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Sustainable Bioenergy: Key Criteria and Indicators

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Contents

Preface

This paper was prepared within the Biomass Futures project[1], and is based on previous work of Oeko-Institut from 2005-2011, funded by a variety of donors, and carried out in cooperation with several partners[2].

It represents Deliverable D 4.1 of the Biomass Futures project, and the authors hope that it will provide orientation and beneficial information to those working towards sustainable bioenergy production and use.

This paper is a revised version based on the April 2011 draft which received extensive feedback and valuable comments from stakeholders and interested parties during project workshops and teleconferences as well as by emails and in bilateral discussions. The authors **appreciate all comments received and are grateful for the excellent inputs**.

The paper also benefitted from intense discussions on sustainability criteria and indicators for solid bioenergy[3].

Still, the sole responsibility for the content of this publication lies with authors.

It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.

Darmstadt, March 2012 Uwe R. Fritsche

1 "Biomass Futures: Biomass role in achieving the Climate Change & Renewables EU policy targets. Demand and Supply dynamics under the perspective of stakeholders" (www.biomassfutures.eu) funded by the Intelligent Energy Europe programme of the European Commission, DG Energy (IEE 08 653 SI2. 529 241).

2 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, Copernicus Institute, DBFZ, DLR, Ecofys, IFEU, IUCN, JGSEE, SEI and WWF, and the participants and observers of the GBEP Sustainability Task Force, those participating in the CEN/TC 383 process, and IEA Bioenergy colleagues.

3 See 1st and 2nd Joint Workshops on extending the RED sustainability criteria to solid bioenergy: http://www.oeko.de/service/bio/en/bru_ws.html and http://www.oeko.de/service/bio/en/hag_ws.html

Introduction

The use of biomass for energy and materials, as well as for food, feed and fiber is rising globally in parallel with increases in population, income, fossil energy prices, and concerns about energy security, and climate change (OECD/FAO 2009; IEA 2011+2012). 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 2010+2011a+b; IEA Bio 2011).

Biomass production and use for electricity, heat and transport fuels will continue to increase, with global trade in biomass rising in parallel (IEA 2011+ 2012). Currently, only about 2% of biomass used for energy purposes (including liquid biofuels) is internationally traded, representing a small mass share (< 1%) of the total world trade in all biomass, i.e. industrial and agricultural products (Heinimö, Junginger 2009; Heinomö 2011; Junginger 2011).

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[4].

This paper provides a compilation of science-based criteria and indicators to determine the sustainability of bioenergy production. This list was derived from a variety of activities to establish sustainability schemes especially for biofuels, but is **not** restricted to indicators and criteria being compatible with current trade law.

The aim was to identify, define and quantify (where possible) the main sustainability criteria and indicators and to provide input to the Commission on possible "RED plus" criteria and indicators. The work builds on existing activities, but goes beyond:

The current voluntary certification systems have limited scope with regard to quantitative requirements for bioenergy (e.g. focus on liquid biofuels, exclusion of quantitative GHG reduction levels), and lack of a consistent approach for bioenergy in general. The sustainability issues addresses here focus on

- dealing with direct and indirect land use change, and biodiversity
- dealing with impacts on air, water and soil quality
- dealing with (global) food security impacts, and specifying other relevant social criteria and indicators

in order to establish a coherent and consistent set for **all** bioenergy applications across the heat, electricity-CHP and transport sectors.

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4 It should be noted that environmental and social impact of bioenergy were discussed critically already in the 1990s (OTA 1993). A few sources for the more recent discussion are Best (2008); CBD (2010); CCC (2011); CE. OEKO (2010); CIFOR (2010); ESA (2010); FAO (2012c); GNESD (2010); IEA Bio, IEA RETD (2009); MNP (2008); OEKO, IFEU, CI (2010); PBL (2012); UN-Energy (2007); UNEP-IRP (2009); WBGU (2009)

Sustainability Criteria and Indicators for Bioenergy

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[5].

The EU Renewables Energy Directive (RED) adopted in April 2009 (EC 2009) 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 2012, 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)[6].

In the US, negotiations concerning federal biofuel standards were completed in May 2010 with a final rule of EPA on GHG emissions[7], whereas the Low Carbon Fuels Standard (LCFS) has already been implemented in California[8], also regulating GHG 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.

UN Energy organizations such as the FAO and UNEP as well as UNCTAD and especially the Global Bioenergy Partnership (GBEP)[9] are taking on the task to support developing countries in such activities, with parallel efforts from bilateral donor organizations such as DFID, GIZ, NL Agency, SIDA, and USAID, among others.

