that are still being debated[5].
Biomass for energy is **only one** option among many for land use and markets for bioenergy feedstocks and agricultural commodities are closely linked. Thus, LUC effects which are 'indirect' for bioenergy are 'direct' effects of changes in agriculture (food, feed) and forestry (fibre, wood products). They can be dealt with only within an overall **framework of sustainable land use** and in the context of **overall** food and fibre policies and respective markets[6].

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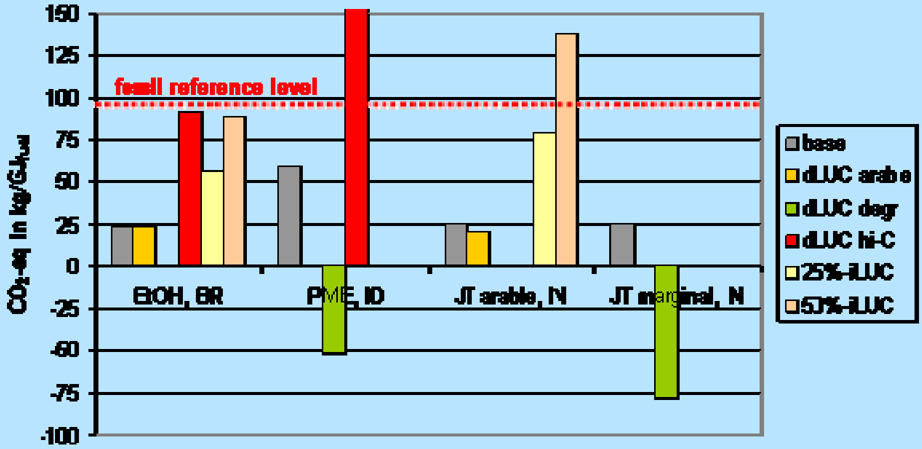
[4] Note that potential indirect land use change effects are not included in these calculations; these will be discussed below.

[5] See, for example, the recent workshops of IEA Bioenergy Task 38 http://ieabioenergy-task38.org/workshops/helsink09/, IEA Bioenergy Exco www.ieabioenergy.com/DocSet.aspx?id=6214, GBEP www.globalbioenergy.org/events1/gbep-events-2009/other-events-2009/en/ and IPIECA-UNEP-RSB www.ipieca.org/activities/fuels/workshops/nov_09.php

[6] See the IEA Bioenergy Position Paper on Bioenergy and Land Use (forthcoming).

Figure 8 Sensitivity of biofuel GHG balances with respect to direct and indirect LUC



Source: Review of Bioenergy Life-Cycles: Results of Sensitivity Analysis for Biofuel GHG Emissions; study for UNEP DTIE, Paris 2009; EtOH= bioethanol; BR= Brazil; PME= palm oil-methyl ester; ID= Indonesia; JT= Jatropha oil; IN= India; dLUC= direct land use change; iLUC = direct + indirect LUC; degr.= degraded land with low-carbon stocks; hi-C= land with high carbon stocks (above- and below-ground).

Despite the large variations between specific routes and the data uncertainties involved, two ‘robust’ conclusions can be drawn[7]: replacing fossil fuels by biomass in heat and electricity generation is generally less costly and provides greater GHG emissions reduction per unit of biomass than converting biomass to biofuels for the transport sector.

There are exceptions to this rule, however. For example, ethanol from sugarcane can deliver nearly the same GHG results and costs as bioenergy produced from wood. Similarly, biodiesel from palm oil could perform very well if the crop were grown on degraded land instead of converting peatland or tropical forests.

When assessing the issue of GHG emission reduction, one should also look at the possible alternative options, either on a national or regional scale or in the various sectors. For example, it is argued by some that biofuels routes should be supported despite their higher cost and sometimes inferior environmental performance because there are very few other attractive GHG reduction and renewable energy options available in the transport sector. Similarly, within the transport sector it could be argued that biofuels should preferably be used by aviation, maritime shipping and/or trucks rather than cars, because of the lack of GHG reduction alternatives in these end-uses.

A more detailed assessment of these issues is provided in Annex B and in the relevant sections of the following chapters.

[7] See, for example, EEA, 2008; IEA Bioenergy, 2009 and UNEP, 2009; WBGU, 2009.

1.5.2 Other environmental impacts

Besides impacting on greenhouse gas emissions, bioenergy production and use may also affect other environmental themes like acidification, eutrophication, water quality and availability, soil erosion, nutrient balance and biodiversity.

When waste or agricultural or forestry residues are used as a feedstock, the non-GHG impact is typically limited to local air quality, with combustion of the biomass product possibly leading to different emissions of pollutants like NO_x, PM_{10} and SO_2 compared with the fossil fuel used otherwise.

The far larger range of environmental impacts listed above are typically related to bioenergy routes requiring dedicated biomass cultivation. As with any agricultural activity, cultivation of biomass crops such as vegetable oil, corn, sugar beet and so on may lead to acidification and eutrophication, and requires significant amounts of water for irrigation. Land use change induced by increasing biomass demand (direct or indirect) may also impact on local and regional biodiversity (cf. Section 2.3.2).

On the other hand, the avoided impacts resulting from the replacement of fossil fuels – not only GHG emissions – also need to be considered: Thus, there are water impacts from coal mining and biodiversity impacts from (especially unconventional) oil and gas development, and in the event of spills exploration, production and transport of crude oil and fossil diesel, for example, may have a negative impact on large areas of natural habitat. Still, the comparatively high land use of bioenergy crops per unit of useful energy could intensify problems relating to biodiversity as well as water resources.

1.6 Security of supply: important, but hard to quantify

Another common driver of bioenergy use in OECD countries is the aim to diversify energy sources and reduce energy imports, i.e. improve energy security of supply. Replacing fossil fuels by bioenergy from biomass can indeed contribute to these goals, in tandem with energy efficiency measures and use of hydro, wind, solar and other renewables. Of greatest interest in this respect is replacement of oil and gas, the two fuels for which security of supply concerns are highest for most countries. As the transport sector is today overwhelmingly dependent on oil as an energy source and many countries worldwide are (net) oil importers, it is no surprise that security of supply is a key driver for promoting use of biofuels in that sector. A more extensive discussion of the potential role of biomass for energy in the security of supply debate can be found in Annex C.

It is sometimes argued that GHG reduction and security of supply/fossil energy reduction weight in almost equally as indicators. The two indicators are indeed linked, but in many cases they are not the same (as can be seen from Figure 17 in 0). Especially for 1st generation biofuels based on agricultural products, the reduction in fossil energy use may be considerably higher than the GHG reductions achieved – if low energy input is combined with high N_2O emissions from fertilizer use and possible carbon emissions from land use changes. In addition, the GHG emissions of the fossil fuels replaced are not correlated with their security of supply characteristics: to enhance security of supply it is generally most appealing to replace oil or gas (depending on national or geopolitical circumstances), whereas GHG reduction can typically best be increased by replacing coal. Apart from these considerations, security of supply also has an important geographical component that is hard to quantify: for the EU, for example, replacing gas from Russia is not the same as replacing gas from Norway (ECN/CIEP, 2007).

1.7 Role of biomass in global and national climate policies

Biomass in general, and forests in particular, are important elements of the global carbon cycle. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) calculated that approx. 20% of anthropogenic CO_2 emissions during the 1990s resulted from land use change (LUC), primarily deforestation. In parallel, the IPCC estimated that 25% of total emissions were reabsorbed by terrestrial ecosystems through replacement vegetation growth on cleared land, land management practices and the fertilizing effects of elevated CO_2 levels and nitrogen deposition (IPCC, 2007).

Depending on age, management regime, and extraneous factors such as fires, forests can act as reservoirs, sinks (removing carbon from the atmosphere) or sources of CO_2. Thus, reducing emissions from deforestation and forest degradation (REDD) could, in principle, be a mitigation strategy under the global climate negotiations for the post-2012 regime. It was discussed favourably during the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC COP15) in December 2009 in Copenhagen, but the success of REDD depends largely on available financing.

However, including forest-related activities in a carbon accounting system is itself also a complex issue, for various reasons, including the non-permanent nature of carbon uptake by trees, the temporal variability of the carbon cycle and potential displacement of emissions as deforestation moves elsewhere (IEA Bioenergy, 2010). There are also critical social and environmental considerations to be taken into account, such as biodiversity and the existence of forest-dependent indigenous peoples and local communities.

With forests being potential sources for biomass feedstocks - with regard to both forest residues and forest products - and with the potential longer-term extension of a REDD mechanism to agriculture in general, bioenergy could be an important element in climate negotiations (see the text box below for details):

1. Bioenergy production and use could help reduce net GHG emissions through substitution of fossil fuels in both developing and industrialized countries. With global trade in bioenergy being a potential source of revenue for many biomass-rich developing countries, the prospective future restrictions and respective reductions of GHG emissions under a post-2012 climate regime could boost the economic perspectives of biomass.
2. Bioenergy production and use could serve as a source of revenue for developing countries, especially through the Clean Development Mechanism (CDM).
3. Bioenergy production and use could create positive income and employment effects for local communities, thus reducing pressure on forests or forested land.
4. Biomass feedstock production could potentially enhance terrestrial carbon sinks in forestry, and agriculture in general, but could also lead to deterioration of biological carbon stocks through unsustainable extraction or management practices.

With biomass being a resource available in and to nearly every country, and being a cross-sectoral issue involving not only agriculture, energy, forestry, and transport, but also trade, it has important potential to foster pro-climate economic development in all countries, which could help secure agreement on the complex issues of the post-2012 global climate regime. However, its potential negative impacts should also be carefully considered and where possible appropriately managed.

Forests in the Climate Negotiations: REDD

Under the UNFCCC, forests are considered as both emission sources and sinks. Article 3 states that policies and measures to combat climate change should "be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases …and comprise all economic sectors". Article 4.1 calls on all parties to develop and update inventories of GHG emissions and removals; formulate programmes and make efforts to address emissions by sources and removals by sinks; promote technologies that lead to lower GHG emissions in the forestry sector; and promote sustainable management of sinks and reservoirs.

Although under the UNFCCC all countries are expected to include their emissions and removals from land use change and forestry in their national inventories, only industrialized countries with binding commitments under the Kyoto Protocol (Annex I parties) are obliged to report on emissions and removals from certain land use, land use change and forestry (LULUCF) activities as part of their reduction targets.

In addition, the Kyoto Protocol's Clean Development Mechanism (CDM) allows afforestation and reforestation project activities undertaken in developing countries to count towards emission reduction targets by Annex I parties.

Also, the number of credits that Annex I parties can obtain through CDM projects is capped.

At COP11 in 2005, forests were included in the Convention under the agenda item 'Reducing emissions from deforestation in developing countries: approaches to stimulate action.' Since then, there have been ongoing discussions on existing and potential policy approaches and positive incentives, as well as the technical and methodological requirements related to their implementation.

The Bali Action Plan ('Bali Roadmap') agreed upon at COP13 in December 2007 called for the development of a mechanism to reward reduced emissions from deforestation and degradation (REDD) as an issue to be considered in the post-2012 climate regime and requesting the Subsidiary Body for Scientific and Technical Advice (SBSTA) to work on methodological issues related to potential policy approaches and positive incentives for REDD.

The main methodological issues in need of further consideration were identified in an Annex to the SBSTA draft conclusions on REDD at its session held in June 2008 (FCCC/SBSTA/2008/L.12), including: means for estimating and monitoring changes in forest cover, carbon stocks and emissions; means to establish reference emission levels; means to identify and address displacement of emissions; implications of national and sub-national approaches; capacity building; criteria for evaluating effectiveness of action; and cross-cutting issues (e.g. non-permanence, comparability and transparency, implications of different definitions, means to deal with uncertainties in estimates, and implications of methodological approaches for indigenous peoples and local communities.

The United Nations Development Programme (UNDP) recently created UN REDD, a partnership of the Food and Agriculture Organization of the United Nations (FAO), UNDP and the United Nations Environment Programme (UNEP) in response to the Bali Roadmap. This partnership has funds to work at the country level to: build REDD readiness for monitoring, assessment, accounting and verification of emissions; support risk management; give technical and scientific assistance; design pro-poor financial transfers; and facilitate dialogue. UN REDD organizations engage in knowledge management and REDD awareness and data collection on, inter alia, global carbon stock mapping, biodiversity and REDD co-benefits.

As part of the SBSTA programme of work, the UNFCCC Workshop on Methodological Issues Relating to REDD was held in June 2008 in Japan, with presentations and discussions on the development of methodologies specific to REDD, issues and challenges related to estimating, monitoring and reporting GHG emissions from deforestation and forest degradation, and options for assessing the effectiveness of actions and criteria. Participants also discussed needs and implications related to linking methodologies and policy approaches.

There was general agreement that:

- Cost-effective systems for estimating and monitoring deforestation and changes in carbon stocks can be designed and implemented.
- Guidance is needed to ensure comparable estimates when remote sensing is used, along with access to data, know-how and capacity building.
- The IPCC Guidelines and Good Practice Guidance provide methodologies that can be serve as the basis for estimating and monitoring emissions reductions and carbon-stock changes, but their applicability needs to be assessed.
- Addressing forest degradation is more difficult than addressing deforestation.
- New remote-sensing technologies permitting estimation of changes in biomass will take some years to become routinely available for developing countries.
- Reference emission levels should be flexible, adaptive, based on reliable historical data and periodically reviewed.
- Discussions on policy approaches and incentives can be initiated given the current knowledge of methodological issues, while the implications of different approaches will need to be further explored.
- Co-benefits such as protecting biodiversity and water resources should be promoted.
- A conservative approach could deal with uncertainties in estimates to ensure that there is no over-estimation of emissions reduction.
- Further work is needed on how to address displacement of emissions.

At COP14 held in Poznan in December 2008, progress was made on how a REDD mechanism could be designed and financed, but important issues remain to be resolved. These include questions like how REDD actions should be dovetailed into the existing institutional framework (a separate protocol or not?), whether or not a global target should be set for REDD, how costs can be accounted for and what should be measured, and how consistency with other global conventions (like the Convention on Biological Diversity) can be ensured.

With regard to the post-2012 negotiations under the UNFCCC which were to be finalized at COP15 in Copenhagen in December 2009 and the role of biomass, it is important that parties may need to coordinate their sectoral policies with regard to REDD, as it can have many implications on specific land use (e.g. forest residue availability for bioenergy, forests or forested land to be used for biofuel feedstock production).

At COP15 in Copenhagen in December 2009 REDD was discussed further, with several countries already making offers for funding. It is still an open question, however, to what extent REDD will help mitigate the LUC-related risks associated with bioenergy development.

1.8 Structure of this report

This report is structured as follows.

- Chapter 2 describes the main issues, opportunities and potential solutions regarding *better biomass supply and production*. The chapter considers such issues as the environmental and socio-economic effects of biomass production and land use change due to biomass cultivation, and identifies opportunities for sustainable biomass production.
- Chapter 3 focuses on *better biomass conversion and use*, discussing such issues as conversion efficiencies, contribution to energy security, and the cost and cost effectiveness of using biomass for electricity, heat or transport.
- Chapter 4 looks at the *policy implications*: what issues are key to better bioenergy policies? This chapter also addresses the variety of sustainability criteria and certification systems for bioenergy.
- In conclusion, Chapter 0 then provides a *roadmap for policy-makers* for making better use or biomass for energy. It lists the general criteria for

better use and defines the crucial milestones for the short, medium and longer term.

2 Key issue: Better supply and production

2.1 Introduction

When seeking potential improvements of biomass use for energy, we can distinguish between supply (production) of the biomass on the one hand and biomass conversion and bioenergy use on the other. This chapter focuses on the first part of this bioenergy chain, i.e. the feedstock supply.

In this part of the bioenergy chain, better use of biomass basically implies utilizing only that biomass potential which can be supplied and produced sustainably and cost effectively. This can be addressed at different levels, ranging from the local level, where the impacts of specific biomass supply and production streams are assessed and optimized, to the global macro level, where the impact of biomass supply and production on a larger scale is also included. Recent studies on the indirect effects of land use change and assessments of the impact of increased biofuel demand on the prices of various food and feed commodities have, for example, provided strong evidence that the second, macro-type of analysis is required for strategic analyses.

As discussed in the previous chapter, bioenergy can be derived from a wide variety of biomass sources, ranging from organic waste and residues from agriculture, forestry and households to cultivated commodities such as sugar cane, vegetable oils, switchgrass and so on. In the future, other options may be added, such as cultivated aquatic biomass from macro- and micro-algae. The cost of the resulting bioenergy and its environmental and socio-economic impacts may differ significantly from option to option and will depend among other things on the origin and type of biomass used, on agricultural practices and location and on potential alternative uses of the feedstock. This means that improving supply and production of biomass for bioenergy can be very feedstock-specific and may often depend on local conditions. Nevertheless, a number of general conclusions and recommendations on how to improve these links in the bioenergy chain can be derived.

2.2 Domestic biomass supply and global trade

From the perspective of both economics and energy supply, many counties are seeking to use domestically supplied and produced biomass for their bioenergy production rather than imported biomass. However, global trade in bioenergy feedstocks such as wood chips, agricultural residues and vegetable oils is growing apace, as is trade of biofuels such as ethanol and biodiesel; see, for example, Junginger & Faaij (2008).

The potential for extracting biomass residues and wastes in OECD countries is typically around 5-10% of the current overall energy supply, if biodiversity needs and soil sustainability are duly considered (see e.g. EEA 2007 for the EU). This figure depends mainly on the share and structure of the agricultural/forest and food processing sectors and the systems in place for waste treatment. The potential for domestic land-based bioenergy crops is determined by land availability, while aquatic biomass production is restricted by water resources and coastal sea access.

Clearly, the potential of both residues/wastes and crops varies significantly across countries, as does the position in international biomass trade. Norway and Canada, for example, have large volumes of residues from forestry and the paper and pulp sector available for bioenergy, for export too, whereas other countries have large areas of land available for bioenergy crop production and export. In contrast, a country like the Netherlands has far lower volumes of organic residues and wastes available (relative to national energy consumption) and limited potential for biomass production. This potential should be effectively utilized, but any further increases in bioenergy use then imply a need for greater biomass imports.

In the short-term there seems to be significant potential to increase domestic biomass supply by improving the utilization of forestry and agricultural residues (IEA Bioenergy, 2009). Increasing biomass cultivation in a sustainable manner typically requires a longer time period, in order to avoid biomass cultivation simply replacing food and feed production, resulting in rising imports of these commodities and indirect land use changes (see the following sections). The potential to increase sustainable domestic biomass supply and production in the longer term then depends on:

- Agricultural developments relating to such issues as yield optimization, fertilizer use and water management and supply.
- Environmental and socio-economic constraints put in place to ensure sustainability of the bioenergy supply.
- Local, regional and global logistical developments.
- The cost of increasing biomass feedstocks domestically compared with fossil energy costs, the cost of biomass imports and other means of CO_2 reduction and energy diversification.

An overview of scenarios on regional and short-term biomass utilization is provided in (IEA Bioenergy, 2009).

Example: Biogas in Asia

Production of biogas via anaerobic digestion is a relatively simple carbon-reducing technology that can be implemented at commercial, village and household scales. It allows for the controlled management of large amounts of animal dung and the safe production of gas for cooking, lighting or power generation. In addition, as a by-product, it provides a valuable agricultural fertilizer. Worldwide 25 million households obtain their energy for lighting and cooking from biogas, including 20 million households in China and 3.9 million in India. In China, biogas is heavily promoted by the government by providing subsidies for biogas digesters. Some analysts estimate that more than 1 million biogas digesters are now being produced each year in China. Beyond the household scale, several thousand medium- and large-scale industrial biogas plants are installed at China livestock and poultry farms. This number is expected to increase following a recent national biogas action plan, under which the government aims to have 50 million rural people using biogas as their main fuel in 2010 and 300 million in 2020.

In Nepal, Vietnam, Cambodia, Laos and Bangladesh, with support from the SNV/Biogas Support Programme, more than 244,000 household biogas installations were installed between 2004 and 2008. This has benefited 1.6 million people by reducing household expenses and workload on fuelwood collection, by improving indoor health conditions and by producing high-quality organic fertilizers. In addition, reduced demand for fuelwood has a positive impact on the environment. Dissemination of the digesters was made possible by the development of a tried and tested technology combined with a successful implementation strategy involving households, government services, non-governmental organisations, the private sector and external financing.

Sources:
- SNV, 2008, SNV and energy interventions, on www.snvworld.org.
- REN21, 2008. “Renewables 2007 Global Status Report” (Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute).
- DuByne (2008), D. Biogas? China size it, in Science Alert, May 9, 2008. www.sciencealert.com.au.

2.3 Environmental impact of biomass production

When energy is produced from residues or waste streams from other processes and sectors (agriculture for food and feed, paper and pulp production, forest management, households, etc.), the environmental impact is typically very low and in many cases positive, depending on the type of feedstock and on what would otherwise be done with the feedstock. A positive example would be anaerobic digestion of animal dung and other types of organic waste: this can prevent GHG emissions that would occur if the dung or waste were not processed, and at the same time reduce demand for fossil energy. The (negative) environmental impact of biomass transport to the location where it is converted or used can be lowered by ensuring local use of the biomass, efficient logistics and use of transport modes that have relatively low emissions (e.g. trucks with low pollutant emissions, transport by ship or rail rather than road). In general, however, the impact of biomass transport is very low, compared with the GHG emissions saved or emitted elsewhere in the bioenergy chain.

When biomass is specifically cultivated, however, the situation becomes more complex. It is probably fair to say that as soon as biomass is grown as a dedicated crop, it will have some form of an environmental impact: the carbon content of the land may change compared with its prior use (positively or negatively), there may be an impact on local or even regional biodiversity and water supply, and fertilizers and pesticides may be used that result in emissions to the environment. The extent of these impacts is found to vary significantly with the type of biomass, with local and regional circumstances (soil type, climate, biodiversity, etc.) and even with agricultural practices. Quantifying these effects can therefore be very difficult and needs to be carried out at a rather detailed level.

A full assessment of the environmental impact of biomass for energy should give consideration to the full life cycle of the biomass and to the environmental impact of the energy source replaced. Several examples were cited in the previous chapter. The following sections focus exclusively on biomass production, where in many cases a significant part of the environmental impact occurs – and where many opportunities for improvements can be identified. The potential to improve the environmental benefits in the downstream part of bioenergy routes (conversion and use) will be discussed in Section 3.3.

2.3.1 GHG emissions of biomass cultivation

When biomass is cultivated for energy purposes, GHG emissions will arise from a number of processes, ranging from the energy used by the agricultural equipment, fertilizer use and transport of the biomass through to the carbon emissions from the soil that was (at some point in time and space) converted to cropland to accommodate the growing demand for agricultural or woody products. Clearly, these emissions are directly related to any agricultural or forestry activity and also occur when growing crops for other markets like food or paper. The GHG emissions resulting specifically from biomass cultivation for energy have received particular attention, however, as one of the main drivers for bioenergy is GHG emission reduction in the context of national and international climate agreements. A more extensive overview of this issue is provided in Annex B; the following is an overview of the main conclusions.

One of the main conclusions from recent studies on this issue is that reducing the amount of land used for biomass production is the key to reducing negative environmental effects and to ensure that a reasonable GHG reduction is achieved. Many of today's 1st generation biofuels have relatively high land requirements, while current electricity and heat generation with biomass mainly uses waste and agricultural residues that do not require any land. The 2nd generation biofuels that are currently being developed aim at being able to use these types of feedstock, too.

The potential of wastes and residues is limited, however (Doornburg, 2008), and increasing biomass use for energy beyond this limit requires dedicated biomass cultivation. As the type of feedstocks for 2nd generation biofuels differ from those used at present (grains, sugar, etc.), it is expected that this cultivation will lead to less environmental problems (e.g. fertiliser and water use) than current cultivation of biofuel feedstock.

The debate on the impact of land use change due to bioenergy crops, on the potential for sustainable and economically viable biomass cultivation and on the best policy measures to limit negative land use change effects and ensure maximum GHG savings is still currently ongoing. Whilst a number of reports have been published that conclude there is a risk of bioenergy cultivation leading to land use change and negative environmental impacts, either directly or indirectly (e.g. Gallagher, 2008; Öko, 2010b; PBL 2010a-e), there is as yet no reliable estimate of the magnitude of this effect for different crops, or of how to incorporate it in biomass sustainability criteria.

Despite this ongoing debate, many countries have maintained or strengthened their biofuel and bioenergy policies in recent years. A growing number of countries, including EU member states and the US, have, however, started to implement some sort of criteria to ensure sustainability and limit undesired land use change effects and are working on improving these in the future.

In addition to the land use issue, low fertilizer use is also important, as this may cause high GHG emissions. This can be achieved by improving agricultural practices (whilst maintaining good soil quality), but even more so by using biomass feedstock with low fertilizer requirements: low fertilizer use is one of the main reasons why biofuels from lignocellulosic biomass typically achieve much higher GHG emission reductions than those produced from vegetable oils, wheat or corn.

2.3.2 Impacts on other environmental themes

As with any agricultural or forestry activity, biomass cultivation may also have other environmental impacts. Acidification and eutrophication are well-known potential impacts of agricultural activity, as are impacts on water management (e.g. local and regional water levels and availability) and water quality (e.g. pollution due to pesticide use). In addition, if the biomass production leads to land use change, either directly or indirectly, that change may impact on local and regional and, ultimately, global biodiversity (MNP, 2006). Inadequate agricultural management may lead to soil degradation and erosion. As most bioenergy-related life cycle assessments focus mainly (or solely) on GHG emissions, there are only a limited number of studies that have assessed these other environmental impacts. An overview is provided in UNEP (2009)[8].

As was the case with GHG emissions, other environmental impacts may vary between specific biomass types and between specific feedstock batches. Local conditions, agricultural practices, water management and so on may all play a role (for an analysis of the impact of ethanol production on nutrient cycles and water quality, see e.g. SCOPE (2008, Chapter 9). Comparing air and water pollution of various biomass-to-bioenergy chains, the general conclusion is that the feedstocks for the current generation of biofuels, i.e. agricultural commodities, have the highest (negative) impact on acidification and eutrophication, in some cases far higher than those of the fuels they replace (Ecofys, 2009; UNEP, 2009). On the other hand, the supply chains of biofuels and bioelectricity from lignocellulosic biomass, wood, waste and residues typically reduce air-polluting emissions, compared with the fossil fuels they replace (Ecofys, 2009).

Agriculture requires significant amounts of water, supplied by either irrigation or rain. Any increase or change in agricultural activity may thus have significant impacts on water use. (OECD/FAO, 2009) warn that already some 44% of the world's population are living in areas under severe water stress, mostly in non-OECD countries, and that this share is projected to rise. The expansion of biofuel and bioenergy production could place additional stress on water resources. Based on recent literature, (UNEP, 2009) estimates that on a global scale, roughly 6 times more water - though mostly from rain - was used for biofuels production than for drinking water in 2007, and biofuels feedstock production consumed about 1.7% of total irrigation withdrawals. As some institutions warn that water crises will emerge in many parts of the world if today's scale of food production continues, increasing water demand for biomass production can be expected to further increase this risk.

Expanding agricultural activity for biomass cultivation can also be expected to have a negative impact on biodiversity, due to habitat loss, enhanced dispersion of invasive species and agrochemical pollution (SCOPE, 2009). This impact depends on the scale of the plantation area, the type of crop and the agricultural practices employed, but also on the specific situation (e.g. the local level of biodiversity, or whether habitats are already under pressure from past activities). Land conversion such as deforestation and conversion of grassland to bioenergy cropland may have the highest impact in this respect. (SCOPE, 2009) provides several specific examples of biodiversity hotspots that are under pressure from increased biofuel demand, such as the expansion of sugarcane and biofuel crops in the Brazilian Cerrado region and the conversion of rainforest to palm oil plantations in Southeast Asia, both biodiversity

8 A recent study of the air-polluting emissions of biomass production can be found in Ecofys (2009).

hotspots. However, in the United States and the European Union, too, some lands currently set aside for conservation reasons are expected to be converted to grow crops for biofuel production (SCOPE, 2009).

In a report for the Global Biodiversity Outlook 2 (MNP/UNEP/LEI, 2006) it is concluded that in the coming decades increased biofuel demand is expected to contribute to a reduction of biodiversity on both a global and regional scale. The **main** contributors to biodiversity loss are shifting agricultural production areas, climate change and land use change due to increased food production, though. The report concludes that "the only option that substantially reduces biodiversity loss in the short-term is increasing the extent of protected areas and effectively enforcing their protection status".

In the longer term, though, increasing biofuels production will have a positive impact on biodiversity, by reducing the impacts of climate change.

If waste or residues from agriculture or forestry are used as feedstock, the non-GHG impact is limited mainly to local air quality, as combustion of the biomass product can lead to different emissions of pollutants such as NO_x, PM_{10} and SO_x compared to the fossil fuel that is replaced. An example is provided in the text box on biogas use in Asia, in Section 2.2.

Summarizing, there are wide-ranging concerns that increased biomass cultivation for energy may lead to significant negative impacts on water quality and availability, biodiversity and to some impact on air quality. These issues are inherent to most of today's agricultural activities and are thus 'inherited' if agricultural feedstocks are used for bioenergy. As these effects depend strongly on local conditions, they are difficult to quantify on a more general level. This does not make them insignificant, however, and they should be given due attention both in biomass and bioenergy policies (e.g. in sustainability criteria) and in life cycle impact assessments of specific bioenergy routes.

A number of best practices can be identified that can reduce these negative impacts or create positive environmental impacts.

- Bioenergy from waste and agricultural and forestry residues have no or very little negative environmental impact.
- Biomass cultivation on previously degraded or marginal land can increase carbon content as well as reduce further soil degradation and erosion. However, using these areas for nature restoration would be even more beneficial to biodiversity (WAB, 2008).
- A general guideline is also that growing agro-forestry systems leads to less biodiversity loss than growing woody biomass and that agricultural crops lead to the greatest biodiversity loss. In addition, biodiversity is higher if less intensive agricultural practices are used and if polycultures of native species are grown.

Applying sustainability criteria for biomass may reduce or prevent the negative direct environmental impact, but no methodology has yet been derived that can also prevent indirect impact - unless bioenergy from cultivated biomass is excluded.

2.4 Competition with food and feed and other sectors

Bioenergy may compete with the food sector, either directly, if food commodities are used as the energy source, or indirectly, if bioenergy crops are cultivated on soil that would otherwise be used for food production. Both effects may impact on food prices and food security if demand for the crops or for land is significantly large. Note that thus far this issue has typically been of concern for the biofuels sector, which uses mainly food crops, whereas the electricity and heat sector tends to use non-food biomass as a feedstock.

An overview of the main conclusions from the literature regarding the impact of growing bioenergy demand on food prices is provided in Annex D. Until now, the price increases that this has led to seem to be limited for most crops, and the agricultural sector has responded by increasing production[9]. There are exceptions, though, especially with crops where biofuel demand accounts for a significant share of total demand (e.g. maize, oilseeds, sugar cane). The 2009 Agricultural Outlook of the OECD/FAO (2009) also concludes that “a projected rapid expansion of biofuel production to meet mandated use will continue to have inflating price impacts for such feedstocks as wheat, maize, oilseeds and sugar”.

Furthermore, relatively small price increases can still have a significant impact on those already undernourished, with the poor, and in particular the urban poor in net food-importing developing countries, suffering most[10].

Besides competition with food and feed, increased use of biomass also has its effects on other sectors. Forest-based industries, for example, will be affected by the increased use of wood for energy conversion, both negatively and positively (EC, 2006)[11]:

- Sawmills: Generally sawmills will probably continue to benefit from the development of wood-based energy markets, because saw logs have higher market value compared with energy use, while the prices of secondary products (slabs, chips and sawdust) will increase, as these can be used for on-site heat and power production.
- Panel industry: The production of particleboard, MDF, OSB or plywood will generally be adversely affected, because of the increased competition for slabs, chips and sawdust from sawmills and roundwood.
- Pulp and paper industry: In the medium-term this industry will be affected both positively and negatively. There will be a negative effect from the increased competition for roundwood. The chemical pulp mills will be positively affected, since they are generally net producers of electricity and heat based on biomass. Furthermore, the chemical pulp-producing industry has the potential to develop integrated production processes encompassing pulp, paper, heat, electricity, fuels and chemicals.

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9 Note that the price rises of agricultural commodities in 2008 were not all due to the increase in global biofuel production. Increased demand for food and fodder, speculation on international food markets, failed harvests and high oil prices were also drivers of higher prices.

10 In many low-income countries, food expenditures average over 50% of income.

11 In valuing the effects of increased bioenergy use on non-energy biomass industrial consumers, the relative competitiveness of these industries compared to foreign competitors must also be considered. For example, tropical countries such as Brazil can produce pulp and paper feedstocks from short-rotation forestry far more effectively than countries with boreal forests. Thus, valorizing forest products in the energy sector of those countries could actually stabilize their forest operation.

2.5 Socio-economic effects in non-OECD countries

Promoting bioenergy production and consumption can contribute positively to a range of social and economic policy goals in producer countries, as discussed in detail in Annex E.2. In this context the following three socio-economic policy goals are most commonly cited:
– Energy security.
– Rural (socio-economic) development.
– Improved trade balance.

Few reliable data are available on proven impacts of bioenergy production on these policy goals. In addition, the potential impacts vary strongly between developing and industrialised countries.

However, biomass production for bioenergy may also have several negative socio-economical effects. Rapid expansion of biomass production in developing countries can lead to similar dynamics as those that may be associated with initial phases of rapid area expansion and large-scale production of agro-commodities in such countries (Kessler et al., 2007):
– Land use conflicts.
– Water-use conflicts.
– Labour issues.
– Increased inequality in terms of income, access to land and gender issues.

These potential negative effects are further described and analysed in Annex E.3.

