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Sustainable Bioenergy:
A tool for biodiversity, rural development and food security

Contribution to the Panel Discussion: Renewable Energies, green economies, and carbon offsets

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Preface

This paper was prepared based on previous and ongoing work of Oeko-Institut, funded by a variety of donors, and carried out in cooperation with several partners[1].

We hope that the paper will provide orientation and beneficial information to those working towards sustainable bioenergy production and use.

Feedback and comments are welcome, and substance presented here is subject to change based on results from further work.

For more information on previous and current projects and research activities, see www.oeko.de/service/bio.

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Darmstadt, June 2011 The Authors

1 Previous work is indicated in the text and fully referenced. Sponsoring partners of this work were, among others, BMU, BMZ, EEA, FAO, GEF, IEA, UBA and UNEP. Partners in this work were especially colleagues from Alterra, CE Delft, CI, DBFZ, DLR, Ecofys, IFEU, IUCN, JGSEE, SEI and WWF, and the participants and observers of the GBEP Sustainability Task Force and those participating in the CEN/TC 383 process.

Executive Summary

Currently, bioenergy is the “backbone” of all renewable energy used globally, and its use will increase in the future. Concerns about the **sustainability** of bioenergy are prominent, with food security, greenhouse gas emission balances, and biodiversity impacts being discussed critically. Many voluntary and some mandatory sustainability schemes for bioenergy – especially biofuels – were developed in the last years. However, there are yet **no binding rules** concerning **indirect** effects on GHG emissions and on positive or negative impacts of increased bioenergy production on food security, or its (again: positive or negative) social effects.

On the one hand, bioenergy offers many opportunities for sustainability, but on the other there are massive **risks**. Therefore, bioenergy development **needs “steering”.**

Possible biodiversity effects of biomass cultivation are manifold, from land use change impacts to landscape-level agrobiodiversity. Furthermore, extraction and use of residues could indirectly affect biodiversity through impacts on habitats and soil.

Still, new cultivation systems using non-invasive species could **enrich agro-biodiversity**. Landscape management needed to include structural elements, and to maintain corridors (migration etc.). Better **water management** is important to secure biodiversity and ecosystem functions – bioenergy crops can be more **drought-tolerant** than agricultural crops, and perennials could improve water retention in soils.

Biodiversity is fundamentally endangered by **global climate change**, especially with regard to extended periods of drought, changes in intensity and distribution of precipitation, higher ambient temperatures etc. which all can negatively affect ecosystems, and habitats. Thus, climate protection is a key to biodiversity protection.

Supplying and using bioenergy sustainably can considerably contribute to climate protection by substituting high-emitting fossil energy such as coal or oil. On the other hand, land use change (LUC) associated with cultivating bioenergy crops could increase GHG emissions. Thus, it is important to consider the overall GHG balance of bioenergy systems throughout the entire life cycle, including LUC. To avoid displacement of existing land uses (and, hence, indirect GHG), using currently abandoned or underused land is an important option for biomass feedstock cultivation. In addition, **degraded** land might be interesting as well, but requires special cultivation systems and practices, and the availability of such land must reflect biodiversity and social aspects as well as infrastructure.

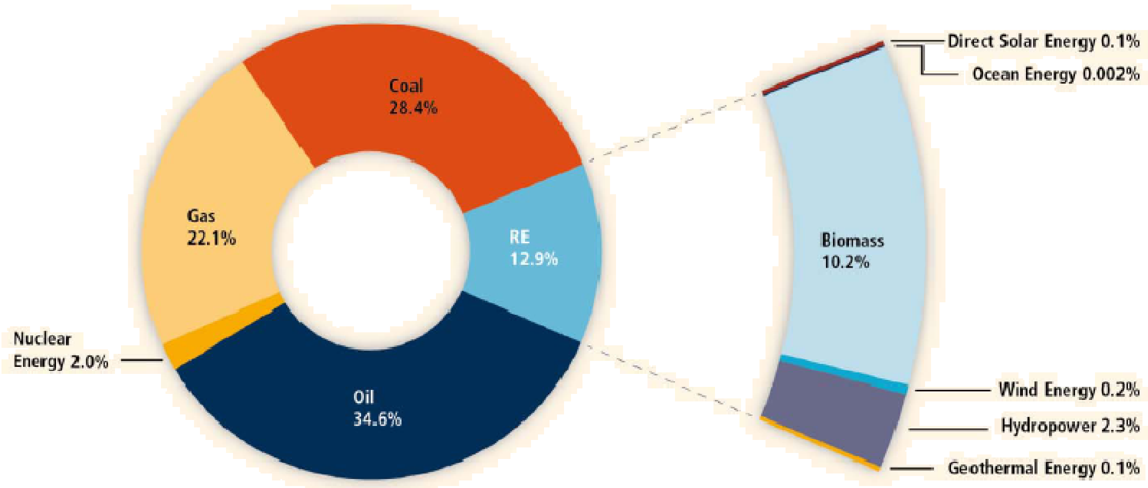
Using landscape/habitat management **residues** for bioenergy is an opportunity to create revenue for nature protection, but extraction rates and practices need care.