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

6 On extending the RED to solid bioenergy see http://www.iinas.org/Work/Projects/REDEX/redex.html

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

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

9 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, refer to www.globalbioenergy.org

The Sustainability Task Force of the GBEP worked out an agreed list of sustainability indicators **for the national level** which could provide a base for global (voluntary) implementation. This list was endorsed in November 2011 (GBEP 2011).

FAO and UNEP have jointly developed the Bioenergy Decision Support Tool (FAO, UNEP 2011), and FAO (2012c) gives a further compilation of available tools.

The Inter-American Development Bank (IDB) has developed a Biofuels Sustainability Scorecard to screen biofuel projects under consideration for financing, based on the RSB criteria (IDB 2009).

The Global Environment Facility (GEF) has funded work to establish sustainability requirements for biofuels projects to be funded (IFEU, CI, OEKO 2012),

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 indicate 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[10] and on positive of negative impacts of increased bioenergy production on food security, or its (again: positive or negative) social effects.

In the following, the key criteria and respective indicators for bioenergy sustainability are presented as a contribution to the ongoing discussion.

It should be noted that the **economic** dimension of sustainability is **not** addressed here, as criteria and indicators are meant for economic **operators** who presumably are taking economic considerations into account on their own.

The presentation is structured in a manner that criteria (key sustainability issues) are presented as individual subsections, and respective indicators (metrics to measure) are summarized in the subsections.

The approach taken in this paper is to suggest a possible “RED plus” set of criteria and indicators, i.e. the existing RED criteria are considered as given, and only **additional** criteria and indicators or **more stringent** versions are presented here to allow for a broader representation of sustainability requirements for bioenergy aiming at the 2030 time horizon.

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10 with the noteworthy exception of the mentioned US EPA rulemaking for the RFS-2 and the LCFS in California, see footnotes 7 and 8.

Standards, Criteria and Indicators: A few words on nomenclature

Standards and **principles** are commonly formulated around a core concept based on societal ethics, values, and tradition as well as on scientific knowledge. Standards are used as the primary framework for the general scope and provide the justification for criteria, indicators and verifiers.

Criteria can be seen as ‘second order’ principles that add meaning and operationability to standards/principles without being a direct measure of performance. Criteria are intermediate points to which information provided by indicators can be integrated, facilitating an interpretable assessment.

Indicators are quantitative or qualitative factors or variables providing means to measure achievement, to reflect changes, or to help assess performance or compliance, and - when observed periodically - demonstrate trends. Indicators should convey a single meaningful message (information). Indicators have to be judged on the scale of acceptable standards of performance. Closely related indicators are **verifiers** which provide specific details that would indicate or reflect a desired condition of an indicator. They are the data that enhances the specificity or the ease of assessment of an indicator, adding meaning, precision and usually also site-specificity.

Monitoring refers to the continuous or frequent measurement and observation on specified indicators, often used for warning and control.

Certification is the (usually) third-party attestation related to products, processes or systems that - following (independent) review - conveys assurance that specified requirements such as conformity to standards have been demonstrated.

In this paper, we refer to criteria and indicators as items to be used in a **legal context requiring compliance** with given standards, targeting economic operators in the bioenergy realm.

In a broader sense, criteria and indicators can be used also for monitoring the state (or dynamics) of countries or regions to allow for evaluating observed trends against desirable states or conditions, or to inform about broader policy impacts.

Source: own compilation based on EC (2010c); FAO (2002); http://stats.oecd.org/glossary/index.htm; http://glossary.eea.europa.eu/terminology/terminology_sources_html

Criterion 1: Sustainable Resource Use

Biomass is a renewable resource, but two specific features distinguish it from all other renewable energy sources:

- The conversion efficiency of solar energy into chemical energy in plants is only 1-3% which implies significantly more land needed to indirectly harvest solar energy through terrestrial biomass cultivation than through more concentrated hydro, direct solar or wind energy systems[11].
- Biomass is the "stuff of life" on this planet so that changes in biomass production, e.g. replacing natural vegetation with cultivated plant varieties, collecting forest residues, or improving crop yields, could have positive or negative impacts on ecosystem services, carbon balances, and human livelihoods.

Thus, **land** is a **fundamental** issue closely related to biomass in general, and to bioenergy in particular. Therefore, the sustainability of bioenergy depends on the productivity of the land use[12].

As bioenergy can also be derived from biogenic residues and wastes stemming from various flows of biomass which has **previously** being grown, harvested and processed for **non**-energy purposes, the efficiency of converting such "secondary" biomass resources into useful energy products is another aspect of sustainable resource use needed to be addressed.

