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What we know
and what we should know

Towards a sustainable biomass strategy

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Abstract

The paper reviews the current knowledge on the use of biomass for non-food purposes, critically discusses its environmental sustainability implications, and describes the needs for further research, thus enabling a more balanced policy approach. The life-cylce wide impacts of the use of biomass for energy and material purposes derived from either direct crop harvest or residuals indicate that biomass based substitutes have a different, not always superior environmental performance than comparable fossil based products. Cascading use, i.e. when biomass is used for material products first and the energy content is recovered from the end-of-life products, tends to provide a higher environmental benefit than primary use as fuel. Due to limited global land resources, non-food biomass may only substitute for a certain share of non-renewables. If the demand for non-food biomass, especially fuel crops and its derivates, continues to grow this will inevitably lead to an expansion of global arable land at the expense of natural ecosystems such as savannas and tropical rain forests. Whereas the current aspirations and incentives to increase the use of non-food biomass are intended to counteract climate change and environmental degradation, they are thus bound to a high risk of problem shifting and may even lead to a global deterioration of the environment. Although the “balanced approach” of the European Union´s biomass strategy may be deemed a good principle, the concrete targets and implementation measures in the Union and countries like Germany should be revisited. Likewise, countries like Brazil and Indonesia may revisit their strategies to use their natural resources for export or domestic purposes. Further research is needed to optimize the use of biomass within and between regions.

Key words: bioenergy, biomaterials, global land use, non-food biomass, environmental impacts

Zusammenfassung

Der Beitrag wertet die vorliegenden Erkenntnisse über den Einsatz von Non-Food Biomasse aus. Er diskutiert kritisch die damit verbundenen ökologischen Nachhaltigkeitswirkungen und beschreibt die Forschungsaufgaben, die gelöst werden müssen, um einen ausgewogeneren Politikansatz zu ermöglichen. Die lebenszyklusweiten Umweltbelastungen des energetischen und stofflichen Einsatzes von Biomasse als Roh- oder Reststoffe zeigen, dass Biomasse basierte Produkte andere, nicht immer bessere Umweltauswirkungen aufweisen als fossil basierte. Eine kaskadenförmige Nutzung, bei der Biomasse zunächst materiell für Ge- und Verbrauchsprodukte eingesetzt wird, deren Energiegehalt am Ende ihrer Einsatzphase genutzt wird, ist tendenziell mit einer höheren Umweltentlastung verbunden als der primär energetische Einsatz. Auf Grund der begrenzten globalen Landflächen kann Non-Food Biomasse nur einen gewissen Anteil an nichterneuerbaren Ressourcen ersetzen. Wenn die Nachfrage nach Non-Food Biomasse und ihren Derivaten, speziell nach Biokraftstoffen, weiter ansteigt, wird dies zwangsläufig zu einer Ausdehnung der globalen Ackerfläche zu Lasten von natürlichen Ökosystemen wie Savannen und tropischen Regenwäldern führen. Wenngleich die gegenwärtigen Hoffnungen und Anreize zum verstärkten Einsatz von Non-Food Biomasse darauf abzielen, dem Klimawandel entgegenzuwirken und die Umweltsituation zu verbessern, sind sie daher mit einem großen Risiko verbunden, Probleme zu verlagern und die globale Umweltsituation sogar noch zu verschlechtern. Wenngleich der “ausgewogene Ansatz” der Biomassestrategie der Europäischen Union als ein gutes Prinzip gelten kann, so sollten die konkreten Ziele und Umsetzungsmaßnahmen in der Union und in Ländern wie Deutschland überprüft werden. In gleicher Weise mögen Länder wie Brasilien und Indonesien ihre Strategie zur Nutzung ihrer natürlichen Ressourcen für den Export oder im Inland überprüfen. Weitere Forschungsarbeiten sind nötig, um den Einsatz von Biomasse innerhalb und zwischen den Regionen zu optimieren.

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1 Biomass: The ultimate solution for sustainability?

Looking back on the last couple of years the topic of biomass can be seen as a shooting star amongst the most discussed options for the development of sustainable energy and resource systems. The heated debate on the security of supply with conventional fossil energy sources such as oil and gas has triggered an intensive search for alternative energy carriers, especially in the transport sector. In addition the pressing need for effective GHG abatement measures provides another argument for bioenergy based on the wide-spread assumption that it is “carbon neutral”.

Similar trends can be observed in the field of biomaterials. Biomass derived materials and feedstocks provide the opportunity to increase the share of renewable resources in construction, chemistry, manufacturing, textile industry etc.

The recent appreciation of biomass induces new dynamics within the primary sector of agriculture and forestry. New growth prospects for so called non-food uses emerge, both on a domestic as well as on an international level.

> *But will biomass really hold the promise? Can it play the role of a silver bullet in implementing sustainable energy and production systems? What about the impacts, the side effects of an offensive expansion of non-food biomass use?*

It is evident that there is no simple answer to these questions. An integrated assessment is needed to derive guidelines and benchmarks for a sustainable biomass strategy, because the issue is far from being one-dimensional.

Currently, any attempt for a political appraisal leads to the divergent policy perspectives on biomass, i.e.

- Agriculture and forestry policy aiming at strengthening and supporting this sector in Europe, searching for additional income for farmers and forest managers
- Environmental policy interested in reducing the ecological impact of biomass routes e.g. with respect to water and soil protection, biodiversity, air quality etc.
- Environmental policy trying to increase the share of biomaterials within the industrial metabolism
- Energy policy striving for reducing fossil energy use and substitution of imported energy
- Climate policy searching for means to reduce sectoral or overall GHG emissions

- Industrial policy focussing on technological opportunities and resulting prospects for commercialisation of biomass technologies
- Regional policy emphasising the contribution of biomass options to regional development
- Foreign policy looking at the geopolitical implications of energy supply and the possible role of biomass to mitigate related tensions and risks
- Trade policy highlighting the emerging biomass markets for the agricultural sector as a chance to increase multilateral trade
- Development aid policy following the objective to create new opportunities and to minimize sustainability risks for developing countries – both internally and on the level of North/South trade relations

Before this background this paper tries to provide a clearer picture on what we know and what we should know for clarifying the route towards a sustainable biomass strategy. The focus will be on the environmental dimension of biomass use, (a) the life-cycle-wide impacts of biomass use (e.g. GHG emissions), (b) the impacts of global land use associated with the supply of biomass. Other dimensions of sustainability will be considered in this context.

The topic of biomass addresses a great variety of specific resources and utilisation pathways. In this paper, we focus on biomass for non-food purposes which stems either from plant harvest in agriculture and forestry or from organic residues in industry or municipal waste for two types of use:

- energy use (heat/electricity, fuel) and
- material use (e.g. bioplastics, chemicals, textiles or construction materials).

Several crops provide base materials like starch, sugars, plant oil which can either be used for food or non-food purposes. This will be considered through the accounting of global land use which is associated with land based biomass production (focussing on agriculture).

As a point of departure this paper starts from the recent initiatives to promote the non-food biomass use. In Germany, for example, in 2007 a biofuel quota law went into force which demands a minimum blend of plant based gasoline or diesel which together shall contribute a share rising from 6.25% in 2009 to 8.0% in 2015. Other prominent examples are the German national biomass strategy currently under preparation, and the German Charta for Wood. In the EU, target reference values had been introduced by the Biofuels Directive[1] of a 2% market share for biofuels in the transport sector in 2005 and a 5.75% share in 2010. In preparation of the biofuel directive, a communication[2] had outlined that a substitution of conventional fuels by alternative fuels in the road

[1] Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport (OJ L 123, 17.5.2003)

[2] Communication on ‘alternative fuels for road transportation and on a set of measures to promote the use of biofuels’ (COM (2001) 547)

transport sector (incl. natural gas and hydrogen) of about 20% by the year 2020 should be aimed at with reference to the Green Paper of 2000. To implement the biofuel directive of 2003, many member states are relying on fuel tax exemptions, facilitated by the Energy Taxation Directive[3]. In 2005, the EU biomass action plan[4] outlined the options to increase the use of biomass for heating, electricity and fuel purposes. It was specified by the EU biofuel strategy[5] which aimed to promote biofuels in the EU and developing countries while ensuring “that their production and use is globally positive for the environment”.

All these initiatives are characterised by a common paradigmatic understanding and share the assumption that

- substantial biomass potentials exist that can be mobilised for non-food purposes without affecting food supply,
- appropriate technologies for conversion and utilisation exist or can be expected from intensified R&D,
- increased biomass use provides environmental benefits through reduction of non-renewable resource use and GHG mitigation,
- economic benefits exist in the area of markets, added value, and employment.

In the following we will have a closer look at some of those assumptions which seem rather critical, while qualifying the prospects and limits for a sustainable biomass use more precisely. Two basic perspectives are of relevance:

- **Optimizing the use pattern**, i.e. given the availability of certain amount of biomass available for non-food purposes the question is how to optimise the benefits by different types of use, e.g. energy vs. material products. Here a life-cycle-perspective is adopted, and the question is raized whether non-food biomass should be used for energy or material purposes (see section 2).
- **The volume of use and the interregional supply pattern**, i.e. the question is what amount of biomass can be provided without overstressing sustainability criteria, what sources are available, and to what extent can and should biomass resources outside the EU be exploited. Here a spatial perspective is adopted in order to assess the land cover related potential impacts (e.g. on nature conservation and bio-diversity) of a growing demand of non-food biomass within Europe and the supplying regions elsewhere (see section 3).

In general, we will focus on the use of biomass in Europe while considering the impacts on a life-cycle-wide or global level.

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[3] Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity (OJ L 283, 31.10.2003)

[4] Commission of the European Communities (2005): Biomass action plan. COM(2005) 628final

[5] Commission of the European Communities (2006): An EU Strategy for Biofuels. COM(2006) 34final

2 Towards optimized use of biomass: The life-cycle perspective

2.1 What are we talking about – the scope of biomass potentials in the EU

In general, non-food biomass resources can be distinguished into three main categories, i.e.

- agricultural crops for non-food purposes
- forestry products, i.e. wood type biomass
- organic residues such as organic municipal waste, agricultural residues, etc.

All three categories are characterised by specific conditions of production and further processing and the associated environmental impacts, and thus, need to be examined separately. However, various interrelations exist. For example, the choice of agricultural land-use and practice affects the amount of by-products or residues such as straw.

The potentials of how much bioenergy can be produced in the EU without harming the environment was outlined by EEA (2006). The study concludes that significant amounts of biomass can technically be available to support ambitious renewable energy targets, even if strict environmental constraints are applied, and that the target of the Biomass Action Plan of the EU, to increase biomass use to 150 MtOE (in primary energy terms) in 2010 or soon after, can be reached, and even more ambitious targets could be set.

In the short-term, the study expects that largest potentials comes from biowaste, with around 100 MtOE, which is assumed to remain more or less constant from 2010 until 2030. Main contributions come from agricultural residues (e.g. straw), wet manures, wood processing residues, biodegradable municipal solid waste and black liquor from the pulp and paper industry.