Note that most of the reasons for these negative socio-economic impacts are general issues not specifically related to bioenergy production, such as tenure insecurity, lack of labour policies and land regulations, limited access to finance, etc. These are discussed in Annex E.4.

Example: Jatropha in Africa

In many countries in Sub-Saharan Africa Jatropha has been known for generations. It has been planted as hedges (to serve as a ‘living fence’) or has been used for artisan soap production or medicinal purposes. Today, a number of investments in cultivating Jatropha as an energy crop are occurring in Africa, where it is being promoted for decentralized rural energy supply (off-grid electrification), for national biodiesel or (if processed) jet-fuel production or boosting exports. An estimated 119,000 ha are now under cultivation, a figure that could rise to 2 million by 2015. The countries with the largest investments are Madagascar, Zambia, Mozambique and Tanzania.

Jatropha has the advantage that it can be produced on relatively infertile soils, needing little water, while offering new employment and income opportunities to local populations. It is, in other words, an interesting crop for Africa’s marginal or ‘idle’ land. Nevertheless, production on fertile land does result in better yields, especially in large-scale plantations systems. Nor is the use of ‘idle’ land without controversy. In Ghana, investments in large-scale Jatropha cultivation on what was assumed to be idle land created much conflict with local populations claiming various user rights. Still, there are various cases of interesting and promising Jatropha projects. Diligent Tanzania Ltd produces biofuel from Jatropha seeds produced by a network of outgrowers. Over 5,000 farmers (mostly smallholders) have planted more than 4,000 hectares of Jatropha, either as a hedge or through intercropping on previously fallow land. Farmers receive planting materials, training and advice and Diligent collects the Jatropha seeds through a network of collection centres and logistical partners. Dilligent owns a factory in Arusha to process bio-oil and biofuel products from presscake (briquettes, biogas, charcoal). Recently, they were the largest single supplier of Jatropha oil for the Air New Zealand test flight conducted in 2008.

Sources:
- Gexsi 2008, Global Market Study on Jatropha, Prepared for WWF, London/Berlin.
- Jatropha Book, www.jatropha-book.com, viewed in April 2009.
- World Rainforest Movement, www.wrm.org.uy/bulletin/129/Ghana.html.

2.6 The crucial issue of land use change

The use of land for bioenergy crop cultivation and the direct and potential indirect changes associated with this cultivation are a key driver for many of the environmental as well as socio-economic impacts described in the previous sections. The type of land use (e.g. agriculture, forestry, nature conservation) goes a long way to determine the precise impacts on ecosystems and biodiversity (CBD, 2008) and influences the GHG balance of bioenergy systems due to changes in above- and below-ground carbon stocks, e.g. through logging of natural forests to prepare land for bioenergy feedstock cultivation[12]. In parallel, changes in land use also potentially affect local communities (e.g. indigenous people) with regard to land tenure, food and feed availability, and infrastructure development[13]. On a global scale, there is the risk of competition between food and feed on the one hand and bioenergy cultivation on the other, possibly pushing up food prices on the global market.

Given these interactions, land use change (LUC) impacts need to be integrated into the criteria for environmental and social impacts. Restrictions on land use for bioenergy as a result of environmental and social criteria are important constrains on the future potential of bioenergy.

Global land use for food, feed and bioenergy

Land use change is not a new concept but is something that has been taking place since the beginning of civilization and continues to do so. In this context, agriculture has always been an important driver, so far mostly for food and feed production. A growing world population and a changing diet have led to continuously expanding areas of agricultural land, despite parallel increases in yields from existing cropland. In addition, cropland is lost due to erosion through chemical and physical degradation, which further increases the requirement for new agricultural land.

Food production currently appropriates about 35% of the global land mass (WAB, 2008), with around 1.4 billion ha of cropland across the world (OECD/FAO, 2009). Currently, only about 1% - and thus a rather small figure - of this area is estimated to be in use for biofuel feedstock production for transport (CE, 2008; Gallagher, 2008).

It is expected that demand for agricultural crops for food and feed will continue to increase significantly in the next decades, owing to an ever-growing world population and changing diets (due mainly to economic development). The FAO (OECD/FAO, 2009) predicts that global food production needs to increase by over 40% by 2030 and 70% by 2050, compared with average 2005-07 levels.
This increase in demand is met to some extent by an increase of agricultural yields. However, as land demand for food increases faster than yields, there will also be an expansion of agricultural land. Over the coming decade this growth in demand is expected to be so high that the agricultural land requirements for food and feed are predicted to grow by 200-500 Mha by 2020. As a comparison: since 1990 the total increase in agricultural land use was 34 Mha (CE, 2008c).

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12 For a more detailed discussion, see Fargione, 2008; Fehrenbach, 2008; RFA, 2008; Searchinger, 2008 and 2009.

13 See e.g., Faaij, 2008; FAO, 2008b; Rosegrant, 2008 and Annex E.

Even though the proportion of global land used for biofuels is currently small, it could reach figures well above the 10% range if future increments in transport fuel demands are met by 1st generation biofuels.

The scenarios of future food and feed demand and related land use reported in the literature vary enormously. Land use for food and feed are typically determined by two parameters: global diet and agricultural yield improvements. With respect to diet, consumption of meat and dairy products is an important driver for land use: on average, 6 kg of plant protein is required to yield 1 kg of meat protein (WAB, 2008). Regarding yield improvements, there seems to be a large theoretical potential for yield improvements throughout the world, especially in the developing countries, but there are still major uncertainties as to what proportion of this potential can be harvested. Gallagher (2008) concludes that "there are realistic prospects for substantial improvements in yields for the future, but such advances are critically dependent on a combination of three drivers:

1. Public investment in research and infrastructure.
2. Supportive legislative and trade agreements. And
3. Private investment supported by profitability of production – hence product prices.

Biofuels provide a mechanism to encourage investment in agriculture to increase yields. Significant growth in biofuels supply will also, in part, depend upon the need to realise these yield improvements."

Food and feed are expected to remain the largest sources of demand growth in agriculture, with growth in demand for feedstock from the growing bioenergy sector being stacked on top of this.

2.7 Opportunities for better production of bioenergy

2.7.1 Increased use of bioenergy from waste and residues

Using organic waste from households and industry (e.g. municipal waste of biological origin, black liquor from the pulp and paper industry, etc.) and residues from forestry and agriculture as feedstock minimizes the risk of land use change, and ensures high greenhouse gas reduction. In addition, the cost of these feedstocks is typically low. Increasing the use of the waste and residues streams that are potentially available should therefore have a high priority when aiming for better use of biomass for bioenergy. However, potential alternative uses should be considered and compared with the bioenergy application. If the biomass is used elsewhere, there is a risk of indirect effects. This is illustrated by a number of case studies in Ecometrica (2009), as summarized in the text box below.

An overview of the type of residues and wastes that can be used for bioenergy can be found in Annex G. Clearly, there is a large range of these feedstocks potentially available, typically at relatively low cost. These can be used for heat and power production, and to some extent also for production of biofuels for transport. Once 2nd generation biofuel production techniques become available, all of these feedstocks can also be converted to biofuels[14].

WAB (2008) estimates the global potential of this type of biomass to be 40–170 EJ per year, with a mean estimate of 100 EJ. Competing applications and consumption changes may push the net availability for energy applications to the lower end of the range. For comparison, current global primary energy demand is about 450 EJ, and current bioenergy production is about 40 EJ (see Figure 2 in Section 1.3).

[14] See IEA, 2010 for a detailed assessment of potential and sustainability of 2nd generation biofuel production from wastes, residues and lignocellulosic biomass.

Wastes and residues may be useful for other applications

Using wastes and residues for bioenergy is typically considered beneficial, as it does not induce land use change and the feedstock is often cheap. However, due caution should be taken in presuming that using these biomass streams for bioenergy is always the best way to create value and reduce GHG emissions and fossil fuel use. Alternative uses of this biomass may be available that may lead to even greater benefits.

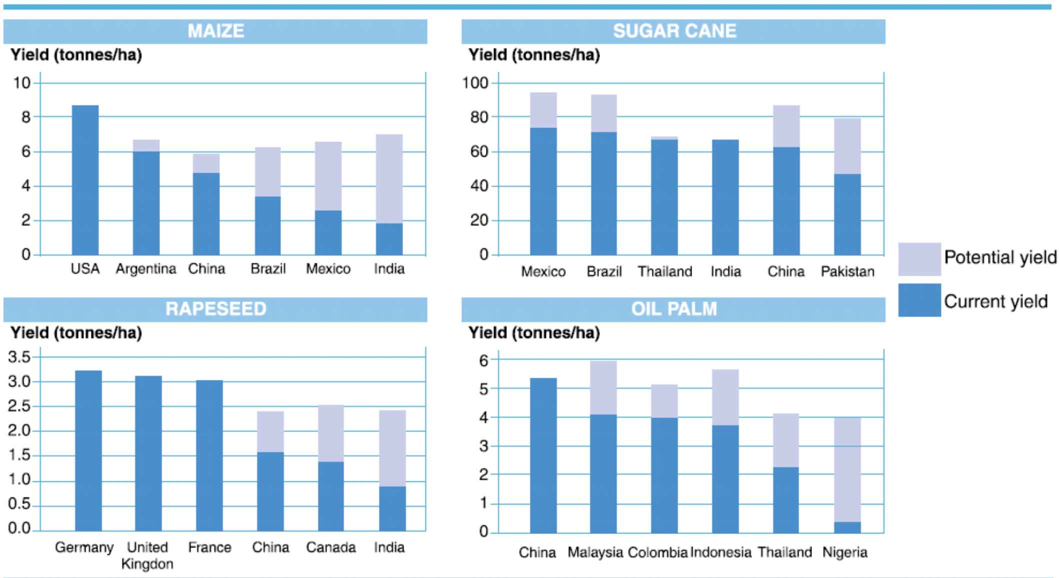
Ecometrica (2009) provides several illustrative case studies in which the effects of using waste and residues for bioenergy and biofuels are assessed. The main conclusion of this study is that using materials which have existing, non-bioenergy uses for bioenergy purposes is likely to lead to higher emissions. On the other hand, using materials which are otherwise disposed of may well have large positive greenhouse gas effects.

2.7.2 Increasing yield, improving agricultural practices

Another opportunity to increase sustainable biomass supply is to increase the yields of agricultural production. This can be achieved either by switching to different crops with a higher yield or by increasing the yield of an already cultivated crop by improving agricultural practices.

In many developing countries, there is significant scope for increasing yields of both food and bioenergy crops, as illustrated in Figure 9 for a number of biofuel crops (UNEP, 2009, based on FAO, 2008). These yield increases can be achieved by a variety of means, such as investments in infrastructure, education and training, more efficient fertilizer use and seed improvement. In developed countries, yield levels have already increased significantly in the past and in many cases seem to have levelled off. In view of the predicted increase in food and feed demand in the coming decades (see text box in Section 2.6), achieving this yield increase is not only important for bioenergy production but also for the agricultural sector as a whole. It is beyond the scope of this report to discuss how these yield increases might be achieved, but harvesting this potential requires investments and education, stable market conditions, suitable trade conditions, etc.

Figure 9 Potential yield increase for selected biofuel feedstock crops



Source: UNEP, 2009; based on FAO, 2008.

A somewhat different option for increasing yields from existing agricultural areas is by shifting to multi-year (perennial) plants with a high per-hectare yield, multiple cropping systems and agroforestry.

Perennial crops and woody energy crops typically have higher yields than the vegetable oil crops and cereals used for current biofuels. In addition, there is a wide variety in yield between crops that can be used for today's biofuels, with yields of sugar cane and palm oil several times higher than those of wheat or rapeseed. This is illustrated in Table 3 from (IEA Bioenergy, 2009).

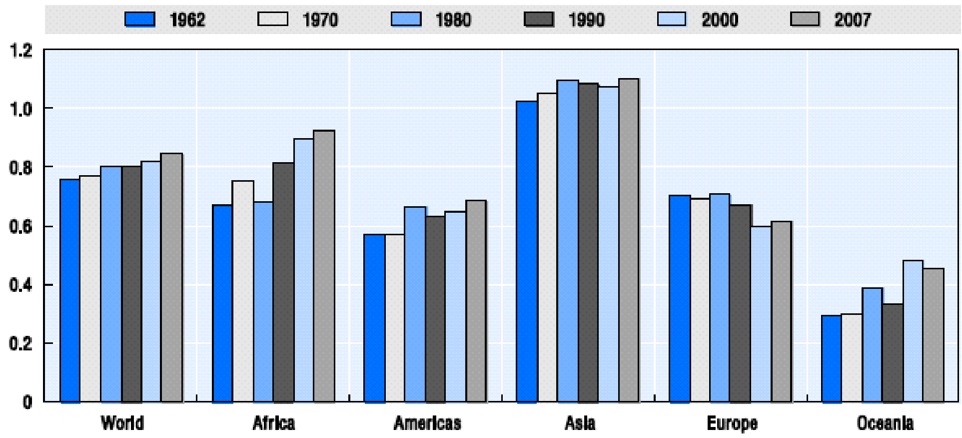
Table 3 **Biomass yields of food and lignocellulosic crops, in tonne/ha/yr and GJ/ha/yr**

Crop	Crop yield (fresh tonne/ha/yr)	Net Energy yield in fuel (GJ/ha/ yr) [3]	By-products
Conventional energy crops [1]			
Wheat	5.1	– 15	Straw
Corn	9.2	19- 37	Stover, straw, DDGS
Sugar-beet	58.5	– 111	Sugar-beet pulp
Sugar-cane	73.1	84-152	Bagasse, tops and leaves
Soy beans	2.7	12-13	Glycerine, seed cake
Palm oil (fresh fruit bunches)	19.2	– 140	Palm kernel shells, PFAD, glycerine
Rape seed	2.9	28	Glycerine, seed cake
Jatropha seeds	4-7	– 40	Seed cake
Lignocellulosic energy crops [2]			
Woody crops, e.g. poplar, willow, *Eucalyptus*	10 – 15	90-110	
Perennial herbaceous crops, e.g. *Miscanthus*, switchgrass, reed canary grass	10 – 30	140 – 230	
Prairie grasses (low-input system, degraded lands)	3 – 6	18-28	

Source: IEA Bioenergy, 2009.

Multiple cropping is the practice of growing more than one crop on the same land during one year and can take various forms, such as mixed cropping, intercropping, double cropping, etc. (OECD/FAO, 2009). The Agricultural Outlook 2009 shows that multiple cropping is increasing steadily throughout the world, mainly because of the growing share of irrigated land. The highest level of multicropping is found in Asia, as can be seen in Figure 10. The figure also shows that whilst cropping intensity continues to increase in most parts of the world on average, in Europe it is has long been declining.

Figure 10 Multiple cropping index over time, for various regions



From: OECD/FAO, 2009. Multiple cropping index is defined as the sum of area harvested divided by total arable land.

2.7.3 Use of degraded and marginal land

There are considerable tracts of land worldwide that are not currently used for agriculture or forestry, but which have a low-carbon content and low biodiversity. Part of this land would, in principle, be suitable for cultivating biomass for bioenergy. Cultivation on these types of land could then prevent the negative environmental impacts associated with changing land use described earlier, and in many cases improve the environmental characteristics of the area and contribute to economic development of the local communities or regions. However, there is still significant uncertainty about the actual bioenergy potential of these lands and about the costs and environmental and socio-economic impacts of bringing them into production.

In general, we can distinguish between 'marginal' land, degraded land and abandoned land (UNEP, 2009):

- Marginal land is land that is currently not cultivated as cropland, where crop production is technically feasible but yields are too low and costs too high to allow competitive agriculture.
- Degraded land is land that has been cultivated in the past, but became marginal owing to soil degradation, erosion or other impacts resulting from inappropriate management or external factors such as climate change.
- Abandoned land comprises degraded land with low productivity and land with high productivity that is currently not in use (e.g. where forest is regrowing).

The extent of this land has not yet been quantified in detail, but is anticipated to be in the range of 1 to 2 billion ha worldwide.
This is clearly a very large potential, but only part of this land is potentially suitable for sustainable and economically viable biomass production. Part of this land is actually too degraded to be converted to biomass cultivation, while in other cases it would simply be too expensive. In addition, making this land productive will not always be a sustainable action: this land, especially the marginal or abandoned land, may actually have vegetation on it, in some cases providing scope for regeneration. Converting this land to biomass cultivation may then have negative impacts on carbon content (i.e. GHG emissions) and biodiversity. There may also be negative socio-economic impacts, moreover, if the land currently provides food and wood for cooking and heating to local communities, or is in use as (extensive) grazing ground for livestock.

On the other hand, some portion of these currently uncultivated lands as well as the local communities is likely to benefit from bioenergy cultivation, as it may improve the overall quality of the soil by, for example, increasing nutrient and carbon content, reducing erosion and retaining (rain) water, and thereby stimulate the local economy.

There is still quite some debate and significant uncertainty about the current extent of these types of land, on their sustainable bioenergy potential and on the investments required to develop them accordingly (WAB, 2008; UNEP, 2009). There are significant knowledge gaps regarding such issues as geographical information on the marginal and degraded land and the quality thereof, and on the amount of land that could potentially be converted to sustainable biomass production, taking costs and socio-economic issues into due consideration as well as the time frame needed to achieve this.

More detailed information on this issue can be found in Annex G.3, while a case study is described in the following text box.

Case study: Degraded land

Cultivating biomass on unused degraded land might serve to safeguard against negative indirect land use change effects from bioenergy development. As there is then no displacement of previous cultivation, biomass production on these lands would not increase pressure on protected areas and unprotected biodiversity-relevant areas by way of indirect land use change (see RFA, 2008 and Searchinger et al., 2008). Hoogwijk et al. (2003) estimate that the amount of degraded land potentially available for energy crop production ranges from 0.43 to 0.58 Gha, resulting in a potential energy supply of 8–110 EJ/yr, while ECN et al. (2009) state that the contribution of water-scarce, marginal and degraded lands for energy crop production could amount to some 70 EJ/yr. Thus, unused degraded lands appear to be priority areas for bioenergy production.

However, it is questionable to what extent these areas are indeed available. Caution is required because some of these unused lands may actually constitute areas of significant biodiversity value (Hennenberg et al. 2009) and because degraded lands are often the basis of subsistence for the rural population (Berndes et al. 2003). In some regions, cultivation of degraded lands may place additional stress on scarce water resources if the crop requires increased irrigation or is characterized by high water use. Furthermore, regeneration of degraded land to natural habitat may be more beneficial in terms of carbon sequestration and biodiversity conservation than any benefits accruing from bioenergy feedstock production. Prior to cultivation, a thorough evaluation of the effects of taking degraded lands into cultivation should be included as an integral part of regional or national land use planning. These evaluations should include the potential costs and yields of bioenergy feedstock production on these lands and assess and mitigate any negative trade-offs for biodiversity, the environment and local communities (Hennenberg et al., 2009).
Within the German Bio-global project (Öko/IFEU, 2010), country studies have been carried out in Brazil, China and South Africa using a top-down approach to identify from existing national and/or global datasets degraded lands potentially suitable for bioenergy cultivation after excluding known areas needed for the protection of biodiversity and carbon stock and those that are already in use. Bottom-up, ground truth has been established for selected degraded land areas identified as being suitable and further information was collected on issues not covered sufficiently by available data (e.g. soil, water, land use, social concerns; see Figure 11 for an example). Furthermore, suitable cropping systems have been evaluated for the degraded lands identified.

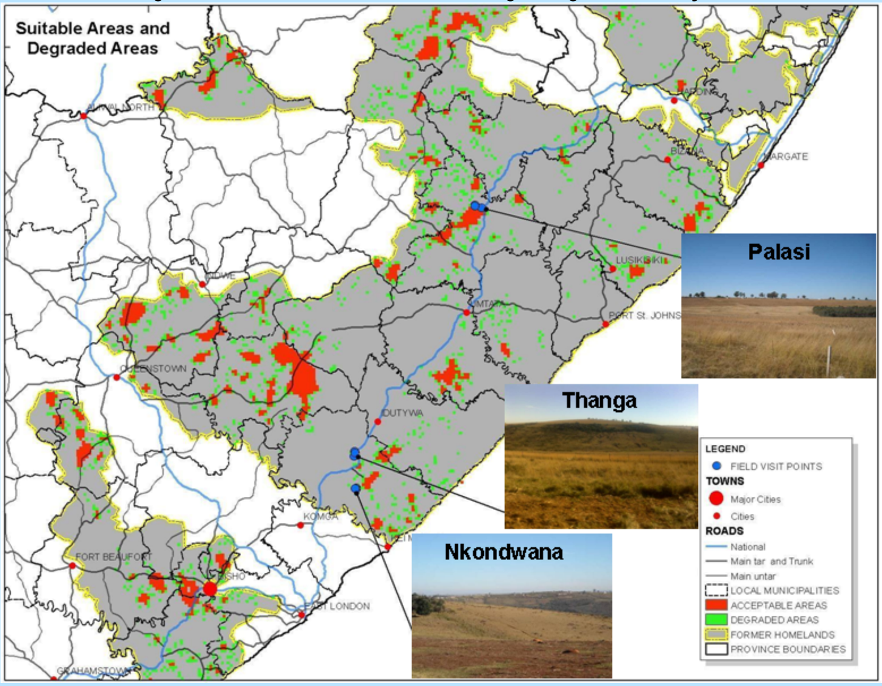
From theses country studies the following key conclusions have been drawn:

1. The approach adopted, combining top-down and bottom-up analysis to identify suitable degraded areas for bioenergy production, is in general feasible. An important point is that the approach can be applied on the basis of globally available data. If more appropriate

national data are available, global and national data can be combined or a complete national dataset used. However, the hit-rate of suitable areas depends on the quality of the top-down data. It also became very clear that the bottom-up analysis is evidentially needed. Information from top-down data is sometimes incorrect (e.g. degraded land and carbon stock) or incomplete (e.g. biodiversity) and important aspects are inadequately covered by available data (e.g. land use).

2. In each country study, promising energy crops and cultivation systems were identified that can be used for cultivation under the environmental and political circumstances in the country concerned, ranging from improved crop-rotation systems with annual crops to agro-forestry systems comprising trees (e.g. Eucalyptus), shrubs (e.g. Jatropha) and herbaceous food and energy plants (e.g. Ricinus). Thus, from a technical point of view, production on degraded lands is possible. In some cases economic feasibility may be questionable, though, owing mainly to the low yields achievable in the areas in question.
3. Assuming that about 20% of the top-down identified degraded areas is available and bearing in mind potential yields in these areas, the South African study estimates biomass potentials of 353,000 t/yr to 1.4 million t/yr. Potentials in China were estimated at about 7 million t/yr, or about 790 million litre/yr of biofuel. Owing to the limitations of the available data, however, the Brazilian team declined to estimate potentials.
4. The bottom-up analysis clearly showed that top-down data alone do not allow reliable estimation of the amount of potentially available degraded lands for biomass cultivation. Estimates of potential energy supply of 8–110 EJ/yr (see above) based on top-down data are very likely overestimates. In this project it was not possible to elaborate a realistic correction term for these estimates, but the amount of available degraded land appears to be at least 10 times lower. Here, further ground truth is needed to derive serious figures.
5. Nevertheless, the country studies have shown that there is certainly potential for producing bioenergy on unused degraded lands. If managed well, this bioenergy production can achieve the promised positive impacts, viz. reduction of GHG emissions, rehabilitation of degraded areas and opportunities for rural development, including access to modern energy.

Figure 11 Degraded land identified as being potentially suitable for biomass cultivation in Eastern Cape (South Africa) and location of test sites. "Acceptable areas" and "degraded areas" show no concerns regarding biodiversity and carbon stock



Sources:

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2.7.4 Other future opportunities

In addition to these options for increasing sustainable biomass potential, there is also research underway on other types of cultivated biomass that can be grown on non-fertile land. This would enable biomass cultivation without creating competition with food and feed, and without converting land with a high carbon content to biomass production.

The main examples of these possible future opportunities are currently various forms of aquatic biomass. Although there are various R&D projects in progress worldwide, costs are still high and yields need to improve significantly before this could provide a commercially interesting option. Jatropha is also being considered, as this is an oil-producing shrub that can grow in semi-arid climates on marginal soil. However, yields from these plants are still limited when cultivated on marginal soils and future developments are still uncertain. Both aquatic biomass and Jatropha are discussed further in Annex G.4.

3 Key issue: Better conversion and use

3.1 Introduction

When biomass is used for energy, it is either used directly (e.g. burned in a stove) or first converted to a convenient form for transport and use (e.g. wood pellets, oil). These latter forms of biomass can then be used for heat or electricity production, and an increasing share of that biomass is processed more extensively to a bio-product such as a liquid (transport) fuel or gas such as methane or hydrogen. Part of the biomass feedstock may also be used as a feedstock in the chemical industry.

As could be seen in Figure 7, there is a wide range of conversion processes available for the various types of bioenergy: heat, electricity and liquid and gaseous fuels. Potential efficiency gains and improvements regarding GHG savings and energy security can be found in all the constituent steps of these processes, varying from process improvements in the conversion process to different choices about where and how the biomass is used.

3.2 Efficiency of conversion and use

Efficiency of biomass use can be defined as creating as much energy (in GJ or kWh) as possible out of a given supply of biomass. Improving efficiency will thus lead to more fossil fuel replacement and in most cases to more GHG savings and better economics, with the latter depending on the cost and energy demands of the efficiency improvement.

Without going into the technical detail of improving conversion efficiencies in the various specific bioenergy routes (which will depend on the specific technical processes in place), it is possible to identify the key issues in this respect:

- Use high-efficiency conversion processes, such as modern, efficient stoves rather than traditional stoves, and CHP instead of power production only.
- Make optimum use of by-products and residues, for example by using glycerine, a by-product from biodiesel production, to replace fossil-based glycerine or by using agricultural residues for bioenergy production. However, care should be taken to ensure that these by-products or residues do not have other, alternative uses that can add more value or save more GHG emissions (MNP, 2008; Ecometrica, 2009).
- Cascading of biomass can also contribute to efficiency improvements, as biomass is then used for different applications during its lifetime and thus replaces more fossil feedstock: biomass can first be converted to biomaterials, which on becoming waste can then used for bioenergy production.
- In the future it is expected that biorefineries will have the potential to make optimum use of biomass, as such installations will be specifically designed to process the feedstock into an entire (and optimized) range of products and energy. The aim will be to convert as much as possible of the

biomass feedstock to high-value products, with the rest being used for energy.

As indicated above, optimum efficiency does not always imply optimum economic performance, at least not in the short-term. For example, large-scale gasification of biomass can be a highly efficient process for converting almost any biomass to fuel gas. Compared to direct biomass combustion, however, the costs are relatively high, operations are relatively complex and their reliability still needs to be fully established (IEA Bioenergy, 2009). The potential benefits, i.e. high efficiency and versatile use of the end product (heat, power and transport) can, however, make this a very attractive technology in the longer term.

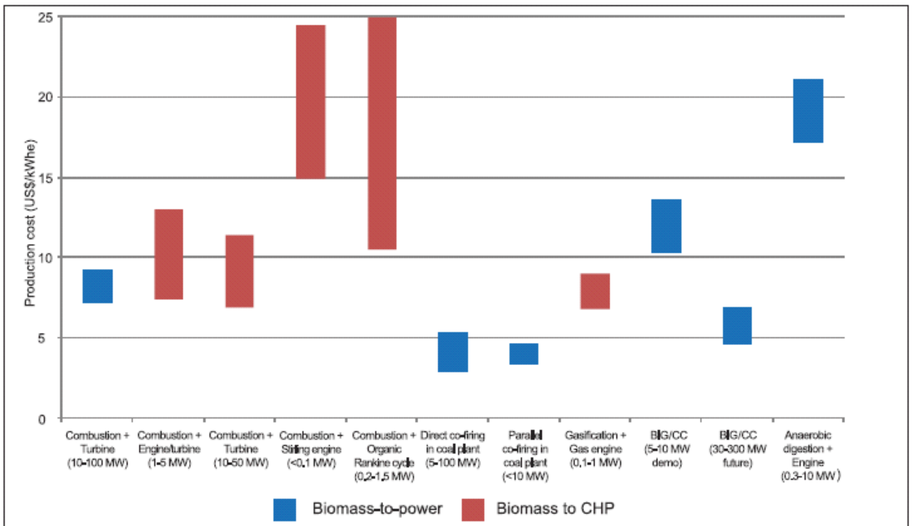
Efficiency of heat production from biomass

A very tangible illustration of the potential for efficiency improvement in some bioenergy routes is domestic heat production from wood. The vast majority of domestic biomass devices in use are traditional cooking stoves common in many developing countries, with an efficiency of 5-30%. Modern units, however, have an efficiency of up to 70%. In industrialized countries, open fireplaces and small wood stoves burning logs can convert up to 50% of the bioenergy into useful heat, but modern pellet boilers achieve up to 90% efficiency.
There is thus major scope for efficiency improvements, especially in developing countries. Improving the efficiency of these processes can significantly improve the scale of potential bioenergy supply and production without increasing biomass volume.
Source: IEA Bioenergy, 2009.

Efficiency of scale can improve economic performance

In many bioenergy routes, increasing the scale of biomass conversion will reduce cost per unit of energy. Examples of this are shown in the figure below, where the production cost (in US$) are shown for a number of technologies for biomass to power (blue bars) and CHP (red bars). More data on the assumptions and costs employed in these calculations can be found in IEA Bioenergy (2009).

Not every increase in scale will reduce costs, however, as the costs of feedstock (i.e. biomass) transport and logistics will rise with increasing scale.



Note 1: Anaerobic digestion can also be operated in CHP mode.
Note 2: Production cost can be reduced by 60-80% (depending on technology and plant size) if free biomass feedstock is used, such as MSW, manure, waste water etc.

Source: IEA Bioenergy, 2009.

3.3 Maximizing GHG emission savings

As discussed in Section 2.3, there is a fair amount of scope for improving the environmental performance of biomass supply and production. Here we consider the downstream aspects of the bioenergy routes, which also provide due scope for measures to ensure that the available biomass supply achieves maximum GHG emission savings.

A number of key issues can be identified that play a role here:

- GHG emissions from the conversion process, which depends on both energy efficiency and the type of energy source used:
  - For example, the bioethanol production process will generate far lower GHG emissions if the process energy is produced from biomass residues rather than coal, or (to a lesser extent) if gas is used instead of coal.
  - Efficiency improvements are already taking place in most OECD countries, where it has been observed that modern bioenergy and biofuel production plants are much more efficient that older ones. This is due to a variety of optimization steps, of which the use of CHP is a well-known example.
- Use of co-products. If co-products from the biomass conversion process are used to power the process, direct GHG savings can be achieved:
  - Note, however, that significant indirect GHG savings can also be achieved if the co-products are used for animal feed, as this will then mean less cultivation of other, comparable feed products (e.g. soy or maize). Optimal use of co-products therefore requires a careful assessment of all the direct and indirect emission effects in a specific situation (RFA, 2009; CE, 2008; Ecometrica, 2009; PBL 2010e).
- The type of fossil energy that is replaced. Different energy sources have different carbon intensities, with lignite typically having the highest GHG emissions per GJ, coal somewhat lower, oil below that and gas much lower (for an indication of emissions of various energy sources see, for example, IEA, 2006). Therefore, if use of biomass leads to less use of lignite or coal power, GHG emission savings will be higher than if the same biomass replaces oil or gas.

Carbon capture and storage could be another option to further increase GHG savings, a topic that will now be discussed in the next subsection.

3.3.1 Carbon capture and storage during conversion

One very specific possibility to maximize the GHG savings embodied in biomass conversion and use in the future is carbon capture and storage (CCS). This can be done in a very similar way to that envisaged for coal power plants, with the CO_2 emissions being captured from the exhaust gases and then stored in depleted oil or gas reservoirs, for example. A very interesting opportunity in this respect is the bioethanol production process, where pure CO_2 is generated that is not 'diluted' by the vast amount of nitrogen present in the flue gas of biomass (or coal) combustion . This 'pure' CO_2 in the off-gas stream can thus be captured at much lower cost than in the case of bioenergy (or fossil fuel) combustion[15].

If this CCS technology is used in conjunction with biomass energy production, it can result in effective CO_2 **removal** from the atmosphere while still creating useful and valuable energy, as the CO_2 that is stored will have been captured by the biomass during cultivation. This can greatly enhance the positive impact that bioenergy can have on global GHG reduction.

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[15] This should be seen as an opportunity. Developments to burn fuels with pure oxygen instead of air to avoid 'nitrogen ballast' are ongoing, but would imply costs for the O_2 production.

3.4 Contribution to energy security

The ongoing international discussion on energy security of supply is a highly political debate that in some countries is the main driver of alternative energy policies, including those on biofuels. While reducing fossil fuel consumption is one means to improve energy security of supply, the main issue in the international debate is securing flows of fossil fuels to the main importing countries in the short and medium term. As the share of biomass in the total energy consumption of OECD countries is currently relatively limited, the contribution of biomass to security of supply is modest, but there are other countries with a far higher share of domestic (or imported) bioenergy. In most nations, if present policy trends continue, biomass will only play a serious role in energy security of supply considerations in the medium term (1 to 2 decades).

Quantification of the contribution of biomass to security of supply is a useful but difficult exercise. It requires political judgment on the political stability of the countries of origin and can consequently never be assessed as objectively as its contribution to mitigating climate change, for example.

3.5 Improving local air quality with bioenergy

The use of bioenergy can also help reduce emissions of (local) air pollutants such as particulates, NO_x and SO_2, which can lead to positive health impacts. There are two separate effects that can potentially improve air quality.

First, the bioenergy can lead to lower emissions than the energy source replaced. This is the case, for example, if biogas replaces coal in power generation or diesel in transport. Improving local air quality is one of the main drivers for various cities that have promoted biogas in public transport (e.g. in Sweden and the Netherlands). Air quality also improves if biogas is used for cooking and heating rather than fuelwood, as illustrated in the text box on biogas in Asia (Section 2.2).