Indicator: Land Use Efficiency

The productivity of converting cultivated bioenergy feedstocks into useful energy products such as gaseous, liquid or solid bioenergy carriers, expressed in terms of available bioenergy carriers per hectare of cultivated area, should be set to a **minimum net energy yield**.

As both cultivation and conversion systems evolve over time, these minimum requirements should be set to different levels for 2020 and 2030 to factor in the learning curve for yields and conversion efficiencies.

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[11] See Table 1 in the Annex for data on life-cycle land use figures for non-renewable and renewable electricity compared to biomass-derived electricity: The overall life-cycle land use intensity of bioelectricity systems (using maize or short-rotation coppices as feedstock) is in the 2030 time horizon around 100-150 m^2/GJ_{el}, while direct solar systems need 2 (CSP in Spain) to 3 m^2/GJ_{el} (PV in Germany), and onshore wind parks require a maximum of 0.3 m^2/GJ_{el}. Fossil fuel and nuclear-based powerplants in 2030 will need again less land (0.02-0.1 m^2/GJ_{el}). Thus, the land use intensity of bioelectricity from biomass cultivation is approx. 50 times higher than direct solar, and 300 times higher than from onshore wind.

[12] Possible effects of land use changes associated with the incremental production of bioenergy are discussed in Criterion 3 (see Section 0) with regard to GHG emissions.

Furthermore, crop yields depend on cultivation system, input levels, bioclimatic conditions, and overall land suitability. Thus, a further differentiation is needed to account for land productivity categories.

In the Annex, results of respective calculations are given for various “settings” to produce liquid biofuels, and solid and gaseous bioenergy carriers[13].

From this data, the following **minimum net energy yield** requirements for bioenergy carriers were derived:

Setting	2020	2030	unit
smallholder, marginal/degraded land	>25	>35	GJ_{bio}/ha
plantation, marginal/degraded land	>50	>75	GJ_{bio}/ha
plantation, arable land*	>100	>150	GJ_{bio}/ha

*Source: compilation by Oeko-Institut; * = mainly for intercropping, agro-forestry systems, etc.*

In calculating the net bioenergy yield (or bioenergy productivity), by- and co-products along the bioenergy life cycles need to be taken into account[14].

Indicator: Secondary Resource Use Efficiency

For bioenergy carriers stemming from the conversion of secondary biomass resources such as residues and wastes, a minimum efficiency, expressed in terms of the heating value of the bioenergy output divided by the heating value of the secondary resource input, should be set to increase the resource-efficient use of those resources.

Taken into account the results of model calculations[15], the minimum conversion efficiencies for biofuels should be set to 55 % by 2020, and 60% by 2030 for biodiesel, and 50 % by 2020 and 55 % by 2030 for ethanol, and 65 % for biomethane (2020 and 2030), again taking into account by- and co-products along the product life cycles.

For conversion to solid bioenergy carriers (chips, pellets etc.), no minimum requirement is necessary, as their conversion efficiency is typically > 85%.

[13] See Table 2 in the Annex for data on life-cycle land use figures for land use productivity of various bioenergy carriers in the EU (2020-2030), and Table 3 and 4 for biofuel settings outside of Europe.

[14] For this, the EU RED approach for factoring in by- and co-products into the GHG emission balance by energy allocation should be used for the land use efficiency as well, i.e. only the energy available in terms of the heating value of the main bioenergy products can be considered for the land-use productivity. If electricity or heat is co-produced and used, their energy value should be attributed to the total productivity, taking into account a multiplier of 2.5 for electricity fed into the grid.

[15] See Table 5 in the Annex for data on life-cycle resource efficiency results for secondary bioenergy resource conversion to biofuels, including biomethane (compressed).

Criterion 2: Biodiversity

The possible effects of biomass cultivation on biodiversity are manifold, ranging from LUC-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.

Indicator: 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. In order not to further increase this trend by 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[16], 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. The **target** should be that **by 2020**, **all** land with a potential for biomass cultivation should be fully recognized in a global GIS database sufficiently in resolution to unanimously identify high-biodiverse areas[17].

Indicator: Land management without negative effects on biodiversity

It is internationally acknowledged that protecting biodiversity in protected zones alone is insufficient to halt the decline of global biodiversity, and especially agro- and forest biodiversity. Therefore, specific activities to cultivate and harvest bioenergy crops and to manage agricultural and wood residue extraction have to be addressed in terms of their compatibility with biodiversity in general, and agrobiodiversity in particular.