In the long-term, bioenergy crops from agriculture are expected to provide the largest potential, from 47 MtOE in 2010 up to 142 MtOE by 2030, using 13 million ha in 2010 and 19.3 million ha in 2030, i.e. 8% to 12% of the used agricultural area. This development depends mainly on the assumptions of additional productivity increases; further liberalization of agricultural markets (e.g. phase out of diary quota will reduce demand for fodder production and the released land is assumed to be available for energy production); and the introduction of high-yield bioenergy crops (e.g. multiple-cropping systems using whole plants which are used for biogas production, or short-rotation trees used for BtL). The scenario highly depends on the introduction of BtL technologies after 2010.

The study applies the important basic rationale that the additional use of bioenergy must not lead to increased environmental pressure. To implement that goal, a number of environmental criteria in each of the three sections was applied.

For agriculture the requirements comprise:

- at least 30% of the agricultural land in most member states is dedicated to "environmentally-oriented farming" in 2030 (defined as High-Nature-Value farm-land or organic farming);
- 3% of currently intensively cultivated agricultural land is set aside fore establishing ecological compensation areas in intensive farming areas;
- extensively cultivated agricultural areas (e.g. grassland or olive groves or "dehesas") are maintained;
- bioenergy crops with low environmental pressures are used.

Unfortunately, the study disregards the effect of competition between bioenergy and food production for domestic food supply, although a competition is assumed between bioenergy and food export production. Thus, the study determines available land for bioenergy consisting mainly of released arable land, set-aside land and land used for exports. The study assumes that the degree of self-sufficiency with regard to food supply should and will not be negatively affected by a growing bioenergy market.

Here, a basic shortcoming of the study turns out. It disregards imports of agricultural goods (either for food, fodder or bioenergy purposes). Therefore, it neglects that the EU is currently not self-sufficient with regard to food and fodder supply because the net global land use exceeded the domestic agricultural area (see 3.1.1). As a consequence, a reduced export of agricultural products – as suggested by the study – would tend to increase the imbalance of the EU´s foreign trade with regard to agricultural goods and the related global land use. Thus, the objective of the study that the projected increase of bioenergy production will not lead to an increased environmental pressure is only valid for the situation within the EU, but may not hold, if the EU´s impact on the global environment will be considered. In the worst case, the conclusions of the study may even enhance the ongoing problem shifting beyond Europe.

As the authors point out, the study also disregards the competition between different uses of non-food biomass, esp. for energy and materials purposes, e.g. between biofuels and biomaterials. The latter represent a growing market, and from an environmental point of view, we will see that several pressures could be mitigated to a higher degree if the biomass is used for materials products rather than for fuels.

2.2 Biomass for non-food purposes: Competition between energy and material use

Compared to other renewable resources, biomass offers a particular variety and flexibility of use what makes it so attractive for many purposes. At the same time, however, biomass flows and utilisation pathways are highly interrelated due to technical or economic interdependencies. A complex system of driving factors triggers the factual supply and availability of biomass resources for non-food purposes.

Main aspects are:

- relative price effects between food and non-food crops within the agricultural sector influencing the economic decision-making and cultivation strategies of farmers,
- competition between conflicting non-food utilisations (e.g. use of waste wood for wood pellets or chip boards),
- exogenous price effects such as the benchmark of oil and gas prices for bioenergy routes,
- availability of arable land for non-food crop cultivation that is influenced by general trends of land use, demographical factors and food consumption habits triggering global food demand, natural conditions and ecological requirements defining limits of cultivation etc.,
- technological opportunities induced by innovative processes that expand the range of use of derived products (e.g. in the case of biomass gasification) or improve conversion efficiencies, cost effectiveness etc.,
- policy framework that directs activities by means of regulation and incentives, often characterised by a multi-criterial set of sometime conflicting policy objectives,
- demand by public and private consumers and corporate strategies for substituting non-renewable use in (global) value chains.

So far, the main debates on biomass feedstock use discuss energy and material use of biomass as competing routes and do no take the potential synergies adequately into account. A priori, if used for energetic purposes biomass resources can be used only once so that a competition for feedstocks occur between energy and material pathways. The question of the most beneficial biomass allocation thus leads to the assessment of relative advantages of energy options versus material options. In the next sections we will elaborate on this. At a later stage, however, we will come back to possible options to reconcile these conflicts by combining material and energy use in the sense of optimised chains of cascading use (e.g. for wood, paper, plastics).

2.2.1 Use of biomass resources for energy production

2.2.1.1 Pathways for the energetic use of biomass

Biomass for energetic purposes can roughly be divided into three feedstock categories: wood, residues from agricultural, industrial or domestic origin, and energy crops from dedicated farming. A multitude of possibilities exist to transform biomass to either solid, liquid or gaseous energy carriers, which can be used in the three energy sectors of power, heat and fuel generation (figure below).

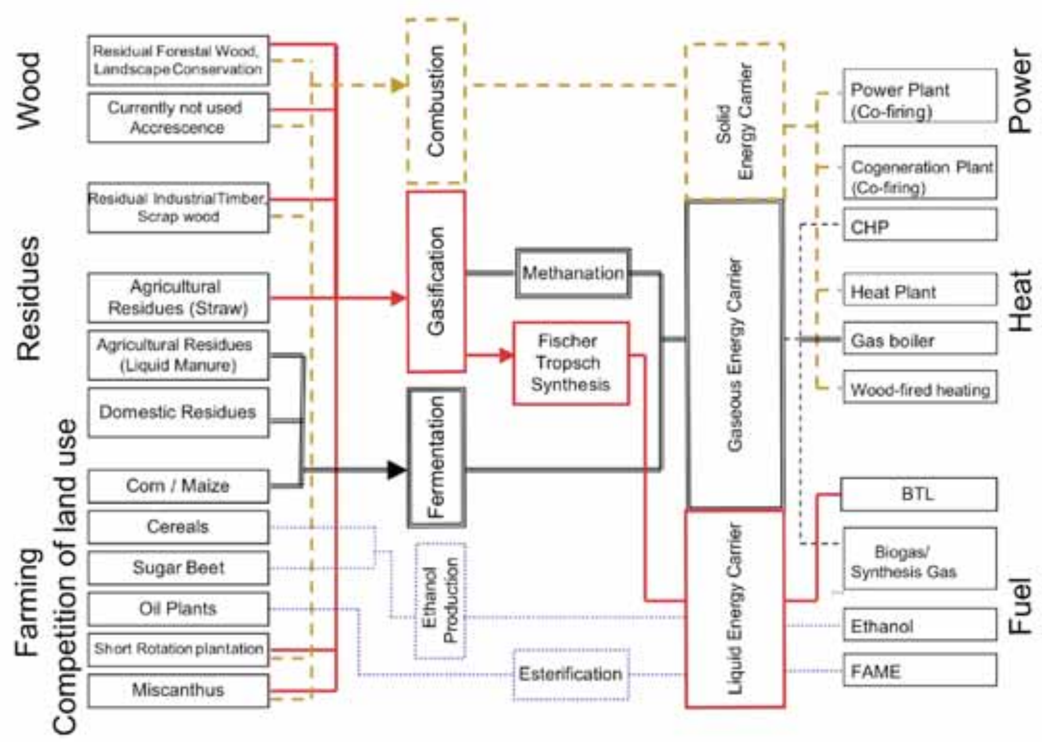

Figure 2.1: Examples of biomass pathways mainly used for energetic purposes

Solid biomass, as wood or straw, can either be directly used in dedicated *power or heat plants* or co-fired in conventional hard coal or lignite power plants. At present, the latter is not an option in Germany, as there are no policy incentives for this kind of regenerative input to power generation. In other European countries as the Netherlands, for example, co-firing is a common option to use biomass in the power generation sector. Further discussion and possibly a change of regulation in Germany may be expected within the next years.

In combined heat and power (CHP) plants, plant oil, solid biomass and biogas can be used for the *distributed co-generation* of heat and power, representing state of the art. However, it is not always possible to make beneficial use of waste heat streams in decentralised plants. As one answer to this problem in the field of biogas use, the possibility of injection of upgraded biogas into the existing natural gas grid is under intensive discussion. The widespread infrastructure of the natural gas grid allows for the transport of biogas and facilitates entering new markets spatially dislocated from the original biogas plant.

When taking this transportation possibility, the use of biogas for *heating* in domestic gas boilers becomes an option, too. Currently, the predominating form of domestic biomass heating is the firing of wood in form of split logs or pellets. Especially the latter has gained increased relevance in Germany within the last two years.

Three different types of *biofuel* currently play a role in a global view, the so-called “first generation fuels”. These are ethanol, “fatty acid methyl ester” (FAME or biodiesel) and pure plant oil (PPO). All have reached a considerably state of the art in production and are commercially available today. Most of the worldwide biofuel production is ethanol, which is mainly produced in the USA and Brazil from either corn or sugar cane. In Europe, potato, wheat, or sugar beet is the common feedstock. Biodiesel is mainly located on the European market, with Germany being a leader in biodiesel production and marketing. Within the last two years, the production and use of biodiesel has reached an enormous increase and is now providing about 3% of the overall German fuel demand (Bockey and v. Schenck 2006).

Pure plant oil has recently begun to enter the world markets. Before that, its use was limited to local markets. As the production is fairly simple and can as well take place in a decentralized manner, so far it has especially been seen as a good option for developing countries. Due to the high productivity per hectare in e.g. Malaysia and Indonesia and the lower production and labour cost compared to Europe, import of PPO (palm oil) from these countries gains importance.

In addition to the 1st generation, a couple of different, *innovative biofuel* options are currently being tested and demonstrated, but are not commercially available today. Among those are the production of ethanol from ligno-cellulose feedstock as wood or straw and the Fischer-Tropsch conversion of solid biomass to a synthetic fuel (*Biomass-to-Liquid*, BTL). Although the technical feasibility of the production processes has been proven, both are expected to enter the market not before 2010 to 2015.

The use of biomethane (biogas and SNG, *synthetic natural gas*) as gaseous fuels is another option for the use of biofuels, promising high yields and greenhouse-gas emission reduction. Via the extension of a CNG network (*compressed natural gas*), biogene gases may begin to enter the fuel market. According to a voluntary commitment of the European gas industry, 10% of the overall gaseous fuel consumption shall be bio-methane until 2010 (20% until 2020). The marketing of CNG as fuel can therefore promote bio-methane in the transport sector as well.

2.2.1.2 Biomass scenarios of energetic use

The share of bioenergy on the overall power, heat and fuel demand strongly depends on the framework and assumptions about the considered energy scenario. Figure 2.2 gives an overview on different scenarios on the European and German level.

For the development of the German energy system framework, a reference case and an efficiency scenario are depicted. The first reference scenario taken from Prognos (2005), describes a business-as-usual case without major policy intervention. In contrast to this reference case, Nitsch et al. (2004) aim at describing an efficient low-emission energy system. Ambitious energy savings lead to lower overall consumption compared to the reference case, especially in the power generation sector. On the supply side, higher potentials of renewable energies are taken into account, which result from the assumption of an active implementation of ambitious climate policies. For the EU-25, data are taken from Mantzos et al. (2006), depicting a reference case. Unfortunately, information about biogeneous heat supply on EU-25 level is not available from this source.