Second, emissions may be prevented that would otherwise have occurred if the biomass had not been used for energy. This effect occurs, for example, if landfill was the alternative destination of the biomass.

Apart from these effects that can be directly attributed to the bioenergy, improved conversion and use of the biomass can also mean reduced air pollutant emissions in the conversion process and use phase. This can be achieved by using appropriate pollution prevention technologies and by using clean energy sources such as gas rather than coal or lignite in the conversion process.

Example: Biogas in Swedish urban transport

Sweden is one of the countries where biogas production and use in the transport sector is being promoted to achieve both climate and air quality benefits. Incentives such as carbon tax exemptions, subsidies for biogas production and for cars running on biogas have boosted biogas use in this sector. Both the number of gas filling stations and the number of vehicles have risen sharply over the past decade, leading to use of almost 35 million Nm^3 biogas in transport in 2008 (19% of Swedish biogas production).

An example of local use of biogas in transport is a project in the Swedish city of Linköping, where urban transport was converted to biogas. The project included construction of a biogas plant and filling stations and promotion of gas vehicles (including 64 buses). According to the

report cited below, this project delivered the following benefits:
- Decreased local emissions of dust, sulphur and nitrogen oxides.
- A CO_2 emission reduction of 9,000 tonnes per year.
- Reduced use of artificial fertilizer.
- Replacement of 5.5 million liters of petrol and diesel. And
- An environmentally sound process for treatment of the organic waste in the region.

Source: 100% Biogas for Urban Transport in Linköping, Sweden; Biogas in buses, cars and trains IEA Bioenergy Task 37.
http://www.iea-biogas.net/Dokumente/casestudies/linkoping_final.pdf

3.6 Local conversion and use?

3.6.1 Local or large-scale conversion

Another issue determining the performance of many bioenergy routes is the scale of the conversion to energy (heat, electricity or fuel). This is typically related to the choice between local, relatively small-scale conversion of the biomass at one end of the spectrum, and larger-scale regional, national or even international conversion at the other.

Conversion close to the source of the biomass has the advantage of reduced transport of the raw biomass, which saves costs and reduces emissions. It can also benefit local or regional economic development and employment. If the resulting bioenergy or biofuel is used locally as well, it can reduce energy imports or, in the case of developing countries, less efficient use of firewood. However, the costs of small-scale biomass conversion are typically higher than those of large-scale conversion, because of the relatively small scale of the conversion process and the often lower efficiencies of conversion.

Larger-scale conversion typically reduces processing costs and boosts the energy efficiency of the conversion process. If combined with flexibility of biomass supply, moreover, it can also have benefits in terms of feedstock costs and security of feedstock supply. However, this route requires transport of the biomass feedstock, leading to additional costs, energy use and emissions. Pretreatment of the biomass before transport can reduce this impact.

Although smaller-scale systems for combined heat and power generation (CHP, or cogeneration) may have a lower efficiency on the electricity side, this could be more than offset by making use of waste heat to replace other heat (or even cooling) systems previously in use in the neighbourhood concerned. On the other hand, available heat sinks might be scarce in some areas, so that moving the biomass to a more central conversion plant where waste heat can be more readily used might be preferable.

Comparison of different conversion options requires an analysis of costs, energy efficiency and emissions, resulting in an optimum scale for a specific route. Note that government policies such as financial support for domestic industry or local biomass conversion may affect the outcome of this assessment.

3.6.2 Domestic use or export

If the biomass or final bioenergy product can be transported, there is also a choice between local/domestic *use* and export. The Linköping case described in the previous text box is an example of the former, while examples of the latter are use of wood pellets from Canada in European power stations and bioethanol exports from Brazil to the US, Sweden, Netherlands and Japan.

The choice between export or domestic use is typically a (socio-)economic one and depends on the opportunities for local use (local demand), transport costs and the associated potential revenues of biomass or bioenergy export, and respective impacts on employment. Government policies, both domestic and in other countries, can have a significant impact on this choice, as many cases in the recent past have shown: in many OECD countries biofuel policies are important drivers behind the export of ethanol from Brazil and biodiesel imports to the EU, electricity policies have led to biomass import in various countries, and national or local policies have led to local use of biomass for cooking, heat, electricity or transport.

If export leads to higher revenues and utilization of biomass that has little domestic use, it may be best from the environmental as well as socio-economic perspective to use the biomass elsewhere. However, if the biomass can also be used domestically, it should be realized that export may also involve environmental and socio-economic trade-offs (e.g. additional transport energy and costs, and less contribution to domestic energy security).

Similarly to the choice of where conversion is to take place, then, the best location for biomass and bioenergy use depends on a range of parameters including transport costs, overall energy efficiency and emissions, as well as on domestic and international demand and price. Government policy can influence this choice, as it may affect demand and therefore the price that domestic consumers or industry are prepared to pay. Policy-makers should then be aware of the trade-off effects of such bioenergy policies on issues like efficiency and emissions.

3.7 Cost and cost-effectiveness

As is currently the case for many renewable energy options, the direct costs of many biomass-to-energy routes are higher than those of fossil fuels at current fossil fuel prices[16]. Exact costs are difficult to determine, however, as the costs and cost effectiveness of the various routes published in the literature range widely (see, for example, JEC, 2007; EEA, 2008). In this context, cost-effectiveness is often expressed in terms of € or US$ per CO_2 eq. reduced.

In general, it can be concluded that in the current situation the costs of the various pathways depend mainly on the costs of the biomass itself. This is an important reason why electricity generation from biomass is generally cheaper than biofuels (per GJ replaced, or per tonne CO_2 avoided): power generation can use relatively cheap biomass waste streams, whereas current biofuel production requires more expensive agricultural commodities such as rapeseed, soy, wheat and sugar beet. This may, of course, change once 2nd generation biofuels processes become available.

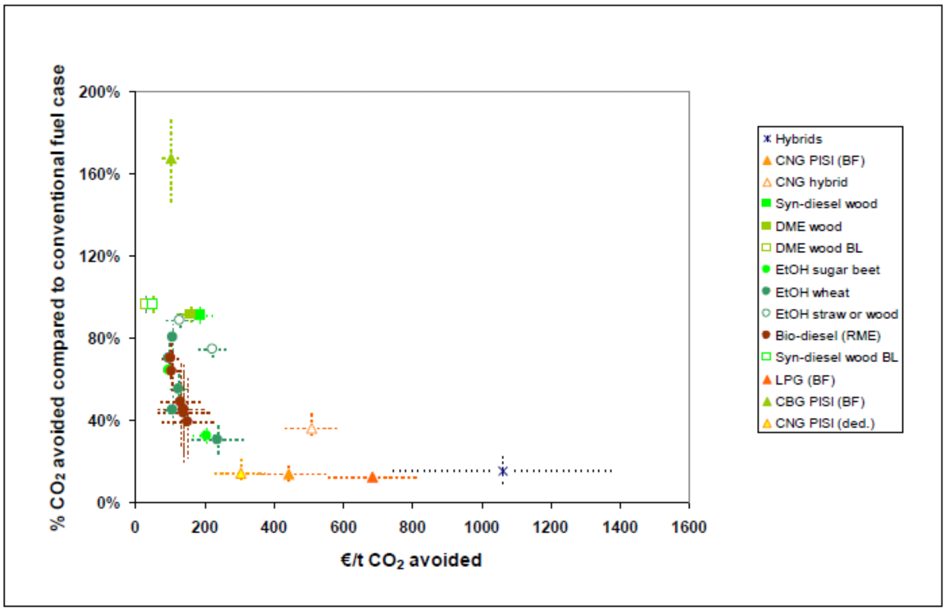
Apart from the costs of the bioenergy itself, policy-makers and consumers will generally be more interested in the additional costs of the bioenergy compared to no biomass use. These costs depend not only on the bioenergy costs, but equally on the cost of the (fossil) fuel that is replaced.

16 By ‘direct costs’ we mean the direct costs to companies and consumers, excluding external effects.

Bioelectricity and bioheat are generally cheaper per GJ biomass or per tonne of CO_2 eq. prevented because of:
1. The cheaper techniques involved. And
2. The cheaper biomass sources that can be used (see, for example, JEC, 2007; CE, 2006).

For industries using biomass as a feedstock, furthermore, production of bioenergy from waste streams is today often economically efficient, too. Examples are the use of wood waste for energy in the paper industry, bagasse for energy in the bioethanol industry and, in some cases, wood pellets for heating.
As an illustration of the spread in cost-effectiveness of various 1st and 2nd generation biofuel pathways, an overview is provided in Figure 12 (JEC, 2007), in which an oil price of € 50/bbl is assumed. This graph illustrates that 2nd generation biofuels such as synthetic diesel from wood, ethanol (EtOH) straw and wood are all expected to achieve high percentages of CO_2 avoided, at less than 200 €/t CO_2 avoided. Many of the current biofuels (bio-diesel and ethanol from sugar beet and wheat) have a cost-effectiveness of about 100-200 €/t CO_2, at CO_2 reduction percentages of about 40-50%. Also note the very high CO_2 reduction potential of biogas (CBG) at relatively low cost.

Figure 12 Cost-effectiveness (€/t CO_2 eq. avoided) versus GHG reduction for various 1st and 2nd generation biofuel-for-transport pathways, at an oil price of € 50/bbl



Source: JEC, 2007.

Note that LPG and CNG are fossil fuels, shown here as alternatives to petrol and diesel. EtOH stands for ethanol, PISI is the engine technology assumed, and BF stands for biofuel vehicle.

Other criteria for better conversion and use: maximising exergy, or quality of energy
It is sometimes argued that 'better' use of biomass could also mean biomass use in energy applications that provide the highest exergy. The term 'quality' is sometimes used in this context as well. Without going into the details of these terms, they typically result in a ranking where electricity is best, followed by transport fuels and high-temperature heat, while low-temperature heat has the lowest exergy or quality.

These indicators were not included here for a number of reasons. Firstly, optimising exergy or quality of energy is not a government goal, in contrast to issues such as GHG mitigation or energy efficiency, security of energy supply, economic impact and employment, socio-economic development (domestic and/or in non-OECD countries), air quality, etc.

Secondly, highest exergy or quality is not always related to market potential and demand, added value to the economy and energy efficiency. These are indicators we consider more important in the debate on better use of biomass.

Implicitly, the various end-use markets for electricity, heat and transport in a given country reflect the overall 'ranking' of the respective services provided by the end-uses, thus reflecting the 'quality' of the end-uses from a customer point of view.

3.8 Learning curves and the question of alternatives

When assessing the scope for better use of biomass for energy, it is important to realize that some of the conclusions regarding better conversion and use presented in the previous sections **might change over time**, for two reasons:

1. Technology research and development and process optimization will continue to reduce costs and GHG emissions of biomass routes and applications, and – thus- increase their attractiveness compared with other options, which might even show an increase in costs or emissions[17].
2. There may be overriding reasons to use bioenergy in sectors that have very few alternatives for GHG mitigation.

The first point is based on the expectation that the conversion efficiencies, GHG emissions and costs of biomass routes will change over time as a result of factors like technological improvements, developments in energy and biomass costs and availability, an increase of production volumes, etc. An example would be a breakthrough in 2nd generation transport biofuel production from non-food crops: if R&D results in a cost-effective conversion process in one or two decades time, the cost-effectiveness of biomass-to-transport routes might improve considerably, potentially making them competitive with biomass-to-electricity. Alternatively, a sharp increase in oil prices would make use in the transport sector more competitive and economically attractive, while an increase in food crop prices would have the opposite effect.

The second issue could play an important role in the longer term, assuming that global CO_2 reduction targets are tightened further. The electricity sector would then have various renewable energy options, of which biomass would be attractive mainly because of its low cost. However, renewable technologies are quite dynamic (e.g. wind and solar-concentrating power becoming more competitive) and other fuel uses such as aviation, international shipping and steel production may have no alternative renewable energy options other than bioenergy. From an economic point of view, use of the biomass in these

17 For example, future crude oil will have to come more and more from 'heavier' and 'dirtier' crudes, and from more 'unconventional' resources such as oil shales, tar sands or even coal-to-liquid processes. Together, this would increase the costs and GHG emissions of the derived fossil fuels, thus shifting the balance towards bioenergy and biofuels.

sectors might then add the most value to society, despite their relatively high cost and perhaps also inefficient conversion methods, compared to use for electricity production. Recently, a number of studies that examined how ambitious GHG reduction targets (80 or 90% reduction) could be met in 2050 concluded that in this situation, biomass will have to be used in sectors where no other renewable energy options exist, which are probably aviation, maritime and inland shipping and long-distance road transport (WWF, 2009; WBCSD, 2010). We would add that the same argument holds for the steel and chemical industries.

4 Key issue: Better policy

4.1 Introduction

The last two chapters considered the various options available for improving the use of biomass for energy – in terms both of utilizing its full potential as an energy source and improving the positive impacts on GHG emissions and the environment, energy security of supply and so on. The challenge now is to translate these results into improved policies that can accelerate these developments, prevent undesired negative impacts and ensure that the necessary actions are taken.

4.2 Biomass and global climate policies

There are already quite a number of regional, national and international policy instruments in place with relevance for biomass use and bioenergy. In general, we can distinguish between global/international policies and national/regional policies, although these may overlap in some cases. An overview is provided in Table 4, while a more detailed elaboration is provided in Annex J.

Table 4 Overview of policies most relevant to the use of biomass for bioenergy

Global policies	National and regional policies
The UNFCCC climate conventions, especially REDD (COP)	Policies related to the various applications of biomass: biofuels in transport, biomass in the electricity sector and biomass for heat production
Development of a global methodology for sustainability certification	National or regional sustainability criteria and certification
Global trade regulations (WTO)	National and bilateral trade regulations, e.g. import tariffs, bilateral agreements, etc.
	Promotion of R&D to improve the effectiveness, cost and sustainability of various biomass applications

In general, one might say that national and regional policies have less impact than global policies, but are easier to adapt, so that modifications can be implemented relatively quickly. These policies also provide scope for intervening in international and global markets, creating an international impact. However, their direct range of influence is typically on the national scale, with the exception of, for example, bilateral trade agreements and sustainability criteria imposed on both locally produced and imported biomass.

Global policies have the potential to encompass the whole biomass-to-energy chain, which is particularly relevant in global markets such as those for biomass and bioenergy. They also provide boundary conditions for national policies, by imposing GHG reduction targets or global trade regulations, for example. Modifying them is much more time-consuming, though, and involves many more parties.

In addition to these policies directly related to bioenergy, there are quite a number of policy options that impinge on other policy sectors that would support the better use of biomass indirectly, as shown in Table 5. For example, agricultural policies can significantly reduce the negative impact and increase the yield of biomass cultivation, forest policies can ensure that yields improve sustainably, and both development aid and waste policies can be targeted at increasing sustainable bioenergy volumes. However, as these policy areas are outside the direct 'sphere of influence' of bioenergy and climate policy-makers, we have not included these in the further analysis of this report.

Table 5 Potential new policies in other sectors that might improve the performance of bioenergy

Type of policy	Specific policy instrument or goal
Agricultural policies	– Prevent the use of high-value conservation areas or carbon-dense areas for agricultural production – Stimulate intensification in areas with low productivity and poor agricultural management – Use land-planning tools to plan agricultural and biomass for energy production – Stimulate sustainable agricultural production – Consider tax differentiations for agricultural products (especially meat and dairy) with high and low arable land use
Forest and forestry policies	– Stop illegal timber production and trade (FLEGT) – Stimulate sustainable forestry – Stimulate combinations of forestry for wood products and energy
Development aid	– Improve the efficiency of traditional biomass use in developing countries – Develop local energy production using biomass
Waste policies	– Stimulate the production of energy from (bio) waste which cannot be used for more valuable purposes or recycled – Implement landfill bans for waste which can produce energy

4.3 Definition of 'better' may vary

Different countries and regions may have different views on what constitutes 'better' use of biomass for energy and these views may well change over time. Optimal bioenergy policies will thus depend on the viewpoint adopted by each specific country or region.

These different views on what is 'better' derive mainly from:
- Different drivers of bioenergy policies (greenhouse gas reduction, energy security, regional or national economic development).
- Whether the country or region has significant biomass resources of its own or potential that can be used for its own benefit (in terms of economics, environment, energy security, etc.), or whether biomass needs to be imported[18].

[18] In the former case countries will aim to optimize the economic benefits their biomass resources can provide, while in the latter case their main aim will be to optimize the cost-effectiveness of their biomass policy.

At the same time, though, there also seems to be agreement on certain issues in OECD countries. First of all, countries will aim to seize any opportunities for favourable economic developments that their local circumstances offer[19]. Secondly, in all OECD countries biomass use for energy is considered to be better if:
– Direct GHG reductions are high.
– Costs are low.
– Basic sustainability criteria are adhered to.

It is on the following issues that views mainly differ:
– Energy security: should biomass address energy security problems, and which fossil fuels should it replace (oil, gas, coal)?
– Use of arable land for biomass production: should bioenergy policies aim to avoid biomass production on arable land, in order to avoid potential GHG emissions and biodiversity loss due to both direct and indirect land use change, and to avoid competition with food?

An illustration of the potential impact of different viewpoints

To briefly assess the effect that different viewpoints and policy goals can have on bioenergy policies, consider the following examples.

First, if a country wants to use biomass mainly for national and global climate policy reasons, it will want to assess the life cycle greenhouse gas reductions and costs of various biomass-to-energy routes. It will then implement policies that provide incentives for those routes that provide the most cost-effective GHG reduction, perhaps with a long-term transition to a low-carbon energy system in mind. Concerns about GHG emissions due to direct and indirect land use change would probably be significant. In the current situation, this country might then focus on the use of biomass wastes and residues for electricity generation in coal power stations, and perhaps also on biofuel routes with high GHG reduction and low arable land use.

On the other hand, if a country is interested mainly in reducing oil imports, its best use of biomass may be in the transport sector, i.e. biofuels (in combination with efficiency measures in that sector). The most cost-effective solutions in that sector would be sought. Environmental performance would be of less importance, albeit that most governments will also want to maximize the co-benefits of their policies.

More examples can be thought of, for example for cases where the main drivers are regional development, reducing dependence on gas imports or optimizing revenues from biomass resources.

Despite their differences, all these countries have in common that they will benefit from optimizing bioenergy potential and domestic economic development, by making best use of their domestic biomass resources.

Figure 13 provides a matrix for visualizing the different views on 'better use' of biomass. Countries or regions that promote bioenergy in order to achieve GHG savings find themselves on the left-hand side of the matrix, countries seeking mainly to address energy security on the right-hand side. Countries that do not see arable land use as a limiting factor in biomass production are situated in the bottom half, others in the top half. For each position, several conclusions regarding the best use of biomass are included.

[19] This may be rural developments in agriculture or forestry, economic development of local industry or ports, etc.

Figure 13 Different country priorities, different views on 'better use' of biomass

Low arable land use

GHG reduction only			Energy security only
	View 3: GHG central Focus on replacing coal Bio electricity and heat Focus on waste and residues and biomass cultivation that does not require arable land	**View 4: Energy + GHG** Focus on replacing oil and/or gas Second-generation biofuels and (bio)electric transport Focus on waste and residues and biomass cultivation that does not require arable land	
	Focus on replacing coal Bio electricity and heat **View 1: Direct GHG**	Focus on replacing oil and/or gas First-generation biofuels **View 2: Energy central**	

Arable land use

As recent bioenergy debates show, views may well change over time. As many countries and the OECD have recognized the importance of reducing land use change that leads to high GHG emissions and also limiting competition with food, these countries have moved from views 1 and 2 upwards, towards the more 'sustainable' views 3 and 4.

The examples of 'better uses' shown in this matrix illustrate the most cost-effective use of biomass in a given view, but only provide a very rough outline. A much more in-depth assessment of biomass routes and specific regional and country opportunities is required to derive the best and most cost-effective policy package and bioenergy use for a given country or region.

4.4 Sustainability criteria for bioenergy

Quite a number of global and national initiatives to improve the positive impacts and prevent the negative impacts of biomass-to-bioenergy routes are currently ongoing.

The rapidly developing area of sustainability requirements for bioenergy and especially liquid biofuels can be described by three trends:
- Industrial countries develop and establish both mandatory and voluntary sustainability standards.
- Developing countries - with the noteworthy exception of Brazil - are subject to those standards, but the majority have yet to consider participation in the discussion and/or establishing their own standards.
- On the global scale, there are both governmental and non-governmental initiatives to establish joint views on sustainability standards and criteria, with the G8 Global Bioenergy Partnership (GBEP) Sustainability Task Force and the Roundtable on Sustainable Biofuels (RSB) the most active[20].

Table 6 lists a selection of existing certification schemes dealing with biomass for energy, wood and timber, agricultural products and specific social aspects.

[20] Also active in this regard is the IEA Bioenergy Task 40 'Sustainable Bioenergy Trade'; see www.globalbiofueltrade.org.

Table 6 Selected existing certification schemes

Biomass for energy
RSPO* Roundtable on Sustainable Palm Oil
RTRS* Roundtable on Responsible Soy
GGL Green Gold Label (Eugene)
Forestry
FSC Forest Stewardship Council
PEFC Program for Endorsement of Forest Certification
MTCC Malaysian Timber Certification Council
Agriculture and agricultural production (mainly organic agriculture)
IFOAM International Federation of Organic Agriculture Movements
SAN Sustainable Agriculture Network
EUREP-GAP Euro-Retailer Produce Working Group – Good agricultural practice
ISQF Safe Quality Food
BIO Organic Farming – EC Label/control system
CCCC Common Code for the Coffee Community
Social standards
ETI Ethical Trading Initiative Code of Conduct
FLO Fair-trade Labelling Organisations International
FLP Flower-Label Program

* = Not specifically designed for bioenergy.

Source: Own compilation based on Van Dam (2008).

From this selection and a variety of other initiatives and studies discussed in the literature (IFEU, 2008; Öko, 2006; Dam et al., 2008 + 2010), the most relevant criteria for sustainability certification systems were derived and are reported below in Table 7.

Table 7 Key criteria in sustainability certification schemes

Environmental Issues
Greenhouse-gas reduction
Conservation of biodiversity, protection of species/ecosystems
Soil – erosion, contamination
Water – resource depletion, contamination
Chemicals – nutrients/pesticides
Genetically Modified Organisms
Socio-economic issues
Land rights (indigenous peoples, local communities, ….)
Freedom of association, collective bargaining
Labour conditions, wages, occupational health and safety
Child and/or forced labour.
Discrimination (e.g. religion, race, nationality)
Poverty reduction and equitable distribution of proceeds
Fair-trade conditions

Source: Own compilation based on IFEU, 2008; Öko, 2006; Dam et al., 2008 + 2010.

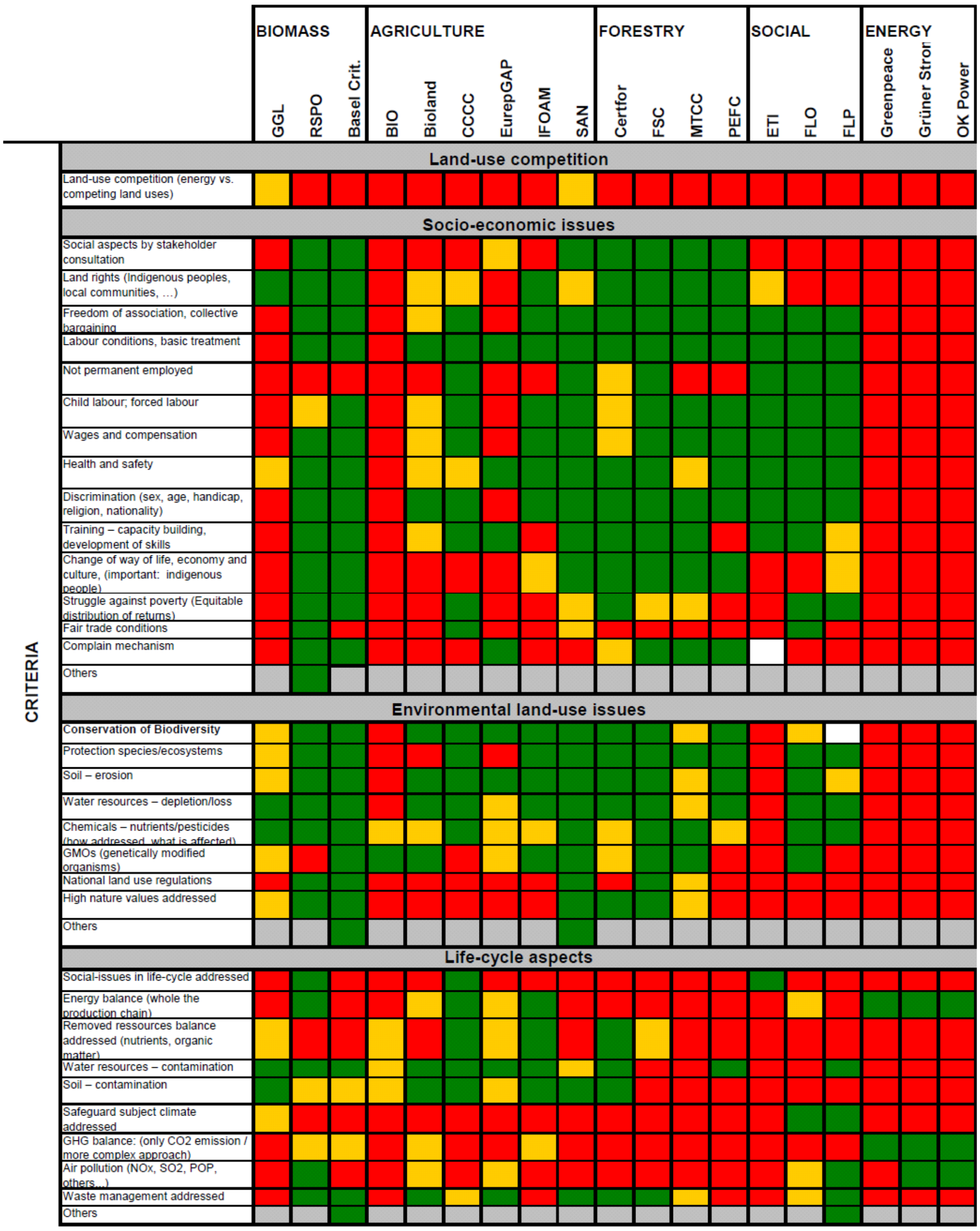
With regard to biomass for energy (especially biofuels) and the perspective of the global biofuels trade it has been argued that only two 'core issues' could be subject to mandatory national sustainability standards, as they are covered by international treaties on global public goods (Öko, 2006):

– Greenhouse gas emission reduction.
– Biodiversity impacts from land use change.

Still, in voluntary standards, or in mandatory schemes not subject to the international trade rules of the World Trade Organization (WTO), a larger variety of criteria can be found.

The following matrix is based on an evaluation of the coverage and relevance of various criteria in selected sustainability schemes and depicts the results in a 'traffic-light' colour coding.

Figure 14 Evaluation of selected sustainability certification schemes



Source: IFEU, 2008; colour code for boxes: red = not included; yellow= partially covered; green = fully included.

As can be seen, there is no clear pattern of how to deal with sustainability, but a strong 'signal' that the globally important aspect of GHG emissions is not (yet) subject to being included in existing certification schemes. Accordingly, current activities on the sustainability of globally traded biofuels concentrate

on GHG emission balances, with the EU RES Directive[21], the California Low Carbon Fuel Standard (CARB, 2010) and the ongoing work of the GBEP GHG Task Force (GBEP, 2008a) being the most prominent drivers on this issue.
In parallel, the discussion of a ‘generic’ - and voluntary - sustainability standard for biofuels continues to address a variety of criteria and issues. With the release of its ‘Version 1’ standard for sustainable biofuels in 2009 (RSB 2009), the RSB started implementing the standard.
The European Standardization Organization CEN began its work on a voluntary standard for sustainable bioenergy in Technical Committee 383, and work on a respective standard on the global level was started in 2010 by the International Standardization Organization (ISO). Recently, the Inter-American Development Bank (IDB) released its ‘Sustainability Scorecard’ for screening biomass projects under consideration of funding (IDB, 2008). This approach also uses most of the ‘generic’ RSB criteria for sustainable biofuels.

Beyond the environmental criteria, further international discussion relates to economic and social issues, as the GBEP Sustainability Task Force introduced three respective ‘baskets’ for possible standards and criteria (GBEP, 2008b).

Near-term trends in sustainability regulation

As can be seen from the trend figures for biofuels (IEA Bioenergy, 2009), the global markets for certified biofuels will remain in the EU (mainly biodiesel, with ethanol rapidly increasing) and the US (mainly ethanol). It can be expected that the EU sustainability criteria, together with the California Low Carbon Fuel Standard (LCFS) and the US EPA Renewable Fuel Standard (RFS2), will determine the rules under which biofuels can be exported to both prime markets. As the EU and the US schemes are already in force, they will set examples for others, though not necessarily in detail (e.g. level of GHG reduction, inclusion of LUC).

Brazil introduced mandatory sustainability zoning for sugarcane expansion in 2010, thus creating a benchmark for other developing countries interested in exports (e.g. Argentina, Indonesia, Mozambique, and South Africa), and is continuing work on a sustainability standard for ethanol. In parallel, international finance institutions such as the World Bank and regional and bilateral development banks will work out sustainability standards for project financing in the bioenergy area. In addition, major private-sector investors in bioenergy supply are likely to commit to voluntary standards under development by CEN, ISO [22] and the RSB[23].

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21 The EU Renewable Energy Sources Directive (RED) includes mandatory sustainability requirements for liquid biofuels and was finally decided upon by the EU Council and the European Parliament in December 2008. The legally binding text was published in the Official Journal of the EU in June 2009.

22 By 2011, the CEN TC 383 standard is supposed to become operational, possibly being extended to a global ISO standard a few years later.

23 The RSB released a ‘version 1’ of its voluntary biofuel sustainability standards in late 2009 and is now working with the private sector on pilot implementation.

4.5 Removing barriers to better use of bioenergy

In pursuit of better use of biomass for energy, i.e. when aiming to optimize performance on the issues discussed in this report and the sustainability criteria provided in the previous chapter, a number of technical, political and practical barriers are inevitably encountered. Removing or lowering these barriers will thus be beneficial for harvesting the full potential of biomass for energy.

In Annex H the main barriers are identified and discussed; the most important ones at present are the following:

Technology barriers

- Quality of the biomass feedstock for electricity production – various types of biomass are unsuitable.
- Lack of continuous heat demand required for optimal use of efficient combined heat and power production.
- Costly fuel-gas cleaning for small-scale installations.
- Lack of commercial-scale processes that can convert lignocellulosic and waste biomass to transport fuel at reasonable cost.
- High cost and limited range of electric vehicles.
- Need for further development of biorefining.

Trade barriers

- Import tariffs.
- Non-tariff trade barriers such as different technical requirements and logistical barriers.

Political barriers

- Policies, including targets for CO_2 mitigation, are typically national rather than global. However, global biomass trade reduces emissions in the receiving county (when replacing fossil fuels) but may increase them in the exporting country.
- Differences in biomass support policies between countries lead to inefficient trading and transport of biomass between countries.
- The (perceived) risk of changing policies over time is a barrier to investments by the industry.
- Different support policies per sector, leading to artificial price increases (such as recently happened in the food sector) and biomass demand in specific sectors that may not be optimum.
- Potential political reactions to impacts on geopolitical issues and fossil fuel demand.

Practical barriers

- Different domestic priorities in the countries or regions where the biomass is cultivated.
- Problems with supply chain interaction, e.g. owing due to price volatility, lack of (reliable) information on technology, markets, etc., and financing.
- Restrictions on infrastructure development, e.g. regarding pipeline networks for biomethane, transport options for biofuels, problems with financing of investments in infrastructure, etc.

Level playing field

Besides differences in policies *between* countries, there are also differences in policies for various bioenergy routes and uses *within* countries. For example, subsidies may be provided for bioelectricity, whereas biofuels in the transport sector are promoted through obligations. This leads to different impacts on biomass prices in the various sectors, resulting in market distortions, so that it is not demand and added value that drive the biomass market but rather policies. This may be a conscious choice, for example to promote R&D and initial market uptake in a specific sector or for a specific route, but it may also lead to reduced cost-effectiveness of biomass use.

There are various policy options to achieve a level playing field between the various bioenergy applications (CE, 2010):
1. Uniform subsidies for all relevant sectors and applications.
2. Uniform bioenergy obligations in all sectors.
3. Alternatively, uniform renewable energy obligations in all sectors.
4. Uniform CO_2 reduction targets for all energy forms (comparable to the CO_2 reduction of transport fuels agreed in the European Fuel Quality Directive[24] and the Californian Low Carbon Fuel Standard[25]).
5. A uniform CO_2 tax on all types of energy (as implemented in parts of Canada and Scandinavia, for example), possibly implemented through an emission trading system.

All these options have their pros and cons in terms of practical feasibility, efficiency regarding promotion of bioenergy use, cost to governments etc. CE (2010) concludes that for the Netherlands, a CO_2 tax (option 5) would only result in a limited uptake of bioenergy (whilst providing a level playing field for all CO_2 mitigation options), whereas options 2, 3 and 4 may be the best means to promote bioenergy deployment via a level playing field for all bioenergy options.

24 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0088:0113:EN:PDF

25 http://www.arb.ca.gov/regact/2009/lcfs09/finalfro.pdf

5 Conclusions: Roadmap for better use of biomass for energy

5.1 Introduction

This concluding chapter provides an overview of what policy-makers can do to further improve both the potential and the positive effects of bioenergy. The chapter addresses criteria, milestones and better practices.