Investment in bioenergy **can help** improving agricultural yields and infrastructure, and intercropping with food, agroforestry, use of residues and freed land from better yields can “decouple” food from bioenergy. Rural development based on bioenergy and access to modern energy can further improve food security and reduce deforestation pressures.

Finally, biomass use efficiency needs improvement, especially through “cascading”, i.e. to give priority to biomaterials, and recovering energy from organic wastes.

1 Introduction

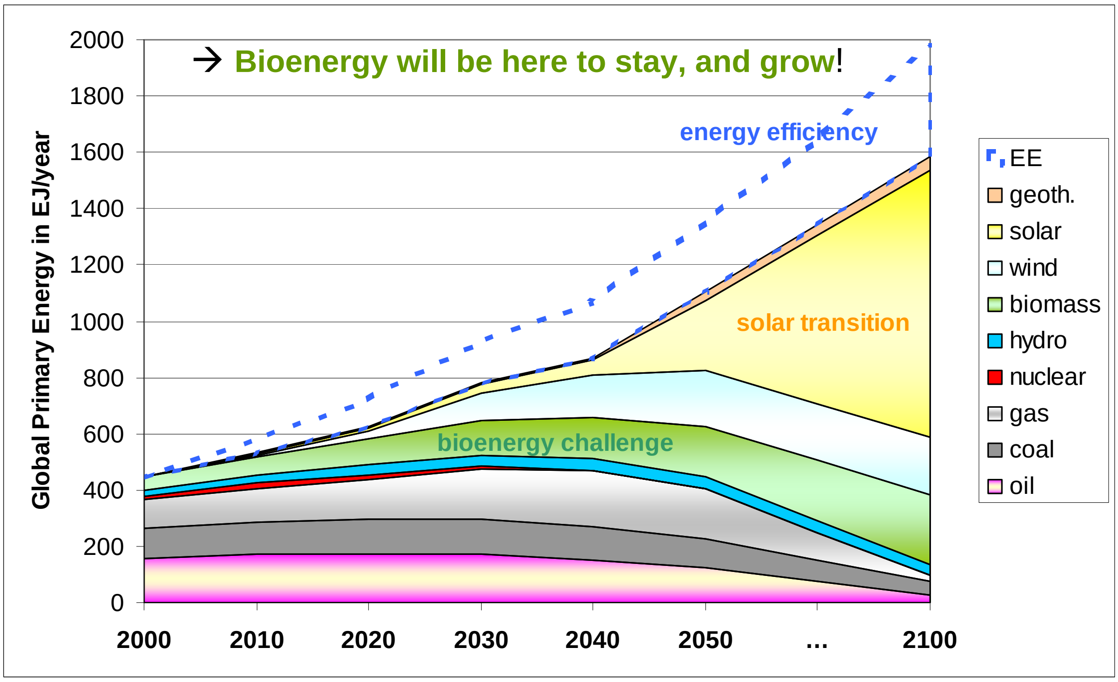
Currently, bioenergy is the "backbone" of all renewable energy used globally – as indicated in the following figure.



Source: IPCC (2011)

Of all primary energy used today (approx. 500 EJ), biomass contributes some 50 EJ, with about 40% of that coming from "modern" bioenergy in the form of electricity, heat, and transport fuels.