		2010			2020			2030		
		electricity	heat	fuel	electricity	heat	fuel	electricity	heat	fuel
EU-25	overall consumption [PJ]	16.327	n.d.	29.181	15.261	n.d.	26.858	14.814	n.d.	25.095
	share of biomass [PJ]	1.955	n.d.	1.127	4.229	n.d.	2.619	5.595	n.d.	3.389
	share of biomass [%]	12,0	n.d.	3,9	27,7	n.d.	9,7	37,8	n.d.	13,5
Germany (Reference case)	overall consumption [PJ]	2.224	4.098	2.611	2.141	3.800	2.566	2.106	3.495	2.496
	share of biomass [PJ]	82	262	71	91	270	149	99	274	181
	share of biomass [%]	3,7	6,4	2,7	4,2	7,1	5,8	4,7	7,8	7,3
Germany (efficiency case)	overall consumption [PJ]	1.723	4.573	2.535	1.586	4.069	2.519	1.501	3.610	2.452
	share of biomass [PJ]	286	343	109	514	533	194	821	769	434
	share of biomass [%]	16,6	7,5	4,3	32,4	13,1	7,7	54,7	21,3	17,7

Figure 2.2: Reference data on the overall energy system in Germany and the EU-25 and an efficiency scenario for Germany (Manztos et al. 2006; Prognos 2005; Nitsch et al. 2004); n.d. = no data available

The impacts of different energy systems on the share of bioenergy are depicted in Figure 2.3. Clearly, the share of bio energy is higher in the German efficiency scenario. This effect is due to both the lower overall energy demand and the assumed higher mobilisation biomass potential. Until 2030, Nitsch et al. conclude that high shares of the German energy demand in the three sectors of power, heat and fuel supply can be met with bioenergy.

In contrast, in the reference case, where no explicit incentives for energy savings and the implementation of renewable energy are given, a share of 20% of bioenergy until 2030 will not be exceeded.

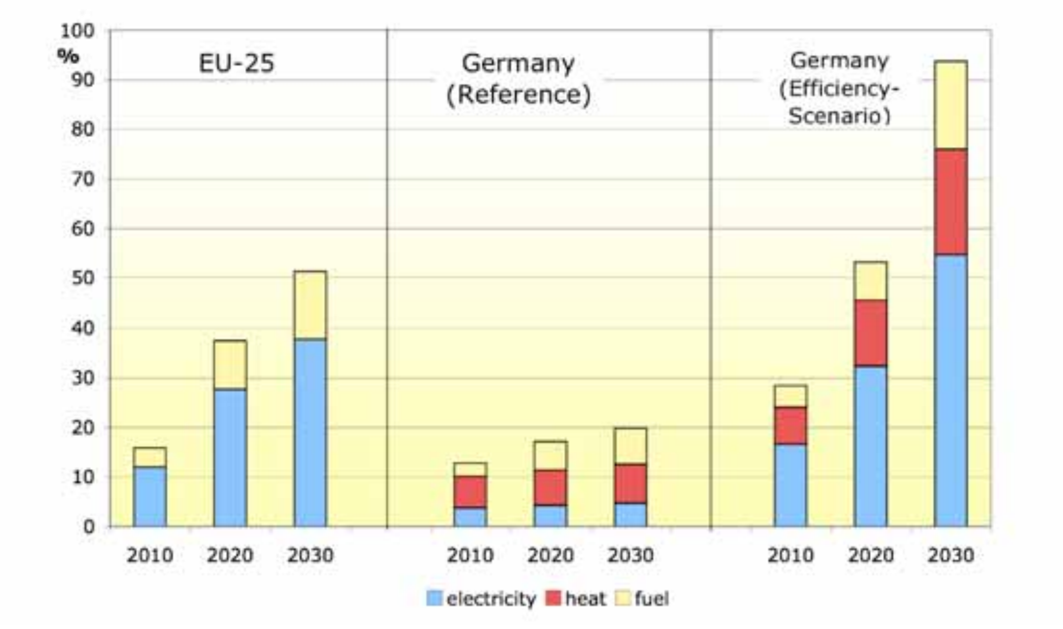

Figure 2.3: Share of bioenergy on the overall final energy consumption in Germany and the EU-25 (Manztos et al. 2006; Prognos 2005; Nitsch et al. 2004)

2.2.2 Use of biomass resources for non-renewable material substitution

2.2.2.1 Pathways for the material use of biomass

Using biomass for material purposes is as old as mankind. With technological development and industrialisation non-renewable materials from metals, non-metallic minerals and fossil fuels have become dominant for constructing buildings and infrastructures, producing machinery and other investment goods, and largely also for producing consumer goods. In view of climate change, peak oil and security of supply, a revival of biomass mainly as a basis for energy generation has started recently and is showing signs of great potentials in the future. Unlike it is the case for biofuels and bioenergy, however, biomaterials have so far not received much political attention. In fact, only one political target has been set in that the USA are to increase the share of biomass-based chemicals from 5% nowadays to 25% in 2030. In Germany, for example, about 10% of the organic raw materials for the chemical industry, or about 2 million tons are from biomass[6], of which two third are imported. This constitutes only a small share of the total raw materials demand of Germany of about 1.2 billion tons (excluding fossil raw materials). Overall, about three quarters of the German total raw materials demand is on a non-renewable basis.

The biomass basis of economies is mainly from agriculture and forestry. Wood has a long tradition and still higher future potentials for use in constructions, furniture and

[6] About 0.8 million tons oils and fats, 0.64 million tons starch, 0.24 million tons sugar, and 0.32 million tons cellulose.

paper and board (Knauf Consulting 2004, Geibler et al. 2006, Behrendt et al. 2007). The main interest in the debate, however, currently lies in some biomaterials derived from agricultural production.

Biomass from agricultural cultivation in the past had only few major non-food applications like cotton for textiles, natural rubber and some plant extracts and fibres. In recent years, new fields of industrial use for manufactures from biomass have emerged. These comprise in general biomass use as lubricants, chemicals, paints and lacquers, pharmaceuticals and cosmetics, packaging materials, fibre composites and shaped parts, textiles, insulation materials (Meo consulting team et al. 2006).

In Germany, research on biomaterials has emerged strongly in recent years, e.g. through the foundation of the "Fachagentur Nachwachsende Rohstoffe (FNR)" (Agency of Renewable Resources) initiated by the Ministry of Nourishment, Agriculture and Forestry in order to support research and development in the subject area of renewable resources (FNR 2006). In this respect, the German Federal Environment Agency has commissioned a study on evaluating the future potentials of the use of biomass for materials as well as for energy and biofuels. This study is conducted by the Wuppertal Institute in cooperation with Fraunhofer Institute for Environmental, Safety and Energy Technology (UMSICHT) and Institute for Energy and Environmental Research (IFEU). A first result of this study was the identification of most promising pathways for biomass use for biomaterials in Germany until 2030 (Wuppertal Institute et al. 2007). These are:

- Starch from cereals, potatoes and related crops for making paper and board, and for use in the chemical industry for the production of biodegradable materials and glue as well as additives and auxiliary materials.
- Sugar from sugar beets and other sugar crops. The variety of non-food products based on sugar ranges from washing powder, biodegradable plastics and cosmetics to medicaments, alcohol as well as additives and auxiliary materials.
- Plant oils from different oilcrops for lubricants, hydraulic fluids, lacquers, paints, linoleum, as well as additives and auxiliary materials.
- Flax and hemp for car manufacturing and insulation materials, flax for textiles. The application of fibres depends on their technical characteristics. Vegetable fibres are a substitute for all glass, asbestos and plastic fibres. Building materials and molded parts like the interior lining of cars as well as coatings, special paper (e.g. bank-notes), fleeces, textiles, insulation material and filters are products that can be build with vegetable fibres.
- Plants for pharmaceuticals: Today, vegetable medicaments have a share of the German market of about 30%. Among most patients the acceptance of medicine containing extracts of vegetable agents is very high and increasing.
- Plants for dye: Vegetable dye can be used for the dying of textile and food as well as for paints, printing ink, wood varnish or tanning substance.

2.2.2.2 Biomass for material use

Comprehensive scenarios for biomaterials use have been developed for Germany (Wuppertal Institute et al. 2007). The focus of this study was on crops for biomaterials, in two business as usual (BAU) scenarios until 2030. BAU Scenario I was to provide a conservative-realistic picture, while BAU Scenario II assumed slightly higher although still realistic potentials for future biomaterials use. The range from BAU I to BAU II thus describes the most probable development corridor, under the assumption that currently valid framework conditions and trends for specified segments of biomaterials continue to prevail.

The results of the two BAU scenarios compared to the status quo in 2005 are shown in Figure 2.4. In 2005, Germany had required about 1.9 million tons biomaterials globally. These were mainly oils and fats, starch, and sugar, and they were mainly produced for the chemical industry. Under conditions of BAU scenario I the German global demand for biomaterials will roughly double until 2030. BAU scenario II arrives at an increase by factor 2.5 from 2005 to 2030, mainly driven by increases of sugar based products (43% of total increase) and oils and fats (27% of total increase).

These increases may appear rather small at first sight. However, when the associated agricultural land requirements are accounted for, it turns out that if we were to replace the total demand of the chemical industry for organic raw materials (currently, about 10% are already biomass based), it would require an equivalent of arable land equal to about half of the total arable land available in Germany. Still, this substitution would just be enough to replace about 5% of the total fossil raw materials consumption of Germany by crop biomass. Increasing the biomass supply for the material basis of the German economy under current patterns of use to a significantly higher extent would inevitably lead to a higher demand for agricultural land in other countries. In view of growing future requirements of the world's population for food and other biomass uses, a growing substitution of biobased materials for mineral products is limited by the available global land surface. Thus within the context of global sustainable materials resource management a mere substitution strategy will not work (Bringezu and Steger 2005).

		BAU I	BAU II
	2005	2030	
Biomaterials from agricultural crops	000 tons	increase from 2005 to 2030 (factor)	
Oils and Fats	861	1.6	1.8
Lubricants, additives and accessory materials	21	3.4	3.9
Starch	656	1.3	1.4
Sugar	270	4.3	5.3
Flax and Hemp	35	9.3	10.7
Pharmaceutics	30	5.3	6.1
Total: Biomaterials	**1873**	**2.1**	**2.5**

Figure 2.4: Global demand for biomaterials in Germany 2005 (from domestic production plus imports) and development until 2030 under BAU scenarios I and II (Wuppertal Institute et al. 2007)

2.3 How to use biomass best? Interim assessment of non-food biomass use in the EU

As long as biomass pathways compete for the some input materials the question for the most preferable utilisation cannot be answered from an isolated view. Unfortunately, policy making stills tends to treat energy and material spheres separately from each other. Accordingly there is still a lack of integrated assessments that provide a sound foundation of comparison of competing options.

In its Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, the EU has claimed that in the measures that they take, the Member States should consider the overall climate and environmental balance of the various types of biofuels and other renewable fuels and may give priority to the promotion of those fuels showing a very good cost-effective environmental balance, while also taking into account competitiveness and security of supply (Article 3,4). However, no such request has been formulated so far for other non-food biomass uses. And indeed, LCA based analyses on the use of non-food biomass so far is concentrated on biofuels. Some LCA studies done in Germany further looked at biomass for electricity and heat, and one LCA study investigated biomass for material uses in comparison with bioenergy and biofuels (Table 2.5).