5.2 Criteria for better use of biomass for energy

To improve the positive effects of biomass for energy, suitable choices can be made with regard to various issues:
- How currently unused sustainable biomass potential can be put to use.
- Which types of biomass to use.
- Where it is cultivated and how (if necessary).
- What type of conversion process is used (if necessary).
- In the case of co-products, how these are to be used.
- In what sector and installation/vehicle the energy is to be applied.

Different answers to these questions may result in different impacts on total bioenergy potentials, GHG emission savings, food prices, security of supply, socio-economic issues, costs and impact on the economy. Choosing the 'best' route thus requires an assessment of these impacts for the various options. In some cases this assessment will result in an unambiguous answer as to what is 'best'. In other cases different indicators will lead to different optimal solutions, with the 'best' choice then depending on which indicators are deemed most important. This may vary across countries and regions and may also change over time.

As a starting point, we define better use of biomass for energy as:
Production, transport, conversion and use of biomass for energy in such a way that it contributes more to the policy aims of governments.

Based on the previous chapters, a set of criteria for 'better use of biomass for energy' has been derived. Because policy aims, i.e. the needs and wishes driving bioenergy policies, vary around the world and often also over time, the value attributed to the individual criteria may vary.

The general criteria that can be applied for better use in all countries are the following.

Improve the efficiency of use of sustainable biomass resources
- Increase the amount of fossil fuels replaced by biomass – measured in terms of GJ output per tonne of biomass in the case of waste or residues, and GJ output per hectare in the case of dedicated biomass cultivation.
- Increase the efficiency of traditional stoves and heating (non-OECD) and use of CHP (OECD).
- Encourage investments in improved energy efficiency (production, transformation and end-use).

Maximize the greenhouse gas reduction

- Demand minimum GHG reduction over bioenergy life cycles, including land use change emissions – measured in terms of CO_2 eq. reduced per tonne of biomass in the case of residues/waste, and CO_2 eq. reduced per hectare in the case of biomass cultivation.
- Provide incentives for bioenergy routes that reduce GHG emissions more.
- Give preference to bioenergy applications in which waste and residues can be used.
- Prevent or at least limit use of arable and grassland for biomass cultivation for energy.

Optimize biomass contribution to security of energy supply

- If a government aims to reduce its dependence on oil, policies should aim to fully utilize the sustainable biomass potential for transport, focusing on development and market deployment of next-generation biofuels and electric vehicles.
- If security of gas supply is a concern, provide incentives to increase sustainable biomethane production.
- Reduce the risks and potential impacts of fluctuating biomass price and availability through effective trade policies and market incentives for non-edible biomass feedstocks.

Avoid competition with food, feed and fibre

- Promote biomass cultivation on agricultural land set free from significantly increasing agricultural yields.
- Promote 'cascading' use of residues and wastes from biomaterials for energy.
- Develop bioenergy strategies together with a strategy for global food security.

5.3 Milestones for better use of biomass

What constitutes 'better' use of biomass for bioenergy will change over time, with possible future pathways and improvements depending in part on achieving technology development goals through learning. Such learning is subject to rising market shares, though, which in turn depends on successful RT&D efforts.

Given the different country situations, 'better' use of biomass for energy needs to be considered in the context of specific national roadmaps depicting possible routes to bioenergy futures. Regardless of the range of possible futures, though, most scenarios nonetheless have critical milestones marking the key 'breakthroughs' needed to advance better use.

As progress on achieving these future milestones is as yet unknown, road-mapping must also give due consideration to flexibility in order to avoid lock-in if expected developments over- or underperform.

In the **near-term**, critical milestones for better use of biomass for energy are:

- Harmonizing sustainability standards, criteria and indicators for biomass trade, especially for GHG emissions, including LUC, biodiversity and social impacts.
- Supporting shifts towards advanced cropping systems, e.g. perennial oil-bearing and lignocellulosic plants which can be grown on degraded lands taken out of agricultural use.
- Adjusting waste extraction, collection and logistics to accommodate 'cascading' use of biomaterial wastes for bioenergy.

– Improving land use policies to integrate agricultural, energy and forestry as well as nature-protection and social-development needs.

The near-term milestones can be achieved with existing regulatory and market-based instruments and will lay the foundation for a better supply of biomass for energy.

In the **medium-term**, key milestones for 'better use' are:

– Successful demonstration and commercialization of next-generation biofuel technologies and biorefineries.
– Development and demonstration of carbon capture and storage (CCS) for larger bioenergy conversion plants as a key longer-term option for reducing atmospheric CO_2 levels.
– Cost reductions and lifetime improvements of electric vehicles that might use bioelectricity.

Achieving the medium-term milestones will rely massively on RT&D activities on a scale requiring international collaboration – mainly within the OECD, but also with other countries.

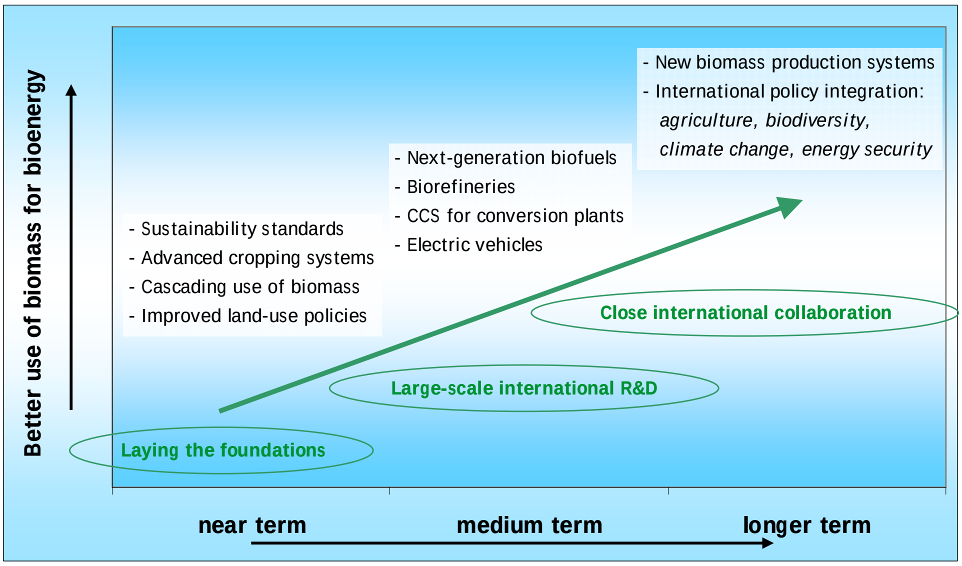
The **longer-term** milestones are:

– RT&D for land-based algae and other new cropping systems (agroforestry, etc.), especially robust production systems which prove resilient against impacts of climate change.
– International policy integration, especially regarding agriculture/food production, biodiversity conservation, climate change mitigation, and improved energy security.

Achieving these long-term milestones will require close interaction and collaboration at a multilateral level as well as inclusive strategies that allow participation of all relevant stakeholders.

This development scenario that follows these key milestones is illustrated in Figure 15.

Figure 15 **Key milestones for better biomass use for bioenergy: timeline**



5.4 Better use of biomass for energy: better practices are crucial

In addition to prospects of better biomass supply, conversion technology and RT&D, better policy is needed to establish and disseminate better practices. In playing its part in providing sustainable bioenergy, the biomass-for-energy industry will undergo rapid growth. The medium- to long-term development options for sustainable bioenergy require substantial investments in new biomass supply and conversion systems, not only in the OECD but also in countries with developing and emerging economies.

The private sector will make these investments only to the extent that rules for national markets and international trade are transparent and policies enabling the development of sustainable bioenergy markets offer adequate and stable perspectives.

In that regard, providing bioenergy should receive policy support for substituting fossil energy to the extent that net reductions of GHG emissions, maintaining biodiversity, energy security and low social trade-offs (e.g. food security) can be demonstrated. Performance-based policies seem suitable for providing incentives proportional to the benefits delivered.

Once policies on better use of biomass for energy have been implemented, the private sector in general and the bioenergy industry in particular will bear responsibility for demonstrating better practices in supply, conversion and use of biomass for energy.

Last but not least, there is a clear need for complementary policies focusing directly on problems going beyond biomass for energy, such as land- and water-efficient food and feed production, overall reduction of agricultural emissions and prevention of habitat loss due to land clearance.

To this end, IEA RETD and IEA Bioenergy will continue participating in and contributing to dialogue on better bioenergy policies with regard to cross-sector integration, e.g. agriculture/energy; electricity/transport; and materials/energy, together with partners from UN institutions, non-OECD countries, industry and civil society.

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Annex A Glossary of terms and acronyms

1st generation biofuels
1st generation biofuels include mature technologies for the production of bioethanol from sugar and starch crops, biodiesel and renewable diesel from oil crops and animal fats, and biomethane from the anaerobic digestion of wet biomass.

2nd generation biofuels
2nd generation biofuels are novel biofuels or biofuels based on novel feedstocks. They generally use biochemical and thermochemical routes that are at the demonstration stage, and convert lignocellulosic biomass (i.e. fibrous biomass such as straw, wood, and grass) to biofuels (e.g. ethanol, butanol, syndiesel).

Agricultural residues
Agricultural residues include arable crop residues (such as straw, stem, stalk, leaves, husk, shell, peel, etc.), forest litter, grass and animal manures, slurries and bedding (e.g. poultry litter).

Anaerobic digestion
Decomposition of biological wastes by micro-organisms, usually under wet conditions, in the absence of air (oxygen), to produce biogas.
Animal residues.

Biodiesel
Biodiesel refers to a diesel-type fuel produced by transesterification of vegetable oils or animal fats. Biodiesel can be blended (with some restrictions on the level of blending) with conventional diesel for use in unmodified diesel-engine vehicles. Its full name is FAME (Fatty Acid Methyl Ester) biodiesel.

Bioenergy
Renewable energy produced from the conversion of organic matter. Organic matter may either be used directly as a fuel or processed into liquids and gases.

Bioethanol
Alcohol, produced from biomass. Bioethanol can be blended with conventional gasoline or diesel for use in petroleum-engine vehicles.

Biofuel
Fuel produced directly or indirectly from biomass. The term biofuel applies to any solid, liquid, or gaseous fuel produced from organic (once-living) matter.

Biogas
A combustible gas derived from decomposing biological waste under anaerobic conditions. Biogas normally consists of 50-60% methane, 25-50% carbon dioxide, and other possible elements such as nitrogen, hydrogen or oxygen.

Biomass
Organic matter available on a renewable basis. Biomass includes forest and mill residues, agricultural crops and wastes, wood and wood wastes, animal wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes.

BTL
Biomass-to-liquid is a (multi-step) process to produce liquid biofuels from biomass. The first step is gasification, while the second step may, for example, be Fischer Tropsch.

By-product
A by-product, or co-product, is a substance, other than the principal product, generated as a consequence of producing the main product. Examples include animal feed, food additives, specialty chemicals, charcoal, and fertilisers.

Chips
Woody material cut into short, thin wafers. Chips are used as a raw material for pulping and fiberboard or as biomass fuel.

CHP, Combined Heat and Power
Combined Heat and Power. The simultaneous production of electricity and useful thermal energy from a common fuel source.

CO_2
Carbon dioxide.

Compressed Natural Gas (CNG)
CNG is made by compressing natural gas to less than 1% of its volume at standard atmospheric pressure. It is used in traditional gasoline internal combustion engine cars that have been converted into bi-fuel vehicles (gasoline/CNG).

Co-product
See By-product.

EJ
Exajoules (1EJ = 10^{18} Joule).

Energy crops
Crops grown specifically for their fuel value. These include food crops such as corn and sugar-cane, and non-food crops such as poplar trees and switchgrass.

EtOH
See Bioethanol.

Ethyl-tertio-butyl-ether (ETBE)
Organic compound with the formula C6H14O. ETBE is commonly used as an oxygenate gasoline additive in the production of gasoline from crude oil.

Feedstock
A feedstock is any biomass resource destined for conversion to energy or biofuel. For example, corn is a feedstock for ethanol production, soybean oil may be a feedstock for biodiesel and cellulosic biomass has the potential to be a significant feedstock source for biofuels.

Firewood
Cut and split oven-ready fuelwood used in household wood burning appliances such as stoves, fireplaces and central heating systems. Firewood usually has a uniform length, typically in the range 150 to 500 mm.

Fischer Tropsch (FT) Process
Catalysed chemical reaction in which syngas from gasification is converted into a liquid biofuel of various kinds.

Forest residues
Material not harvested or removed from logging sites in commercial hardwood and softwood as well as material resulting from forest management operations such as pre-commercial thinnings and removal of dead and dying trees.

Fossil fuel
Solid, liquid, or gaseous fuels formed in the ground after millions of years by chemical and physical changes in plant and animal residues under high temperature and pressure. Oil, natural gas, and coal are fossil fuels.

Fuelwood
Wood fuel where the original composition of the wood is preserved.

Gasification
A thermochemical process at elevated temperature and reducing conditions to convert a solid fuel to a gaseous form (CO, H_2, CH_4, etc.), with char, water, and condensibles as minor products.

Gasifier
A device for converting solid fuel into gaseous fuel.

Gha
Gigahectares (1Gha = 10^9ha).

GHG
Greenhouse gas. Gases that trap the heat of the sun in the Earth's atmosphere, producing the greenhouse effect. The two major greenhouse gases are water vapour and carbon dioxide. Other greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrous oxide.

GJ
Gigajoule (1GJ = 10^9 Joule).

Hectare (Ha)
Common metric unit of area, equal to 2.47 acres. 1 hectare equals 10,000 square meters. 100 hectares = 1 square kilometer. Abbreviated as ha.

Hydrogen
Simplest molecule conceivable, with a molecular formula of H2. Gaseous fuel that can be produced from fossil fuels, biomass and electricity.

IEA
International Energy Agency.

Lifecycle Assessment (LCA)
Investigation and valuation of the environmental impacts of a given product or service caused or necessitated by its existence. The term 'lifecycle' refers to the notion that a fair, holistic assessment requires the assessment of raw material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence.

Methane
Methane is a combustible chemical compound with the molecular formula CH_4. It is the principal component of natural gas.

MJ
Megajoule (1MJ = 10^6J).

Monoculture
The cultivation of a single species crop.

MSW
Municipal Solid Waste.

N_2O
Nitrous oxide or laughing gas. Powerful greenhouse gas that can be emitted from soils with intensive (nitrogen) fertilisation.

Organic matter
Matter that comes from a once-living organism.

Particulate
A small, discrete mass of solid or liquid matter that remains individually dispersed in gas or liquid emissions. Particulates take the form of aerosol, dust, fume, mist, smoke, or spray. Each of these forms has different properties.

Pellet
Densified biofuel made from pulverised biomass with or without pressing aids usually with a cylindrical form, random length typically 5 to 30 mm, and broken ends. The raw material for biofuel pellets can be woody biomass, herbaceous biomass, fruit biomass, or biomass blends and mixtures. They are usually manufactured using a die. The total moisture content of biofuel pellets is usually less than 10% of mass.

Pyrolysis
The thermal decomposition of biomass at high temperatures (greater than 400°F, or 200°C) in the absence of air. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Residues
By-product of agricultural cultivation (e.g. bagasse), farming activities (e.g. manure) or forestry industry (tree thinnings).

Switchgrass
Perennial energy crop. Switchgrass is native to the USA and known for its hardiness and rapid growth. It is often cited as a potentially abundant 2nd generation feedstock for ethanol.

Torrefaction
Mild pretreatment of biomass at a temperature between 200-300°C. During torrefaction of the biomass, its properties are changed to obtain a better fuel quality for combustion and gasification applications.

Wood chips
Chipped woody biomass in the form of pieces with a defined particle size produced by mechanical treatment with sharp tools such as knives. Wood chips have a sub-rectangular shape with a typical length 5-50 mm and a low thickness compared to other dimensions.

Woody biomass
Biomass from trees, bushes and shrubs.

NB. This glossary is largely based on IEA Bioenergy, 2009.

Annex B Greenhouse gas emission reduction and land use change effects

B.1 Introduction

Greenhouse gas savings is one of the main drivers for OECD bioenergy policies, but is also, especially in the case of biofuels, topic of much debate. In the following, the issue of GHG savings is discussed, as well as the impact of direct and indirect land use change effects.

B.2 The importance of land use change for GHG emission reduction

In recent years, the attention for the environmental impact of biomass-to-energy routes has clearly increased, as the potential environmental risks associated to an increasing use of biomass for energy are becoming clear. Research papers and studies conclude that the GHG emission savings of biofuels are not at all certain, and that they may even increase emissions unless their production meets certain sustainable conditions (UNEP, 2009; OECD, 2007; Gallagher, 2008; JRC, 2008; Öko, 2008). Others point out that biofuels have a negative impact on biodiversity, and on regional water availability in some countries (UNEP, 2009; CBD, 2008; MNP, 2007). The result is that governments are now increasingly aware of the risks, and many are in the process of adapting their policies to ensure that only sustainable bioenergy, and in particular biofuels, pathways are supported. The recent development of the renewable energy directive by the European Union is a clear example of how governments are starting to implement minimum sustainability criteria, including a minimum GHG saving requirement (35% at the start, 50-60% in 2017), requirements regarding the type of soil where the biomass is produced, and the intention to included indirect land use change emissions in the GHG calculations[26].

One of the main conclusions from the recent studies is that reducing land use for biomass production is the key to reduce negative environmental effects, and to ensure that a reasonable GHG reduction is achieved. Many of the current, 1st generation biofuels have a relatively high land requirement, whereas current electricity and heat generation with biomass mainly uses waste and agricultural residues that do not require any land. The 2nd generation biofuels that are currently being developed are aimed at also being able to use these types of feedstock.

However, waste and residue potential is limited (MNP, 2008). Increasing biomass use for energy beyond this limit requires biomass cultivation. As the type of feedstock for 2nd generation biofuels is different from the current biofuel feedstock (grains, sugar, etc.), it is expected that this cultivation will lead to less environmental problems (e.g., fertiliser and water use) than the current cultivation of biofuel feedstock.

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26 See http://ec.europa.eu/energy/strategies/2008/2008_01_climate_change_en.htm.

Some potential studies (Faaij, Smeets a o.) stress that this relation between biomass demand and land use change makes it possible to increase the sustainability of biomass production by intensifying agricultural production. Other reports (e.g., Gallagher, 2009) stress that the demand for food and feed is growing rapidly so that this intense relation between biomass production and agriculture is a significant problem[27].

A large number of studies have been published worldwide that aim to quantify the greenhouse emission savings of bioenergy routes (JEC, 2007; EEA, 2008; CE, 2006). Until a few years ago, these studies did not include indirect land use change (ILUC) effects, as this phenomenon had not yet received much attention in the debate. Since then, various reports, working groups and work shops have been devoted at quantifying the ILUC effects of biomass cultivation. This had led to quite a good knowledge about potential risks of this effect (in terms of GHG emission increase). However, until now, ILUC effects have not yet been quantified accurately.

In the following paragraph, we outline some of the main findings regarding GHG emission savings of bioenergy without this ILUC effect. In paragraph B.4, we discuss the potential impact of ILUC emissions on these results.

B.3 GHG emission savings of bioenergy, without indirect land use change

In general, it can be concluded that without ILUC, greenhouse gas savings of bioenergy can be very significant. However, there is a large variation between different biomass-to-bioenergy pathways which implies that there is significant scope to improve GHG savings by focussing on the routes with high savings rather than on the rest.

Important factors in the GHG emissions of a specific pathway are the following:
- The type of biomass used and its source (e.g., region of cultivation). For example, bioethanol from Brazilian sugar cane causes much less GHG emissions and requires much less land per GJ than bioethanol from European sugar beet[28]. Among other things, this is due to more favourable growing conditions in Brazil. As another example, carbon sequestration will be much higher if perennial biomass is used in stead of crops where the whole plant is removed annually.
- The agricultural practices that are applied (in the case of cultivated biomass). For example, emissions will be lower if fertiliser use is lower, and carbon sequestration can be improved with appropriate soil management practices (e.g., if ploughing is reduced).
- Whether or not the biomass production leads to land use change, and what LUC will arise. This is discussed further below.
- Conversion process efficiency. LCAs of different processes used in the biofuel industry (such as JEC, 2007) have shown that GHG emissions can be reduced by using, for example, CHP, low-carbon energy sources (e.g., gas in stead of coal), etc.
- In the case by-products are produced, on the GHG and energy implications of their use. Current biofuel production from crops such as wheat, maize and rapeseed produce valuable by-products. These have a high protein

27 The increasing global food and feed demand and the main issues related to meeting this demand is discussed in more detail (OECD/FAO, 2008).

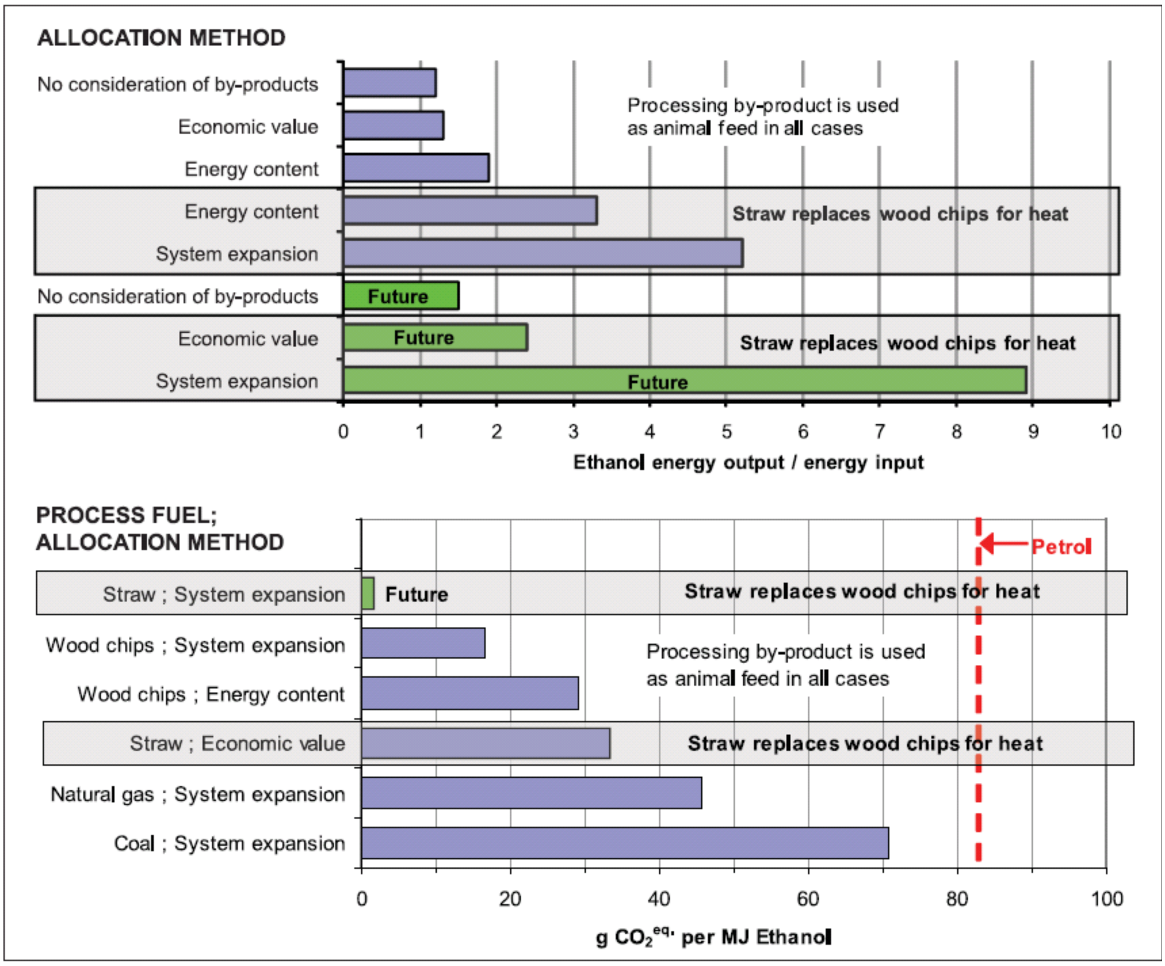
28 This GHG emission advantage is further enhanced in Brazil due to the use of process residues for energy production in the ethanol plant.

content, and can be used as animal fodder. This results in reduced demand of crops grown specifically for animal feed, such as soy. Since soy cultivation causes GHG emissions and (potentially) land use change, these emissions are reduced. An analysis of this effect (CE, 2008) concludes that it can have a significant (positive) impact on both the GHG balance and the land use of these biofuels. This impact has not yet been included in Life Cycle analyses of biofuels, such as in JEC (2007) or www.ghgenius.ca. Note that this effect does not occur in case lignocellulosic biomass or waste is used as feedstock, or if the whole crop is used for energy purposes, as is the case for sugar cane ethanol from Brazil.

- On the fossil fuel that is being replaced. Coal has the highest CO_2 emissions per GJ energy produced, followed by oil and gas. Therefore, the same biomass will reduce much more GHG emissions when it replaces coal rather than gas. Note that it is not always obvious which type of other energy source is replaced. Results will depend on whether, for example, an average power mix or marginal power generation is used in the analysis.
- What would happen to the biomass if it was not used for bioenergy? This is relevant in cases were existing biomass streams are used (i.e. feedstock that is not specifically produced for bioenergy purposes). A good example is the case where manure is converted to biogas, rather than being used as fertilizer. The latter case would lead to significant amounts of methane emissions, which are effectively prevented if the manure is converted to biogas.

Unfortunately, energy use and GHG emission savings of a bioenergy route also depend on methodological issues concerning the life cycle analysis (LCA), in particular the method used to account for co-products. In an LCA, emissions of the biomass cultivation and the conversion process are partly allocated to the bioenergy itself, and partly to the by-products. This can be done using various methods, based on either system expansion or allocation by economic value, energy content or other characteristics such as mass. The graph below from (IEA Bioenergy, 2009) illustrates this effect of wheat-based ethanol production. This effect is especially relevant for the current biofuel processes, but also if CHP is applied in case of bioenergy.

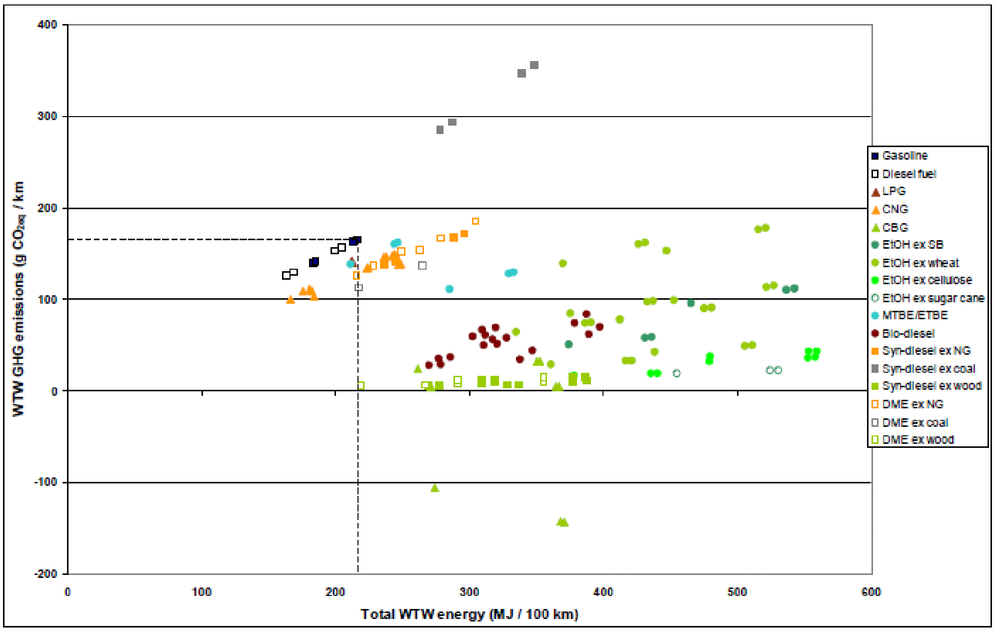
Figure 16 **Energy balance (upper diagram) and GHG emissions (lower diagram) for wheat-based ethanol production in Sweden, taking into account various methods for considering co-product uses The bars designated 'Future' show how the systems can improve due to developments in both feedstock production and ethanol conversion**



Source: IEA Bioenergy, 2009.

As an illustration of LCA results, an overview of results of a comprehensive European study on biofuels is shown in Figure 17. Note that potential indirect land use change effects are not included in these calculations, these will be discussed in the next section. This graph shows that alternative fuels usually require more energy input (over the whole production chain) than fossil fuels, and that most achieve a GHG reduction if no indirect land use change occurs. Many of the fuels that achieve the most GHG reduction are 2nd generation biofuels, such as synthetic diesel (biomass-to-liquid = BTL) and EtOH (ethanol) from lignocellulosic biomass. These cannot yet, however, be produced on a commercial scale. Biogas scores exceptionally well if it is produced from manure that would otherwise cause methane emissions. Current biofuels on the market that are depicted in this graph are biodiesel and ethanol (from sugar beet, wheat and sugar cane), and ETBE.

Figure 17 Overview of well-to-wheel energy use (X-axis) and GHG emissions (Y-axis), for a number of fossil and 1st and 2nd generation biofuels, excl. indirect land use effects



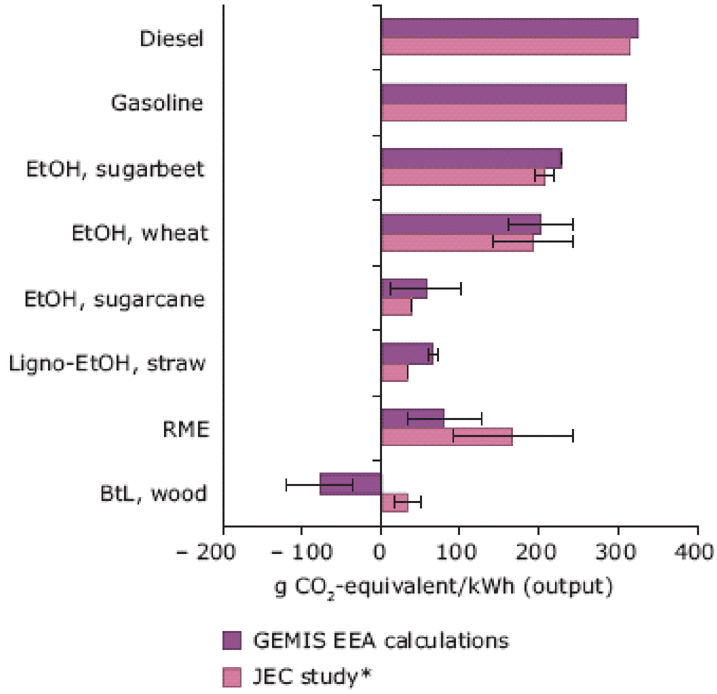
Source: JEC, 2007. CNG = compressed natural gas, CBG = compressed biogas, EtOH = ethanol, DME = Dymethylether.

It is also worth noting that even if LCA is carried out comprehensively and accurately, there can still be quite large uncertainties involved in the results. For example, if agricultural crops are used, the GHG emissions from the soil can be very uncertain[29].

The graphs below, were GHG emissions are shown for different biofuels (Figure 18) and biofuel and bioelectricity routes (Figure 19) illustrate this, Significant gains in GHG reduction and cost effectiveness can thus be gained by focusing on the use of those routes that achieve the largest benefits.

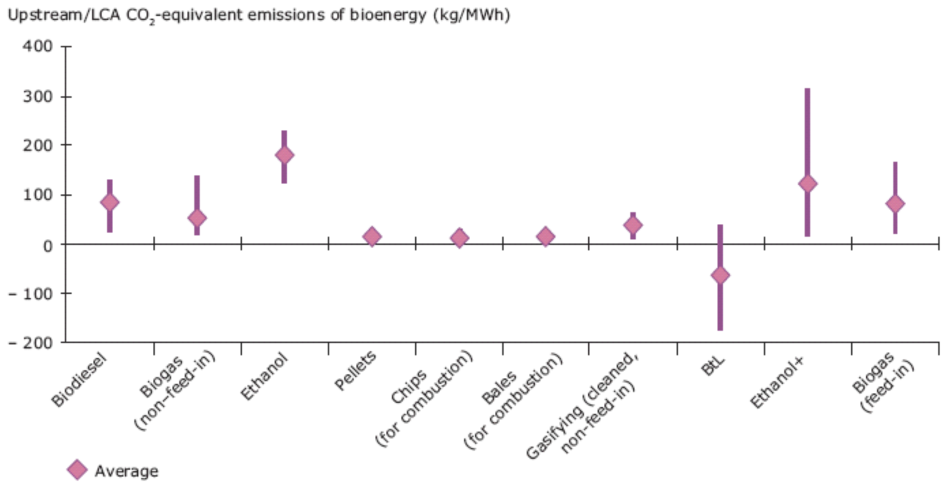
29 Note that potential indirect land use change effects are not included in these calculations, these will be discussed below.

Figure 18 **The net life cycle greenhouse gas emissions of fossil fuels and various biofuels - without land use change emissions**



Source: EEA, 2008.

Figure 19 **Comparison of life cycle GHG (CO_2 equivalent) emissions for bioenergy in EU Member States - without indirect land use change emissions**



Source: EEA, 2008.

Despite the large variations between specific routes and data uncertainties, some 'robust' conclusions can be drawn (see, for example, EEA, 2008; IEA Bioenergy, 2009; WBGU, 2008). One major conclusion is that substituting biomass for fossil fuels in heat and electricity generation is, in general, less costly and provides larger CO_2 emissions reduction per unit of biomass than converting biomass to biofuels to be used in the transport sector. The major reasons for this are:

1. Most biofuels for the transport sector are currently produced from agricultural crops that require fertilizer and energy input during cultivation, and energy for conversion of the crop into a high quality biofuel.
2. Most biomass for the electricity and heat sector are waste streams or wood products with a lower GHG emission for production than agricultural crops.
3. The CO_2 emissions associated with coal use are higher than of oil products such as transport fuels, for the same GJ energy.
4. The feedstock for biofuels (mainly food crops) are more expensive than the sources for bioelectricity and heat (e.g., waste wood and agricultural waste).