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16 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.

17 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.

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.

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

For the extraction of forest residues, the discussion on limitations and thresholds to protect forest biodiversity is ongoing[18]. Thus, no “final” requirement can be derived yet, but need to specified by 2020.

As all of these attributes are scale- and landscape-dependent, the only overall rule is to maintain ecosystem services. The indicator needs spatially disaggregation into agro-environmental zones or similar metrics, and substantiation with regard to different cultivation systems and management practices (especially for forests) within those zones.

As a **target for 2020**, the overall metrics of maintaining ecosystem services should be established and be implemented as indicators.

18 See http://www.iinas.org/Work/Projects/REDEX/redex.html

Criterion 3: Climate Protection

From the environmental policy point of view, using bioenergy sustainably can considerably contribute to climate protection. Thus, giving proof that it contributes towards reducing greenhouse gas (GHG) emissions throughout the entire life cycle is a crucial criterion.

The EU RED requirements for achieving minimum reduction levels (compared to a fossil fuel comparator) of initially 35%, and raising to 60% by 2017 is a good start, especially as GHG effects from direct land use changes (LUC) must be factored into the calculation. Still, there is a longer-term perspective on GHG reduction needed to avoid lock-in effects, and the issue of GHG emissions from indirect land use changes (ILUC) must be taken into account as well.

Indicator: Life cycle GHG emissions and direct land use changes

To ensure that GHG emission reductions from bioenergy are compatible with the longer-term requirement to decarbonize economies by more than 80%, the RED minimum reduction levels for bioenergy should be set also for the 2020 and 2030 time horizons, and should use different fossil fuel comparators to reflect the different market conditions in the electricity, heat and transport fuel sectors.

For bioenergy-based transport fuels, the minimum GHG reduction requirements against the oil-based comparator should be set to 67% by 2020, and be increased to 75% by 2030, taking into account the full life cycles of the bioenergy production, and direct land use changes from bioenergy feedstock cultivation (on land being converted after Jan. 1, 2008).

For bioenergy carriers being used for electricity and heat, the minimum reduction requirements should be based on **natural gas** as comparator, and be set to 55% by 2015, 60% by 2020, and increased to 75% by 2030, taking into account direct LUC.

Furthermore, the extraction of **residues** from agriculture (DBFZ, TLL, ILN, OEKO 2011) and forests (Lippke 2011; Malmsheimer 2011; Whittaker 2011) can significantly impact on the GHG balance due to changes in soil carbon.

Therefore, it should be demonstrated from 2020 onwards that the minimum GHG requirements are met when **soil carbon changes are taken into account**.

Indicator: Inclusion of GHG effects from indirect land use changes

Indirect land use changes (iLUC) occur if a current land use such as food or feed cultivation is crowded out by bioenergy feedstock cultivation. The calculation of CO_2 emissions from displaced land uses is basically the same as for direct LUC. 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[19].

Still, in order to consistently assure net GHG emission reductions from bioenergy development in the longer-term, it is recommended to include a quantitative expression of CO_2 emissions from ILUC in the calculation of the GHG balances of bioenergy systems, i.e. the minimum GHG reduction requirement presented in Section 3.1 should be achieved taken into account an ILUC factor which **develops over time**:

For an initial phase of 2015-2020, the ILUC factor should be in the order of 3.5 t CO_2/ha/year (according to OEKO 2011), and be applied for any bioenergy feedstock cultivation established on previously used agricultural land (including grassland and pasture land). Similar to the direct LUC effects, the cut-off date Jan 1, 2008 should be used, i.e. bioenergy feedstock cultivation on land being already used for this purpose before that date should be considered as ILUC-free.

In addition to grandfathering land cultivated before 2008, a zero ILUC factor should be applied for bioenergy cultivation on land **not** in competition (e.g. unused, abandoned, or degraded areas) and not in conflict with biodiversity protection.[20]

For the time after 2020, a revised ILUC factor should be determined by 2018 which reflects any progress regarding international policies to contain or reduce LUC effects in agriculture and forestry, especially progress on LUC accounting under the UNFCCC, and effectiveness of the REDD scheme currently being introduced in the follow-up to the Cancun Conference.

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. Once full implementation is achieved, the ILUC factor can be reduced to zero.

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19 It is beyond this working paper to fully reflect the ILUC discussion. Interested parties are referred to recent studies, especially and CI/LEI (2011), Ecofys (2010), JRC-IE (2010); JRC-IPTS (2010), ICONE (2011), IEA Bio (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). It should be further noted that during 2012, ILUC will be subject to continuing discussions in the EU, the US and the GBEP.