The listing of LCA based studies in Table 2.5 should not lead to the conclusion that the results of each study are consistently comparable with each other. Despite standard practice for life cycle analyses as defined by ISO 14040–14043, results of different studies for the same bioproduct may differ due to varying crops and cultivation practices, different feedstocks, allocation and valuation of co-products, consideration of effects like land-use changes, or specific regional or local conditions.

Despite these uncertainties, the LCA studies listed in Table 2.5 indicate the following conclusions:

- There is a general trend that bioenergy (including biofuels) and biomaterials from biomass grown on agricultural land are less favourable as compared to the fossil counterpart with regards to acidification, eutrophication and ozone depletion. These effects are less pronounced when short rotation crops are used instead of primary crops from arable land.
- Residuals or by-products from organic biomass get significantly less environmental impact attributed than primary crops. As this reflects also a definition of LCA allocation, the assessment of material or energy use may change if the residual becomes a product.
- Bio-based energy and materials are in general better off than fossil alternatives with regards to fossil energy consumption. Only few exceptions have been found for biodiesel from certain oil palm plantations and liquid hydrogen from lignocellulose (Reinhardt and Helms 2006).

- In most cases, it was found that bio-based energy, biofuels and biomaterials provide advantages as compared to fossil based alternatives with regards to the global warming potential. However, some findings have raised concern on the usefulness of biofuels for mitigating global warming. These are:
  - The most striking example is palm oil from Indonesia which is commonly used for food purposes as well as products of the chemical industry, but in growing amounts (in Germany) for electricity generation and especially (on global scale) for producing biodiesel. Reinhardt et al. (2007) found that the net benefit of palm oil from plantations on former tropical forest area in terms of GHG emissions depends critically on the depreciation time of the carbon which is released by cutting down the natural forest. For a typical economic cycle of a plantation, i.e. 25 years, the balance is negative. A net benefits results if oil palms are cultivated on tropical fallow. In addition, one has to consider that palm oil from Indonesian plantations often stems from areas which had been cleared by forest fire and/or peatland drainage, and for these cases palm oil was found to be a much stronger contributor to global warming than its fossil diesel counterpart. Hooijer et al. (2006) found that the production of 1 tonne of palm oil on peatland in Indonesia causes a CO_2 emission between 10 and 30 tonnes through peat oxidation (assuming production of 3 to 6 tonnes of palm oil per hectare, under fully drained conditions, and excluding fire emissions – see also Chapter 3.6 “The case of Indonesia”).
  - Apart from palm oil, some researchers even claim negative climate balances for biofuels, e.g. through nitrous oxide emissions from fertilizer (cited in World-watch Institute 2006). This needs to be further evaluated.

    Biofuels may enhance greenhouse gas emissions by the agricultural sector (WRI 2007). This finding was reported for bioethanol from corn kernels in the U.S. increasing greenhouse gas emissions of the agricultural sector, particularly through loss of soil carbon, production of agrochemicals, and direct off-gassing from nitrogen fertiliser application.
- In addition to these environmental impacts usually treated by LCA, other environmental and sustainability issues deserve high attention. These are for example “Consumption of non-renewable/non-energy resources” (e.g. Nitsch et al. 2004), “Water pollution” and “Water abstraction”, “Impaired soil quality”, “Habitat quality” (e.g. WRI 2007), “Competition with food production”, “Requirements for nature conservation”.

Study	Scope	Environmental impacts
	Biofuels	
Worldwatch Institute 2006	Review of studies on current generation biofuels for transportation – Global scale	Greenhouse gas emissions
EUCAR, CONCAWE and JRC (2007)	Evaluation of a wide range of automotive fuels and powertrains relevant to Europe in 2010 and beyond.	Energy use and greenhouse gas (GHG) emissions
Reinhardt and Helms 2006	Review of biofuels from crops and from residues, compared against each other and to their fossil fuels counterparts – Global scale	Energy consumption and Greenhouse gas emissions for all fuels studied. In addition, Acidification, Eutrophication, and Ozone depletion for Biodiesel from rapeseed.
Reinhardt et al. 2006	Biomass-to-Liquid (BtL) by different technologies and from different residues or crop biomass, compared to other biofuels and fossil diesel, and compared to electricity/heat generation from biomass – Germany	Energy consumption, Greenhouse gas emissions, Acidification, Eutrophication, Ozone depletion, Photosmog, Toxicity for humans
Reinhardt et al. 2007	Biofuel and electricity/heating from palm oil in South East Asia, derived from cleared natural forest, tropical fallow, or other plantations	Energy consumption, Greenhouse gas emissions
WRI 2007; Marshall and Greenhalgh 2006	Bioethanol from corn kernels and from cellulose (corn stover, switchgrass) – USA	Greenhouse gas emissions, Water pollution (from N-fertilisers, pesticides), Water requirements, Impaired soil quality, Habitat quality
	Bioenergy	
IE 2005	Biogas from manure, crop biomass or organic waste; for electricity, heat or use as fuel – Germany	Energy consumption, Greenhouse gas emissions, Acidification, Eutrophication
IE 2006	Biogas for electricity from manure, crop biomass or organic waste, by farm type (milk producing or pig breeding), and compared to electricity/heat from other sources resp. natural gas used as fuel – Germany	Energy consumption, Greenhouse gas emissions, Acidification, Eutrophication
Nitsch et al. 2004, (resp. DLR et al. 2004)	Biomass for electricity, heat or fuels, compared to electricity mix, heat mix, resp. fossil diesel – Germany. Biomass comprises wood, short rotation wood, biogas from manure, straw from wheat, Ethanol from sugar beets, Biodiesel from rapeseed	Consumption of non-renewable/non-energy resources (iron ores, bauxite); Energy consumption (non-renewable); Greenhouse gas emissions; Acidification; Eutrophication; Photosmog

Biomaterials		
Weiss et al. 2006	45 bio-based and fossil-based product pairs, of which are 21 Materials, 7 Fuels and 17 Energy (power/heat) – Germany	Energy consumption (non-renewable); Global Warming Potential; Acidification Potential; Eutrophication Potential; - detailed and all aggregated to one environmental index

Table 2.5: LCA based studies on non-food biomass

As a consequence, the following interim conclusions may be drawn:

- Biomass from residues from agriculture, forestry, food and woodworking industry, and households (sewage, garden waste), represent an important segment for bio-energy production which relieve the environmental impacts when used as substitutes for fossil fuels; they can be further developed, e.g. with CHP technology.
- Based on current technologies the environmental benefit of first generation- biofuels produced in Germany and Europe (e.g. bioethanol and biodiesel) is rather limited.
- The development of second generation biofuels is associated with high aspirations as well as uncertainties with regard to technical feasibility, economic viability and net environmental benefit (e.g. BtL); in order to mitigate the high risks one should orientate to support those lines of development where technological side-stepping may allow to divert towards material production lines (using the principle of biorefineries).
- Besides environmental aspects other aspects to foster biofuel market penetration should be considered as well (e. g. security of supply, regional economic benefits, employment aspects in agriculture), and in a balanced manner (e.g. to avoid substitution of one dependance – on oil – against others – on biofuel imports).
- A higher degree of mitigation of environmental pressure may be reached in the short-term through direct energy use of non-food biomass (for combined heating/ electricity), preferably from residuals, and in the medium to long term through cascading use for material products (e.g. bioplastics and fibres for packaging, insulation etc.) and subsequent energy recovery of end-of-life products.
- The shift towards biomass should be complemented with efficiency measures within the existing production and consumption patterns. For both non-renewable resource as well as biomass use the apparent potentials of efficiency and reduced consumption should be exploited.
- Any shifts in the resource base of value chains requires an organisational change. Enhancing the organisational capacities of lead firms and key stakeholders should be an integrated element of the strategy.

Open questions for research:

- Which mix of non-food use of biomass (heat/electricity, fuel, material products) seems most adequate to mitigate environmental pressures on a life-cycle-wide basis (considering also which countries and regions bear the environmental burden) and to contribute to sustainable energy and materials supply and use systems? Which policies are required to foster that mix?
- To which extent can current technologies of non-food biomass use (e.g. for biofuels and biomaterials) and those under development serve as stepping stones for subsequent technologies with an expected superior performance?
- Which are the most effective strategies to reduce the dependence from fossil resources, most importantly from oil? How can substitution opportunities be used for cross-sectoral resource policies that account for relative advantages, e.g. if the environmental benefits of material use products of non-food biomass (with subsequent energy recovery) is higher for certain product uses than for fuel or direct energy use?
- What are the perspectives to reconcile the competing spheres of energy and material use by establishing highly efficient chains of cascade use? What are the dynamic effects, e.g. in terms of delaying the material recycling and final energy generation by the time period of utilisation that may cover several decades (e.g. in the case of construction materials)?
- How to optimize the use of biomass for food and non-food purposes along the production and consumption chain with regard to the main products and by-products?
- What steps are needed to promote effective and legitimate policy making for a balanced non-food biomass use? Which policy measures and governance structures should be in place? Which actors should be involved?

As a first step to answer these questions the various biomass pathways need to be made comparable. Taking advantage from existing methodologies and data in the field of life-cycle assessment (LCA), process chain analyses, Well-to-Wheel (WtW) analyses, in general several stages need to be considered:

- Specification of basic biomass resource parameters such as arable land, forest wood, waste wood etc.; and productivity in tonnes of used biomass per hectare arable land;
- Specification of conversion efficiency, i.e. the transformation of the biomass resource into the final output such as unit of base material or final energy;
- Specification of specific emissions and costs related to these conversion routes;
- Comparative analysis between different biomass routes and between biomass products and conventional substitutes in order to derive net benefits and effects, preferably based on a per hectare basis (e.g. Weiss et al. 2004) in order to gain in-sights on most preferable options (e.g. optimal GHG abatement per ha arable land);
- Multifunctional or multibeneficial use of biomass, e.g. through cascading use, should be considered as standard option.

As proxies for assessing the environmental impact the analysis may focus on a limited set of most relevant indicators such as primary energy demand, GHG emissions, eutrophication, acidification, total material requirements and costs. Standards of different cultivation schemes like organic farming can contribute specific quality arguments towards a more comprehensive assessment.

Different to current strands of research e.g. in the field of biofuel assessment (such as the EUCAR/CONCAWE/JRC WtW Studies 2007[7]) special emphasis should be given to the interrelations between energy and material uses and the prospects of joint approaches.

Furthermore, such a quantitative framework will have to be expanded by other dimensions among which infrastructure aspects play a prominent role. From an industrial and political point of view the compatibility of new material and energy flows to the existing system is of utmost importance. Obviously, options that can be integrated smoothly into already established structures have a comparative advantage such as liquid biofuels entering the transport fuel distribution of oil companies. However, in the longer run the benefits of other options may overrule an initial hurdle and may justify the transition towards new infrastructures. The assessment of biomass pathways, therefore, needs to be embedded into a context of systems analysis that take into account the dynamics and turning points of the comparison described. Changing boundary conditions will alter the relative competitiveness of options and must be carefully considered.