Therefore, more emissions are reduced if the biomass replaces electricity from coal rather than if it replaces an equivalent amount of transport fuel[30].

However, it should be realised that these general conclusions are not always true for individual biomass conversion routes. An important exception for this rule is ethanol from sugarcane. In good climate conditions, this crop can deliver nearly the same GHG results and costs as bioenergy produced from wood. Similarly, biodiesel from palm oil could perform very well if cultivation would make use of degraded land instead of converting peatland or tropical forests.

B.4 Land use change: Impact on GHG emissions and sequestration

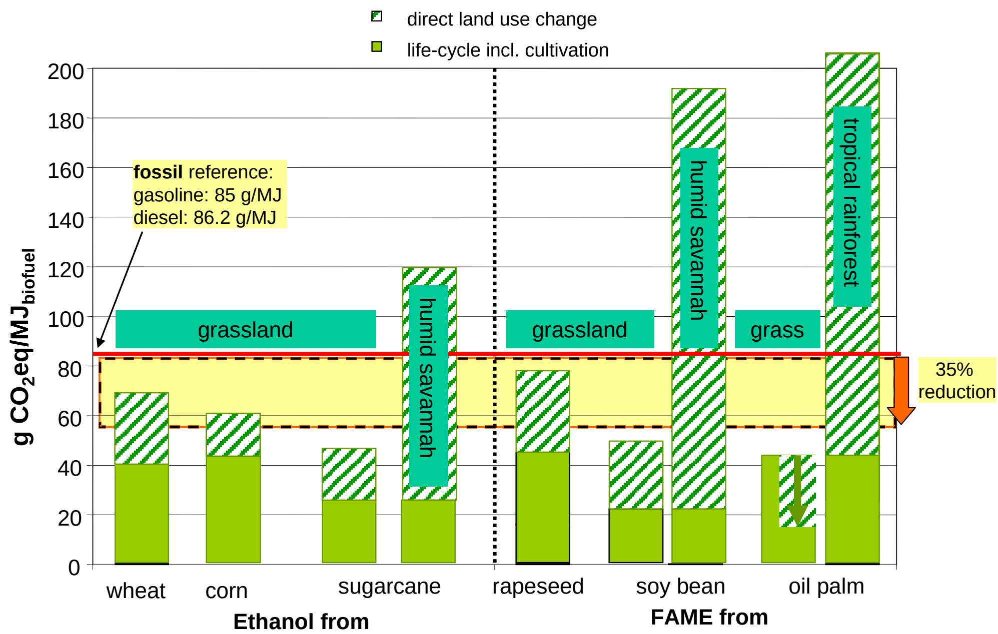
The production of bioenergy feedstocks not only causes GHG emissions from its life-cycle (e.g., fertilizer production and use, fossil fuels in farming), but could also impact on above- and below-ground carbon due to LUC activities. The expansion of energy crop production almost always causes land use change if the production area was previously dedicated to another purpose (i.e. production of food or other crops, settlement, set aside land, forest, natural protection area, set-aside land). Two types of impacts can be distinguished:

- **Direct land use change** (dLUC) occurs whenever a new plantation is established, disregarding if cultivation of crops has taken place on that land before, or if the area might have been under forest or other natural and near-to-nature ecosystems.
- **Indirect land use change** (iLUC) can be described as the potential impact of shifting the land use prior to biofuel production to **another** area (displacement) where then dLUC occurs - this potential is also called leakage.

30 Likewise, the GHG benefit of gas substitution is likely to be less than coal substitution (depending on GHG emissions of the gas used, for example on pipeline leakage). Therefore, if the bioenergy replaces natural gas, it has less GHG benefit then when it replaces coal. On the other hand it can be argued that for security of supply, gas replacement is preferable.

Accounting for the carbon emission impact of **dLUC** requires reliable information on carbon storage above and below ground. The quantification can be based on data from IPCC default (tier 1) or country-specific (tier 2) values[31] which take into account changes in the carbon stocks of biomass, dead organic matter, and soils. The results of such calculations are shown in Figure 20.

Figure 20 Life-Cycle GHG Emissions of Biofuels and Impacts from Direct Land Use Change (excl. indirect LUC)



Source: based on IFEU/Öko (2008), updated with data from Öko (2010b)

As can be seen, the GHG emissions changes drastically if conservative assumptions are made for direct land use change. If biofuel feedstocks are grown on low-carbon soils, the impact can be positive, though: for example, perennial plants such as oil palm or short-rotation coppice store carbon in their root system so that a biological sequestration takes place and GHG emissions are reduced when direct LUC is factored in

For GHG balancing with regard to **iLUC** it is irrelevant at which location the biomass is actually produced and used, since the previous production could be displaced to **any** suitable other area, as agrarian markets are global. The estimate of indirectly caused GHG emissions should take all countries into account that trade agrarian products, and must deal with the potential dLUC effects caused by the displaced previous production.
In principle, there are three basic approaches to deal with GHG emissions from potential iLUC:

a Implementation of global land use policies or GHG regimes which either restrict the conversion of high-carbon land (e.g., forests, peatland, savanna) and/or require carbon offsets for LUC.
b Biomass feedstocks could be preferred which **avoid or minimize the risk of displacement** and, thus, emissions from potential iLUC. Such feedstocks are biomass residues and wastes, biomass grown on previously unused land (e.g., set-aside, abandoned, or degraded), or from intensified production.

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31 See IPCC, 2006. The IPCC approach is valid for above- and below-ground carbon, though less is known for the latter, and very few data exist on the changes in N_2O emissions.

c Including iLUC-related emissions in bioenergy life cycles GHG emission balances through default data derived from modeling, and taking into account the net results through either bonus or malus schemes in quota systems, emission trading, tax credits or other regulation favoring bioenergy market shares.

Option a) would be the most comprehensive one which would lead to eliminate iLUC as a driver of GHG emissions. Still, the ongoing global climate negotiations show that the inclusion of LUC-related GHG emissions is a very complex issue (see Section 1.5 for COP15 and REDD), and a scheme which could effectively avoid all potential iLUC-related emissions would have to cover all countries participating in global trade of agrarian products, and would have to include respective monitoring and verification of all LUC. To negotiate and implement such a scheme will take several years at least, and depend strongly on the acceptance of effective GHG emission 'caps' not only for industrialized but also developing countries. A potential global land use regime to address LUC would face similar challenges, with the additional problem that there is currently no global convention under which such a regime could be negotiated.

Option b) could be introduced by any country or international body as a part of the respective regulation of bioenergy markets, thus reducing iLUC-related emission risks for the respective biofuels markets. For example, the EU RES-D includes a bonus in its accounting for eligible biofuels under its quota for feedstocks stemming from residues or wastes, or coming from previously unused land, and a NGO-industry collaboration is working on the concept of "Responsible Cultivation Areas" for biofuel feedstock production which tries to **avoid** ILUC risks (CI, 2010)

Option c) would be the most flexible one, but to date, there is no scientifically agreed approach on how to derive default data[32]:
Economic models for global agro-commodity markets are available, and can be coupled with land use models and respective data so that - in principle - the land use change resulting from changes in agricultural production could be determined, and from that, GHG balances using default dLUC emission factors could be established (see the text box below).
The discussion is on the data input for the models (e.g., price, cost and productivity assumptions), their disaggregation with regard to time and commodities, their treatment of by-products, and their spatial resolution. Also it is disputed whether short- or longer-term and marginal or average effects should be used to define iLUC impacts.
The EU RES-D includes a bonus of 29 g of CO_2 eq. per MJ for biofuels derived from degraded land in its GHG accounting rule, but this does not differentiate between feedstocks and is seen as a first step in considering iLUC-related GHG emissions quantitatively. By the end of 2010, the EU is required to present a report on the possibilities to consider iLUC more explicitly in a revised GHG accounting rule.
On the other hand, the Californian Low Carbon Fuel Standard (LCFS) includes iLUC in its GHG accounting for biofuels, similar to the US EPA regulation on biofuels under the Federal Renewable Fuels Standard[33].

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32 See e.g., Öko (2010b) and PBL (2010a-e) for a more detailed discussion of the current state.

33 see CARB (2010) and EPA (2010) for details

Conclusions on LUC-related GHG Emissions

Due to the large impact of potential GHG emissions from iLUC, it is quite important for the future development of bioenergy to improve understanding of and harmonize methodologies and default values for potential GHG emissions from indirect LUC. There are national and international efforts currently underway to standardize GHG emission for bioenergy systems:

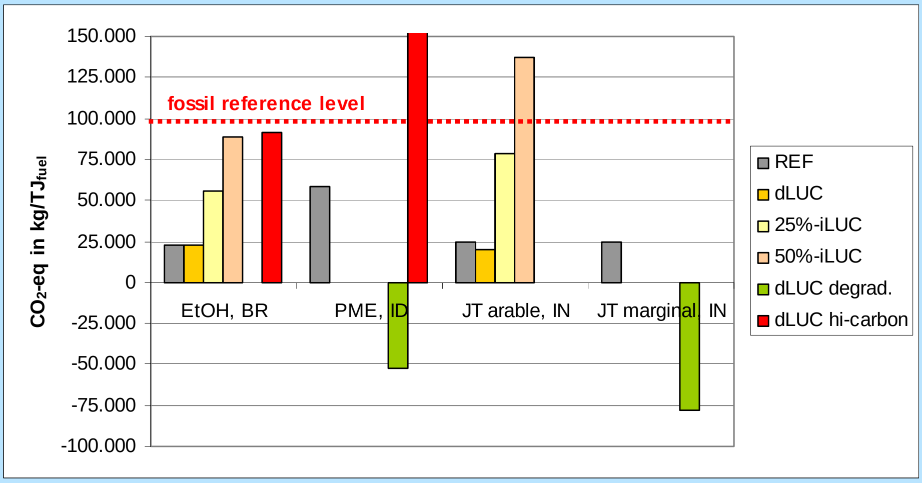
– The EU RES-D includes a 'full' methodology as well as default data for most liquid biofuels and fossil reference systems; the methodology is **mandatory** for all EU Member States as far as biofuels are eligible for the national biofuel quota. In 2010, the EU will present a report on possibilities to include iLUC-related emissions in its GHG accounting rules for biofuels.
– The Global BioEnergy Partnership (GBEP) Task Force on GHG Accounting is working on harmonizing GHG methodologies and aims at a joint report of the G8 countries plus several developing countries in 2009.
– The IEA Bioenergy Task 38 'Greenhouse Gas Balances of Biomass and Bioenergy' works since several years on methods, tools and data[34], and contributes to the GBEP GHG Task Force.

Sensitivity of LUC Effects for the GHG Emission Balances of Selected Biofuels

UNEP recently carried out a review of LCA work on biofuels with regards to GHG emissions in which the issue of potential GHG emissions from indirect LUC was addressed through sensitivity analysis (Öko, 2009). In parallel, the EEA held a series of workshops which also addressed the issue in the wider scope of bioenergy in general (EEA, 2008).

The results of the sensitivity of selected biofuels with regard to assumptions for direct and indirect LUC are shown in Figure 21.

Figure 21 Sensitivity of GHG Emissions of Biofuel: LUC



Source: Öko, 2009; EtOH= bioethanol; BR= Brazil; PME= palmoil-methyl ester; ID= Indonesia; JT= Jatropha oil; IN= India; dLUC= direct land use change; iLUC = direct + indirect LUC; degrad.= degraded land with low-carbon stock; hi-carbon= land with high carbon stocks (above and below-ground).

The sensitivity of taking into account dLUC effects is small if **arable** land is considered (EtOH, Jatropha) - but then iLUC is rather high, depending on the level of the iLUC factor assumed.
The dLUC effects are extreme if high-carbon stock land is concerned - in those cases, there are no iLUC effects, but the magnitude of **d**LUC emissions leads to very small or no GHG reductions compared to fossil fuels.
If biofuel feedstocks are grown on **degraded** land, the overall GHG balance becomes even

34 See http://www.ieabioenergy-task38.orgfor an overview of work, and selected publications.

negative - slightly less than zero for EtOH, and even higher reductions for PME and Jatropha. The reason for this is the absence of indirect effects, and the **increase** of carbon stock on the cultivated land.
These results clearly indicate that LUC is a **key driver** for the GHG results, and can lead to very positive and very negative impacts, depending which LUC is assumed. The magnitude of the LUC sensitivity is **higher** than **any** of the other factors.

Impact on biodiversity

Besides the GHG emission impact from LUC, biofuel feedstock production could also effect biodiversity positively or - if unregulated - negatively (CBD, 2008). In that regard, the clear definition of **areas suitable** for feedstock production, and the promotion of production schemes compatible with agrobiodiversity are urgently needed (FAO, 2008d).
Arable land to grow biofuels on is a scare resource, and might become even scarcer in the long-term, with a growing global population, changing diets, and impacts from climate change (MNP, 2008a; Rosegrant, 2008). Furthermore, biofuel feedstock cropping needs water, and thus competes with water demand for feed and food crops (Berndes, 2008). Both factors could restrict globally available land for biofuel development.

Several scientific initiatives exist to 'map' potential land which could be used for bioenergy feedstock production without negative biodiversity impacts[35], and the recently introduced EU regulation on sustainable biofuels restricts feedstock provision to areas without severe biodiversity impacts. Still, there is no firm 'map' of such land available yet, so that there is uncertainty for countries and investors about the overall potential and location of 'low-impact' land use for bioenergy provision.

On the other hand, feedstock cultivation for biofuels can make use of non-edible plants such as short-rotation coppice and perennial grasses, and can take place on land unsuitable to food and feed production (e.g., Jatropha on degraded lands). Plant varieties and cropping schemes with low water demands are more feasible for bioenergy production than for food and feed schemes, thereby, in principle, reducing competition.

Still, options to minimize or avoid competition of biofuel feedstocks with biodiversity, food and feed crops could lead to higher production costs, as feedstock yields will be reduced by minimal irrigation, marginal soil fertility, and low-input farming, and further infrastructure investments could be needed.

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[35] The EU has carried out such 'mapping' for their territory (EEA, 2006+2007). Several developing countries have started such 'mapping' exercises: Brazil, China, Mozambique, and South Africa, among other, see 'International Joint Workshop on Bioenergy and Biodiversity and Degraded Land', Paris, June 30-July 1, 2008 held jointly by Öko-Institut, RSB and UNEP and in collaboration with CI, FAO, IUCN and WWF: http://www.bioenergywiki.net/index.php/Joint_International_Workshop_Mapping and also the 2nd International Workshop: http://www.bioenergywiki.net/index.php/2nd_Joint_International_Workshop_Mapping

Annex C Energy security

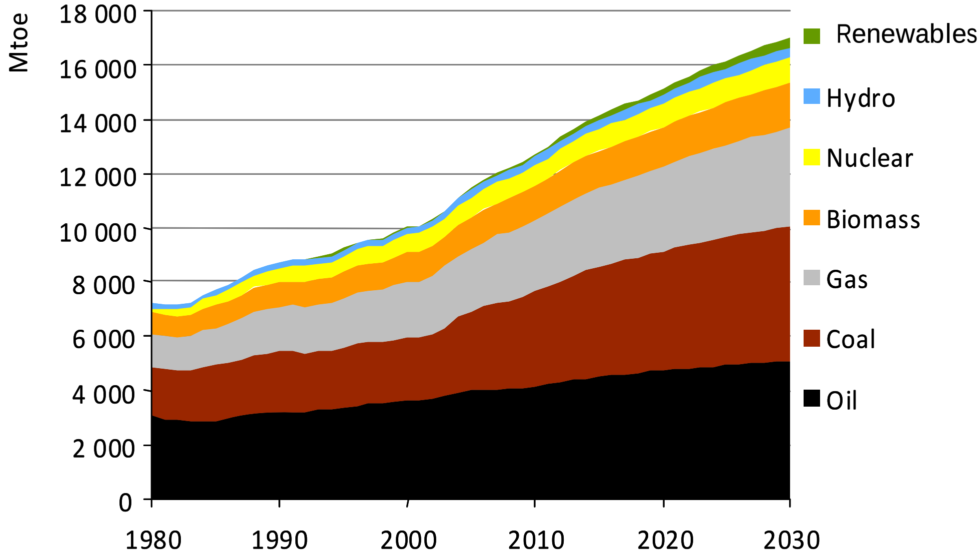
C.1 Introduction

Security of supply is one of the often quoted three main priorities of energy policies worldwide: Environment, Costs and Security of Supply. The contribution that biomass can make to the global energy sector and to the energy sectors of individual nations has to be assessed in the light of these three objectives. This section will outline in more detail the international security of supply discussion and analyse the relationship between biomass for energy and security of supply.

C.2 The international security of sypply discussion

The existing constellation of the international energy sector is based on fossil fuels. Current world energy demand consists for 80% of fossil fuels and, with continuation of present policy trends in 2030 still will consist for 80% of fossil fuels – although at a 50% increased demand (see Figure 22).

Figure 22 Global energy demand 1980-2030 according to the Reference Scenario of the International Energy Agency



Source: IEA, 2008b.

For combating climate change a much faster transition to a low-carbon energy sector would be needed. For that reason also two ambitious policy scenarios are outlined by the International Energy Agency. One of them is directed at limiting climate change to 3 degrees Celsius ('550 ppm scenario'), the other at the even more ambitious target of maximising global temperature change to 2 degrees Celsius ('450 ppm scenario'). Despite drastic low-carbon measures required to realise these two scenarios, even in the 450 ppm case a rise in the global demand for oil and gas until 2030 is foreseen[36].

The international security of supply discussion is triggered by the fact that in most countries worldwide fossil fuels are a dominant part of the present energy mix, and will be so in the near future (see e.g. CIEP, 2004). As many countries do not have access to domestic fossil fuel reserves sufficient to fulfil their demand they have to import these resources, in particular oil and gas. Traditional main fossil fuel importing regions are the United States, European Union and Japan. In the future these traditional oil and gas importers increasingly will have to compete with newcomers. Important new importers with sharply rising future energy demand are particularly China and India. These countries account for just over half of the increase in world primary energy demand between 2006 and 2030 (IEA, 2008b). The economic and political competition between the fossil importing countries and regions becomes even more critical as main reserves of fossil fuels – in particular oil and gas - are increasingly concentrated in just a few countries: The Middle East and Russia, with some less abundant reserves also concentrated in the Caspian Sea region (BP, 2008).

Concerns about the political stability of these oil and gas exporting nations have induced several policy responses in importing countries (van der Linde, 2005): As a way to counteract immediate supply disruptions, emergency stocks of oil and gas have been created in importing countries. As another response directed at the short and middle term, importing countries seek more close political ties with oil and gas exporting nations in order to ensure a continuity in oil and gas flows. Simultaneously, importing nations try to become less dependent on the main exporters by trying to attract oil and gas flows from other than the main exporting nations. A fourth response, for the longer term, is directed at diversifying imported energy flows away from oil and gas and to reduce the demand for imported energy by stimulating domestic production and energy efficiency.

C.3 The position of biomass in the international security of supply discussion

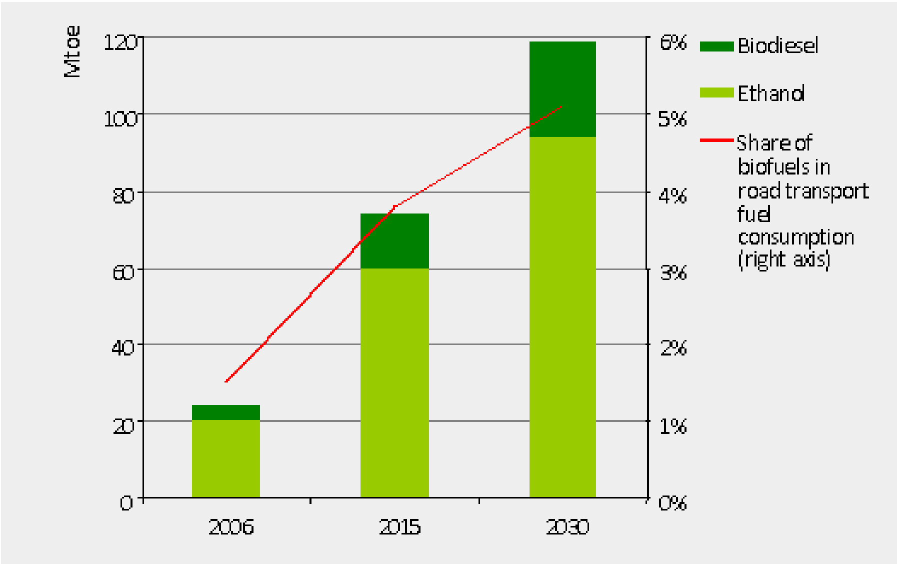
Biomass comes into play in the security of supply discussion as one of the means, next to energy efficiency, hydro, wind, solar and many other renewable energy sources, to substitute demand for oil and gas. With continuation of present global energy policy trends however, its contribution to overall global energy supply is likely to remain limited. Of the present share in world primary energy demand, 10% is supplied by biomass (IEA Bioenergy, 2009).
60% of this supply is traditional biomass, which does not play a role in the security of supply discussion. In 2030 biomass will still have a share of only 10% in global demand according to the IEA Reference Scenario. Hence, although certainly not unimportant, the relevance of biomass for the international security of supply discussion in the coming decades should not be overestimated either.

A main advantage of biomass lies in its diversity. There are many potential sources, which can be processed in a variety of ways to be applied potentially in all end-use sectors: heating/cooling, electricity and transport (see also Figure 3 in Chapter 1). In relation to security of supply however in particular

[36] In the IEA 450 ppm scenario, global oil demand in 2030 is 7% higher than in 2006, gas demand 23%, and coal demand is 22% lower than today.

the use of biomass in the transport sector got much policy attention. Whereas for electricity generation and heating/cooling many renewable energy sources are already tested on a large scale in practice, biofuels constitute at present the only feasible short-term alternative to oil in the transport sector that can be applied without mayor changes needed in the present supply infrastructure. Moreover, its practical application and blending into existing motorfuels has already been tested in practice for more than 30 years in Brazil (e.g. Nass et al., 2007). This has made that, although biofuels are not the most attractive application route from an greenhouse gas emissions point of view (see Section 1.5.1), its growth is expected to outweigh by far that of biomass use for electricity: Whereas the use of biomass for electricity is expected to double until 2030, biofuels use might increase six fold (IEA, 2008b). Most of this growth will be in bioethanol rather than in biodiesel (see Figure 23).

Figure 23 Expected growth of biofuels demand from 2006 to 2030 according to the IEA Reference Scenario



Source: IEA, 2008b.

C.4 Domestic production of biomass and security of supply

One of the ways in which biomass can contribute to security of supply is by the stimulation of domestic production of biomass. Here the ‘security of supply’ component of biomass meets another argument in favour of biomass for energy use: The stimulation of domestic employment, either in agriculture or in innovative industry.

Agricultural rationalisation in OECD countries and over-supplies of food have left the agricultural sectors in many of these countries with important questions for the future (OECD, 1999). The use of crops, trees or biowaste for bioenergy in recent years has provided new sources of income to these sectors that were more than welcome. Indeed it is no surprise that in particular the traditionally grown crops of sugar cane, corn and rapeseed became the preferred sources of 1st generation biofuels in respectively Brazil, the United States and in Germany. Whereas for security of supply reasons biomass imports from non-oil and gas exporting countries would equally serve, and for climate change reasons neither corn nor rapeseed would be preferential options, it was in particular the domestic employment component that triggered developments into the respective directions in the three countries.

Similarly, being still a primarily subsidy-driven sector, governments want to direct funding primarily to domestic innovative industries. Rather than biomass imports therefore, development of domestic technologies is stimulated. The security of supply component in these cases, although officially highly advertised, in practice in these cases is subordinate to stimulation of domestic employment.

C.5 Measuring the contribution of biomass to security of supply

A final element to be discussed here is the quantification of the contribution of biomass to security of supply. Several attempts in this direction have been made (e.g. ECN, 2007; IEA, 2007), though none has resulted in an unambiguous method for measuring security of supply.

Indeed quantification of the extent to which biomass contributes to security of supply is difficult. It is in theory possible to identify the extent to which biomass replaces either oil, gas or coal, although here already difficult decisions have to be taken: How can one for instance in all cases be sure if biomass replaces a gas or a coal power plant that otherwise would have been built?

A qualitative element in the analysis of security of supply is certainly introduced when one has to consider the origins of biomass and the oil, gas or coal that is substituted and the extent to which these origins are 'secure'. Not only needs the whole supply chain to be evaluated for this, but also an assessment has to be made of the political stability of the countries of origin of biomass and of the safety of transport routes – compared to that of the fossil fuel substituted.

Measuring security of supply in the end therefore is prone to a qualitative and a political discussion. This makes it very hard to balance the contribution of biomass to security of supply against other potential benefits of biomass such as the reduction of greenhouse gas emissions or against domestic employment in countries.

C.6 Conclusions

Main conclusions of the analysis of the relationship between biomass and security of supply are:
- The present international energy security of supply discussion is a highly political discussion on an international level. Its main content, however, is not focused on biomass. Rather it concentrates on securing flows of fossil fuels on the short and medium term to the main importing countries.
- The contribution of biomass to security of supply seems somewhat overrated. For most nations, with continuation of present policy trends biomass will only play a serious role in energy security of supply considerations in the middle term (two or more decades).
- Sometimes the 'security of supply discussion' on biomass in fact is a discussion in disguise about the stimulation of domestic agriculture and/or domestic innovative industry. Treating it as such would contribute to transparency in the biomass for energy debate.
- Quantification of the contribution of biomass to security of supply is a useful but difficult exercise. It requires political judgement on the political stability of the countries of origin and therefore never can be made as objective as e.g. its contribution to mitigating climate change.

Annex D Competition with food and feed

D.1 Introduction

As especially the biofuel sector uses food and feed crops as feedstock, there is concern that the fast increase of global biofuels demand in the past years has resulted in increasing prices of these commodities. Even though it is difficult to distinguish effects of biofuel demand from other effects such as natural changes in harvest, food and feed demand developments, market speculation with commodities, etc., it has become clear that the biofuel sector currently operates on the same market as the food and feed sector.

D.2 Impacts of biofuel demand on food and feed

The impacts of the increasing demand for biomass on a global scale are quite significant. In recent years more research has been done to quantify the effects of the growing market of biomass for energy and the production of food and feed. These studies mainly focus on modern applications of biomass (feedstock for power/heat and biofuels) and less on traditional biomass (wood for heating and cooking).

Biomass competes on two levels with food and feed: on an economic level and on land use level. In this section the economic level will be explained. An additional distinction will be made for short-term effects and long-term effects.

Economics

Although there still are many uncertainties, the overall picture is that the increasing demand for biomass for energy applications has an upwards effect on the prices of food and feed (OECD/FAO, 2009; LEI, 2008; ODI, 2008; RFA, 2008). Especially of those crops that are either biofuel feedstock or close substitutes for them. The analysis of Rosengrant et al. (2008) shows that the tension between provisioning of food, feed, fiber and fuel from the agricultural landscape, in order to meet the growing global needs, poses a fundamental trade-off with the health and quality of the wider ecosystem and the divers services that it provides.

According to the Agricultural Outlook 2008-2017 of the FAO (2008) food and feed will remain the largest sources of demand growth in agriculture. But in the past years the fast growing demand for feedstock to fuel the growing bioenergy sector is stacked on top of this. At this moment already 5% of global oilseed production is processed to biodiesel or is used directly for transportation and 4.5% of global cereal production is used for ethanol production (LEI, 2008). These extra marginal demands triggered the markets and increased the commodity prices. In an update of the Agricultural Outlook (OECD/FAO, 2009), it is concluded that 'a projected rapid expansion of biofuel production to meet mandated use will continue to have inflating price impacts for such feedstocks as wheat, maize, oilseeds and sugar.'

Not all crops are victim of steep rising prices. Crops like rice show little impact of biofuels. Price rises for potential feedstock crops such as oilseeds, maize and sugar cane are much higher. For example, the impact on world price levels of corn is relatively high due to the fact that most US ethanol production is corn-based. For cereals like wheat and rice, where the use for biofuels is almost zero, only indirect effects over the land use affects the world price level (LEI, 2008). Figure 24 gives an overview of the changing prices from biofuel expansion for different crops and different areas in the World.

As result of the increasing food and feedstock prices biofuels become less profitable and food more profitable. This results in a shift in production back from biofuels to food, which is already visible in the USA (LEI, 2008). The high prices for soybeans resulted in negative margins for biodiesel resulting in a lower biodiesel production.

The 2008 price rises of agricultural commodities can not all be explained by the developments on biofuel production. Increased demand for food and fodder, speculation on international food markets, failed harvests and high oil prices are also due to an increased price (Faaij, 2008; LEI, 2008).

All studies agree that the poor, and in particular the urban poor in net food importing developing countries, will suffer more than the rich. Because the poor spend more of their income on food, see higher losses of real incomes to rising food prices and may have to cut their consumption of food. In many low-income countries, food expenditures average over 50% of income and higher prices will push more people into undernourishment (OECD/FAO, 2008).

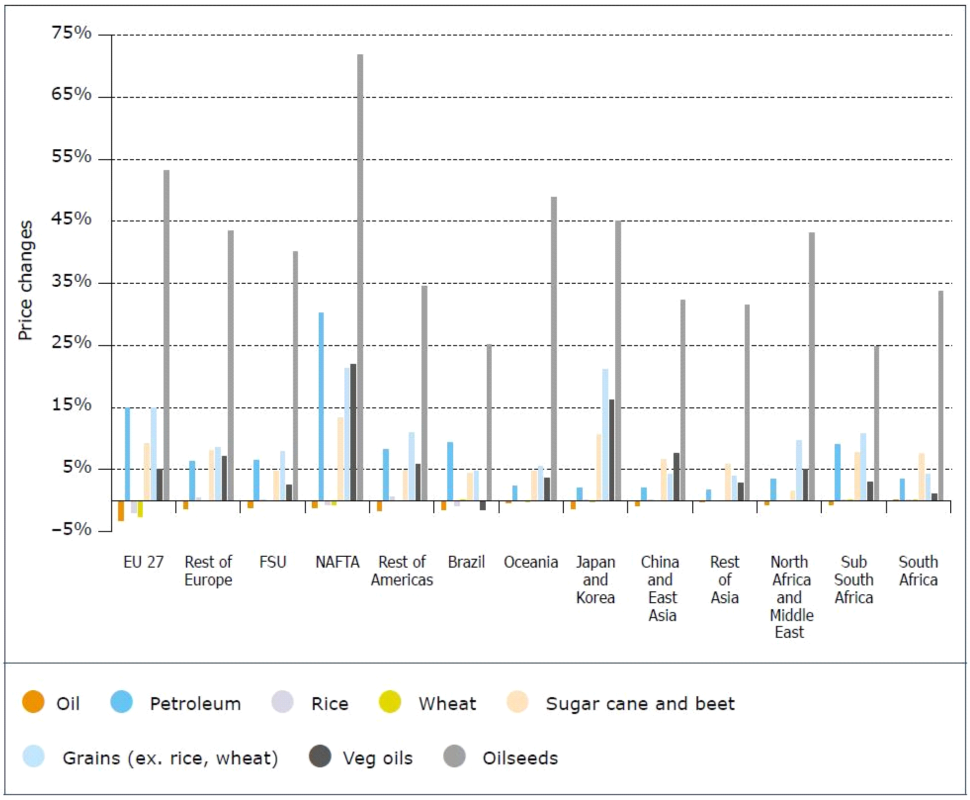
However, these effects might not be that severe. Calculations show that a 10% rise of food prices across the main categories of food would raise poverty in a sample of nine developing countries by just 0.4% points. Moreover, given that some of the largest countries with malnourished persons in them, such as India, have rice as a staple and there are virtually no effects of biofuels predicted on the price of rice.

Short versus long-term

The economic consequences of the increased demand for biomass are different for the short-term and medium term. According to ODI (2008) the medium term consequences show less impact on prices on most crops, other than maize, oilseeds, vegetable oils and sugar, with a maximum price rice of 5%. Crops like maize and oilseeds show rises of up to 72% (see also Figure 22). The short-term results show substantial price impacts for important foods, where prices in the best of circumstances could rise between 16 and 43%.

These price changes are the result of different degrees of adjustment. In the short-term, fewer adjustments are 'allowed' for production and consumption especially across sectors of the economy. This way the prices bear the weight of adjustment and thus move considerably more. The medium term prices are the result of almost complete adjustment throughout the economy and hence patterns of production, consumption and trade can change substantially.

Figure 24 Changing prices from biofuel expansion



Source: ODI, 2008; RFA, 2008. Calculations based on the general equilibrium view.

Annex E Socio-economic effects in non-OECD countries

E.1 Introduction

Global trade in biomass for bioenergy has developed rapidly in recent years. Bioenergy demand, especially in developed countries, has increased more rapidly than their domestic production, resulting in increasing biomass imports (see Chapter 1). On the other hand, many developing countries have a large technical potential for agricultural and forest residues and dedicated biomass production (IEA Bioenergy, 2009). Increasing production in these countries for both domestic use and export can therefore provide an attractive opportunity for economic development, on both a local and national scale. However, these developments can also have negative socio-economic effects, especially related to rapid area expansion and large scale production of biomass.

The following annex therefore focuses on the socio-economic effects in non-OECD countries, discussing both the potential positive and negative effects, and identifying the barriers that may hamper realisation of the potential benefits of these developments.

E.2 Positive social and economic effects

Promoting bioenergy production and consumption can contribute to different social and economic policy goals in producer countries. The following three socio-economic policy goals are most commonly mentioned: energy security, rural (socio-economic) development and improved trade balance. This section discusses briefly the potential effects of bioenergy production on these policy goals. We should consider these effects as 'potential' or plausible, because few reliable data is available of proven impacts of bioenergy production on these policy goals. Also, the potential impacts vary strongly between developing and industrialised countries.