20 for details see Wicke (2011) and results of international workshops on biodiversity mapping and degraded land: http://www.bioenergywiki.net/index.php/Joint_International_Workshop_on_High_Nature_Value_Criteria_and_Potential_for_Sustainable_Use_of_Degraded_Lands#Workshop_Outcome and http://www.bioenergywiki.net/index.php/2nd_Joint_International_Workshop_Mapping

Criterion 4: Soil Quality

Soils are the literal fundament of cultivating both bioenergy feedstocks, and biomass for food, feed and fiber. Thus, ensuring and sustaining soil quality is fundamental for the future productive use of land as well as for biologically sequestering carbon, and for hydrological functions such as buffering and filtering.

Indicator: Avoid Erosion

The establishing of bioenergy crops and their cultivation can, similar to other agricultural production, directly lead to loss of topsoil, and can indirectly increase erosion by soil compaction. There are bioenergy feedstock cultivation systems and practices which avoid erosion, though, and their application should become mandatory not later than by 2020. For this, a list of cultivation systems and practices must be developed which are acknowledged as “zero erosion”.

Indicator: Soil Organic Carbon

To assure that the cultivation systems and practices maintain or improve soil quality, the soil organic carbon content of land being used for bioenergy feedstock cultivation or for extracting surplus biomass growth (e.g. grass cuttings from permanent grassland) must be at least maintained. This requirement should become effective for all bioenergy systems by 2015.

Indicator: Nutrient Balance of Forested Soils

For the extraction of forest residues, the discussion on limitations and thresholds to protect forest soils with regard to nutrient balances is ongoing[21]. Thus, no “final” indicator can be derived yet, but need to specified by 2020.

As nutrient balances are location-dependent, the indicator needs to be spatially explicit. It is recommended to develop traffic-light soil maps which identify “go” areas (those insensitive to nutrient depletion), “warning” areas where nutrient balance needs consideration (e.g. with regard to amelioration, biomass ash recycling etc.), and “no-go” areas which would undergo nutrient depletion if forest residues would be extracted beyond the balancing level.

As a **target for 2020**, a generic traffic light system for soil maps should be established and be implemented as an indicator.

[21] See http://www.iinas.org/Work/Projects/REDEX/redex.html

Criterion 5: Water Use and Quality

Cultivating biomass with high productivity and conversion facilities for bioenergy carriers both need water. Furthermore, pollutant emissions to water bodies and negative environmental consequences of (inappropriate) irrigation could occur.

Indicator: Water Availability and Use Efficiency

Water for irrigation of bioenergy feedstock cultivation and for process water used in bioenergy conversion facilities must, together with existing agricultural, industrial and human (residential) water uses, not exceed the average replenishment from natural flow in a watershed, expressed in total actual renewable water resources (TARWR). The water use efficiency of existing and new uses can be increased to compensate for additional water requirements of bioenergy feedstock cultivation or conversion, though.

Furthermore, the establishment of new bioenergy cropping systems and bioenergy conversion facilities must be placed outside of areas with severe water stress.

For both water indicators, GIS-based mapping is needed with adequate spatial resolution, and the seasonal variations of water flows must be considered.

Thus, these indicators need significant data development before being subject to use in operational requirements for bioenergy so that the water requirements should be introduced by 2020.

Indicator: Water Quality

The monitoring and limiting of pollutant loadings to waterways and water bodies attributable to bioenergy feedstock cultivation and effluents from bioenergy processing should be required for all bioenergy by 2015. The metrics of this indicator should cover annual nitrate, phosphorous and pesticide loadings, and the biochemical oxygen demand of effluents. Due to the large regional variation of pollutant loadings, no general thresholds can be suggested.

Criterion 6: Limit Airborne Emissions

Airborne life-cycle emissions of non-GHG pollutants[22] from bioenergy should be limited to a maximum of those of competing fossil energy.

For the EU and OECD countries in general, emissions from modern gas-fired systems (electricity, heating, transport) should be the benchmark.

In developing countries, the generic benchmark should be oil-based, and in developing countries and emerging economies with a share of more than 50 percent of coal in the energy matrix for heat and electricity, the benchmark should be coal.

Indicator: Emissions of SO_2 equivalents

Economic operators must demonstrate that the life cycle emissions of SO_2, NO_x, NH_3 and HCl/HF from bioenergy provision, expressed in SO_2 equivalents and calculated in accordance to the life cycle emission methodology for GHG, are lower than the respective benchmark. If parts of the bioenergy life cycle emissions occur in non-EU or non OECD countries, this share is to be compared to the respective benchmarks of the non-OECD countries.