Since the political debates on energy and material uses of biomass are still not linked a broader debate on an integrated strategy is needed. This debate should be based on a solid assessment and involve the relevant stakeholders. The debate should prepare the ground for decisions on competing uses of biomass. The process of setting up effective and legitimate governance structures should be based on experiences from existing global governance regimes e.g. in the area climate policy or forest certification.

The abovementioned considerations start from the assumption that a given amount of biomass is available (user perspective). The aim is to achieve an optimisation of use. But what about the supply perspective? What degree of non-food biomass provision is acceptable at all? How can problem shifting due to an increased use of (non-food) biomass be minimized (e.g. shifts between different environmental pressures, and shifts between regions)?

The next sections will address these issues.

[7] EUCAR, CONCAWE and JRC (2007): Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. WELL-to-WHEELS Report. Version 2c, March 2007. http://ies.jrc.ec.europa.eu/WTW.

3 Towards a sustainable level and pattern of biomass supply: The regional and international perspective

The production of biomass by agriculture and forestry requires fertile land which is limited. Given a certain productivity per area, a rising demand for biomass may only be fulfilled through expansion of agricultural or forestry land. While the use of organic residuals does not require extra land for production, biomass based on primary crops will require an extension of arable land, usually at the expense of natural ecosystems, savannas and grasslands on the one hand, and forests on the other hand.

Land-use and land-cover are linked to ecological issues in complex ways. Major impacts related to Land-use and land-cover change (LULCC) are (Ellis and Pontius 2007):

- Biodiversity loss
- Climate Change
- Pollution (air, water, soil)
- Other impacts such as stratospheric ozone depletion; altered regional and local hydrology; long-term threat to future production of food and other essentials by the transformation of productive land to non-productive uses; degradation of productive land by soil compaction and erosion.

Biodiversity is often reduced dramatically by LULCC, e.g. through transformation from a primary forest to a farm, from relatively undisturbed lands transformed to more intensive uses, through fragmentation of existing habitats, or through species invasions by non-native plants and animals.

LULCC plays a major role in *climate change* at global, regional and local scales. At global scale, LULCC is responsible for releasing greenhouse gases to the atmosphere, thereby driving global warming. LULCC can increase the release of carbon dioxide to the atmosphere by disturbance of terrestrial soils and vegetation, and the major driver of this change is deforestation, especially when followed by agriculture, which causes the further release of soil carbon in response to disturbance by tillage and/or by drainage (see also “The case of Indonesia”). Changes in land use and land cover are also behind major changes in terrestrial emissions of other greenhouse gases, especially methane (altered surface hydrology: wetland drainage and rice paddies; cattle grazing), and nitrous oxide (agriculture: losses of inorganic nitrogen fertilizers through denitrification, also linked to irrigation; influence of the cultivation of nitrogen fixing plants).

A further source of uncertainty in estimating the climate changes caused by LULCC is the release of sulfur dioxide and particulates by biomass combustion associated with agriculture, land clearing and human settlements. These emissions are believed to cause regional and global cooling by the reflection of sunlight from particulates and aerosols, and by their effects on cloud cover.

Changes in land use and land cover are important drivers of *water, soil and air pollution*. Perhaps the oldest of these is land clearing for agriculture and the harvest of trees and other biomass. Vegetation removal leaves soils vulnerable to massive increases in soil erosion by wind and water, especially on steep terrain, and when accompanied by fire, also releases pollutants to the atmosphere. This not only degrades soil fertility over time, reducing the suitability of land for future agricultural use, but also releases huge quantities of phosphorus, nitrogen, and sediments to streams and other aquatic ecosystems, causing a variety of negative impacts (increased sedimentation, turbidity, eutrophication and coastal hypoxia). Mining can produce even greater impacts, including pollution by toxic metals exposed in the process. Modern agricultural practices, which include intensive inputs of nitrogen and phosphorus fertilizers and the concentration of livestock and their manures within small areas, have substantially increased the pollution of surface water by runoff and erosion and the pollution of groundwater by leaching of excess nitrogen (as nitrate). Other agricultural chemicals, including herbicides and pesticides are also released to ground and surface waters by agriculture, and in some cases remain as contaminants in the soil. The burning of vegetation biomass to clear agricultural fields (crop residues, weeds) remains a potent contributor to regional air pollution wherever it occurs. Although it has now been banned in many areas it is still practised widely.

Other environmental impacts of LULCC include the *destruction of stratospheric ozone* by nitrous oxide release from agricultural land and *altered regional and local hydrology* (dam construction, wetland drainage, irrigation projects, increased impervious surfaces in urban areas). Perhaps the most important issue for most of Earth’s human population is the *long-term threat to future production of food and other essentials* by the transformation of productive land to non-productive uses, such as the conversion of agricultural land to residential use and the degradation of rangeland by overgrazing.

Therefore, impacts on global land use which may result in significant changes of land cover deserve special attention. They are directly related to the survival or extinction of plants and animals (e.g. in case of forest clearance) and whole species (e.g. if the cleared area exceeds the population area). On the one hand, one may argue, that land use changes are just another environmental impact category besides more specific impacts such as global warming, acidification and eutrophication (which may also impact survival of certain species). On the other hand, any assessment should not allow for unlimited trade-offs between those different impacts. Even if fuelcrops had a beneficial impact with regard to global warming (which seems highly questionable, at least limited, according to recent analyses) the unlimited expansion of arable land at the expense of major destructions of natural ecosystems will probably not be regarded as sustainable solution. Thus, the question arises how such “side-effects” may be analytically detected and politically controlled.

Agricultural land use plays a prominent role, resulting from the close interaction of food to non-food sectors, the variety of crops and utilisation pathways, the economic relevance, and last but not least, the current dynamics in the area of agriculture based biofuels. We will therefore have a closer look at the actual global land use associated with the EU´s consumption of agricultural goods, and discuss the consequences of increased use biomass for non-food purposes through global land cover change (chapter 3.1). Chapter 3.2 will discuss the global environmental impacts of European wood imports and alternative options for increased wood use in Europe.

3.1 Agricultural land use

3.1.1 The actual global land-use of the EU

Recent policies on biofuels have been developed under the assumption that the EU has significant amounts of free space (set aside land) for additional domestic production, and that additional imports may not be relevant with regard to global land use. Empirical analysis, however, shows that these assumptions should be considered with great caution.

Schütz (2003) and Steger (2005) accounted for the global land use of the EU-15 associated with domestic consumption of agricultural goods. Land use of imports and exports were considered to provide a net foreign trade balance in terms of land use which adds to the domestic use of agricultural land to indicate the net global land use. In 2000, global land use of the EU-15 exceeded the domestic agricultural area used by 18%, i.e. nearly one fith. In other words, the phenomenon of set-aside land does not reflect the actual situation characterized by the fact that the EU uses more land for agriculture based its consumption than is available within its territory.

Following the assumption, that autarchy may be an obsolete objective, and that international trade may contribute to an effective use of global resources, the observation that a country or region uses more land of a certain type than it possesses does not necessarily indicate a problem. A reference is needed to assess the relevance of the global land use of a country or region in the world-wide context. Bringezu and Steger (2005) suggested to consider the global per capita use of arable land as a reference to indicate the extent of intensively cultivated agricultural land.

Based on this reference, the EU-15 in 2000 – i.e. without significant use of biofuels – with a global land use of 0.43 ha/cap already exceeded the world average use of intensively cultivated agricultural land (0.25 ha/cap) by a factor of 1.7. Considering the growth of world population and an projected extension of global arable land by 120 million ha (conservative assumption) this situation will worsen until 2030, when the global reference value will drop to 0.18 ha/cap.

Altogether, this indicates that the EU in terms of global land use for agriculture is already living beyond its "global fair share". Any additional use of agricultural products such as biofuels will increase the actual imbalance if no compensatory measures are taken to reduce the global land use of current production and consumption patterns. One example of such compensatory measures would be policies to shift the support from animal based production (which responsible for 75% of global land use) to non-food biomass.

The enlargement of the EU-15 to EU-25 certainly has some influence on global land use, however, based on the assessment of existing and potentially more widely applicable technology, Kavalov et al. (2003) found that new member states "should be seen more as a positive but small complement to EU-15 biofuel production, rather than as a large scale supplier of biofuels for the enlarged EU." In contrast, EEA (2006) estimated 13 Mio ha to be available in 2010 in EU-22 for bioenergy production of which 59% are within 8 new member states. The study assumed relative high rates of productivity increase, so that this share would increase to 64% of 19 Mio ha in 2030.

Questions for research:

- To which extent will the ongoing CAP reform lead to a reduction of *global* land use through a reduction of animal production? Will unchanged consumption pattern of animal based diet only lead to a shift from domestic to foreign cattle production?
- By which degree need the animal based consumption be reduced to compensate for the increasing demand for non-food biomass production land?
- Which policy measures would be most effective to reduce the global land use associated with the consumption of agricultural goods in the EU to foster a more balanced land use? What is the role of a shifting diet compared to a more efficient use of biomass (e.g. by reducing the amount of wasted biomass)?

3.1.2 Prospects and limits for increasing land-use productivity

Limits for the expansion of arable land direct the attention to options to increase the productivity of arable land. With regard to historical records of productivity gains in agriculture (e.g. in Germany about 1–2%/a since the 1950's) one may assume that total biomass output can be increased on a smaller area giving room for the production of non-food biomass.

However, the picture is not as clear as it seems to be. The available key scenarios for increased biomass use especially in the EU are associated with high uncertainties with regard to the development of productivities per hectare. This relates to established crops like wheat where productivities may not grow further like in the past, and to new cultivation methods like whole-plant-cropping systems which may be expected to be further optimized. A big uncertainty is related to the question whether and to which degree GMOs are increasingly used on the open fields. There is, however, an additional aspect to be considered (with or without GMOs). As soon as the efficiency of nutrient conversion into biomass is going to approach its maximum, the increase of ha productivities will be limited through the maximum tolerable level of nutrient losses e.g. to ground and surface water.

Last but not least, climate change will probably lead to increased weather extremes which tend to decrease average rates of production.

Questions:

- How will hectare productivities develop in the future?
- How far can the nutrient efficiency be developed in relation to hectare productivity?
- Which will be the maximum biomass production in various regions?

3.2 Forestry

3.2.1 Global perspective of European forest biomass use

Due to high levels of consumption, varying levels of production costs and low transport costs there are intensive forest product trade relationships within the European Union and with other countries. The following table illustrates the structure and trends in intra and extra European imports.