In the future, the use of biomass for energy and materials, as well as for food, feed and fiber will rise globally in parallel with increases in population, income, fossil energy prices, and concerns about energy security, and climate change (OECD/FAO 2009; IEA 2010b). A long-term scenario indicating the role of bioenergy in a sustainable global energy system is presented in the following figure.



Source: own compilation based on IEA (2010b), IPCC (2011), and WBGU (2009 + 2011)

Many countries established policies to increase utilization of domestic biomass resources, recognizing biomass as an option to reduce import dependence and improve rural development, employment, and income (GBEP 2007; FAO 2008). Some countries also envisage export opportunities, especially for liquid biofuels (IEA 2010a).

Biomass production and use for electricity, heat and transport fuels will continue to increase, with global trade in biomass rising in parallel (IEA 2010b + 2011).

Currently, only about 2% of biomass used for energy purposes (including liquid biofuels) is internationally traded, representing a small mass share (< 0.2%) of the total world trade in all biomass, i.e. industrial and agricultural products (Heinimö/Junginger 2009).

In parallel to rising interests in bioenergy, concerns about its **sustainability** became more prominent, with food security, greenhouse gas emission balances, and biodiversity impacts being discussed critically (IEA 2009; IEA Bioenergy 2010a).

This paper gives some brief remarks on the overall sustainability of bioenergy production and use, and its perspective.

2 Sustainable Bioenergy

Sustainability is considered as a core prerequisite for future bioenergy and biomaterial developments, disregarding if implemented by voluntary or mandatory sustainability schemes, and **not** restricted to indicators and criteria being compatible with current trade law.

Key sustainability issues are

- direct and indirect land use change with related impacts on emissions of greenhouse gases (GHG), and biodiversity
- impacts on air, soil and water quality as well as water quantity
- food security and land tenure impacts
- rural development, employment and income generation.

Since 2007, the landscape of the previously **voluntary** and manifold sustainability standards for biomass – from cotton and wood to organic food, flowers, coffee and "green biopower" – has changed: both the US and European countries and the EU as a whole developed **mandatory** standards and criteria for liquid biofuels[2].

The EU Renewables Energy Directive (RED) adopted in April 2009 (EC 2009)[3] established **mandatory** sustainability requirements for bioenergy carriers used as transport fuels and for liquid bioenergy carriers in general.

In March 2010, the EU Commission (EC) presented a report on the extension of the RED to **all bioenergy carriers** and proposed that the RED criteria could be **voluntarily** adopted by the EU Member States to apply to solid and gaseous bioenergy carriers as well (EC 2010). In late 2011, the EC will report on developments in that regard, noting that several EU countries began introducing broader sustainability requirements for bioenergy (e.g., BE, DE, NL, UK).

In the U.S., negotiations concerning federal biofuel standards were completed in May 2010 with a final rule of EPA on GHG emissions[4], whereas the Low Carbon Fuels Standard (LCFS) has already been implemented in California[5], also regulating GHG

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2 In parallel to these statutory provisions, RSPO (www.rspo.org) and RSB (www.rsb.org) are voluntary sustainability standards, and the European standardization organization CEN as well as the global ISO body are also working on own drafts.

3 Basically, the RED aims at GHG reduction and biodiversity protection, whereas local environmental and social aspects were excluded due to their likely non-conformity with trade law (WTO rules). Previous discussions dealt with the concepts of **voluntary** certification (Cramer Report in the Netherlands) or **reporting** requirements on sustainability aspects (RTFO in UK).

4 see EPA (US Environmental Protection Agency) 2010: Renewable Fuel Standard (RFS2): Program Amendments; Washington DC http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm

5 see CARB (California Air Resources Board) 2010: Low Carbon Fuel Standard (LCFS) http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

emissions from biofuels (and both including GHG emissions from indirect land use changes).

Outside of the OECD, countries such as Argentina, Brazil and Mozambique as well as Thailand, among others, are in the process of establishing and implementing national legislation and subsequent or alternative voluntary schemes with criteria and standards for bioenergy development, especially regarding biofuels for transportation, and the UN Energy organizations such as the FAO and UNEP as well as UNCTAD are taking on the task to support developing countries in such activities.

Internationally, the Sustainability Task Force of the Global Bioenergy Partnership (GBEP)[6] agreed on a list of sustainability criteria and indicators for the national level which could provide a basis for global (voluntary) implementation. This list was formally endorsed end of May 2011 (GBEP 2011).