The EC JRC will develop default data for SO_2 equivalent emissions from key bioenergy life cycles, and the respective benchmarks.

Indicator: Emissions of PM_{10}

The methodology to quantify and limit emissions of particulates in the micro scale should be the same than for SO_2 equivalents.

22 The GBEP Sustainability Task Force proposes to also include air toxics (e.g. heavy metals, volatile organic compounds) in this indicator. Due to restrictions of available data and severe data uncertainties and variability, we refrain from doing so here.

Criterion 7: Food Security

Food security is a key element of social sustainability, and is defined by FAO as follows: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".[23]

Land used to cultivate biomass feedstocks for bioenergy in general, and for biofuels in particular, is a limited resource that may already be in use, so that increased competition for this land might affect food security both directly in crowding out food and feed production, and indirectly through food and feed price feedbacks.

It must be ensured that bioenergy feedstock production does not directly worsen food security in the country or region where the bioenergy feedstock cultivation occurs.

High levels of price variability (i.e. volatility) tend to have negative impacts on food security, especially in net-food-importing countries and for net-food-purchasing (and in general vulnerable) households. The prices of main staple crops determine together with the income levels the ability of households to ensure food security in terms of affordability.

Indicator: Price and supply of national food basket

The indicator aims to measure the impact of bioenergy use and domestic production on the price and supply of a food basket in the context of all relevant factors. The food basket is defined on a regional and/or national level and includes staple crops, i.e. the crops that constitute the dominant part of the diet and supply a major proportion of the energy and nutrient needs of the individuals in a given country. In addition, the indicator aims to assess the impact of changes in the prices of the food basket components on the national, regional and household welfare levels.

This indicator is strongly inter-related with numerous issues of sustainability including land use, infrastructure and income.

The measurement of this indicator consists of five steps, plus additional methodologies for the assessment of the welfare impacts at national and household levels (GBEP 2011):

1. Determination of the relevant food basket(s) and of its components;
2. "Initial indication" of changes in the price and/or supply of the food basket(s) and/or of its components in the context of bioenergy developments;
3. "Causal descriptive assessment" of the role of bioenergy (in the context of other factors) in the observed price increases and/or supply decreases; and
4. Computable general equilibrium (CGE) or Partial equilibrium (PE) modeling of the impacts of bioenergy production and/or use (in the context of other factors) on the price and supply of the food basket(s) and its components.

[23] World Food Summit, Rome 1996

The following data will be required to determine the indicator:

- Calorie contribution by crop;
- Production of main staple crops (both nationally and regionally/locally);
- Changes in stocks of main staple crops;
- Exports and imports of main staple crops;
- Energy costs and their impact on agricultural production and distribution costs;
- Impacts of weather on crop production;
- Price inflation;
- Change in demand for foodstuffs;
- Shares of main staple crops used for food, feed, fibre and fuel;
- Prices of main staple crops;
- Household income and expenditure by crop; and
- Data required for the Causal Descriptive Assessment (see annexed table).

These data, collected at the national or regional level can be sourced from national or international statistical accounts. If necessary, these data can be gathered through interviews and surveys.

It should be further considered to test the new approach developed by FAO BECSI which translates the GBEP food security indicators to the economic operator level (FAO 2012b).

Criterion 8: Social Use of Land

Land use is not only a key issue for biodiversity and climate protection, but also has direct implications in the social realm.

As bioenergy development could be socially beneficial from a development point of view, possible negative impacts associated with land use should be minimized in the near-term and avoided in the longer-term.

The social use of land is primarily related to the theme of access to land, water and other natural resources. Land access is a consequence of land tenure. From a social sustainability perspective, this might be one of the major concerns associated with bioenergy development in some areas.

The social sustainability of bioenergy development is directly related to changes in land tenure and access. In many developing countries no land market has been established. The local poor population grow agro-products (food and feed mainly) even without having any kind of legal title or security of the land used. Similarly, common permanent meadows and pasture lands are essential to communities' livelihoods that depend on breeding livestock and consuming livestock sub-products. When arable lands and lands under permanent crop, permanent meadows and pastures and forest areas are given in concession or leased to private bioenergy investors, the local poor population might lose their capabilities to ensure their life subsistence.