From / forest product	EU-25 Intra		EU-25 Extra	
	2001	**2005**	**2001**	**2005**
Wood and wood articles	69,02	69,93	35,02	42,16
Pulp (incl. recovered paper)	16,22	19,01	9,87	10,65
Paper and Paperboard	47,75	53,71	7,35	7,86

Table 3.1: European forest product imports in million tons (Source: Eurostat Comext 2006)

The table shows that both the intra and extra European trade increased between 2001 and 2005. The extra-European imports were dominated by wood and wood articles. In 2005 the extra-European imports of wood and wood articles mainly came from Russia (21,5 million tons), Belarus (2,2 million tons), Switzerland (2,2 million tons), Brazil and Ukraine (both 1,8 million tons). The main origins of extra-European pulp imports (incl. recovered paper) were USA (2,5 million tons), Canada (2,6 million tons), Brazil (2,4 million tons) and Chile (0,8 million tons). The 2005 imports of paper and paperboard were dominated by imports from Switzerland (1,4 million tons), USA (1,2 million tons), Canada and Russia (both 0,8 million tons) and Brazil (0,46 million tons) (Eurostat Comext 2006).

With respect to the forest products imports for heat and energy generation in Europe the data are limited. The wood pellet market appears to be the major extra EU import market. The major exporter of wood pellets to Europe at the global level is Canada with 0,3 million tons in 2004. In the context of increasing fossil fuel prices and the implementation of European renewable goals, the amount of traded wood for energy purposes is likely to increase (Thrän et al. 2005).

Germany is European largest and the world's second largest importer of forest products (in 2004), following USA and followed by China. The main German imports come from Sweden, Finland, Austria, France, Canada, USA (see UNECE/FAO, 2006). The amount of wood product imports corresponds approximately with the export of wood products. Also the structure of import and export flows (share of industrial roundwood, wood waste, semi- and manufactured products) are balanced (Mantau/Bilitewski 2005).

The *main environmental impacts of forest product imports* are beside transport emissions related to the destruction of natural forests, including deforestation. According to UNEP and FAO the forest land per capita is shrinking drastically worldwide. At the beginning of the last century there was 3,18 ha per capita available. A hundred years later it is just about 0,64 ha per capita. The worldwide deforestation was about 9,4 million ha per year (1990–2000), mostly in Brasil, Indonesia and Sudan (UNEP 2006, and FAO 2003, p.135). A study by Greenpeace (2006) on intact forest landscapes highlighted that less than 10 percent of the planet's land area remains as intact forest landscapes and that 82 countries out of 148 countries lying within the forest zone have lost all their intact forest landscapes. According to this study the majority of the world's last remaining intact forest landscapes consist of two major forest types – tropical rainforest and boreal forest: 49 percent are the tropical forests of Latin America, Africa, Southern Asia and Pacific; 44 percent are the great boreal forests of Russia, Canada and Alaska.

Tropical forests, which provide habitats for more than 50 percent of worldwide plant and animal species, are specifically affected from unsustainable forest management practices. In 2000 the OECD Environmental Outlook complained about the use of tropical forests, that has „reached environmentally unsustainable levels in many regions, and pressures on biological diversity and ecosystems continue (…) with significant economic, financial and social costs (…)." (OECD 2001, p.5). The European and German international trade relationships have to consider negative environmental impacts, because the import of forest products can influence the available forest land in other regions. In the year 2004 Germany imported forest products to the amount of 272 million Euro from Brasil, where the estimated amount of illegal logging is about 80% (BMU 2005, p.2). Imports can be linked to severe environmental damages, since there is currently limited control about forest management practices for imported wood.

Private forest certification schemes and voluntary agreements are important steps towards improvement. However, since these systems are emerging their longterm effectiveness remain to be seen (see e.g. Burger et al. 2005; Cashore et al. 2006). It is unclear if the Voluntary Partnership Agreements under the EU's Forest Law Enforcement, Governance and Trade (FLEGT) licensing system (European Commission 2003) will be effective means to combat illegal logging.

3.2.2 Prospects and limits for increased wood use within Europe

To understand the prospects and limits of enhancing European forest productivity the *multifunctionality* of European forests and the entire life cycle of the forest-timber chain have to be taken into account. The same area of forest has often multiple functions. According to FAO „(…) 72 percent of the forest area of Europe (not including the Russian Federation) provides social services” (FAO 2005, p.7). Examples of those services are recreation, tourism, education or conservation of cultural and spiritual sites. Important environmental functions are the protection of soil and water, conservation of nature and biodiversity. The economic function of wood production for material and energy use is consequently only one function among others.

There are a number of options for Europe to increase the timber use for material and energy uses. Beside increasing imports (which is probably not a preferred option without ensuring sustainable production, see above) there are two distinct options: increasing efficiency of wood use and increasing forest productivity and/or forest area.

Increased forest productivity and area

The productivity as well as the environmental pressure of forest biomass production depends on which tree species is cultivated how and where. A sustainable forest management should ensure that the yield of all forest products harvested is limited to the specific growth rates and regeneration. At the national scale for instance, Germany satisfies this criterion. Within German private forests there is still a certain potential to increase the amounts of wood used, but there are a number of barriers for biomass mobilisation such as organisational or technical barriers. However, additional sustainability criteria need to be considered, which are partly site and crop specific. For example, the long-term yields and sustainability depend on local soil nutrient balance and risk of soil erosion. In addition, the site condition are likely to change under climate change effects such as increase storms, droughts, heavy rain.

Productivity of forests can be increased by fast growth, short rotation systems, increased complementary fellings and the use of forest residues.

Short rotation crops are woody crops such as Salix, Populus, Robinia and Eucalyptus with coppicing abilities as well as lignocellulosic crops such as reed canary grass, Miscanthus and switch grass. Their cultivation is limited to arable land and therefore competing with food, fodder, ecological set-aside area and forest area. Main environmental pressures include soil erosion, soil compaction, nutrient inputs into ground and surface water (EEA 2006). Additionally the climate change is going to influence the forests (increase in extremes, distribution of forest species and area). Plant breeding for increased productivity is commonly accepted, well researched and widely used in practice. In contrary, the growth of genetically modified trees as well as foreign species are connected to uncertainties, which need to be researched and discussed (see Lang 2004).

Fellings and residues of fellings could be an additional source of biomass. According to an EEA study, the potential of residues of regular fellings for heat and power generation amounts to 15 million tons in the year 2010 (16,3 million tons in 2030). The quantity is directly depending on round wood demand and prices. The potential of complementary fellings including their residues for heat and power generation amounts to 28 million tons in the year 2010, 23 million tons in 2030 (EEA 2006). However, the ecological functions of residues and deadwood within a forest ecosystem may be negatively influenced by an increased use of residues, i.e. conservation of soil fertility, source of nutrients, regulation of water flows, prevention of soil erosion or creation of habitats. Prospects of increased use can be the prevention of forest fires or nutrient removal at sites suffering from eutrophication. The EEA concludes that depending on site conditions the use of residues is limited to maximum of 75 percent of residues. As it is most important to leave foliage and roots at site as well as a certain amount of deadwood supporting the biodiversity, the EEA report suggests a minimum of 9 m3 per ha (EEA 2006, pp.33).

The *forest area* in Europe is slightly increasing. In the year 2000 there was about 1,4 ha/ capita forest land available and the forest land cover increased from 1990 to 2000 annually about by 360.000 ha (FAO 2003, p.133 and EEA 2006, p.41). The question if forest area for wood production should be increased or not is heavily discussed. Some environmentalists call for an increase of protected areas for nature conservation, representatives from the wood industries call for higher yields and intensification of use in protected areas (see Kronauer 2006).

Efficient use of wood

With respect to the use phase of wood there are several positive and negative environmental impacts of an increased biomass utilization for energy purposes. For example with respect to emissions to air, it seems possible to avoid greenhouse gas emissions compared to incineration of fossil fuels. However, the level of particle emissions from wood incineration depends heavily on the feed and the technology used (e.g. Hartmann et al. 2006). Consequently, modern and efficient technologies should be promoted and used for energy uses.

Cascade use of wood and wood products is an important option to maximise the value from a given amount of input and to increase the efficiency along the value chain. The idea is to use the wood first for material uses, if possible recover (e.g. from recycled construction timber or as recycled paper), and generate power and heat only in the end of a longer life cycle. Implementing cascade use requires a number of changes such as adjustment of consumer behaviour, logistical efforts, which potentially may cause additional transport. The best use of wood waste from by-products of wood industry, recovered wood, construction wood, packaging should be promoted. However, to avoid waste generation in the first place, it is most important to follow a waste hierarchy: avoidance, reuse, recycle, recover, energetic use.

More efficient use of wood does not need any additional forest area (EEA 2006). With respect to employment effects, the material use of wood (as pulp and paper or the wood industry) appears to generate more employment than energy uses per ton of wood (Jaako Pöyry 2003). A more radical innovation is the dematerialisation of (also wood) products. This is the provision of the same service of a (wooden) product with less material input (e.g. use of emails instead of paper based mails). But an increased efficiency can cause the so-called rebound effect, i.e. an increased demand for these products, that overcompensates the savings by increased consumption.

Questions for research:

- What land use and other environmental impact is associated with the EU trade of forest products and other non-agricultural biomass based goods?
- How to define a reasonable balance between multiple forest functions such as raw material provision, social services or nature conservation? How to integrate and balance multiple functions? How to best solve conflicts between energy and material uses of wood?
- What are the influences of climate change on forestry and wood processing industries Which forest cover change would be adaptive to climate change?
- What are environmental benefits of cascading use of wooden biomass? What are good practice examples of cascading use? What are the technical and organisational conditions for an efficient cascading use?
- How to improve the effectiveness and legitimacy of sustainable forest management and chain-of-custody certification?
- How to promote international harmonisation of geographic data on forest management regimes and forest types?

3.3 International trade of biofuels: An example for complexity

In general any further expansion of arable land incorporates the risk of proceeding at the expense of natural ecosystems and habitats, thus threatening biodiversity, water systems etc. This holds especially for those regions where bioenergy and biomaterial cropping is economically most viable and governance not strong enough to withstand that pressure and to enforce absolute limits to the destruction of natural ecosystems.

For that reason the “side effects” of significant growth of demand for non-food biomass need to be taken into account – not only on a domestic or European level but as well on a global scale. Enhanced biomass demand in the EU will induce impacts on the global level through changes of the geographical pattern of non-food biomass supply which impacts environmental and socio-economic conditions and food supply in other parts of the world.

3.4 Accessing global biomass resources: The balanced approach of the EU

The balanced approach of the EU Commission as formulated in the biomass action plan[8] to meet the biofuel targets may serve as an illustrative example. From the intermediate target of providing 5,75% of the EU transport fuel demand in the year 2010 a corresponding demand for some 18 Mtoe of biofuels had be derived. Three scenarios were discussed to meet this demand:

- **Scenario 1: minimum share for imports**
  From the Commission's perspective this strategy would touch upon the technical limits of biofuel potentials and in addition would incorporate severe disadvantages with regard to international trade politics, high costs of domestic production and insufficient incentives to increase biofuel use worldwide.
- **Scenario 2: maximum share for imports**
  Taking advantage from cheaper biomass resources this approach would lower costs of compliance drastically but on the contrary induce environmental damages in production regions due to overstressed expansion of capacities.
- **Scenario 3: balanced approach**
  In this approach the Commission sees an opportunity to reconcile conflicting dynamics by balancing domestic and foreign share of biofuel supply, e.g. by eliminating hurdles to biofuel trade and establishing minimum sustainability standards as a prerequisite for acceptance for compliance.