The Global Environment Facility (GEF) has work underway to establish sustainability requirements for biofuels projects to be funded, and the Inter-American Development Bank (IDB) has developed a “Sustainability Scorecard” system to screen biofuel projects under consideration for financing.

In parallel, work of the International Standardization Organization (ISO) is aiming to develop voluntary criteria for sustainable bioenergy, but results of this process cannot be expected before 2013.

All these activities are encouraging indicators that sustainability issues of bioenergy development are taken up by many parties and in various fora, and underline that **guidance** for economic actors in the bioenergy field is seen as necessary.

However, there are yet **no binding rules** concerning **indirect** effects on GHG emissions[7] and on positive or negative impacts of increased bioenergy production on food security, or its (again: positive or negative) social effects.

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6 GBEP is a partnership of the G8+5 (G8 states plus Brazil, China, India, Mexico and South Africa) founded at the Gleneagles G8 summit in 2005; its Secretariat is hosted by the FAO in Rome. Meanwhile, more international institutions including FAO, UNEP and UNIDO as well as industrialized and developing countries have joined GBEP. For more information, see www.globalbioenergy.org

7 with the noteworthy exception of US EPA rulemaking for RFS-2 and LCFS in California, see footnotes 4 and 5.

3 Bioenergy and Biodiversity

The possible effects of biomass cultivation on biodiversity are manifold, ranging from land use change related impacts to landscape-level agrobiodiversity effects (ESA 2010; Hennenberg et al. 2010). Furthermore, extraction and use of biogenic residues (e.g., straw) could indirectly affect biodiversity through impacts on habitats and soil.

3.1 Conservation of land with significant biodiversity values

The loss of valuable habitats continues to be a key factor for declines in biodiversity, with agriculture and unsustainable forest management being key drivers. To avoid further pressure from incrementally cultivating dedicated bioenergy crops, it is necessary to protect high-biodiverse areas, including existing protection areas. The EU RED criteria on high biodiverse land are a good first step into this direction.

However, there are many other areas that deserve the same protection status: existing identification approaches such as *Key Biodiversity Areas*, *Important Bird Areas* and *High Conservation Value Areas* should be used as a starting point for this purpose. To fulfill the principal RED criterion on protecting high biodiverse land, more work is necessary to complete the globally available GIS data concerning such areas[8], and quality assurance (validation), monitoring and updates of GIS data with a sufficiently high resolution are required for many regions and countries.

The substantiation of the EU RED criterion needs continuous improvement with regard to scope and qualifying maps. It is necessary that **all** land with a potential for biomass cultivation is fully recognized in a global GIS database sufficiently in resolution to unanimously identify high-biodiverse areas[9].

3.2 Biodiversity-compatible agricultural and forestry practice

It is internationally acknowledged that protecting biodiversity in protected zones **alone** is insufficient to halt the decline of global biodiversity.

Therefore, activities to cultivate and harvest bioenergy crops and to manage agricultural and wood residue extraction have to be compatible with biodiversity in general and agrobiodiversity in particular.

Cultivation practices which are compatible are based on the following principles: Use of domestic species and local varieties, avoiding monocultures and invasive species, preferring perennial crops and intercropping, use of methods causing low erosion and machinery use, low fertilizer and pesticide use and avoiding active irrigation.

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8 For example, the current network of protected areas has significant gaps, according to IUCN and CBD, in ensuring sufficient biodiversity protection. With respect to *Key Biodiversity Areas*, so far, approx. 40% of the worldwide land area is accounted for in studies.

9 It should be noted that although restrictions for establishing dedicated bioenergy cultivation systems on such land are needed, this does **not** translate simply into “no-go” areas for bioenergy development: Often, there is a **surplus** of biomass growth which could – and in some cases should - be extracted without negatively affecting the protection status of the land, and – hence – might serve as a residue which can be converted into bioenergy carriers, see Section 3.3.

In addition, buffer zones must be established to protect sensitive areas, and corridors and stepping stone biotopes must be preserved on the cultivated land in order to improve the exchange of species between habitats and movement along migration paths (Hennenberg et al. 2010).