E.2.1 Energy security

The increasing costs of fossil fuels and uncertainty regarding future energy supply will especially affect oil importing developing countries. At least two-thirds of the commodity dependent developing countries are net oil importers. Oil import dependency is especially acute in Sub-Saharan and East Asian countries, where 98% and 85% of their oil needs are met by imports, respectively (ESMAP, 2005; cited in CFC, 2007). Oil imports often constitute a large part of total imports. In Africa, 28 countries spend more than 10% of their total imports on oil alone (see Table 8).

Table 8 **Oil Imports as a percentage of total imports of African oil-importing countries**

Category (in %)	Number of Countries
Less than 5	5
(5-10)	14
(10-15)	16
(15-20)	10
(20-25)	1
More than 25%	1

Source: ADB, 2006.

Rising oil prices and uneven distribution of oil supplies imposes extra energy security risks to these countries. Energy diversification is an important strategy to counter these risks (CFC, 2007) and promoting bioenergy is part of that strategy. The production of biomass for energy is a rational choice in those countries where feedstocks can be produced at reasonable cost without adverse social and environmental impacts. This is especially relevant to land-locked countries with poor infrastructure and high transportation costs of fossil fuels, and those countries with the right natural endowments and sufficient scope for increasing agricultural production.

The potential positive effects of energy diversification vary widely according to national energy consumption levels. For an average African (developing) country, a handful of plantations producing feedstocks for biofuels may easily cover 10% of the domestic demand for transport fuels. In 2020, 10% ethanol blending target would require Tanzania to have 13,000 ha of well managed sugarcane production and one ethanol plant (Wetlands International, 2008). This very different from an industrialized country as the U.S. For instance, in 2006/07, around one-fifth of the U.S. maize harvest was used for ethanol but displaced only about 3% of gasoline consumption (World Bank, 2007). It is not yet clear whether and how second-generation technologies could make a medium-term and cost-effective contribution to energy security.

On the other hand, diversification into bioenergy introduces new risk factors jeopardizing energy security. If energy needs are increasingly covered by feedstocks such as sugarcane, corn and palm oil, price volatility on agro-commodity markets and climate risks will have its influence on the energy market. Furthermore, some countries will become increasingly dependent on policy decisions on major production and consumption markets for bioenergy. A slight change of mandatory blending targets in the EU could have significant impacts on the demand for a certain feedstock in a certain country.

E.2.2 Rural development

Rural development is commonly cited as one of the major benefits of increased biomass for energy production. These benefits differ for developing and industrialized countries. In industrialized countries rural development is seen as a way of differentiating and supporting the agricultural sector and rural areas in general. In developing countries most people live in rural areas and agriculture contributes to a large extent to the national GDP (see Table 1). In these agriculture-based countries rural development should be seen in a broader livelihood and rural development context. It is an important goal for poverty alleviation by creating employment, income and a stimulus to develop the agricultural sector. This underlines the potential benefits of bioenergy production in terms of rural development for these countries.

Table 9 **Characteristics of three country types**

	Share population is rural (%), 2005	Share of agriculture in GDP (%), 2005
Agriculture-based countries	68	29
Transforming countries	63	13
Urbanized countries	26	6

Source: World Bank, 2007.

An increased demand for biomass for energy creates an additional demand for agricultural crops. This demand can lead to higher prices for feedstocks and this may lead to increased income-generating opportunities for farmers (FAO, 2008d). In practice, these relations are difficult to capture because several factors interplay. It also strengthens the agricultural sector by creating opportunities for new crop types, farming techniques and value added processing. In addition, the development of second generation biofuels and biogas sectors will provide opportunities to new and diversified income streams from agricultural and forestry residues (e.g. grasses).

It is generally accepted that biofuel production generates more employment per unit of energy than conventional fuels. Biofuel industries may require about 100 times more workers per unit of energy than the fossil fuel industry (CFC, 2007). The Worldwatch Institute (2007) provides examples of realised and expected employment figures in biofuel sectors: in the U.S. the ethanol industry is credited with employing up to 200,000 people; in Brazil, the ethanol industry employs half a million workers; in China the liquid biofuel sector could create more than nine million jobs over the long-term; a region-wide blend of biofuels in Sub Sahara Africa - 10% for petrol and 5% for diesel – could yield between 0.7 to 1.1 million jobs.

Table 10 **Labour intensity of selected oilseed crops in Brazil**

Feedstock	Jobs per hectare
Castor	0.3
Jathropha	0.25
Palm	0.2
Soybeans	0.07

Source: Worldwatch Insitute, 2007.

In remote areas, locally produced biofuels can offer a reliable and less costly alternative to other fuels, such as diesel for powering agricultural and processing equipment. This contributes to the modernization of the agricultural sector. If agriculture can be made more efficient and competitive, it could spur development, providing jobs and income in rural areas.

Locally produced bioenergy could also improve access to energy, especially electricity and gas. In many rural and peri-urban areas access to energy is very low and primarily relies on fuel wood. In a country such as Tanzania, more than 90% of the total population has no access to electricity. In rural areas only 1% is connected to the electricity grid (Johnson and Rosillo-Calle, 2007). Small-scale biogas installations reduce time spent on fuel wood collection and provide cheaper and healthier energy for cooking and lighting to the rural poor. In South East Asia, more than 220,000 biogas plants have been installed at household level, benefiting to 1.35 million people. As many of them are connected to latrines, human health risks have been reduced and sanitation improved on large-scale (SNV, 2008).

Decentralised bioenergy programmes in remote rural areas offer an alternative to high priced diesel and kerosene for off-grid electrification. For instance, in Mali the government and several development agencies are implementing small-scale rural electrification schemes based on Jatropha (IIED, 2008). These Jatropha plants are not demanding in terms of soil and water requirements and adapted to semi-arid conditions. On the other hand, a high dependence on large-scale local bioenergy production and single feedstocks may create new risks, such as climate risks, changing commodity prices, land degradation and farm input supplies.

E.2.3 Improved trade balance

The policy goal of reducing the oil import bill is closely linked to energy security. As described in a previous section, energy supply in many developing countries depends on oil and gas imports. In certain countries, fossil fuel imports form a large share of total imports. Increased oil and gas prices are putting great strain on national budgets in import-dependent nations. The 2005 oil price surge reduced GDP growth of net oil importing countries by almost 50%, and, as a consequence, the number of people in poverty rose by up to 6% (ESMAP, 2006; cited in CFC, 2007). Domestic biofuel production offers oil importing countries an opportunity to replace oil imports and improve their trade balance. The experience in Brazil, for instance, shows that replacing imported gasoline by bioethanol saved the country some US$ 43.5 billion between 1976 and 2000 (US$ 1.8 billion/year) (CFC, 2007).

Another option to improve the trade balance is the development of new export markets for biofuels from agricultural produce and thus increase export revenues. This stems from the fact that the comparative advantage of developing countries located in tropical and subtropical areas to produce biomass for energy. On average, biomass in tropical and subtropical areas can be five times more efficient, in terms of photosynthetic efficiency, than biomass produced in temperate regions (Johnson et al., 2006; cited in CFC, 2007). An important assumption is that agricultural production systems are modernised and intensified.

Countries currently responding to growing global demand for biofuels are those with large land endowments and commodity production, with experience in feedstock production and trade, and those enjoying preferential access to consumer countries. Targets involve North-South as well as regional South-South trade (CFC, 2007). Besides Brazil, China, several EU countries and the U.S., Pakistan and Ukraine are among the world's top 10 ethanol exporting countries in 2006, while Malaysia is exporting biodiesel to Europe (GBEP, 2007).

E.3 Negative social and economic effects

Whereas biomass to energy production has several potential positive effects, in practice it also has several negative effects. Similar dynamics can be expected for rapid expansion biomass production as those that can be associated with initial phases of rapid area expansion and large-scale production of agro-commodities, in developing countries (Kessler et al., 2007). The following negative socio-economic issues can then occur: land use conflicts, water use conflicts, labour issues and increased inequality in terms of income, access to land and gender.

E.3.1 Land use conflicts

High pressures on existing arable lands and the need to reduce production costs favours large-scale agribusiness operations and concentrated land ownership. This causes land conflicts in countries with poor land tenure regulations or poor law enforcement. Between 1990 and 2006, 13% of the land occupied by palm oil plantations has been involved in land conflicts (Sawit Watch data; cited in Aidenvironment, 2007), amounting to 500 active land conflicts by January 2008. Similar cases are reported by IIED (2008) in Latin America. In Brazil, smallholders and indigenous people lost access to their land due to the expansion of the sugarcane and soybean industry. In certain Brazilian states 80% of land ownership is obtained illegally. Sometimes violence is used to evict local people from plantation sites. In Colombia, the expansion of oil palm plantations has been accompanied by armed groups, driving black and indigenous people off their land.

An additional problem may arise due to the influx of migrant labour causing land pressure and conflict between original inhabitants and migrant labourers. The influx of migrant labourers is commonly triggered by political motives such as in the case of the Amazon in Brazil and forest inlands in Indonesia.
The notion of using use 'idle' land for feedstock production does not necessarily avoid land conflicts. There are growing concerns that lands perceived to be 'idle', 'under-utilised', 'marginal' or 'abandoned' provide a vital basis for the livelihoods of local communities, by crop farming, herding and gathering of wild products (CFC, 2007). In India, for instance, the widespread planting of Jatropha on 'wasteland' has been brought into question because of the heavy reliance of rural people on these lands for collecting fuelwood, food, and fodder (Rajagopal, 2007; cited in FAO, 2008c). Local or customary land tenure regulations and the displacement issues linked to local land use dynamics are often poorly understood or ignored (CFC, 2007). In Tanzania, a planned sugarcane production scheme in the Wiami Bassin will involve the displacement of thousand people using these wetlands for rice cultivation (African Biodiversity Network, 2007). Land conflicts over 'idle' land are a potential issue in the production of second generation biofuels or biomass for heat and electricity production as the large-scale production of short-rotation woody crops and tall grasses is likely to be concentrated on less fertile or degraded soils. There are, however, also good potentials of merging the objectives of land rehabilitation with production of biofuel feedstocks.

E.3.2 Water use conflicts

In many regions water availability is the key limiting factor of biofuel feedstock production and processing. Many crops currently used for biofuel production – e.g. sugar cane, oil palm and maize – have high water requirements at commercial yield levels. Even perennial plants such as Jatropha that can be grown in semi-arid areas on marginal or degraded lands may require some irrigation during hot and dry summers (FAO, 2008). Already about 2% of all irrigation water withdrawals is used for biofuel crops (De Fraiture et al., 2007). Processing feedstocks into biofuels requires large quantities of water, for washing plants and seeds and for evaporative cooling. Irrigation and processing related water needs increases water scarcity and may lead to water conflicts. In Mozambique, a planned 30,000 ha sugarcane plantation raises concerns with regards to the effect on access to water for local groups. The plantation will extract water from a dam which also supports smallholder agriculture (IIED, 2008).

Table 11 Water requirements for biofuel crops

	Evapotranspiration equivalent	Potential crop evapotranspiration	Rainfed crop evapotranspiration	Irrigated crop water requirement	
	(litres/litre fuel)	(mm/ha)	(mm/ha)	(mm/ha)	(litres/litre fuel)
Sugar cane	2,000	1,400	1,000	800	1,333
Maize	1,357	550	400	300	857
Oil Palm	2,364	1,500	1,300	0	0
Rapeseed	3,333	500	400	0	0

Source: FAO, 2008d.

Water conflicts could well remain an issue in second generation biofuel and biogas sectors, as short-rotation woody crops, such as willow, poplar and eucalyptus have relatively high water needs.

E.3.3 Labour issues

There is general concern about the quality of employment in biofuel production within large-scale operations (Worldwatch Institute, 2006, UN-Energy 2007, FAO, 2008d). Poor working conditions and health and safety risks are generally associated with large-scale plantations, notably sugarcane and palm oil. A study in 2002 among oil palm plantation workers in Malaysia reported widespread pesticide poisonings and significant problems among approximately 30,000 women working as pesticide sprayers (Oxfam, 2007). Since working and living conditions are often inseparable in rural environments, exposure to pesticides extends to the entire household (World Bank, 2007). In Brazil, various cases of forced labour have been reported in sugarcane plantations. In certain cases excessive working conditions have even caused deaths (FIAN International, 2008).

Improved employment opportunities do not necessarily lead to a decent living wage. Wages in the sugarcane and palm oil sector are generally very low. For instance, in Indonesia many oil palm plantation workers are paid according to their production targets. To reach these targets, they need structural - unpaid - help from their wives and children. Plantation wages are at a subsistence level, barely covering the costs of sending a child to school. Minimum wage legislation is neither consequently applied (Friends of the Earth, 2008).

Prospects for improved wages are poor in the bioenergy sector because the greatest savings over time can be made through reducing production costs. This will pressure large-scale operations and small-scale farmers to reduce labour costs and employ people at lower wages (ODI, 2007; cited in CFC, 2007).

There is evidence that working conditions on plantations (including those of biofuel feedstocks) can have a differentiated gender impact. Landowners tend to prefer women workers because they accept lower wages than their male counterparts, are more docile and dependent. Women working on plantations therefore tend to be disadvantaged as compared to men (ILO/FAO/IUF, 2007; cited in FAO, 2008c).

E.3.4 Inequality and market concentration

Biomass for energy production can benefit smallholder farmers through employment generation and higher rural incomes, but the scope of these impacts is likely to remain limited in many parts of the world. For instance, ethanol production with current technologies requires fairly large economies of scale and vertical integration and may do little to help small-scale farmers (World Bank 2007). Evidence from areas with rapid expansion of agro-commodity production shows that the likely result is increased inequality in terms of income, access to land and gender (Kessler et al., 2007). For instance, oil palm smallholders in Indonesia and Malaysia fully depend on neighbouring plantation companies for inputs, such as seedlings, credits, and fertiliser, and on the use of palm oil mills. These companies have in general a local monopoly position. There are reports of companies exploiting their bargaining power to offer very low prices to smallholders (Aidenvironment, 2007a). In Indonesia and Papua New Guinea the expansion of the oil palm sector has been characterised by the erosion of land rights (CFC, 2007). Large investments are signaling the emergence of a new 'bioeconomy' in the coming decades (WWI, 2007). There are thus risks that farmers will be squeezed out by companies that control the feedstock market.

Development in second generation of liquid biofuel production facilities is expected to increase these risks. Cellulosic ethanol plants are expected to require even greater capital investments of at least US$ 100 million. Individual plants must also be part of a marketing alliance in order to get their products to global markets. There is evidence that capitalisation and concentration of market power within the agro-fuels industry is taking place. The US biofuels sector has seen a shift away from farmer ownership. Based on announced plant developments, farmer owned projects represented only 26% of new capacity in 2006 (Kenkel and Holcomb, 2006; cited in CFC, 2007).

Bioenergy production is expected to increase gender inequalities as the burden of most social and economic effects will weigh heavier on women and women-lead households (FAO, 2008c). For instance, the conversion of marginal or less productive land into cropland for bioenergy crops will particularly affect women because women use these lands to grow crops for household consumption.

E.3.5 Conclusions

Although the promotion of biomass for energy production can be a driver for rural development, this long-term positive potential appears to be overshadowed by various short-term negative social and economic effects. The existing evidence and expectations from the production of feedstocks for biofuels is in line with the conclusions from large-scale agro-commodity production showing that inequalities generally increase and local production areas and communities do not benefit as expected (Kessler et al., 2007). For instance, despite years of large investments in the palm oil sector in West Kalimantan Indonesia, the region continues to score considerably worse than the national average on several indicators, such as the Human Development Index, GDP growth per capita and child nutrition, than the national average (Kessler et al., 2007).

The main conclusion is that a positive balance of socio-economic effects of biofuels production does not primarily depend upon the type of feedstocks and the type of energy being generated (e.g. electricity or biofuel), but depends upon conditions such as: initial level of development, scale of production and level of mechanisation, governance context, and local land availability. Rapid land use changes and large-scale production systems (e.g. as a response to global demand) are generally detrimental to local communities in developing countries.

E.4 Barriers

Different barriers can be identified which help explain why negative social and economic effects prevail and why potential benefits of biomass for energy production are not easily realised. The following is a short-list of priorities.

E.4.1 Tenure insecurity

Clear rules on land ownership are a pre-condition to avoid land conflicts in case of land expansion for biomass production. It also enhances security against eviction and thus competitiveness by encouraging land-related investment (World Bank, 2007). This is relevant to both small-scale and large-scale production. To avoid land conflicts, tenure policies should protect customary land rights, which can consist of communal lands and common property resources, including grazing and indigenous lands.

E.4.2 Lack of land and water use regulation and plans

Local and regional land use planning is one strategy to minimize the negative social and environmental effects of biomass for energy production. These planning processes should take into account water and land resources and their multiple functions. However, in many countries, the regulations and capacities to do so are weak, and so are the mechanisms to involve stakeholders.

E.4.3 Lack of labour policies

Underlying barriers to labour issues in the biomass for energy sector are the lack of agreed or enforceable working standards and lack of labour representation in many countries (FAO, 2008c). Basic ILO regulations on forced labour, child labour, wages, working time, discrimination on gender and race, and the right of association are either not or vaguely included in regular labour standards. If they are included, workers may still not be aware of them and enforcement can be weak.

E.4.4 Poor law enforcement

Law enforcement is required to apply good tenure or labour policies, but is often missing due to corruption of bad governance. For instance, Indonesia has various regulations on land tenure, the protection of indigenous people and protected areas. Nevertheless, the combination of bribes, lax administration and poor performance by government officials regarding adherence to legal requirements or procedures, has resulted in considerable illegal forest conversion and contributed to palm oil related conflicts across the country (Colchester, et al, 2006). Various cases exist in which plantations exist in National Parks, Wildlife Reserves and other protected areas (CSPI, 2005). Other governance related barriers are the absence of a sound macro-economic environment, the establishment of a clear, stable and transparent legal and fiscal framework and an efficient administration (CFC, 2007).

E.4.5 Lack of infrastructure

The potential for biomass production is affected by inadequate or lack of infrastructure, especially in remote areas where the promise of biofuels is greatest, and thus undermines the commercial viability of biofuels production (CFC, 2007). For instance, transport costs make up about one-third of the farmgate price of urea fertilizer in African countries (World Bank, 2007). Likewise, the sale price of Brazilian bioethanol in the EU varies in the range of € 200-300/tonne of oil equivalent (toe) and transport and distribution costs can add an extra € 150-200/tonne (GAIN, 2007; cited in CFC, 2007). Infrastructure involves suitable roads, waterways and pipelines to transport products to the markets, as well as communication infrastructure, which is essential for notifying producers, processors and traders on weather and market conditions.

E.4.6 Limited access to knowledge, science and technology

Access to or knowledge of biofuel technologies is rather limited in developing countries, or skewed in favour of large-scale commercial companies, which is one factor causing inequality. For instance, there is a lack of reliable data on energy planning, land potential, optimal land use, crop production potential and agronomic techniques. Hardly any research is done in testing seed varieties under the local conditions and identifying those with higher yields or with greater resistance to diseases and pests. Little attention is given to R&D and capacities for operation and maintenance of processing and distribution equipment are generally not available (Gueye and Siegel, 2008). Especially in Sub-Sahara Africa, at farm level, there is insufficient knowledge on farming practices such as integrated soil fertility management, integrated pest management and conservation tillage (FAO, 2008d). In many countries extension services and training opportunities, facilities and infrastructure are poorly developed. This could especially hamper small-scale production schemes to meet consistent quality standards for wider markets (World Bank, 2007). Capacity building is particularly critical at the early stage of the biomass for energy industry (UN-Energy, 2007).

However, many challenges exist for the agricultural sector in general to fullfil its potential to meet the development and sustainability goals. AASTD (2008) stressed in its recent synthesis report that for successfully meeting development and sustainability goals, a fundamental shift in agricultural knowledge, science and technology is still needed to enhance sustainability while maintaining productivity in ways that protect the natural resource base and ecological provisioning of agricultural systems.

E.4.7 Limited access to finance

Especially in developing countries financial systems are poorly developed or skewed in favour of certain types of investments. This gives large private or public enterprises with their own funding resources an advantage in responding to global market demands. The consequence is an increasing dependency of smallholders. Small-scale decentralized processing units can be a commercial viable option to meet local energy demands but must be supported by appropriate credit facilities.

At farm level, the lack of access to finance is also a barrier. If farmers are too poor to purchase new seed varieties or apply fertilizers they risk to be excluded in the chain. The ability of agricultural enterprises and rural households to invest for the long-term and make calculated decisions for risky and time-patterned income flows is shaped by the access to financial services. Unfortunately, rural financial and credit markets are often poorly developed and difficult to establish. In rural Honduras, Nicaragua, and Peru, the credit-constrained population constitutes some 40 percent of all agricultural producers (World Bank, 2007).

E.4.8 Power asymmetries

Power asymmetries cause differences to benefit from bioenergy potentials, and affect security of local producers. In practice, access to information and capacity to make use of the law is often skewed. Many investors in bioenergy are powerful operators in the agribusiness and energy sectors. Power asymmetries exist between these large investors and, for instance, a cooperative of oil palm producers. Power asymmetries involve a range of different factors: differences in the capacity to influence decision-makers and opinion formers to mobilise political support and to draw power from parallel processes of negotiation; differences in access to land rights, finance, technology, information and skills; differences in social status and networks; and differences in the degree of internal cohesion, for instance where local groups are divided in their position on proposed investment projects (FAO, 2008c).

E.4.9 Limited access to standards by smallholders

While standards promise to be a viable mechanism to improve social and environmental performance in the bioenergy chain, they can act as a powerful non-tariff barrier to especially small and medium sized producers to enter the market. Especially smallholders have significant difficulties to comply with standards. They lack the basic skills and means to come over the threshold of certification. Without special attention to smallholders in criteria development and without sufficient attention to financing and technical assistance, standards could well drive them further away from the income opportunities that bioenergy sector could offer.

E.4.10 Insufficient attention for social-economic effects in biofuel standards

Voluntary and mandatory standards and certification systems can be effective tools in enhancing sustainable biofuels production, but it has appeared to be very difficult to integrate social and environmental effects. This is mainly due to the assumedly uncertainties associated with these effects. There is a lack of common understanding of expected positive and negative social and economic effects. Likewise, indirect social and economic effects, for instance due to land use changes, are very important but so far unaccounted for.

Annex F Cost and cost effectiveness

F.1 Introduction

One of the main barriers for biomass use for power generation, CHP and biofuels are their costs - many of the applications are more expensive than their fossil alternatives. Government support and regulations are in place in many countries to overcome this barrier, and promote biomass use for electricity and heat generation and biofuels, despite the additional costs.

In the following, a brief overview is provided of the cost of various forms of bioenergy. Literature on this topic is, however, relative limited, compared to literature on the GHG effects of bioenergy.

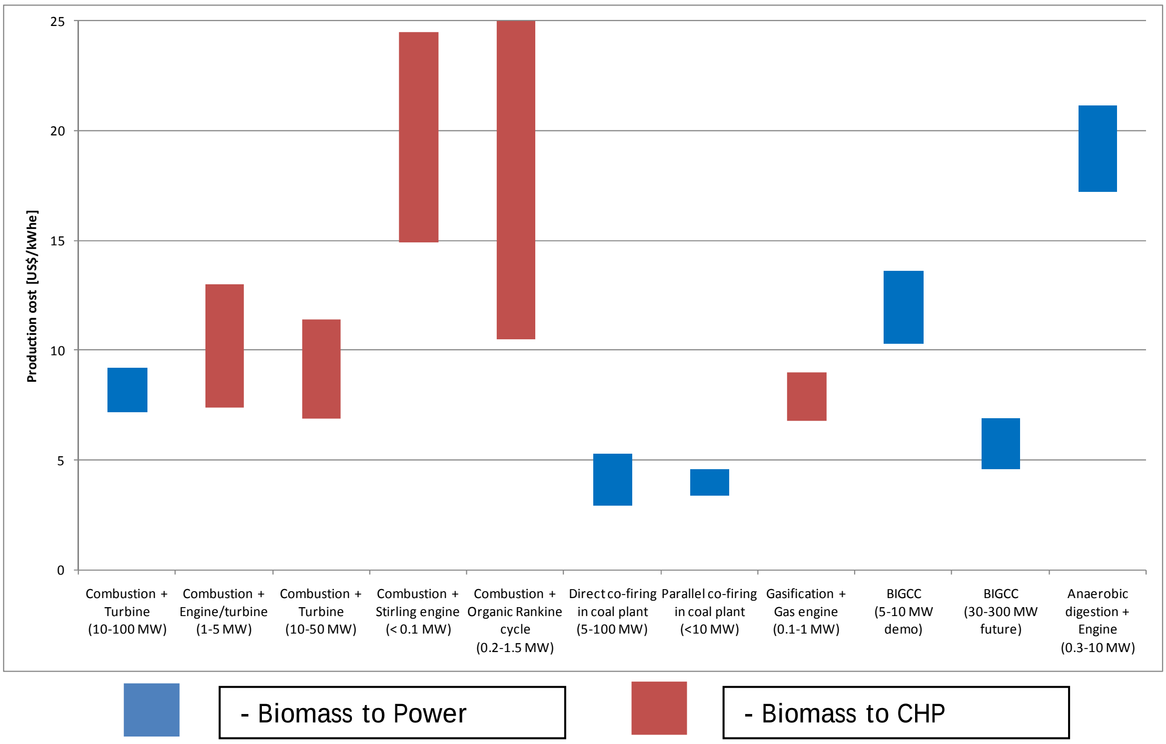
F.2 Costs of bioenergy

However, the literature is not clear about the cost of these government policies, the ranges given are quiet large. For example, costs of biofuel policies were recently analysed by the OECD (2008). They conclude that the current[37] biofuel support policies in the US, EU and Canada will cost taxpayers and consumers about US$ 25 billion on average for the 2013-2017 period (at an assumed oil price of US$ 90-100 per barrel). In terms of cost effectiveness, this is estimated to be equivalent to between US$ 960 and US$ 1,700 per tonne CO_2 eq. saved (excl. indirect land use change), or between US$ 0.80 and US$ 7 per litre of fossil fuel not used. These estimates are relatively high, compared to cost and cost effectiveness estimates of the European JRC/Eucar/Concawe WTW study (JEC, 2007). At an oil price of € 50/bbl, their results indicate cost levels of € 100-250/tonne CO_2 eq. avoided, or € 0.15-0.3/litre fossil fuel replaced. The JEC (2007) results were depicted in Section B.3, Figure 17.

Estimates of production costs of various biomass-to-power and CHP pathways are shown in Figure 20 (from IEA Bioenergy, 2009). The sometimes very significant ranges relate to economy of scale, and, in case of the Stirling Engine, BIGCC and the Organic Rankine cycle, to the early stage of technology development. If the latter technologies develop successfully in the future, costs may be expected to reduce.

[37] 2008 status, not considering new US and EU initiatives.

Figure 25 Production cost of available biomass-fuelled technologies to power and CHP (IEA Bioenergy, 2009)



Source: IEA Bioenergy, 2009.

In a recent analysis for the German WBGU, Müller-Langer et al. (2008) estimate and compare the costs of various biomass applications and pathways. They conclude that costs of biofuels are relatively low, between 12.5-33.7 Euro/GJ_{EE}[38]. Heat production with biomass results in costs of about € 45/GJ_{EE}, and power generation costs about € 11-120/GJ_{EE}. According to (Müller-Langer et al., 2008), low-cost options in biofuels are biodiesel and ethanol from sugar cane, low-cost options for power generation are co-firing of pellets in coal-fired power stations, and biogas from cheap agricultural residues and manure.

The modelling results of the 2008 EEA report 'Maximising the environmental benefits of Europe's bioenergy potential' (EEA, 2008) may also provide useful insight in the cost differences between different bioenergy applications of biomass. They conclude, for example, that giving priority to biomass in transport (2020 target) will increase costs, whereas utilizing heat (in CHP) will reduce cost and increase GHG reduction.

38 EE = end use energy, final energy.

F.3 Key issues

From recent literature, a number of cost-related issues can be identified that are key to better use of biomass:

- Biomass that is produced sustainably (and certified) can be expected to be more expensive than biomass that does not adhere to sustainability criteria. This is due to a number of factors, including more expensive land, investments in more sustainable agricultural practices and processes, certification and monitoring costs, etc.
- According to IEA Bioenergy (2009), costs of US$ 3-4/GJ for primary biomass are seen as a threshold to compete with current fossil fuel prices. Use of more expensive biomass requires stringent policies (e.g., regulations) or financial incentives. This cost level threshold (and therefore the biomass volume that can compete with fossil fuels) increases with higher fossil fuel prices.
- As discussed in Section 2.2, governments may decide that biomass should be used in the transport sector to improve security of supply and reduce oil imports. In most cases, this is a more expensive application than biomass use for electricity or heat (both in terms of cost per GJ energy replaced, and in cost per ton CO_2 reduced), but it should be noted that there are exceptions to this rule.
- Research and development of new technologies (see Section G.2) will require significant funding and investments in R&D, pilot plants, etc. As is concluded in (IEA Bioenergy, 2008), multi-million dollar government grants or other policies are required to encourage the private sector to take the risk of developing a commercial scale, 2nd generation biofuel processing plant[39].
- Also in the longer term, beyond the R&D phase, some processes for 2nd generation biofuels are expected to require a large scale to be profitable, and also in power plants economies of scale exist. This results in high investment costs, and potentially high logistical costs, as very large quantities of biomass have to be transported to the site (see, for example, OECD/IEA,2008).

[39] This should be seen, of course in the context of other CO_2 reducing technologies that need to be developed. The development of fuel efficient cars, carbon capture and storage, other renewable energies, etc. also need large scale investments.

Annex G Opportunities

G.1 Introduction

In Chapter 2, a number of specific opportunities to increase sustainable biomass use are identified:
- Residues and waste as feedstock.
- Biomass production on marginal and degraded land. And
- Other types of feedstock such as algae and Jatropha.

These will be discussed in more detail in the following.

G.2 Residues and waste as feedstock

The possibility to use residues and wastes as a biomass feedstock enables the production of tremendous quantities of energy and environmental benefits. The availability of biomass feedstock from residues and waste is very large all over the world and this feedstock does not have any fertile land use and does have minimal competition with food or feed. Because the residues and wastes are part of the short carbon cycle, the use of residues and wastes for energy purposes has a minimal extra GHG emission. And because these feedstock sources are wastes and residues, the costs of the feedstock are generally very low.

The use of residues and waste as a feedstock for bioenergy is very divers. Different definitions for feedstock of residues and wastes are used, but most of them are considered to be second generation biomass (IEA Bioenergy, 2008). Three main sources can be identified: forestry residues, agricultural residues and process wastes.

Forestry residues are residues that remain after stem wood removal, such as stem top and stump, branches, foliage and roots or complementary felling (EEA, 2006). The use of forest residues vary throughout the world, depending on the amount of forests available in the country, amongst things. For example, in countries like Canada and the United States a large feedstock of forest residues is present. These can be converted into hog fuel (an unprocessed mix of coarse chips of bark and wood fiber), wood chips or pallets and used for heating and power by local users. Also in Europe, countries like Sweden, Germany, France and Finland have large forestry industries and large quantities of forest residues.
The use of forest residues does have some constraints (EECA, 2005):
- In some situations, collection and processing costs are too high to warrant extraction of wood residue. Collecting and transporting bulky woody material from a forest is often expensive compared with using coal or natural gas.
- Traditionally, harvesting trees in a forest would leave behind large volumes of woody biomass in the form of branches, tops and damaged stem wood pieces, which would eventually rot and provide nutrients for subsequent crops. If all this woody biomass is used as an energy source, the removal of nutrients in some regions could eventually reduce the soil fertility to an unacceptably low level. Spreading nutrient rich wastewater over the land could overcome this problem.

Agricultural residues can be divided between those residues that are predominantly dry and those that are wet. Dry residues like straw from wheat, barley, rye and oats, stalk and maize residues are the most abundant crop residue in terms of energy (Ericsson and Nilsson, 2006). As a general rule only part of the residues should be harvested to avoid depletion of organic matter in the soil, thus to ensure long-term productivity. For example per tonne maize only a quarter of a tonne residue is available (Hall et al., 1993). As to be expected, large quantities of dry agricultural residues are available in regions with large cereal production, like the US, Ukraine, France or Germany.

Residues with high water content are energetically much less efficient for combustion or gasification techniques then dry residues. And because of the high water content, wet residues like manure or grass silage are less suitable (energetically and financially) to be transported over long distances. So they are best used on site. The wet residues are currently best used for the production of biogas by digestion.
Combinations of dry and wet residues are also possible. Adding dry residues to wet residues can lead to higher energetic and financial output, compared with 100% wet residues.