The Commission expects that under the balanced approach

- price dynamics of crops can be mitigated,
- the major share of biofuels will come from domestic sources,
- the developing countries will get the chance to enter the EU market for biofuel products,
- the deforestation and habitat destruction will be prevented.

8 Commission of the European Communities (2005): Biomass action plan. COM(2005) 628final, p. 10, and Annex 11

With regard to the current developments, however, these aspirations deserve a closer look and a critical assessment.

More precisely than the biomass action plan, the impact assessment for the recent EU Strategy for Biofuels[9] assumes that 30%[10] to about one half[11] of the biofuel requirements of the EU-25 will be met by imports, based on a balanced approach in order to meet the policy target of 5.75% biofuels in 2010.

Increasing production of feedstocks would be reached by expanding domestic cereal and oilseed production by 4.1 million hectares. This would represent around 4% of the total arable land of the EU25 and contribute 21% to biofuel demand. Use of sugar beet could contribute 4%. Thus, 25% of the demand could be met by increasing production of EU feedstocks.

A shift in domestic demand due to increase of feedstock prices, in particular for cereals, is expected to decrease use for animal feed and non-energy industrial purposes (i.e. material use of non-food biomass) in favour of biofuels; this shift would contribute further 11% of the EU biofuel demand.

In total, 8.25 million hectares will be used for biofuel production within the EU, in addition to biofuels and feedstock materials imported.

In addition, exports would be replaced in favour of domestic biofuel use, which would add further 17% of targeted domestic biofuel needs. The rest would have to be supplied by imports (47%).

In its own impact assessment, the EU foresees that “there will be increasing pressures on eco-sensitive areas, notably rainforests, where *several millions of hectares*[12] could be transformed into plantations.” It considers that a free trade scenario (maximum imports) would have the biggest impact, and that business-as-usual (minimum imports) would lead to minimal effects. The impact assessment notes “that these effects are likely to occur regardless of EU policy towards biofuels, as increased demand from elsewhere (China, Japan) will have similar effects. However, EU demand will add to and magnify these effects.”

In this context the following cases will illustrate the state of biofuel production in developing countries. It becomes evident that further analysis is needed and current practices are far from being sustainable.

9 CEC (2006): An EU Strategy for Biofuels. COM(2006) 34 final; the IA annexed as SEC (20006) 142
10 p. 20
11 p. 22
12 italics set by the authors

3.5 The case of Brazil

Only in tropical regions with sufficient rainfall can biocrops such as sugar cane (like in Brazil) and oil palms (like in Malaysia) be cultivated with maximum productivities per hectare. As a consequence those regions are capable to produce biofuels which are competitive on global markets. Policies in the producing countries (also fostered by benign although somewhat reserved support by consuming countries) still tend to foster the expansion of the production in order to enhance export of products such as bioethanol and palm oil for diesel (REN21 2005; Kaltner et al. 2005; Worldwatch Institute 2006; current market reports[13]). .

From an economic point of view it seems rather questionable to produce bioethanol at competitive prices for export as long as there will be significant net import of oil which is going to require even higher expenditures in the future. In other words, (net) export only pays after domestic demand for biofuels have been fulfilled[14].

In Brazil, in recent years about 50% of the sugar cane crop – 2.75 million out of 5.5 million planted hectares – was dedicated to produce ethanol in the order of magnitude of about 40% of the non-diesel transport fuel demand (Kaltner et al. 2005[15]). This implies that the total area for sugar cane cropping would not suffice to fulfil the current demand within Brazil. Keeping in mind that fuel demand of developing countries such as Brazil is expected to increase significantly in the future (Worldwatch Institute 2006), domestically grown biofuels would only be able to fulfil that domestic demand (or additional demand for export), if the cropping area were to be expanded significantly.

In order to supply the consumption of diesel in Brazil in 2020 (Kaltner et al. 2005) completely with biodiesel from soybeans, and assuming that soybeans yields could even be increased over the same period by 25%, about twice the current total arable land of Brazil were to be planted with soybeans, about 115 million ha. And indeed, Brazil plans to increase its cropping area for soybeans from currently 23 million ha to about 100 million ha in 2020 (Kaltner et al. 2005). For comparison: the total arable land of Brazil currently covers about 60 million ha. Recent developments show that more and more refineries for biodiesel from soybean oil are taking up production, are built or are planned[16]. In addition, Brazil plans to increase the area for palm oil production the relevance of which for future biodiesel production however remains unclear. Oil plants

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13 e.g. article „Indonesia's Sinar Mas to build two biodiesel plants" of 29 March 2007, reporting that the Sinar Mas Group's alternative energy chairman, Mr. Jozal, said, that the production of about 600,000 tons biodiesel a year will be exported to the United States and Europe (www.theedgedaily.com). Or, on 23 Nov 2006 Australia's first palm oil based biodiesel plant with a capacity of about 140 Million liters of biodiesel annually was opened in Darwin (http://en.wikipedia.org/wiki/palm_oil).

14 For example, market experts suspect that many of the planned biodiesel ventures based on palm oil in South-East Asia will not materialise because of currently rising crude palm oil prices while crude oil prices drop (Asia Analytica report on: www.theedgedaily.com of 2 March 2007).

15 cited in Worldwatch Institute (2006)

16 Gateway Brazil – AgNews – AgTours – AgInvestments. Newsletter 31 August 2006: http://www.brazil.studyintl.com/news/agnews/agnews_sugarcane.htm

like castor could – under social aspects – contribute to regional sustainability, and this development is also selectively supported by the Brazilian government. This would however not result in potentials for export because significant crop land would be required in order to satisfy the own domestic consumption of diesel.

In Brazil, the expansion of sugar cane for ethanol and oil seed crops such as soy beans for biodiesel is indeed currently ongoing (e.g., from 2000 to 2005 the area for sugar cane in Brasil has increased by 20%, that for soybeans even by 69%, after data from FAO). The expansion of sugar cane production via large monocultures has replaced pasturelands (extensively used savannas or prairies) and small farms of varied crops (Nastari 2005[17]). Plantations for sugar and ethanol production have expanded predominantly into areas once used for cattle grazing, as cattle move on to new pastureland (often cleared rainforests) (Coelho 2005[18]).

Worldwatch Institute (2006) states that "Brazil's center-south region contains the vast cerrado prairies, perhaps the largest land area in the world available for increasing agricultural acreage, and a region capable of growing highly productive sugar cane varieties. Already today, large soybean plantations spread in the formerly forested savannah landscapes, leading to severe ecological damages (Global Nature Fund 2007[19]). The cerrado is also highly diverse and sensitive ecoregion." The cerrado savanna is home to half of Brazil's endemic species (found nowhere else on Earth) and a quarter of its threatened species. Expansion of agricultural production into the region's complex ecosystem could result in irreversible ecological damage (Kaltner et al. 2005; Global Nature Fund 2007).

The cerrado is not the only Brazilian ecosystem at risk. In the country's southwest, the construction of ethanol plants along the Upper Paraguay River is about to start[20] which runs through the Pantanal, one of the world's largest wetland areas. The plants and future plantations may severely impact the ecosystem. Along with the extension of the transport infrastructure towards the Amazonian region, one may also expect that crops such as soybeans, sugar cane and derived products will expand into sensitive areas where they are currently not economically viable yet (Kaltner et al. 2005).

One of the most discussed consequences of the increasing land use for sugar cane and soybeans plantations on natural forest areas especially in the South-eastern regions of Brazil is its impact on global climate change. There is currently no model available which could exactly describe what the effects of deforestation and land use changes on climate change and vice versa are. What is for sure, however, is that forest destruction

[17] Worldwatch Institute (2006) chapt. 12, note 17

[18] ibid. chapt. 12, note 17

[19] Global Nature Fund 2007: Bedrohter See des Jahres 2007: Pantanal – Brasilien, Paraguay und Bolivien (www.globalnature.org, 30.3.2007).

[20] Despite massive protest by environmental protectors, the government of the Brazilian Federal State Mato Grosso do Sul has recently given permission to build ethanol distilleries in the catchment area of the Pantanal (Global Nature Fund 2007).

leads to severe changes of the hydrological cycle in the whole Amazon region and thereby accelerates irreversible ecosystems destruction and biodiversity loss. Global efforts are required to support a more sustainable development, e.g. by compensating countries of the South for keeping their tropical forests out of destructive kinds of use.

3.6 The case of Indonesia

In Southeast Asia, palm oil expansion is meanwhile one of the leading causes of rainforest destruction. Palm plantations are expanding rapidly in eastern Malaysia as well as in Indonesia where, despite laws prohibiting clearing for palm oil plantations, natural forests are being felled at a rapid pace (Glastra et al. 2002[21]). Palm oil producers are expanding into forestland rather than planting on abandoned agricultural land, since recently cleared forests need less fertilizer and profits are higher (Clay 2004[22]).

In Malaysia and Indonesia development plans foresee increased production of palm oil and biodiesel mainly with a view on growing demands in Europe, USA and China[23]. So far the share of palm oil of global biodiesel production was only about 1%. Recently, however, increased production of palm oil in Malaysia and Indonesia was by 95% driven by the growing global demand for biodiesel. New biodiesel plants are built partly with support from foreign enterprises and with the clear focus on export to the U.S. and to Europe[24]. Linked to this development large scale land use changes like in Kalimantan are expected to continue with severe further consequences on global climate, biodiversity and existence of indigenous people.

In Indonesia, degradation of natural rain forests and peatlands due to land development for agricultural cultivation is going on since decades and reached a remarkable extent in the course of the Mega Rice Project on 1 million hectares natural forest and peatland area in Central Kalimantan initiated by the Indonesian president Suharto in the mid 1990s. As a consequence of increasing land use and land cover changes, huge forest fires in 1997/1998, destroyed 10 million hectares rain forest area in Borneo, Sumatra and New-Guinea, boosting global atmospheric CO_2 concentrations in 1997 to almost twice the average values of years before and after 1997 (Schimel and Baker 2002, Page et al. 2002). In recent years, increasingly rain forest and peat land is cleared for planting oil palms (Hooijer et al. 2006; see also UNEP 2006).

21 Worldwatch Institute (2006) chapt. 12 note 30
22 Worldwatch Institute (2006) chapt. 12 note 31
23 e.g. article „Indonesia's Sinar Mas (see footnote above); for example, China has been the biggest buyer of Malaysian palm oil for the past five years, and accounted for 25% of total palm oil exports (Asia Analytica report on: www.theedgedaily.com of 2 March 2007).
24 Reuters of 3.4.2006: http://www.bkpm.go.id/en/share.php?mode=baca&info_id=565

In the past, the palm oil has been mainly used to produce margarine, and the oilcake has been used as animal feed in European intensive animal production. More than 90% of the palm oil were for the European market. The area for oil palms increased from 600.000 ha in 1985 to about 5 million ha; applications for another 20 million have been submitted. This area is equal to the remaining area of rain forests in Indonesia.