Similarly, the extraction of agricultural and forest residues could negatively affect soils and, indirectly, biodiversity by reducing soil organic carbon, water retention capacities, and overall biological activity of soils, especially through compaction, and salinization.

3.3 Opportunities for Biodiversity from Bioenergy Development

New cultivation systems for bioenergy crops could **enrich agro-biodiversity**, especially in areas where monoculture is prevalent. Still, it is important to avoid invasive species, and to consider landscape management to avoid monotony of bioenergy crop land, and to maintain corridors (for migration etc.).

Better **water management** is also important to secure biodiversity and ecosystem functions – some bioenergy crops can be **more drought-tolerant** than agricultural crops, and **perennials** could improve water retention in soils

It should be further noted that **income** from landscape/habitat management **residues** could be used for bioenergy, but care is needed with regard to extraction activities, and level. This is an **interesting opportunity** - see German examples (http://www.lpv.de and http://www.oeko.de/service/naturschutz).

It would be very worthwhile to analyze global potentials from such activities, and to develop best-practice examples in several countries.

4 Climate Change and Biodiversity

Biodiversity is fundamentally endangered by global climate change, especially with regard to extended periods of drought, changes in intensity and distribution of precipitation, higher ambient temperatures etc. which all can negatively affect ecosystems, and habitats. Thus, climate protection is a key to biodiversity protection.

Supplying and using bioenergy sustainably can considerably contribute to climate protection by substituting high-emitting fossil energy such as coal or oil. On the other hand, land use change associated with cultivating bioenergy crops could increase GHG emissions. Thus, it is important to consider the overall GHG balance of bioenergy systems throughout the entire life cycle.

To ensure that GHG emission reductions from bioenergy are compatible with the longer-term requirement to decarbonize economies, bioenergy must demonstrate minimum GHG reduction compared to coal and oil of more than 75% in the longer-term, taking into account the full life cycles of the bioenergy production, and direct land use changes from bioenergy feedstock cultivation.

As indirect land use changes (ILUC) can occur if a current land use such as food or feed cultivation is displaced by bioenergy feedstock cultivation, the calculation of CO_2 emissions from displaced land should be considered in the GHG balance. However, displacement effects may occur outside a region or country due to global trade and reduced exports so that they can only be allocated to bioenergy cultivation through a **model exercise**. Consequently, calculating CO_2 implications of ILUC is highly controversial both in scientific and political discussions[10].

Still, in order to consistently assure net GHG emission reductions from bioenergy development in the longer-term, it is necessary to include a quantitative expression of CO_2 emissions from ILUC in the calculation of the GHG balances of bioenergy systems which should be adjusted over time to reflect future developments.

The practical implementation of REDD and the future inclusion of all emissions resulting from LUC in a global regime or a corresponding, cross-sectoral certification system will reduce GHG emissions from ILUC in a long term perspective. Once full implementation is achieved, the ILUC factor can be reduced to zero. But in the short/mid-term perspective an integration of ILUC emissions into the GHG balances is essential to reduce the risk of ILUC.