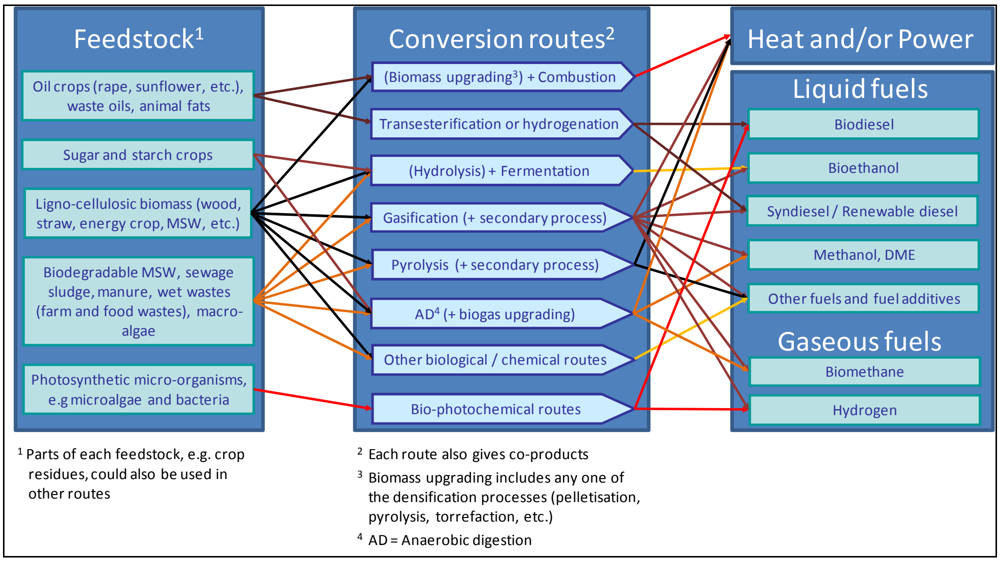
The third category of waste are so called *process wastes*. These include municipal solid waste (MSW, the component with biological origin), black liquor (liquid by-product from the pulp and paper industry), wood-processing waste wood (like sawdust and off cuts), construction/demolition wood, packaging waste wood, household waste wood, sewage sludge and food processing wastes (EEA, 2006). Like the first two categories (with the exception of manure), the biological component of the process wastes is lignocellulosic feedstock.

Lignocellulosic feedstock can be converted into many different biofuels for energy. At present, many waste streams are being combusted to produce heat and power. For example the combustion of MSW in waste incineration plants, by which power and heat are produced and that (partly) can be attributed to the lignocellulosic biomass. Strong differences can be seen in the last decades between the US and Europe (and even between EU member states). In the US the amount of waste incinerators decreased significantly over the last decades, declining the amount of energy produced from MSW, as in Western Europe an increase was seen in both. In 11 EU-27 countries no waste incineration at all took place, mostly in the New Member States (EIA, 2009; Eurostat, 2009).
Because lignocellulosic materials are more complex to break down than starch, other uses than combustion require more advanced pretreatment and conversion processes than those used in the production of ethanol from feedstock like corn or sugarcane (IEA Bioenergy, 2009).

The technology to convert lignocellulosic biomass (such as the above-mentioned residues and wastes) into bioethanol or other biobased materials is still in the R&D phase. Although several stages of the conversion process are already commercially available, technological advances must be made in several process steps to ensure a commercially competitive bioethanol production. Most of the R&D in bioethanol is taking place in the US. Northern Europe and Brazil are very interested. Especially Brazil, where currently extensive bioethanol production is taking place from sugarcane, which can compete with food and feed (production).
In Figure 26 an overview is given of the variety of conversion routes of different types of biomass. Table 12 shows several products which can be made from biomass. From both, the same picture arises: lignocellulosic biomass can be converted in many different ways and lead to many different

products, enlarging the overall possibilities for the adaptation of large scale application of the waste and residues to produce biobased (energy) products.

Figure 26 **An illustration of the various bioenergy conversion routes**



Source: IEA Bioenergy, 2009.

Table 12 **Biomass-to-product conversion routes**

Biofuel group	Specific biofuel	Biomass feedstock	Production process
Bioethanol	Cellulosic ethanol	Lignocellulosic materials	Advanced enzymatic hydrolysis and fermentation
Synthetic biofuels	Biomass-to-liquids (BTL) Fischer-Tropsch diesel (FT) Synthetic diesel Biomethanol Heavier alcohols Dimethyl ether (DME) P-series (ethanol + MTHF etc)	Lignocellulosic materials	Gasification and synthesis
Biodiesel	NExBTL H-Bio Green pyrolysis diesel Algal oil	Vegetable oils and animal fats Lignocellulosic materials Algae	Hydrogenation (refining) Pyrolysis Cultivation
Methane	Bio synthetic natural gas (SNG)	Lignocellulosic materials	Gasification and synthesis
Bio hydrogen	Hydrogen	Lignocellulosic materials	Gasification and synthesis or biological processes

Source: IEA Bioenergy, 2008.

A comprehensive overview of conversion technologies can be found in two publications from the IEA: From 1st-to-2nd-generation biofuel technologies (IEA Bioenergy, 2008) and Bioenergy – A Sustainable and Reliable Energy Source (IEA Bioenergy, 2009).

As said, lignocellulosic biomass has many possibilities. Lignocellulosic biomass can be found all over the world: every country has its wastes and residues. Of course regional differences can be seen. Regions with large areas of forests and extensive wood and paper industries like Canada, US, Northern Europe and New Zealand have large potential feedstock of forestry residues. Regions with large agricultural sectors like the US, France, Germany, Ukraine, Brazil have a large potential of lignocellulosic feedstock in the form of agricultural residues. Regions like North-West Europe with very a intensive livestock industry have agricultural feedstock like manure from pigs, cows or hens. The availability of process waste is global, the amount depends on factors like the size of the population or the industrial sector.

Although waste and residues feedstocks are low cost, the conversion techniques often are not, especially the ones in development. In the coming decades a lot of research and development is still needed to mature the conversion technologies and optimize the feedstock logistics to reduce the overall costs of bioenergy and make it more competitive with fossil fuels.

G.3 Marginal and degraded land

There are considerable amounts of land worldwide with low-carbon content and low biodiversity, that would, in principle, be suitable to cultivate biomass for bioenergy. Biomass cultivation could then prevent any of the negative environmental impacts related to changing land described above, and perhaps even improve the environmental characteristics of the area. However, there is still significant uncertainty about the actual bioenergy potential of these lands and about the costs, environmental and socio-economic impacts of bringing them into production.

In general, we can distinguish between 'marginal' land, degraded land and abandoned land. The definition of these types of land are not always clear, but the following provides some guidelines (UNEP, 2009):
- Marginal land is land that is currently not cultivated as cropland, where crop production is technically possible but yield are too low and cost are too high to allow competitive agriculture.
- Degraded land has been cultivated in the past, but became marginal due to soil degradation, erosion or other impacts resulting from inappropriate management or external factors such as climate change.
- Abandoned land comprises degraded land with low productivity and land with high productivity, that is currently not in use (e.g., where forest is regrowing).

Not all of this land is potentially suitable for sustainable and economically viable biomass production.
First of all, within these categories different levels can be identified. For example, the degree and severity of degradation can vary from 'light' degraded to 'severe', as well as the type of degradation (i.e. the reason why it is degraded). This will obviously have an impact on the (technical) possibilities available and costs associated with bringing these lands back into production. Part of this land will be too costly to use, part of it will be technically impossible.
Also, the carbon content and biodiversity of these lands may vary, resulting in limited or even negative changes to biodiversity and carbon content when they are converted to biomass cultivation. For example, the biodiversity of marginal and especially abandoned land can be significant, especially if not used for a longer period of time. Converting this land to biomass cultivation is then likely to reduce environmental quality of that area.

And finally, part of these lands may be of value to the local communities, e.g., it may provide food and wood for cooking and heating, or is in use as (extensive) grazing ground for livestock.

On the other hand, it is expected that part of these currently uncultivated lands and the local communities could benefit from bioenergy cultivation, as it may improve the overall quality of the soil by, for example, increasing nutrient and carbon content, reducing erosion and retaining (rain) water, and stimulate the local economy.

There are various options to bring marginal land into production or restore productivity of degraded land, very much depending on the local situation (a brief overview of measures can be found in UNEP (2009)).

However, there is currently still quite some debate and significant uncertainty on the current extent of these lands and on the sustainable bioenergy potential from them (WAB, 2008; UNEP 2009), and research is ongoing to progress this topic (e.g. a joint GEF/UNEP/FAO/UNIDO project[40]). Knowledge gaps exist regarding:
- Reliable geographical information on the marginal and degraded land and their quality.
- Which of these lands could potentially be converted to sustainable biomass production, taking cost, economical and socio-economical issues into consideration.
- On the optimal crops and technology to be used for specific situations;
- Crop yield that can be achieved on these soil.
- Costs of this biomass, including the initial (investment) costs required to make this land productive.
- The time frame needed before a degraded land area is recovered, and can produce at sufficient yields and reasonable cost.

Estimates of potential marginal and degraded land

WAB (2008) estimates that almost 2,000 million ha, about 15% of the total land surface, has been subject to land or soil degradation (based no GLOASOD data). Degradation is mostly due to water erosion (56%), wind erosion (38%, chemical deterioration (12%) and physical deterioration (4%). This degradation is in almost all cases human induced, due to deforestiation and removal of natural vegetation, overgrazing, improper agricultural management, industrial activities, etc.

A light degree of soil degradation was identified for 38% of all degraded soils (750 million ha), 46% has moderate degradation (910 million ha). These could potentially be converted to an agricultural function again in the future – with the appropriate financial support and technology. The rest, about 300 million ha strongly and extremely degraded soils is considered to be unrecoverable.

Regarding marginal land, very little data is available. UNEP (2009) provides estimates ranging from 100 million to 1 billion ha. To determine the actual feasible and sustainable potential for marginal land and associated biomass production would require a detailed analysis of these lands, taking into account many factors including the question whether the land is currently in use by local communities and therefore what the impact of a conversion to biomass cultivation would be. This kind of analysis has not yet been performed.

40 See for example http://www.bioenergywiki.net/index.php/2nd_Joint_International_Workshop_Mapping.

G.4 Other types of feedstock: aquatic biomass and Jatropha

Besides the opportunities described in the former paragraphs, additional opportunities of biomass feedstock are available. The list of opportunities is almost endless, ranging from perennial grasses (like Miscanthus, switchgrass and prairie grass) and short-rotation forest species (e.g. Eucalyptus, poplars or Robinia) to genetically modified crops, aquatic biomass (algae) and non-food oilseed species (like Jatropha).
In this paragraph the later two, aquatic biomass and non-food oilseeds, will be elaborated in more detail.

Aquatic biomass

The most important resource of aquatic biomass is algae. Algae are considered to be 3rd generation biomass[41] and can be separated into two distinct groups: macroalgae and microalgae. An overview of various cultivation methods and conversion technologies can be found in, for example, Ecofys (2008). The aquatic biomass can be converted to biodiesel or biogas.

Macroalgae (like seaweed) are currently used for non-energy purposes such as food, vitamins and pharmaceuticals. They could be used for energy purposes like other forms of wet biomass by producing biomethane via anaerobic digestion. Or by producing liquid biofuels via fermentation (bioethanol), hydrothermal upgrading (HTU) (bio-oil) or gasification of dry biomass (a number of fuels, such as hydrogen) (IEA Bioenergy, 2009).

The macroalgae have a large potential (no land use, and large areas of sea and lakes are potentially available), but there are still a lot of barriers that need to be taken. Such as barriers in the production (how to contain, how to harvest) and the conversion; the conversion techniques are not commercially proven.
Microscopic photosynthetic organisms (microalgae) such as diatoms, green algae, golden algae or blue-green algae produce chemicals and substances that can be harvested to produce a variety of useful products. Microalgae have high concentrations of lipids, which seems to be a promising resource for the production of biodiesel. Microalgae are currently already cultivated on a smaller scale for shrimp farms.

Microalgae potentially have a very high oil yield per hectare, depending on the strain of algae (variations between 15-70% oil production by weight). They are quoted to yield up to twenty times more oil per unit of land area devoted to their production than conventional crops like palm oil. More realistic estimates are 6-10 times more (IEA Bioenergy, 2009).
The cultivation of microalgae is simpler than macroalgae, because of its characteristics and it is easier to manage in an enclosed system. At present two types of systems are deployed: the open system and the so called photo-bioreactors (tubes or bags in which the algae grow). The open systems are primarily raceway ponds as seen in Figure 27 (left picture). These facilities are being set up all over the world from the EU to Australia. Especially in the US very large production facilities are being set up (several square kilometers). Bioreactors are much smaller scale facilities than open systems, but they create a system in which water, light, CO_2 and nutrients can be managed in a very highly controlled manner, without infection by foreign species of algae (Figure 27, right picture).

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41 3rd generation biomass generally include advanced biofuel production routes which are at the earlier stages of research and development or are further from commercialization than 2nd generation (IEA Bioenergy, 2009).

Figure 27 Cultivation of microalgae, open and closed systems

Note: Open ponds (left, source: Seambiotic, 2009) and bioreactors (right).

The application of microalgae seems very promising, although developments are still at an early stage and estimates of future production potentials are still very rough. Cultivating microalgae can have positive side effects. For example, some algae can be used to clean waste water and produce biofuel feedstock at the same time. The addition of CO_2 to cultivation process improves the growth of the algae, so the co-siting of algae farms and CO_2 emitting industries like power stations is very beneficial. The open pond as seen in the figure above uses the flue gasses of a coal burning power station.

The conversion from algae to energy related applications can be done via two routes. The preferred route is producing algal oil by mechanical or chemical extraction. By means of expellers, presses, solvent or supercritical fluid extraction, between 70 and 95% of the oil can be extracted from the algae. The algal oil can be used directly or converted in biodiesel (and glycerol) by transesterfication or in bioplastics.
Gasification of algae to produce biogas is the less preferred option, because the amount of energy produced per tonne algae is much less than with the production of algal oil.

Aquatic biomass can be cultivated in contained facilities on land such as those shown above, or at sea. In the latter case, there is a risk of negative environmental impacts, due to for example invasion of the area by exotic species, eutrophication and other modifications to the ecological balance. Ensuring the sustainability of biomass cultivation is then an important issue, and changes in sea use, rather than land use, should then be considered (Öko, 2009; Ecofys, 2008).

The development of algae as a biomass feedstock is still in the early research and development stage, and costs of the biomass are currently high. in addition, other uses like high end products (e.g. food supplements) are more likely to be economically feasible in regions with less solar radiation like Northwestern Europe.

Jatropha

To avoid complications biomass feedstock preferably does not compete with food or feed demand and land use. Many non-food oilseeds are available for producing bio oil, but not all are as promising as Jatropha (*Jatropha Curcas).*
Jatropha is a non-edible, perennial poisonous shrub that produces fruits and can be grown in semi-arid climates with marginal soils.
By crushing the seeds of the plant, oil can be extracted which can be processed to biodiesel. The press cake residue can also be processed and used as biomass feedstock to power electricity plants or used as fertilizer. It is believed by some experts that Jatropha will have a significantly higher output

per hectare than corn or soybeans, however other experts doubt that (ref. ODI report).
It is currently too early to judge whether claims that Jatropha will have a very large potential will become true. Especially in countries in Southern Africa and South East Asia, but also in China and India projects are being set up to produce, results of these projects will help clarify the costs and benefits, and potential improvements of these shrubs. Not everywhere Jatropha is embraced as a new biomass feedstock. In Australia Jatropha is categorized as a weed and is as such prohibited to be cultivated (Biodiesel Magazine, 2009).

Annex H Barriers to the better use of bioenergy

H.1 Introduction

This annex focuses on the various barriers to better use of bioenergy. We can distinguish between barriers related to:
- Technology.
- Trade.
- Politics.
- Practical issues.

When assessing ways to improve bioenergy potential or performance it is important to be at least aware of these barriers. Efforts can then be directed at reducing them, making room for further improvements.

H.2 Technology barriers

A number of barriers to the best use of biomass for energy are related to limitations of current technology.

Regarding bioenergy, one of the most important technical barriers is fuel quality, more specifically ash melting behaviour and presence of halogens and sulphur. These limit applicable types of biomass. Biomass types with high contents of high alkali and halogen ashes with low ash softening temperatures - e.g. chicken manure, straw, grasses - are a challenge for thermal conversion processes. Such ashes generate high risks of corrosion, erosion, agglomeration and clogging in furnace, boiler and flue gas cleaning and require dedicated and adapted conversion processes, e.g. cigar furnaces for straw. This barrier can or could be overcome by pretreatment in which the ash is separated from the fuel, e.g. pyrolysis, gasification, torrefaction with associated washing of the torrified material.

For thermal conversion processes limited net electric efficiency of small scale units might also be regarded to be a technical barrier, but only if electricity is valued higher than heat. In that case the alternative is utilizing the biomass in a large scale facility, e.g. a large scale CFB.

For optimum biomass energy utilization, maximum combined heat and power production is preferable. However possibilities for such operational management year round are limited to industrial processes.
For other forms of heat consumption - e.g. space heating - heat demand is a function of time of day and year, fluctuating largely between day and night, summer and winter. In winter continuous operation is often possible. But in late spring, summer and early autumn heat requirement is often very limited, e.g. to hot water for showering. Ideally - aspiring maximum optimum biomass energy utilization - the CHP is only operational periodically during those parts of the day during which maximum CHP operation is possible and switched of for the rest of the day. Heat for other minor heat requirement can be stored in a buffer.

However the technologies required for solid biomass conversion (combustion, gasification) can only follow load changes slowly[42]. These technologies also require high investments, resulting in the necessity for high operational time during the year to remain economically profitable. Because of this discrepancy the installation will have to run partly in only/maximum power mode part of the year.

Elaborate flue gas cleaning for small scale installations in case of stringent emission limits is rather an economic and not so much a technical problem. Gas cleaning equipment that allows extensive cleaning of gas streams exists for small scale combustion plants and gasifiers (e.g. scrubbers, wet electrostatic filters, SCR $DeNO_x$, fabric filters), but these are rather expensive because of size of scale.

Regarding biofuels for transport, it is expected that sustainability can be improved significantly once significant volumes of biofuels can be produced from lignocellulosic biomass and (other) waste streams. Land and fertiliser use is then reduced, resulting in an increase of the sustainable biomass feedstock volume, and more GHG reduction, compared to many of the current biofuels. However, even though conversion of these types of biomass to a high quality liquid biofuel has been demonstrated on a small scale (in laboratories and pilot plants), these technologies are not yet tested and proven on a large scale.

An extensive overview of the technological opportunities and challenges regarding 2nd generation biofuels is provided in OECD/IEA Bioenergy (2008). Clearly, there are some promising techniques that have shown considerable progress in the last decade. However, technological improvements are still required in many different aspects of the process, including biomass pretreatment, enzymes in case of biochemical processing, gasification in case of thermo-chemical processing. At the same time, significant cost reductions are still necessary in all parts of the process chains to become economically viable.

Another route that might prove to be an attractive application of biomass in transport, is the use of electric vehicles, powered by electricity from renewable sources - including biomass. In this scenario, biofuels might only be used for vehicles that can not be powered electrically, such as airplanes, ships and long distance heavy duty vehicles. The share of biomass in electricity could then increase, to compensate for the reduced biofuels demand. The main technical barrier to this route are the limited performance of batteries - despite recent advances in this field for mobile appliances such as mobile phones and laptops, the development of batteries for electrical cars has only just started. In addition, the necessary infrastructure for (smart) loading of the batteries has to be developed and implemented.

Biorefining is a technology in development that is mainly thought of as a plant analogous to petroleum refinery, were a multitude of products is made from a feedstock. A biorefinery is thought to be able to process all or most of a biomass feedstock, and converts this feedstock to chemicals, materials, fuels, electricity, heat, etc. An extensive overview of the current status of technology, and the various processes that are being research, is provided in IEA Bioenergy (2008). If waste streams and, in particular, ligno-cellulosic feedstock can be used in this concept, it is expected to offer environmental, economic and energy security related benefits, especially compared to current biofuel routes.

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42 CHP internal combustion engines and anaerobic digestion facilities with a gas storage can.

Pilot scale biorefineries have been developed successfully, but more R&D is required to advance technological development and reduce cost.

H.3 Trade barriers

Depending on source, conversion and end-use, there exists a large variety of bioenergy markets, each with their specific characteristics. In all of these markets, barriers to international trade play an important role. These barriers consist of *import tariffs* on one hand, and of *non-tariff trade-barriers* on the other hand. Import tariffs are charged because of the wish of national governments to protect domestic industries and agricultural sectors. Non-tariff trade barriers consist of a multitude of factors that are usually not directly linked to the aim of governments to protect their domestic economic sectors. However, in practice these also constitute important hurdles for foreign parties to compete on an equal basis with domestic parties in a certain national market. Examples of non-tariff trade barriers may include technical barriers (e.g. differing characteristics of national certification schemes) and logistical barriers (lack of technically mature pretreatment, low volumes of biomass, missing or expensive access to transport).

Interactions between national policies, import tariffs and non-tariff trade barriers are complex, with 'loopholes' in national legislations leading to radical and mostly undesired shifts in international trade flows. These are aggravated by the fact that international trade flows in bioenergy markets are still relatively low compared to fossil fuel markets, making that changes in legislation in one country or region can redirect the majority of all flows worldwide in a particular bioenergy market. Interactions between national policies, import tariffs and non-tariff trade barriers are also complicated by the cross-links of bioenergy markets to food- or industrial commodities markets.

IEA Bioenergy Task 40 (2006) states that 'a multitude of different barriers currently exist, hampering the development of international bioenergy trade. These include economic, technical, logistical, ecological, social, cognitive, legal, and trade barriers, lack of clear international accounting rules and statistics, and issues regarding land availability, deforestation, energy balances, potential conflicts with food production and local use vs. international trade'. To address these barriers, IEA task 40 has identified a number of issues for further consideration:

To ensure *biomass sustainability*, it is recommended for actors in the various bioenergy routes both in importing and exporting countries to seek agreements on short-term (minimum) sustainability criteria, and to support a long-term development of international standards for important and generally accepted issues. Some of the Task 40 members advocate an international certification system for biomass embedded in (inter)national regulations, while others would preferably see a voluntary approach.

For *market transparency*, Task 40 recommends to the IEA, UNCTAD, WTO and national trade organisation to include (new) biomass types in their statistics, and to include the final application (e.g. energy, chemical feedstock, fodder etc.) where possible. Furthermore, it is recommended that the various standards that are applied today are developed into internationally accepted quality standards for specific biomass streams (e.g. CEN biofuel standards).

To *stimulate international trade*, Task 40 identifies import barriers for certain biomass and biofuels types to be a major obstacle for a smooth further development of international bioenergy trade. Some Task members emphasise that on the short-term, local industries should also be given the opportunity to develop innovative and improved processes for biomass and biofuels production. Other task members stress that such a process should be coupled to a clear agenda for a phase-out of these barriers.

To *create a stable demand-side*, on the longer-term market support policies in the various countries, etc. should be designed to promote and stimulate international trade when and where trade would be the logical option. The EU Renewable Energy Directive is an example where this is taking place. It is further recommended that policy incentives could also include requirements for energy and/or CO_2 balances, and that policy-makers in countries with biomass targets (or renewable energy targets in general) are advised to formulate sound long-term biomass policies, including new targets with a time horizon of at least 10 years or longer, e.g. 2020, in order to create clarity and security for the industry for long-term investments.

To stimulate a stable supply side,
- Improved logistical infrastructure on the supply-side is needed, such as low-cost longrange shipping.
- Further technology development of pretreatment technologies should be stimulated.
- Projects by e.g. the World Bank or FAO should recognize and increasingly stimulate the use of residues as important (by-) products and actively promote energy crops as bioenergy source.
- Stimulate and support capacity building on bioenergy trade related issues.

From the above, import (tariff) barriers for certain biomass and biofuels types are identified by IEA Task 40 as a major obstacle for a smooth further development of international bioenergy trade. The following case-studies of developments in the ethanol and biodiesel markets in the United States and in the European Union illustrate the effects of import tariffs as trade barriers. Ethanol and biodiesel are some of the most internationally traded bioenergy commodities.

Table 13 Import tariffs for various bioenergy feedstocks

	United States	European Union
Bioethanol (denat)	2.5% ad valorem and \$ 0.54 per gallon (CRS, 2008) => \$ 0.14 per litre ~ 0.12 EUR/litre	0.192 EUR/litre (undenatured) 0.102 EUR/litre (denat)
Biodiesel	PM	6.5% (Kommerskollegium, 2008)

Case study 1: Bioethanol trade barriers in the United States and the European Union

The United States and Brazil are the world's largest *ethanol* producers and consumers, covering almost 90% of the 40 million m^3 (20 MtOE) produced globally in 2006. In 2005, 6 million m^3 (15%) of total production) was traded. The world's largest exporter by far is Brazil (48%), followed by the United States (6%) and France (6%). Major import markets are the United States, the European Union and Japan. An estimated 24-46 million m^3 could be traded in 2030. Brazil alone could supply this demand, but other (mostly developing) countries in the world have the potential to become large-scale producers and consumers as well.

US

Main issue for bioethanol trade to the United States are the imports from Brazil via Caribbean Basin Countries and their supposedly negative effect on domestic bioethanol production. In 2005, the United States imported around 720 million litres of ethanol, representing 5% of domestic consumption. Imports originate mainly from Brazil and reach the US market either directly or via Caribbean countries. The United States imposes Most Favoured Nation (MFN) import duties of US$ 14.27 cent/litre (US$ 0.54/gallon) plus a 2.5% *ad valorem* tariff on fuel ethanol. In many cases, this tariff regime offsets lower production costs in other countries and represents a significant barrier to imports as well as a tool to guarantee a captive market for US ethanol producers (UNCTAD, 2006).

A recent report from the US Congressional Research Service (2008) states that: 'The US duty effectively negates the tax incentives for covered imports, and has been a significant barrier to ethanol imports. However, under certain conditions imports of ethanol from Caribbean Basin Initiative (CBI) Countries (Costa Rica, Jamaica, El Salvador) are granted duty-free status. This is true even if the ethanol was actually produced in a non-CBI country. In this scenario, the ethanol is dehydrated in a CBI-country, then shipped to the United States. This avenue for avoiding the duty by imported ethanol has been criticized by some stakeholders, including some members of Congress.'

There has been a discussion in the United States to eliminate tariffs on imported ethanol so as to increase supply and mitigate fuel price increases. Critics of such a measure argued that expansion of duty-free imports from CBI would undermine the domestic US ethanol industry, in particular through increased imports from Brazil via the dehydration route in CBI countries. Proponents of the measure stated that the numerous state level subsidies provide so many incentives to domestic production that significant barriers to imports would remain even if import tariffs were to be removed.

EU

Far after the United States and Brazil, and slightly after China, the EU is the fourth largest producer of bioethanol worldwide. Production in 2007 amounted to 1,770 million litres and import to 1.000 million litres (56%) (Biofuels platform, 2008). Preferential trade arrangements play a crucial role in origins and volumes of imports (UNCTAD, 2006):

'The EU imported more than 250 million litres of ethanol during the period 2002-2004. About 30% of this volume was imported as normal Most Favoured Nations (MFN) trade and subject to specific import duties of Euro 0.102/liter on denatured alcohol and Euro 0.192/liter on undenatured alcohol. Brazil is the largest ethanol exporter to the EU with all of its exports subject to MFN tariffs. During the 2002-2004 period, 25% of EU ethanol imports were from Brazil.

The remaining 70% of EU alcohol imports entered under preferential trade arrangements (61% entered duty free and 9 per cent at reduced duty), including the Generalized System of Preferences (GSP, applying to many developing countries), the Cotonou Agreement (for ACP countries), the Everything But Arms (EBA) Initiative (for LDCs), amongst others. Pakistan, with a 20% share of EU ethanol imports, was the largest exporter under preferential trade arrangements. Other ethanol exporting countries that benefited from EU trade preferences included Guatemala, Peru, Bolivia, Ecuador, Nicaragua and Panama (which benefited from unlimited duty-free access accorded under special drug diversion programmes); Ukraine and South Africa (under the GSP); the Democratic Republic of Congo (under EBA); Swaziland and Zimbabwe (as ACP countries); Egypt (under the Euro-Mediterranean Agreement); and Norway (under special quota).

Recent GSP Regulation no longer provides for any tariff reduction for either denatured or undenatured alcohol. However, the Regulation includes an

incentive scheme for sustainable development and good governance. The scheme provides unlimited and duty-free access to denatured and undenatured alcohol. All countries that already benefited from the previous drug scheme, plus Georgia, Sri Lanka, Mongolia and Moldova, are included in the incentive programme. Pakistan, one of the most competitive ethanol producers and exporter, lost its privileged status under the GSP in October 2005 and no longer appears to be competitive in the European market. In May 2005 the European Commission initiated an anti-dumping investigation against Pakistan and Guatemala - the largest duty-free exporters over the 2002-2004 period - for dumping of ethanol. The proceedings were officially dropped one year later when the full customs tariff was restored on Pakistani imports.
Duty-free and quota-free access is granted to the least-developed countries under the 'Everything but Arms' (EBA) Initiative. While exports of ethanol from EBA countries have so far been negligible, new opportunities may emerge in those countries, particularly as a result of increased sugar cane cultivation. Under the Cotonou Agreement, ACP countries qualify for duty-free access for both denatured and undenatured alcohol.'
UNCTAD also states that 'As in other sectors, export performance is often penalized by the graduation of successful countries from the preferential schemes. As an example, the case of South-Africa is mentioned. This country managed to export approximately 5 million litres per year to the EU market over the 2002-2004 period, as a result of which the country found its imports from 1 January 2006 subject to the full MFN duty'.

Case study 2: Biodiesel trade barriers in the United States and the European Union

With 5.7 million tonnes in 2007, the EU is world's largest producer of *biodiesel*, covering some 87% of supply. The United States accounts for most of the remaining production. Most biodiesel trade concerns imports to the EU, recently mostly from the United States.

US

The production capacity of biodiesel in the United States grew rapidly in recent years, from 5 million gallons in 2001 to 700 million gallons (2.6 billion litres) in 2008 (NBB, 2008). However, demand for biodiesel did not grow as rapidly, hence in 2007 a large part of the biofuel produced was exported to the EU favoured by subsidy schemes ('$1 per gallon biodiesel initiative') that do not require the use of the biodiesel produced in the United States. Recent legislation (Emergency Economic Stabilisation Act, October 2008) closed a so-called 'splash and dash' loophole, according to which foreign finished fuel could be sent to the U.S 'splash blended' to claim the tax incentive; and then shipped to a third country for final use. In practice, 'third countries' mainly involved EU countries.

EU

EU imports of biodiesel are subject to an *ad valorem* duty of 6.5%. Until 2005, biodiesel production outside of the EU was still limited and there was no significant external trade (UNCTAD, 2006). However, due to American subsidies also for exported biodiesel and a free import of B99 biodiesel blends (99% biodiesel) on the grounds that they are classified as 'organic chemicals', in 2007 biodiesel exports from the US to the EU have risen dramatically. Industry price figures show B99 blends from the US (99% biodiesel) undercut EU producers' supplies by up to Euro 150 per tonne (HCGA, 2008). The EU ambassador to the US, John Bruton, commented on this issue that 'US subsidized exports to Europe, which grew by 1,000% in 2007 to 1 million tonnes, now represent 20% of the European market, and that as much of US$ 300 million of US taxes are spent in support of the biodiesel incentives granted on fuel for the European market.' On these grounds, the European

Biodiesel Board in June 2008 has lodged an anti-dumping complaint with the European Commission (Biofuel Digest, 2008). The Commission has nine months from the start of this investigation to decide on provisional measures and 13 months to impose five-year anti-subsidy - or 'countervailing' duties - and 15 months to impose definitive anti-dumping measures (Stearns, 2008). Recently, this issue has been solved.
As far as raw materials for biodiesel (oilseed crops and vegetable oils) are concerned, imports are virtually duty free. No tariff is applied to oilseed in the EU and tariffs on vegetable oils are 0-16% (Kommerskollegium, 2007). Imports to the EU of these feedstocks therefore are attractive. Between 1999 and 2005, EU imports of palm oil (primarily from Malaysia) have more than doubled to 4.5 million tonnes (representing 18% of world palm oil imports) (UNCTAD, 2006).

H.4 Political barriers

A number of political barriers exist that can also hamper the best use of biomass.

Kyoto targets, national GHG reporting and the ongoing COP process tend to approach climate policy from a country perspective, setting goals for individual (groups of) countries. However, biomass is traded globally, resulting in a shift of emissions from one country to another. If, for example, the Netherlands imports bioethanol from France and Brazil, emissions will increase in these two countries, and decrease in the Netherlands.

Bioenergy support schemes are different per country, which may cause suboptimal biomass use. Some countries support some techniques, others only support some crops; some support big installations and others only small installations. For example, in 2006, CE Delft compared the Dutch and German support scheme (CE, 2006) and concluded that significant amounts of biomass were traded from Germany to the Netherlands that received more support in the Netherlands, and vice versa.

Change of policies over time (or the perceived risk of changing policies) can be a barrier to industry investments. Many countries subsidize bioenergy but change this subsidy over time, the same holds for recent biofuel policies. Germany is an example of a country with a rather stable system in the bioelectricity sector and in general this scheme is seen as a success (however, the rapidly changing German biodiesel support policy has received much criticism).

There is often no level playing field between various biomass markets, and the competition between the options varies per country. Biomass can be used for energy, fuel or products. In most countries the support schemes for these three options are not in line. Most countries support biofuels. Many countries support bio energy but with lower support per ton biomass and only some have support for biochemistry or bio-based products.

Another barrier to the development of bioenergy of a more political character is linked to fossil fuel markets. Compared to fossil fuels, present bioenergy markets are very small and, despite huge growth rates, are expected to remain a fraction of fossil markets until at least 2030 (IEA, World Energy Outlook 2008). As over the same period with continuation of present trends world energy demand is foreseen to increase by about 50% (IEA, 2008b), also huge investments in new fossil fuel capacity are needed. This still holds despite the 2008 financial crisis, which has reduced energy demand growth projections somewhat and partly eased concerns about an anticipated 'supply crunch' around 2015.
New production capacity for fossils is particularly needed in the Middle-East, where most of the global reserves of in particular oil and gas are concentrated. In the end-1970s oil crisis, Middle East countries found themselves confronted with a call from consuming countries to invest in production capacity similar to the present one. Investments that were made as a response to the former call and that came onstream in the 1980s found themselves confronted with a lower energy demand in consuming countries as a result of intensified energy efficiency and renewables policies in these countries after the oil crisis. Although positive from an environmental point of view, the negative economic effects of this reduced demand for fossil-producing countries were quite well noted. Present calls from the International Energy Agency and world leaders to step up fossil production capacity in the Middle East are therefore received in those countries with some scepticism. Even more so, as former US President Bush in 2006 explicitly called for reducing oil dependency of his country from the Middle East.
The rapid development of biofuels markets worldwide is therefore also received with some reserve in OPEC countries. In June 2007 this even led to a warning by Mr El-Badri, secretary general of the OPEC, that OPEC 'was considering cutting its investment in new oil production in response to the moves by the developed world to use more biofuels' (Financial Times, 5 June 2007, 'Drive on biofuels risks oil price surge').
Stimulation of bioenergy markets in fossil fuel importing countries should therefore be accompanied by a dialogue with fossil fuel exporting countries about this development.