Because of the dwindling area of low-land forests, swampy peat areas are increasingly converted to oil palm plantations. This leads to drainage of the peat and thereby to the release of carbon which was bound there for 5,000 to 10,000 years before. Oxidation of the carbon leads to the emission of carbon dioxide and thus contributes significantly to global climate change. In addition, dehydration of the peat increases the risk of fires. Forest fires were also laid in the past to enforce the development of palm oil cultivation in Indonesia.

In a recent study by Hooijer et al. (2006) it was found that current CO_2 emissions caused by decomposition of drained peatlands in South-East-Asia amount to 632 Mt/y (between 355 and 874 Mt/y). This emission will increase in coming decades, unless land management practices and peatland development plans are changed, and will continue well beyond the 21st century. In addition, over the period of 1997–2006 an estimated average of 1400 Mt/y in CO_2 emissions was caused by peatland fires that are also associated with drainage and degradation. The current total peatland CO_2 emission of 2000 Mt/y equals almost 8% of global emissions from fossil fuel burning. These emissions have been rapidly increasing since 1985 and will further increase unless action is taken. Over 90% of this emission originates from Indonesia, which puts the country in 3rd place (after the USA and China) in the global CO_2 emission ranking.

Hooijer et al. (2006) found that “apart from logging for wood production, an important driver behind peatland deforestation is development of palm oil and timber plantations, which require intensive drainage and cause the highest CO_2 emissions of all possible land uses.” The authors state that “a particular point regarding CO_2 emissions from SE Asia peatlands, which requires attention from the international community, is that of the relation between palm oil production and peatland drainage. A large fraction (27%) of palm oil concessions (i.e. existing and planned plantations) in Indonesia is on peatlands; a similar percentage is expected to apply in Malaysia. These plantations are expanding at a rapid rate, driven in part by the increasing demand for palm oil as a biofuel on Western markets. Production of 1 tonne of palm oil causes a CO_2 emission between 10 and 30 tonnes through peat oxidation (assuming production of 3 to 6 tonnes of palm oil per hectare, under fully drained conditions, and excluding fire emissions). The demand for biofuel, aiming to reduce global CO_2 emissions, may thus be causing instead an increase in global CO_2 emissions.”

It is concluded that deforested and drained peatlands in SE Asia are a globally significant source of CO_2 emissions and a major obstacle to meeting the aim of stabilizing greenhouse gas emissions, as expressed by the international community.

Hooijer et al. (2006) therefore recommend that international action is taken to help SE Asian countries, especially Indonesia, to better conserve their peat resources through forest conservation and through water management improvements aiming to restore high water tables.

Indonesia has the largest peat forest areas worldwide covering about 10% of the country's land area (about 20 million ha). The vegetation in peat forest is unique and still largely unknown, the ecosystem has so far not been sufficiently investigated. Further conversion will inevitably lead to biodiversity losses, for example, the peat forests of Central Kalimantan are the last remaining retreat area of the Orangutan (Aldhous 2004; Siegert 2004).

The massive enlargement of the area for oil palm cultivation has also consequences for development policy and human rights. As observed in the past, the local population may be cut off its traditional ways of life and driven out without remuneration from its own land property[25].

3.7 Interim assessment: Shall developing countries export biofuels or consume them for their own?

The example cases underline the complexity of the problem. The assessment of single biofuel options need to account for the interdependencies of different types of land use and various strategies to make use of biomass resources. This leads to an integrated assessment of the biomass system at a regional level considering global implications. With regard to the most pressing environmental problems of deforestation and climate change two aspects appear to be crucial:

- First, there is a need to preserve ecosystems from agricultural use and deforestation which sets limits to the availability of arable land for any kind of cultivation.
- Second, within these limits of land availability the choice of crops and state of cultivation needs to be orientated to sustainability criteria, e.g. by imposing quality standards and the need for certification.

It is evident that isolated approaches such as product based labels are likely to fail if they are not embedded into combined strategies that apply a policy mix.

Therefore, also region based policies are required to set limits to the overexploitation of natural resources. For instance, resource exporting countries like Brazil will have to consider the establishment of national resource management plans which comprise targets for the conservation of natural ecosystems (rain forest, wet lands, savannas etc.),

[25] after: Kein Palmöl in den Tank! Christian Offer, Berlin, 16.07.2006: http://www.regenwald.org/news.php?id=474

land use for agriculture and forestry (considering sustainability standards which may include mixed uses) for food and non-food production, while considering sustainable supply for domestic consumption and impacts on foreign trade balance (in monetary as well in physical terms).

Considering the interconnetiveness of global markets and the current situation that countries like Brazil where strict laws for forest protection de facto cannot be sufficiently enforced, complementary action is required. Also resource importing countries and regions such as the EU need to establish resource management plans, including the use of minerals and biomass, and considering the balance between domestic production and (net) imports. In other words:

- **Developing countries** in tropical regions where biomass productivity per hectare reaches maximum levels should widen their policy debate and enable empowered decisions on the relation of export of non-food biomass and domestic use, and on the extent to which cultivated land, esp. monocultures, should expand at the expense of natural ecosystems.
- **Industrial countries and regions like the EU** should critically consider whether fostering of imports from regions with sensitive ecosystems and/or support of the export of those regions should be continued. From an overall global perspective it should be discussed whether an optimized local and regional use of biomass could be much more effective with regard to the intended policy goals and which kind of successful incentives could foster such a development.

Research questions:

- Which biomass potentials can be used by sustainable cultivation for food and non-food purposes in the various regions, based on existing arable land and forests already under management?
- What aspects does a sustainable cultivation include beside ecological criteria (e.g. social aspects)?
- What is the right balance between food and non-food biomass production, and how can conflicts in land use be mitigated?
- Which area should remain for nature conservation?
- How can viable labels for sustainable land use be specified and how can effective control schemes can be developed and implemented?
- What are the reasons for exporting biofuels while at the same time importing oil on fossil basis?
- Who are the stakeholders relevant for non-food biomass production and use and how can they be motivated to embark onto a more sustainable way?
- How to determine and control a proper balance between domestic production and imports?

- How can this balance be defined under sustainability criteria?
- Which are the reference criteria which are internationally acceptable in order to use mainly domestically produced biomass and limit the pressure to global natural ecosystems through limited net import of biomass and related products?
- Can Global Land Use Accounting (GLUA) provide an indicator to answer that question?
- What should be the global reference to compare with the actual global land use of a country (is the per capita normalization an acceptable basis for international negotiations on the fair and thus targetable share of global land use)?
- Are there economic thresholds beyond which ecological problem shifting becomes critical (e.g. which price differences in production costs between countries induce significant pressure on the expansion of arable land)?

4 Conclusions on steps towards a sustainable biomass strategy

The current debate about the future perspectives of biomass concentrates on selected aspects such as energy use, technological developments, economic potentials, and regional benefits. A broader sustainability strategy should consider the embeddeness of these issues in a larger system of resource use, material paths and interactions (Table 4.1).

Table 4.1: Resource use and multi-scale influences

Primary resources	Biotic resources: Raw materials from agriculture, forestry and fishery	Abiotic resources: Metals, construction minerals, fossil fuels			
Types of use	Energy (heat, fuel, power),	Material use (e.g. construction, packaging, textiles),	Food	Combinations (e.g. cascading material/energy use, edible packaging)	
Life cycle stages (examples of improve-ments)	Resource extraction (e.g. breeding and material development aiming at high productivity and multifunctionality or specialized use)	Design of materials and products (e.g. for recycling, long-life and cascades use)	Material processing and use of by-products (e.g. industrial symbiosis)	Efficient use (e.g. service – orientation or consumer integration)	Waste management (e.g. through recycling/ener gy recovery technologies)
Spatial scale of impact	Local	Regional	Global		
Acteurs of production and consumption	Industry (e.g. agriculture, forestry, energy producers, retailers)	Consumers (households, public organisations)	Intermediaries (e.g. associations, development agencies or fincance sector)	Other stakeholders (e.g. environmental or social NGOs)	
Influencial policies	Distributive policies (e.g. research funding, spending for infastructure, energy subsidies/ taxation)	Regulatory policies (e.g. trade regulations, ban of hazardous materials)	Information policies (e.g. consumer awareness policies, environmental and economic reporting, research)		
Research arenas	Natural science (e.g. life, earth or environmental science)	Social science (e.g. economics, geography, policy research)	Interdisciplinary and applied sciences (e.g. engineering, material science, cognitive science, sustainability research)		

The steps towards an improved life cycle of biomass and the optimised mix of renewable and non-renewable resources need to be analysed and developed considering these interlinked aspects. Effects on other fields of use (food, energy or material use or combined systems of renewable and non-renewable resources) should not be neglegted.

Within a consistent sustainability strategy the level of regional consumption of any raw material should not deteriorate critical environmental resources on a global scale. Therefore, life-cylce oriented strategies need to be complemented by policies which adjust the volume of biomass flows to to regional and global land capacities. Furthermore, a biomass strategy should be defined based on scientific grounds and consider relevant policy fields and acteurs.

So far, key issues for a sustainable use of biomass are still marginalized in the debate. Specifically, these are:

- **Limited potential for biomass production and trade due to land availability:** Energy and material crops can contribute only a certain share to the countries´ and the world regions´ material and energy supply. The various countries and world regions should strive towards developing their own potentials for sustainable cultivation and refining of food and non-food biomass and primarily serve domestic demand; under the assumption that domestic conversion routes are as efficient as elsewhere export should only be supported in cases of net surplus of material or energy resources (considering all relevant substitutes).
- **Integrated international assessments of sustainability impacts:** Environmental and social impacts of increased biomass use should be considered and include global challenges such poverty reductions, access to water and energy, implications of climate change etc. Existing scenarios are partly linked to high uncertainties, e.g. regarding development of productivity per hectare.
- **Need for a cross sector strategy:** Due to substitution and competition effects, any biomass strategy needs to consider the interrelations of material, energy and land use and should be embedded into a cross sector strategy for sustainable use and management of resources. Furthermore, this strategy should be linked to political initiatives at global, international and national levels and integrate governmental, business and civil society perspectives.
- **Importance of resource efficiency potentials:** A significant increase in resource efficiency considering renewable and non-renewable resources is necessary to fulfil a rising demand of the world economy for material and energy services. Any aspiration to circumvent the need for reducing the absolute amount of resource consumption by simply substituting non-renewable (minerals) by renewable (biomass) resources is not only bound fail, it will contribute to worsen the global situation and enhance the extinction of the remaining reservoirs of nature.
  The potentials, strategies and instruments to increase resource efficiency of the use of renewable and non-renewable resources in production and consumption have been described extensively by various publications of the Wuppertal Institute, and have already been acknowledged as important field of research.

Based on these observations there are still a number of research questions to be answered. Besides of the specific questions listed in the chapters above, the general challenges are:

- How to determine a sustainable level and pattern of resource use for the various countries and regions? Considering the balance between the use of non-renewable minerals and renewable biomass, as well as the balance between domestic and foreign supply?
- Which normative settings are required in order to minimize burden shifting across regions and allow a fair share of using resources distributed amongst various countries? How far need precautionary or preventive action go if resources located in other countries are to be sheltered?
- Which instruments (such as investments, subsidies, certification or labelling) or combinations of instruments need to be developed to implement a sustainable biomass and resource policy at the national and international level?

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