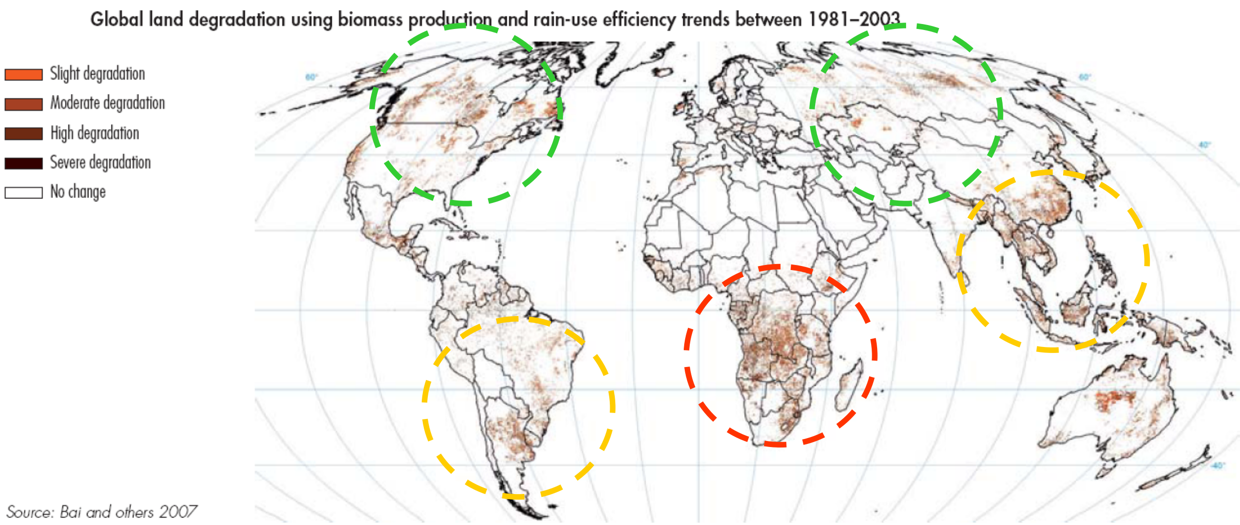
[10] It is beyond this paper to fully reflect the ILUC discussion. Interested parties are referred to recent studies, especially CI/LEI (2011), JRC-IE (2010); JRC-IPTS (2010), ICONE (2011), IEA Bioenergy (2010), IFPRI (2010), OEKO (2011), and to the EC report on ILUC (EC 2010b) as well as to summarizing articles (Börjesson/Tufvesson 2011; Fritsche/Sims/Monti 2010). In should be further noted that during 2011, ILUC will be subject to continuing discussions in the EU, the US and the GBEP.

5 Bioenergy from Degraded Land

To avoid displacement of existing land uses (and, hence, ILUC), the use of land which is currently abandoned or underused (e.g. intercropping) is an important option for biomass feedstock cultivation.

In addition, degraded land might be interesting as well, but requires special cultivation systems and practices.

Degraded land has been mapped globally by FAO (see following figure), and is increasing due to overuse, and other factors.



As part of its work on sustainable bioenergy potentials, Oeko-Institut carried out a mapping exercise for degraded land and biodiversity, with country studies in Brazil, China und South Africa (OEKO 2010).

Examples of degraded land from these countries are shown in the following figure.

Source: OKEO (2010)

Several studies tried to identify the overall global potential for bioenergy from abandoned, marginal and degraded land, as the following table shows.

Land type	Area	energy	reference
degraded land	**0.4-0.6 billion ha**	**8 - 110 EJ/a**	**Hoogwijk et al. (2003)**
	2.50 billion ha (19% of land area)	**~ 500 EJ/a**	**Metzger/ Hüttmann (2009)**
abandoned land	**0.4 billion ha**	**27 EJ/a**	**Field et al. (2008)**
marginal and degraded land	**1.1 – 1.4 billion ha**	**150-200 EJ/a**	**Cai, Zhang, Wang (2011)**
		90 EJ/a	**Wicke (2011)**
water-scarce, marginal + degraded lands		**70 EJ/a**	**ECN et al. (2009)**

Source: own calculations

The data given above are from global studies **without** ground truthing – but our country studies show that a correction factor is needed, i.e. approx. 20% of the overall potential could be a conservative estimate.

This would translate in an overall potential of some **5% of global energy demand.**

The **most important aspect** of using degraded land for biomass cultivation is **not** the energy this could provide, though: It is the perspective to convert the degraded land – over several rotation periods – **back into arable land** with significant soil organic carbon. Surely, degraded land can be restored without going through a biomass cultivation cycle, but costs for doing so would be prohibitive if no revenue from biomass is available.

Thus, the "willingness to pay" for low-ILUC biomass feedstocks cultivated on degraded land is key to the concept. It must be noted, though, that there are many obstacles to be overcome before degraded lands will be turned into biomass cultivation sites:

- Often, degraded land is very remote, with no adequate access due to missing infrastructure. Investment costs to extend transport systems can be high and need to be distributed over many actors and hectares to reduce specific costs.
- Water availability is a pre-requisite – even drought-tolerant plants need water during the establishing of the culture.
- Cultivating biomass crops sustainably on degraded land requires low-input (preferably perennial) cultivation systems which in turn require labor-intense preparation, and provide comparatively low yields. "Magic" plants such as Jatropha reveal their real opportunities only if village- and farmer-based concepts are realized instead of plantation-style agro-industrial approaches. It should be further noted that there are many more possibilities to grow plants even in semi-arid areas and on degraded, low-precipitation land than Jatropha, but agricultural research is lacking[11].
- **Social** displacement must be considered carefully, as degraded land might not only harbor endangered species, but also be the only opportunity for landless people to sustain their lives though subsistence farming, and extensive herding[12].