H.5 Practical barriers to the effective implementation of policies

Examples of more practical barriers that stand in the way of effective policy implementation are:

- Countries and regions where the biomass is cultivated or harvested may have other domestic priorities.
- Problems with supply-chain interaction.

These are discussed in the following section.

H.5.1 Other domestic priorities

Issues such as sustainability of biomass production and forest conservation (for both biodiversity and carbon storage) may be a strong issue for many OECD countries, most developing countries will have a primary aim to enhance their economic development, reduce poverty, etc. There are opportunities to combine these economic and environmental aims, but there are also risks that other domestic priorities hamper implementation of sustainable biomass policies.

H.5.2 Supply-chain interaction

Beside the 'hardware' side of bioenergy, the supply-chain interaction and respective infrastructure requirements could be barriers for bioenergy development.

In most cases, there is a - sometimes complex - interaction of regional and local players and market actors to arrange the provision of biomass feedstocks, their transport and conversion, and the delivery of fuels for the various end-uses[43].

The cooperation of these actors is not only influences by logistics, but also by governmental regulation of (sometimes fragmented) markets and respective trade, and financing needs. With modern bioenergy supply chain interaction still in its infancy, barriers concern mainly the overall governance:

- Feedstock provision actors face the volatility of prices for their commodities due to sectoral and regional competition.
- Information on technologies, markets, and available supply options as well as on access to and costs of logistics is crucial, but only few reliable sources exist, especially in developing countries. Furthermore, international access to information is restricted through language barriers.
- Availability of financing for all steps in the supply chains could be restricted through uncertainty in market development and respective revenues.
- Transaction costs for adequate information on regulation, economic conditions and potential partners could be high especially for smaller-scale market actors.

In addition, there are restrictions in infrastructure development for bioenergy, e.g., pipeline networks for biomethane or road, rail and riverway options for solid and liquid biofuels. Investments in establishing or upgrading such infrastructure, and adequate regulation for access to infrastructure grids depend on market expectations.

Given the current focus on liquid biofuels for international markets, initiatives on governance mainly focus overall supply issues (e.g., sustainability standards, characterization of fuel quality).

Related to these issues is that the uptake of biogas as a transport fuel, which usually has a much better environmental performance than liquid biofuels (e.g., regarding GHG emission reduction), is hampered by the limited market share of gas vehicles. In addition, gas infrastructure and pumps are lacking in many countries. This seems to change, however, now that an increasing number of countries promote the use of compressed natural gas (CNG) as transport fuel, mainly for air quality reasons. Biogas can be treated to meet CNG specifications.

[43] The mostly 'local' markets for traditional biofuels (e.g. charcoal, unprocessed wood) in developing countries or the direct conversion of e.g., manure to biogas for local use have typically few players, but are exceptions from the overall complex network of actors in bioenergy supply chains.

Annex I Overview of Key Sustainability Certification Schemes

Table 14 **Overview of Key Sustainability Certification Schemes**

Description	Sustainability Requirements
In December 2007, the **German Bioenergy Sustainability Ordinance** (BSO) which is linked to the German Biofuel Quota Law has been decided by German government. Currently in hold by the European Commission, it will be revised according to the European Directive on the promotion of the use of energy from renewable sources. Only sustainable biofuels, as defined in the Ordinance, will count towards the national quota of biofuels. Also the revised Renewable-Energy-Act and a new Renewable Heat Act came into force in January 2009 which covers also sustainability requirements for the feedstock. The respective standards and certification systems will be implemented by ordinances to be passed in early 2009.	In the German ordinance the whole life chain - including direct land use change - is considered. Current **included principles cover the following environmental issues**: – Significant contribution to greenhouse gas mitigation (for biofuels at least 30% improvement, 40% from 1 January 2011). – Effects from direct land use changes (competition) have to be considered. – Loss of habitats of high conservation value shall be prevented. – Loss of biodiversity shall be prevented (incl. criteria considering farmland biodiversity). – Negative impacts on soil, water and air shall be minimized. The ordinance will be adapted to the regulations of the EU RES Directive. Ongoing R&D projects propose social-economic and environmental requirements, and make recommendations to indirect land use change.
Netherlands: Certification system for biofuels was first discussed in a report issued in 2003 by NOVEM, the Netherlands Agency for Energy and the Environment. The scheme proposed was inspired from a certification system for the Electricity market.	Criteria for Sustainable Biomass Production' have been published (July 2006). In the system that was developed sustainability criteria for 2007 are distinguished from those for 2011. In the criteria for 2007 minimum requirements have been formulated to prevent unacceptable biomass flows from being used. The criteria for 2011 have been tightened and are aimed at providing an active protection of nature and the environment and of the economic and social circumstances. **The criteria and indicators have been divided into six themes**. The first three themes are specific themes, relevant for biomass. The last three themes relate to the triple P approach (people, planet, profit), which are the starting-points for corporate social responsibility. The six themes are the following: – Greenhouse gas balance. – Competition with food, local energy supply, medicines and building materials. – Biodiversity. – Economic prosperity. – Social well-being. – Environment. In April 2007 NOVEM published '**Testing Framework for Sustainable Biomass**'. The Dutch government is considering **imposing minimum sustainability requirements**.

Description	Sustainability Requirements
UK **Renewable Transport Fuel Obligation (RTFO)** Starting in 2008 the RTFO, implemented by the UK Department of Transport, places an obligation on fuel suppliers to ensure that a certain percentage of their aggregate sales is made up of biofuels. **The percentage increases, with 3.63vol% of all UK fuel sold on UK forecourts being required to come from a renewable source, by 2010, 5.26vol% in 2013**. Biofuel producers will have to report on the green-house gas balance, and environmental impact of their biofuels. This information **will be used to develop sustainability standards, which may be imposed on any extension of the RTFO.**	Sept. 2007 - Seeking information from suppliers on carbon savings and sustainability impacts of their biofuels for RTFO; Oct. 2007 - Parliament approved RTFO; With the RTFO the UK government intends to set targets for: – The level of greenhouse gas savings from biofuels used to meet the RTFO. – The proportion of biofuels from feedstock grown to recognized sustainability standards. – And the amount of information to be included in sustainability reports. In 2008 RTFO standard (i.e. **minimum blending mandate**) has been set, these were revised in 2009 following the Gallagher review. The government has asked the Low Carbon Vehicle Partnership to **explore the feasibility of a voluntary labeling scheme**, allowing responsible retailers to show that the biofuels they supply are genuinely sustainable
US Low Carbon Fuel Standard (LCFS) issued on January 18, 2007, **calls for a reduction of at least 10% in the carbon intensity of California's transportation fuels by 2020**.	The LCFS instructs CalEPA to coordinate activities between the University of California, the California Energy Commission and other state agencies to develop and propose a draft compliance schedule to meet the 2020 target. In August 2007, UC Berkeley published A Low-Carbon Fuel Standard for California, Part 2: Policy Analysis. Directed ARB to consider initiating a regulatory proceeding to establish and implement the LCFS. In response, ARB identified the LCFS as an early action item with a regulation to be adopted and implemented by 2010.
US Renewable Fuel Standard program (EPA) began on September 1, 2007. Congress set the **minimum volume of renewable fuel that must be used in the U.S. each year through 2012.** Parties meet their obligation by acquiring **credits** generated by renewable fuel producers and importers which correspond to the type/volume of renewable fuel they produce/import. Program creates incentive for second-generation ethanol production by allowing cellulosic biomass and waste-derived ethanol producers and importers to generate credits at a rate of 2.5 per gallon for their fuel versus 1 credit per gallon for corn- and other starch-based ethanol.	Gasoline refiners and importers are required to use **5.4 Bgal of renewable fuel in 2008**. Annual volume requirement will increase to **7.5 Bgal in 2012**. Beginning in 2013, the 2.5:1 extra credit will be phased out and a **minimum volume of cellulosic biomass ethanol will become part of the annual standard** for gasoline refiners and importers. Beginning in 2013, EPA, in coordination with USDA and DOE, must determine the applicable volume for the renewable fuel standard for the year 2013 and subsequent calendar years. Also beginning in **2013**, gasoline refiners and importers will have to meet the **250 million gal cellulosic biomass ethanol standard**.

Description	Sustainability Requirements
EU **Directive on the promotion of the use of energy from renewable sources** (RES-D) In January 2007 the European Commission sets out in the Renewable Energy Road Map the long-term strategy for renewable energy in the European Union (EU). In December 2008, the RES-D establish an overall **binding target of a 20% share of renewable energy sources in energy consumption and a 10% binding minimum target for biofuels in transport** to be achieved by each Member State.	The RES-D creates a number of mandatory **environmental sustainability** criteria **for biofuels and other bioliquids**: – The greenhouse gas emission saving from the use of biofuels and other bioliquids taken into account shall be at least 35%, rising to 50% by 2017. – Biofuels and other bioliquids taken into account shall not be made from raw material obtained from land with recognized high biodiversity value. – Biofuels and other bioliquids taken into account shall not be made from raw material obtained from land with high carbon stock. – Agricultural raw materials cultivated in the Community and used for the production of biofuels and other bioliquids shall be obtained in accordance with the minimum requirements for good agricultural and environmental condition. Social requirements are not included, but **reporting obligations** for the EU and Member States on social impacts are established.
The Forest Stewardship Council (FSC) is an **international organization** that brings people together to find solutions which promote responsible stewardship of the world's forests. FSC is an international standard, developed and reviewed according to the ISEAL Code of Good Practice for Setting Social and Environmental Standards. This ensures that FSC certification does not constitute a technical barrier to trade under the rules of the World Trade Organization. Compliance is determined at the Criterion level, and indicators to the P&C are developed by FSC accredited national initiatives and by certification bodies for use in the absence on nationally developed ones. FSC has an Accreditation Program which is in charge of providing accreditation services to certification bodies and National Initiatives. The Accreditation Program is based on international standards and complies with ISO 17011 requirements. Project funding for FSC is provided by various foundations and companies around the globe. Core funding is derived from membership and accreditation fees.	Based on FSC's **10 Principles and 56 Criteria** for Forest Stewardship, the scope involve **environmental, silvicultural, social and economic issues**. These principles are global - they can apply to any forest around the world - and they assure: 1. Compliance with laws and FSC principles. 2. Tenure and use rights and responsibilities. 3. Indigenous peoples' rights. 4. Community relations and worker's rights. 5. Multiple benefits from the forest. 6. Assessment of environmental impact. 7. Management planning. 8. Monitoring and assessment of management impact. 9. Maintenance of high conservation value forests. 10. Responsible management of plantations Principles for Forest Stewardship. Three product labels: 1. FSC pure label for 100% certified product group. 2. FSC mixed label with a minimum threshold of 10% certified and 60% post consumer content. And 3. FSC recycled label for product groups with 100% post consumer content. It prohibits use of sources that are illegally harvested and derived from a high conservation value forest. Since 1994 **over 99 million hectares in 75 countries have been certified** (over 34 million hectares in North America) according to FSC standards while **several thousand products are produced using FSC certified wood** and carrying the FSC trademark. FSC operates through its network of National Initiatives in 40 countries.

Description	Sustainability Requirements
IFOAM Norms: Started in 1972 by the president of the French farmer's organization to ensure a future of worldwide organic agriculture. IFOAM is comprised of a variety of committees each with specific mandates. The IFOAM General Assembly is the main decision-making body. IFOAM groups together 750 organic institutions worldwide and ensures some equivalency of standards in 108 countries. It elects the World Board for a three year term. The World Board appoints members to official committees, working groups and task forces based upon the recommendation of the IFOAM membership, and IFOAM member organizations also establish regional groups and sector specific interest groups. IFOAM label is a means of guaranteeing **fair and orderly trade of organic products**. Accreditation facilitates equivalency of organic certification bodies worldwide by confirming whether they meet IFOAM's international norms.	IFOAM Basic Standards (IBS) cover **social, economic and environmental sustainability**) and establish the requirements for certification bodies seeking IFOAM accreditation. Democratically and internationally adopted, they reflect the current state of organic production and processing methods. These standards should not be seen as a final statement, but rather as a work in progress to contribute to the **continued development and adoption of organic practices** throughout the world. The IBS are structured as 'standards for standards.' They provide a **framework for certification bodies and standard-setting organizations** worldwide to develop their own more detailed certification standards which take into account specific local conditions.
Better Sugarcane Initiative BSI is a collaboration of sugar retailers, investors, traders, producers and NGOs who are committed to sustainable sugar by establishing principles and criteria that are applied in the sugar growing regions of the world through regionally specific strategies and tools. The BSI **aims to reduce the impact of sugarcane production on the environment in measurable ways** that will also enable sugar production in a manner that contributes to social and economic benefits for sugar farmers and all others concerned with the sugar supply chain. The goal is to reduce farm and other sugar processing impacts, through the encouragement of better management practices (BMP's).	BSI is establishing Technical Working Groups (TWGs) - teams of technical and scientific experts - with global representation. These TWGs will assess **Better Management Practices** being used by sugar growers across the globe under three categories: – Environment and agronomy. – Social and community. – Milling and co-products. Based on good practice achievements around the world, the TWGs **will develop a set of universally-applicable guidelines** for consideration by the BSI membership. The guidelines will follow the Quadruple Bottom Line approach which seeks to: – Minimise the effects of sugarcane cultivation and processing on the off-site environment. – Maintain the value and quality of resources used for production, such as soil, health and water. – Ensure production is profitable. – Ensure that production takes place in a socially equitable environment. Guidelines requiring further consideration **will be tested in different cane-growing scenarios** around the world to ensure that they are practical and achievable, and have the desired effect of improving the economic, environmental and social sustainability of sugarcane farming.

Description	Sustainability Requirements
European Green Electricity Network (Eugene) is an **independent network** that pursues no commercial interest and acts to bringing together non-profit organisations such as national labelling bodies, experts from environmental and consumer organisations, and research institutes. The Intelligent Energy Europe project, 'Clean Energy Network for Europe (CLEAN-E)', was designed to accompany the establishment of new green electricity product labels and the improvement of existing ones in selected EU Member States. The CLEAN-E project has supported the efforts of Eugene and correspondingly Eugene has served as the major point of orientation for the project. Among other things the project has explored the development of **ecological minimum standards for biomass**.	Eugene has **created a standard of quality for green power** to provide a benchmark for environmental labelling schemes. The Eugene Standard applies to geothermal, wind, solar, electric, hydropower and biomass energy and is given to defined 'eligible sources.' Eligible sources for biomass include dedicated energy crops, residual straw from agriculture, etc. Specific criteria for eligible biomass resources, such as production methods, are not specified by the standard. The studies undertaken by the project are meant **to support the possible certification of biomass and included a proposal of biomass criteria for application by the Eugene Standard**. The project has published a **report** evaluating the experiences with the pilot application of the developed biomass standards.
EurepGAP started in 1997 as an initiative of retailers belonging to the Euro-Retailer Produce Working Group (EUREP). It has subsequently evolved into an equal partnership of agricultural producers and their retail customers. The organization's mission is **to develop widely accepted standards and procedures for the global certification of Good Agricultural Practices (GAP).** Governance is by sector specific EurepGAP Steering Committees which are chaired by an independent Chairperson. The Technical and Standards Committees working in each product sector approve both the standard and the certification system. These committees have 50% retailer and 50% producer representation creating an effective and efficient partnership in the supply chain.	It provides standards for fruit and vegetables, flower and ornamentals, integrated farm assurance, integrated aquaculture, coffee. While biomass production is not specifically mentioned in any of these standards, it appears **integrated farm assurance** would be the most relevant. Standards cover both **social** and **environmental** issues. Accreditation granted by an independent third party certification body that has been approved by EUREPGAP.
The **PEFC** (Programme for the Endorsement of Forest Certification schemes) is an independent, non-profit, non-governmental organization founded in 1999, which promotes sustainably managed forests through independent third party certification, acting as a global umbrella organization for the assessment of and mutual recognition of national forest certification schemes developed in a multi-stakeholder process. PEFC allows certification and labeling of forest based products which cover both wood based (timber, paper) as well as non-wood forest products. PEFC has in its membership 35 independent national forest certification systems of which 23 to date have been through a rigorous assessment process involving public consultation and the use of independent assessors to provide the assessments on which mutual recognition decisions are taken	Standards cover **social, economic, silvicultural and environmental development issues**. In February 2002 PEFC launched on the web the **World's first Interactive Database on Forest Certification** which allows customers to gain valuable information on the origins of the timber they are buying and which carries a PEFC logo. North American SFI system and German forest and Austrian scheme have been endorsed. These 23 systems account for **more than 200 million hectares of certified forests** (monthly updated statistics are available on the website) producing millions of tons of certified timber to the market place making PEFC the world's largest certification system.

Description	Sustainability Requirements
by the membership. PEFC is primarily funded by PEFC National Governing Bodies. Current members are Australia, Austria, Belgium, Brazil, Canada, Chile, Czech Republic, Estonia, France, Finland, Ireland, Italy, Luxembourg, Malaysia, Norway, Portugal, Russia, Slovak Republic, Spain, Sweden, Switzerland, UK, and USA.	
The stated goal of the Round Table on Responsible Soy **(RTRS)** is to promote economically viable, socially equitable and environmentally sustainable production, processing and trading of soy.	In November of 2006, a final draft of the principles of the Round Table on Responsible Soy was approved. The RTRS has put forth three main principles: – Economic responsibility. – Social responsibility. And – Environmental responsibility. each with a number of sub-principles. Currently, the RTRS is inviting nominations for participation in the RTRS Principles, Criteria and Verification Development Group (DG). The DG is tasked with producing a set of verifiable **principles, criteria and indicators that define responsible production** at early stages of processing of soy beans and with developing a **verification system**. It facilitates discussions on biomass and biofuels certification among stakeholder groups, promoting certification initiatives by providing a forum for developing principles, criteria and indicators, and carrying out pilot studies to better understand the implication of certification implementation. Additionally, these efforts may have the advantage of being able to develop sustainability schemes and achieve results in relatively short time frames in comparison to multilateral/international processes, which are inherently long and complex.
Roundtable on Sustainable Biofuels (RSB) is an international initiative by the Ecole Polytechnique Fédérale de Lausanne (EPFL) Energy Center. Its aim is to bring together farmers, companies (i.e., BP, Shell, Toyota), non-governmental organization (i.e., Forest Stewardship Council, NWF, WWF), experts (UC Berkeley; Michigan State University), governments (Swiss Federal Office of Energy; Swiss State Secretariat for Economic Affairs), and intergovernmental agencies (UNCTAD) concerned with ensuring the sustainability of biofuels production and processing.	In June 2007 the RSB released its 'Draft Global Principles for Sustainable Biofuels Production' for global stakeholder feedback and discussion: 1. Legality (biofuel production shall respect all applicable laws of the country in which they occur, and all international treaties and agreements to which the country is a signatory). 2. Consultation (biofuel projects shall arise through fully transparent, consultative and participatory processes). 3. Climate change and greenhouse gases (biofuels shall contribute to climate stabilization by reducing GHG emissions as compared to fossil fuels through their life cycle). 4. Human and labor rights (biofuel production shall not violate human rights or labor rights, and shall ensure decent work and the well-being of workers). 5. Socio-economic development (biofuel production shall not violate land or water rights, and shall contribute to the social and economic development of local, rural

Description	Sustainability Requirements
	and indigenous peoples and communities). 6. Food security (biofuel production shall not impair food security). 7. Conservation (biofuel production shall not directly or indirectly endanger wildlife species or areas of high conservation value). 8. Soil (biofuel production shall not directly or indirectly degrade or damage soils). 9. Water (biofuel production shall not directly or indirectly contaminate or deplete water resources). 10. Air (biofuel production shall not directly or indirectly lead to air pollution). 11. Biotechnology (if biotechnologies are used in biofuels production, they shall improve the social and/or environmental performance of biofuels, and always be consistent with national and international biosafety and transparency protocols). In October 2007 RSB published a second version of principles for comments. According to the RSB, the 11 draft principles are highly aspirational, and represent an ideal performance of biofuels. Their purpose is to indicate the ideal scenario towards which stakeholders should be progressing. In Sept. 2008, draft criteria and indicators ('Zero Version Sustainability Standard') were published.
'**Roundtable on Sustainable Palm Oil (RSPO)**,' established 2004 under Article 60 of the Swiss Civil Code with a governance structure that ensures fair representation of all stakeholders throughout the entire supply chain. The seat of the association is in Zurich, Switzerland, while the secretariat is currently based in Kuala Lumpur. RSPO's objectives are to promote the use and growth of sustainable palm oil through cooperation within the supply chain and open dialogue with its stakeholders. It was agreed that in order to promote the use of sustainable palm oil it would be necessary to have a mechanism for linking the palm oil being used by RSPO members and other responsible users (including industrial users of palm oil based substances) with the oil palm plantations being managed in accordance with the RSPO criteria. RSPO is managed by an Executive Board comprised of sixteen members, designated by the General Assembly for a period of two years. Members include representatives of Oil palm growers, Palm oil processors and/or traders, Consumer goods manufacturers, Environmental/nature conservation NGOs, Retailers, Banks/investors, Social/development, NGOs. The decisions are made on consensus basis.	In September 2006 (updated March 2007) RSPO published the RSPO Draft Verification Systems. The guidance document defines indicators and guidance for each criterion. Indicators are specific pieces of objective evidence that must be in place to demonstrate or verify the criterion is being met. The guidance consists of useful information to help the grower/miller and auditors understand what the criterion means in practice, including in some cases specific guidance for national interpretation of the criterion and application by small stakeholders. Dialogue among stakeholders has resulted in a set of 8 principles defined by criteria, indicators, and guidance for national interpretation. They **include social (1), economic (1) and environmental (2) standards for sustainable palm oil production** adopted in Nov. 2005: 1. Commitment to transparency. 2. Compliance with applicable laws and regulations. 3. Commitment to long-term economic and financial viability. 4. Use of appropriate best practices by growers and millers. 5. Environmental responsibility and conservation of natural resources and biodiversity. 6. Responsible consideration of employees and of individuals and communities affected by growers and mills. 7. Responsible development of new plantings.

Description	Sustainability Requirements
	8. Commitment to continuous improvement in key areas of activity. In June 2007, the principles were applied for an initial **pilot implementtation period of two years** from the date of adoption to enable field testing and thereby allow the indicators and guidance to be improved, including guidance for application by smallholders; national interpretations have also been commenced during this period. In Nov. 2007 the final draft **National Interpretation of RSPO Principles and Criteria for Sustainable Palm Oil Production** was published.

Source: Own compilation by Öko-Institut.

Annex J Relevant policies

J.1 Introduction

Quite a number of national and global policies are relevant to the use of bioenergy. An overview was provided in Table 4 of Section 4.2, a further elaboration can be found here.

J.2 The UNFCCC climate conventions (COP process)

The relevance of this policy process was discussed earlier, in Section 1.5, where a number of reasons were given it was concluded that biomass was relevant to the process: bioenergy can help to reduce GHG emissions, bioenergy projects may provide a source of revenue for developing countries through CDM (the Clean Development Mechanism), and bioenergy is linked to the REDD (Reducing emissions from deforestation and forest degradation) process. On the other hand the REDD mechanism could prevent deforestation which can be due to (indirect) land use change caused by unsustainable biomass production and stimulation.

Due to the global nature of both the COP process and the biomass market, and due to the fact that biomass is likely to be produced and/or used by most (if not all) participating countries as a means to reduce GHG emissions and meet COP goals, this policy process could be key to future bioenergy developments.

An important issue in this respect is whether or not land use change emissions are included in the COP agreement. If they are, *and* if the COP agreement has global coverage, i.e., if all countries have emission goals and agree to participate, the need to account for indirect land use change effects of bioenergy is greatly reduced: any additional emissions due to land use change will then have to lead to emission reductions elsewhere.

If stringent GHG reduction targets including land use change are agreed during the COP15 in Copenhagen in December 2009, the interest in biomass for bioenergy, and especially in the potential to reduce GHG emissions with biomass, will be increasing. Within the framework of CDM, biomass projects could provide a source of revenue for developing countries, and a relatively cheap means to reduce emissions, and meet the target.

If land use change is not included in the COP agreement (no REDD agreement) then the risk of indirect GHG emissions by (indirect) land use change remains to be a problem linked to stimulation of bioenergy. It then has to be seen if indirect effects can successfully be prevented by sustainability certification. If this is not possible, this will implicitly mean that the role of bioenergy in the reduction of GHG emissions will be much smaller, as sustainable bioenergy has to be limited to non-arable land, waste and biomass residues.

J.3 A global methodology for sustainability certifications

The overview in Section 4.4 and Annex I clearly shows that there are many different initiatives ongoing aimed at improving the sustainability of biomass production and use. Some are national initiatives, often aimed at biofuels, others are international but limited to one type of crop or product (e.g., palm oil, sugar cane, wood, biofuels). Some already exist (FSC, RSB, RSPO, ...), others are still under development (GBEP, CEN, IDB, ...). Some focus on, or are limited to, GHG emissions, others are much broader and also include other environmental and socio-economic criteria.

In view of the global nature of the biomass market, a globally accepted and applied methodology for sustainability certification of biomass would be easier and cheaper to implement than different national methodologies. A global system would also limit trade issues potentially arising from national schemes. However, a global scheme that covers all (potential) biomass and all (potential) sustainability issues may take a long time to develop, as many different stakeholders will have to participate and agree. The latter makes it also less likely that a global scheme sets stringent standards. This may be solved by focussing on the development of a global methodology and some basic, minimum standards, and let individual countries set their own, more stringent standards if they like.

Note that there are links between the COP process and the development of sustainability standards. First of all, CDM also uses sustainability standards. Secondly, as mentioned above, if the COP agreement includes LUC emissions, and if all countries participate, there is no need to derive and include a methodology to calculate indirect land use change emissions in the sustainability criteria. Any emissions, either from agriculture, transport or biomass conversion, will then be regulated by the COP regulation and by sector specific policies that the participating countries will implement, so that there would be no need for any additional well-to-wheel (WTW, or seed-to-end use) policy.
We would argue against that, however, as specific bioenergy policy can be very effective in improving the GHG emission reduction potential of the policy. We know that there is a large variation of GHG emission savings in bioenergy, and promoting bioenergy that hardly reduces or even increases GHG emissions seems to be inherently ineffective. Global or national policies aimed at enhancing GHG savings of bioenergy can thus lead to efficient use of resources, and promote innovation in that area.

J.4 Global Trade regulations (WTO)

Global Trade Rules have several important effects on the global potentials and effects of bioenergy.
- Import and export tariffs for biomass limit the trade in biomass and limit the efficiency of production and land use.
- WTO rules limit the sustainability criteria in certification schemes.
- WTO rules limit the aspects which may be used to subsidize or oblige products or production. This could be used to steer toward biomass with a secure GHG reduction.

These points are discussed further in the following.
Especially for biodiesel and bio ethanol many countries have substantial import or export tariffs to support local production. In many cases this means indirect governmental support for biofuels with higher prices, lower GHG reduction potential and higher land use. In addition, the money collected with import tariffs on biomass is usually not spent on bioenergy. This high taxation of global biomass development and trade therefore hinders the further development.

In many sustainability certification development processes, the question if criteria are WTO proof is considered. In general criteria related to the environment are considered WTO proof, but social criteria not.

WTO rules forbid subsidy or obligations for similar products, except if the subsidy or obligation is for the general interest of the world. Reduction of GHG emissions is such an interest, but support for local farmers not. In this way WTO rules could be used to steer towards support schemes for bio energy aimed at GHG reduction and abandon support schemes which support litres of biofuels or kWh of electricity without making a distinction between levels of GHG reduction.

The following policy options could be considered:
- Reduction of import tariffs for sustainable produced biomass.
- Spending the money collected with import taxes on biomass on sustainable production of biomass.
- WTO complaints for biofuel and bioelectricity programs which in practice support local production without clear GHG or biodiversity results.

J.5 National/regional policies

Despite the increasingly global nature of the bioenergy market, and the potential relevance of the COP negotiations, national bioenergy policies have been the main driver for the bioenergy increase in recent years, and there is no reason to expect that this will change in the (near) future.

We can distinguish between policies for biofuels and biomass use in electricity and heat generation. We can also distinguish between different types of policies, namely between non-financial policies such as biofuel obligations and financial policies such as subsidies (e.g., on bioelectricity production), tax exemptions (e.g., on biofuels or bioelectricity) or feed-in tariffs. The different types of policy all have different key characteristics. They can then be combined with sustainability criteria and R&D programmes, specific trade or industry policies, etc.

In most countries, separate policies exist for the different biomass applications, as national policies are often aimed at and limited to specific sectors. Biofuels policies will exist for the transport sector, and renewable energy or specific biomass policies exist for the electricity sector. In that case, policy-makers need to balance the incentives of the various applications so that the policy goals are met in the most efficient way.

As long as the feedstock used by the different applications differs, this assessment and policy design may be done separately for the different biomass applications. If, however, the applications compete for the same feedstock, for example when biofuels are also produced from the waste streams and lignocellulosic biomass that can also be used for heat and electricity generation, more careful balancing of policies may be required to ensure optimal use of the scarce feedstock available.

Harmonization of national policies between countries is beneficial both for the biomass and biofuels industry, and for the effectiveness of the policies. Differences in national policies may lead to market distortions, as the examples in Annex H.3 illustrate.

Another important factor is the stability of policies. It is important to ensure that government policies are predictable and stable over time, and provide the right incentives. This will reduce financial risks to investors and thus attract resources, and ensure that investments are directed at the right projects, i.e. at projects that help to meet the long-term goals. Ambitious biofuel and bioelectricity goals require significant investments by the industries in the sectors involved, such as in biofuel plants, in R&D (in case technological improvements are required to meet future goals), in biomass cultivation (i.e., agriculture), transport (e.g., pipelines), automobile industry, etc. These often have a long lead time, their return on investment need to be sufficiently attractive over a long period of time[44], and risks need to be acceptable.

What do you support: Litres, kWh's, GHG reduction or land use?

An import issue for all biomass support schemes is the goal you aim for. Because in the biomass world a portfolio of options is possible, the indicator which is used to steer is determining which result you get.

For biofuels for transport market you could think of the following performance indicators:

- Litres of biofuels.
- Litres of bioethanol and biodiesel (separate goals).
- Litre of biofuels with some preferences for high GHG reduction biofuels.
- Amount of direct GHG reduction.
- Amount of direct plus indirect GHG reduction.
- Amount of energy security (= biofuel energy – fossil energy used).
- Amount of GHG reduction per ha arable land used.

For bio electricity a similar list can be presented only with litres of biofuels replaced with kWh of bio electricity or heat.

Many management theories teach us that the performance indicator you use to steer with is crucial for the result you get. You get what the indicator represents.

J.5.1 National sustainability criteria and certification

Quite a number of countries is developing sustainability criteria for biomass, especially aimed at biofuels where sustainability issues are more prominent than in the case of bioelectricity. Clearly, a global set of criteria and certification schemes that all countries support would be preferable to national schemes, as it will have a much larger scope and thus potential impact. However, as long as that does not exist, countries or regions (such as the EU) can implement their own set of rules, which will then, of course, also be input to the global developments.

[44] The life time of a factory is typically at least 15 years or more.

Without sustainability regulations, bioenergy policies only create incentives to use the cheapest bioenergy route. Companies that want to use sustainable biomass will be faced with higher costs, and will be less competitive. The need for sustainability criteria seems to be highest in the case of biofuels, where the use of agricultural crops as feedstock creates issues regarding GHG emissions, land use change, competition with food and feed, and negative socio-economic impact. However, the same problems may also occur in other bioenergy routes, as a fierce debate on the desirability of subsidies for the use of palmoil in Dutch power stations has recently shown.

J.5.2 National and bilateral trade regulations, e.g., import tariffs, bilateral agreements, etc.

In many OECD countries, national trade policies may have a very strong impact on the cost, effects and potential of biomass on a national level. The potential of (relatively cheap) feedstock is often greatly enlarged by removing barriers to biomass import. However, this may result in reduced demand for national biomass production and for the development of a national biomass and bioenergy industry.

J.6 Promotion of R&D

Most countries have specific research programmes in place to improve the effectiveness, cost and sustainability of various biomass applications. Programmes for the development of 2nd generation biofuels (e.g., ligno cellulosic ethanol, Fischer-Tropsch diesel, etc.) are probably the most well known in this context.

Supporting R&D can be a very effective means to develop a technology further that is still in an early stage of development. However, the outcome is usually uncertain, and it typically take years (or even decades) before the technology is mature enough to enter the market successfully. This makes it a policy aimed at the medium to long-term.

A difficult issue regarding this type of policy is that the distribution of the limited resources requires an assessment of the potential benefits and chances of success of different technologies. Part of the supported R&D programmes may not result in a successful market introduction, whereas some potential breakthrough technology may not get any funding.

Without going into the details of what should be promoted, we can conclude that the effectiveness of R&D policies can be improved by the following:
- Ensure that the market conditions are favourable for the technology, once it has been successfully developed. It should be attractive for industry to invest in the further development, up-scaling of the technology or production process, and market implementation. This effect may be enhanced by harmonization of technology incentives across countries.
- International cooperation between countries and research institutions, as investment needed can be very significant.