Indicator: Allocation and tenure of land

This indicator aims to measure the percentage of land – total and by the land-use types which has been leased by the state or a domestic authority and/or sold through one-to-one negotiations to individual or corporate investors for new bioenergy production. Therefore, these investors will want to secure their new lands and will intend to receive some kind of formal contract or titles from the government. This indicator would serve as a proxy to assess how new bioenergy production and use influence land tenure as well as local communities livelihood conditions and land customary rights. Measuring changes in land tenure might help to assess how bioenergy activities might influence the social sustainability of local populations in developing countries.

The indicator aims at measuring two aspects:

- degree of legitimacy of the process related to the transfer (i.e. change in use or property rights) of land for new bioenergy production. This legitimacy can stem from either a legal process or a socially recognized domestic authority, including customary ones.
- extent to which due process is followed in the determination of the new title. Following due process with regard to land transfers means that all procedural requirements are followed, including the assessment and recognition of the rights of current owners and users under the national legal framework and customary practices; and compensation measures according to the assessment results.

The indicator should take into consideration the national-level elements such as the policy and legal framework, and national practice related to informal authorities and processes. Regarding the latter, in addition local-level information might help the elaboration of the indicator value by providing examples and empirical information that prove or disprove an impact of bioenergy on social sustainability and land tenure. Information regarding protected areas or forest concessions might not be available or already collected by the government. In this case, NGO/research organizations could develop studies at the very local level.

The indicator will be based on the following data collection:

- Land area (ha and percentage of total country land area) used as common or open access land by local population, and land privately owned by local population, then given in concession to new bioenergy investments in bioenergy production areas (BEPA). Special relevance should be given to the overlap of BEPA and community forests and indigenous or poor communities as these are likely to be most dependent on forest resources.
- Titles, contracts and any other formal registration of land tenure held by bioenergy investors and companies that have been registered in a national or local registry/cadastre
- Existence of community/local population rights to lands, amount (ha and %) of lands legally recognized as community/common lands
- Information about qualitative aspects of the issuing of new bioenergy concessions, in particular whether (FAO, 2002):
  a) land rights are granted by constitutions, statutes and official tribunals;
  b) land rights are granted by other laws – customary, informal, secondary, tertiary;
  c) there is security of the aforementioned rights in terms of enforcement and application;
  d) there are land-related or subsidiary rights that women are free to exercise without specific mention in formal or informal laws;
  e) there is effective access to fair adjudication, including the court system or other dispute resolution processes;
  f) the public land allocation procedure has followed due process
  g) land rental and sales contracts including contracts for temporary use agreements are accessible to all;
  h) periodic monitoring is carried out to assess the impacts of bioenergy on changes in access to and use of natural resources by local communities;
- If the land used by investors is recognized as community/common land it is important to gather information regarding mechanisms of participation or consultation carried out by the investors with the local community. If the land is recognized as land with secure rights by national legislation, it is important to gather the evidence of the negotiation agreement for any contingent compensation between the investor and the land owner.

These data can be gathered at the national level through national/international accounts if available, or through interviews and surveys at the household, villages or local government units (districts or regions) level, since these resources tend to stretch beyond administrative boundaries.

Criterion 9: Healthy Livelihoods and Labor Conditions

Human health and labour conditions are closely related, as workers occupied in crop cultivation and harvesting procedures can be exposed to human health risks from pesticides, emissions from burning fields, and occupational risks from e.g. accidents.

Therefore, the key labor standards and principles of the ILO Declaration on Fundamental Principles and Rights of Work must be met which – in addition to meeting the criteria 2-7 – will massively reduce possible negative impacts on the overall livelihoods of people living in bioenergy feedstock cultivation areas.

Indicator: Adherence to ILO Principles for Labor Rights

Biofuel production includes employment opportunities, but labor conditions are key, especially with regard to wages, child labor, and safety. Jobs in the bioenergy sector should adhere to nationally recognized labor standards consistent with the ILO Declaration on Fundamental Principles and Rights at Work. This includes the following ILO standards:

- freedom of association and collective bargaining[24]
- elimination of forced and compulsory labor[25]
- elimination of discrimination in respect of employment and occupation[26]
- abolition of child labor[27], health and safety[28] and
- working conditions and wages[29]-

[24] ILO Convention 87, 98, 135

[25] ILO Convention 29

[26] ILO Convention 100, 111, 169

[27] ILO Convention 138, 146, 182

[28] ILO Convention 155, 164, 183

[29] ILO Convention 1, 116, 131

Outlook: Sustainable Criteria and Indicators for All Biomass

Sustainability criteria and indicators for bioenergy can **basically** be transferred to **all** biomass. However, three problems would have to be addressed in such an endeavor:

- So far, no reference system has been defined for GHG reduction from biomaterials and for food, feed or fiber provision.[30]
- Biomaterials feature a greater variety of co-products than bioenergy so that the appropriate allocation needs further discussion. Multiple material use (cascading, down- and recycling) has also to be considered in that regard.
- For biomaterials, genetic engineering may play an important role, with correspond-ding risks from releasing GMOs[31].This also applies to **algae** which are currently being used as raw materials, but might be used for energy production in the future.