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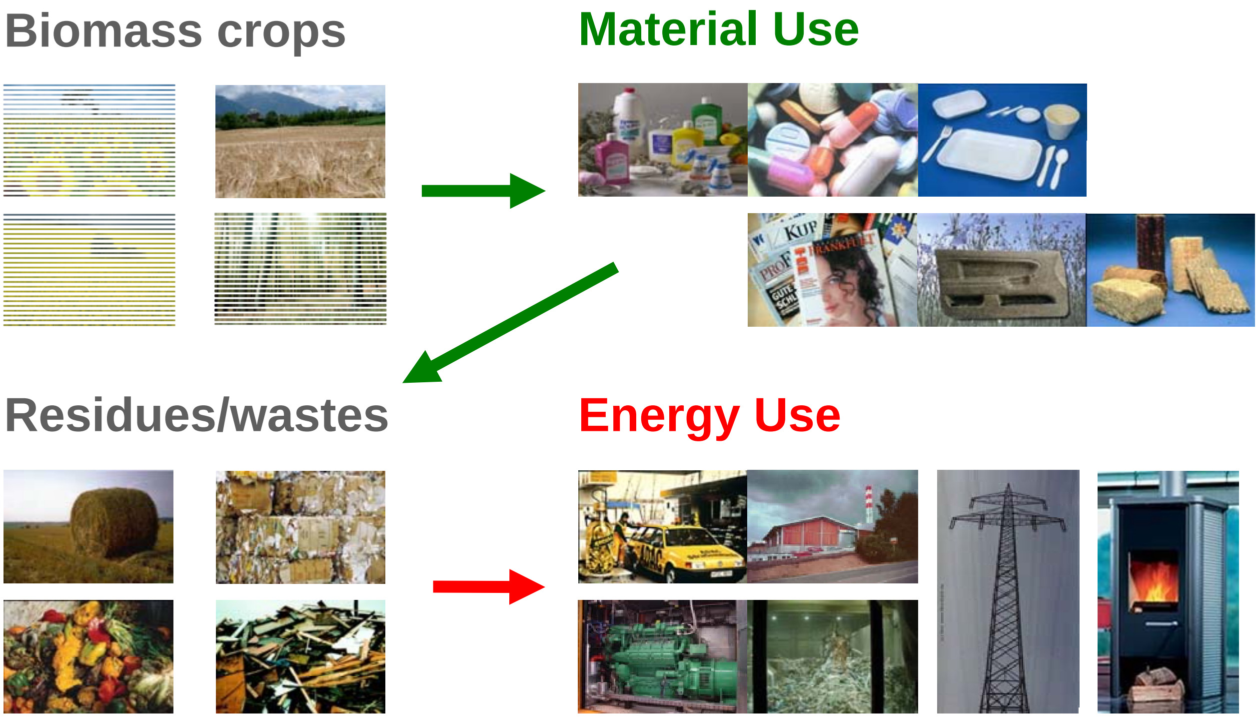
11 JRC (European Commission Joint Research Centre)/EEA (European Environment Agency) 2006: Proceedings of the Expert Consultation Meeting "Sustainable Bioenergy Cropping Systems for the Mediterranean" Madrid, February 9-10, 2006; organized by the European Commission Joint Research Centre (JRC-Ispra IES) and the EEA together with CENER and CIEMA http://re.jrc.ec.europa.eu/biof/pdf/documents/madrid_bioenergy_cropping.pdf

12 See Sugrue (2008) for a brief discussion, and the results of the international workshops on "degraded land mapping" (http://www.bioenergywiki.net/index.php/Joint_International_Workshop_Mapping and http://www.bioenergywiki.net/index.php/2nd_Joint_International_Workshop_Mapping) as well as the country reports from the "Bio-global" project (OEKO 2010).

6 Increasing Overall Land-Use Efficiency of Biomass Use

Finally, biodiversity impacts could be reduced and overall opportunities from bioenergy could be increased if the use efficiency throughout the biomass life-cycles were improved.

As a key longer-term approach for this, the so-called "cascading use" of biomass has been suggested (OEKO/IFEU 2010). The principle is shown in the following figure.



Source: Oeko-Institut

The "cascade" begins with crops (cultivated on land **not** in competition with food & feed, and biodiversity) which are used **first** for "material services", e.g. as fiber or plastics.

Once the products made from this biomass reached the end of their useful "life" (after one or more recycling stages), the heating value of the biomaterial is still available and could be recovered for energy uses.

7 Some Conclusions

Bioenergy has opportunities for improving sustainability, but its **development needs “steering”** – otherwise, risks are high that negative impacts prevail, especially through unintended indirect effects.

The new GBEP Sustainability Indicators (see GBEP 2011) could help assuring adequate country policies and strategies, building on earlier work regarding environmental (OEKO/IFEU/CI 2010) and social (FAO 2011b) safeguards.

As agriculture is often underdeveloped, investment in bioenergy **can help** improving yields and infrastructure. **Intercropping** with food, agroforestry, use of residues and “freed” land from improved agriculture **are key**.

Furthermore, **reducing food waste** is also important to “free land” (FAO/SIK 2011), and logistics (e.g. food/feed distribution) as well as infrastructure (e.g. storage) have relevant roles in minimizing waste (BIO 2010).

Besides improving yields and reducing food losses, **change in diets** especially in industrialized countries and emerging economies are of highest importance for future land use (PBL 2011; WBGU 2011). Due to the link between meat (and dairy) production and land use, both directly for grazing, and indirectly from land needed to grow feed, **reducing meat production** could “free” not only land, but would create also other benefits such as reduced GHG and nitrogen emissions (IFF 2009).

With regard to developing countries, bioenergy can contribute to rural development and income, and increase access to modern energy which both can help to reduce deforestation pressures, while reducing GHG emissions (Best et al. 2008).

Cultivation of perennial crops on low-carbon and degraded land improves the C balance and helps restoring soils. After a few rotations, land could be used again for food/feed production so that biomass cultivation should be seen as an **interim step** which reduces land competition.

In the longer-term, biomass from cultivation should be used first for biomaterials, and only the biogenic wastes should be used for bioenergy. This “cascading use” would avoid competition between bioenergy and biomaterial markets which both are assumed to grow in the future.

Further pressure on biodiversity arising from increased biomass cultivation can (and must) be avoided through land-use planning and “zoning”, and through biodiversity-compatible land use management.

Thus, **de-coupling both** arable land use and food/feed crops from biomass cultivation is the fundamental base for longer-term sustainable biomass development. It will require a “great transformation” in the way agriculture, energy, food and fiber are managed, and how people participate (WBGU 2009; 2011).

All of this may not be cost-effective, but it may well be worthwhile still.

8 Outlook: Sustainable Requirements for All Biomass

The future will show increased **links** between biomass markets (agriculture, energy, forestry) so that **consistent** – although not necessarily identical – sustainability requirements are needed in order to avoid shifts and "transfers" between markets.[13]

The issue of iLUC has received global concerns especially in the biofuels discussion, but it is relevant for **all** incremental biomass uses. Thus, an accounting approach is needed at the global level for all biomass and land-using products (WBGU 2009), as well as for integrating food and fuel demands (von Braun 2010).

It has been shown that **in principle,** sustainability criteria and indicators for bioenergy can be transferred to **all** biomass (OEKO/IFEU 2011), but further discussions and research is needed to determine the specific requirements for e.g. food, feed, and biomaterials provision.

Disregarding those open questions, sustainable biomass potentials are likely to be sufficient to allow biomass to continue playing a significant role in future global energy supply even if stringent sustainability requirements are to be met and demands for bio-based products continue to grow.

Still, the overall first priority should be given to ensure food security, and maintain biodiversity. Careful, “pro-poor” oriented sustainable bioenergy development will have to be considered as one of the key options in that regard, and **better** use of biomass for energy is a prerequisite also for industrialized countries (CE/OEKO 2010).

13 The consistent application of the GHG life cycle assessment to **all** biomass types cultivated on **all land** would especially solve the problem of "indirect" effects of growth in one sector on related submarkets, and thus the issue of GHG emissions from indirect LUC.

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