Due to the increased **links** between biomass markets (agriculture, energy, forestry), **consistent** – although not necessarily identical – sustainability requirements are needed in order to avoid shifts and "transfers" between markets.[32]

The issue of iLUC has become an issue of global concern for all biomass uses, so that 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).

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.

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30 However, a conversion of the energy-related requirements to material-related reference variables is basically possible using the calorific value of fossil fuels.

31 This mainly refers to improvements of the **structural properties** of plants supplying renewable raw materials through genetic modification (e.g. higher oil content of soybeans, starch-optimized potatoes, wood poor in lignin, etc.). In the field of bioenergy carriers, GMO are not entirely ruled out, either (e.g., rapeseed). However, GMOs have not played a major role in this field so far because, for the time being, higher yields (e.g. "biogas maize") and tolerances (e.g. to salt), can be achieved by conventional cultivation methods.

32 The consistent application of the GHG life cycle assessment to all biomass types 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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Abbreviations

BioNachVO	German Biofuels Sustainability Ordinance
BioNachSt	German Sustainability Ordinance on Liquid Bioenergy Carriers for Electricity Generation under the Feed-In Law
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BOD	biochemical oxygen demand
BSI	Better Sugarcane Initiative
CBD	United Nations Convention on Biological Diversity
CCD	United Nations Convention to Combat Desertification
CDM	Clean Development Mechanism
CI	Copernicus Institute, Utrecht University
CEN	Comité Européen de Normalisation (Europäisches Komitee für Normung)
CoP	Conference of the Parties (to a UN Convention or Protocol)
CSD	United Nations Commission on Sustainable Development
DBFZ	German Biomass Research Center (Deutsches BiomasseForschungsZentrum)
DLR	German Aerospace Center (Deutsches Zentrum für Luft und Raumfahrt)
EC	European Commission
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCCC	Framework Convention on Climate Change
FSC	Forest Stewardship Council
GBEP	Global Bioenergy Partnership
GDP	gross domestic product
GHG	greenhouse gas(es)
GIS	Geographic Information Systems
GMO	Genetically Modified Organisms
IEA	International Energy Agency
IFEU	Institute for Energy and Environment Research (Institut für Energie- und Umweltforschung)
ILO	International Labour Organization

iLUC	indirect land use changes
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standardization Organization
IUCN	International Union for the Conservation of Nature and Natural Resources
IWMI	International Water Management Institute
JGSEE	Joint Graduate School for Energy and Environment, King Monkut's University of Technology Thonburi (Thailand)
LUC	land use changes
RRM	renewable raw materials
PEFC	Pan-European Forest Certification
RED	EU Directive for the Promotion of Renewable Energy Sources
REDD	Reduced Emissions from Deforestation and Degradation
RSB	Roundtable on Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTFO	Renewable Transport Fuel Obligation
RTRS	Roundtable on Responsible Soy
SEI	Stockholm Environment Institute
UBA	German Federal Environmental Agency (Umweltbundesamt)
UK	United Kingdom
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNIDO	United Nations Industrial Development Organization
WBGU	German Advisory Council on Global Change
WTO	World Trade Organization
WWF	World-Wide Fund for Nature

Annex: Data Background

Table 1 Data for land use from electricity generation in the EU, year 2030

electricity from	land use m^2/GJ_{el}	Note
el-mix EU27	0,29	Excluding transmission and distribution
coal	0,06	import coal (surface mining), new steam-turbine powerplant
lignite	0,10	Lignite in Germany, new steam-turbine powerplant
natural gas	0,02	EU supply mix incl. imports, new combined-cycle powerplant
nuclear	0,04	German supply mix, steam-turbine powerplant
hydro ROR	0,03	100 MW run-of-river plant
wind onshore	0,26	10 x 2 MW onshore wind park
solar-PV-poly	2,7	1 kW_{el} (peak) system, full land use
solar-CSP	1,9	80 MW_{el} system in Southern Spain
geothermal	1,2	1 MW_{el} ORC system
biogas-maize ICE	106	Biogas from maize in internal combustion engine cogeneration plant (energy allocation)
SRC cogen	112	Woodchips from short-rotation coppice in steam-turbine cogeneration plant (energy allocation)
bio-SNG SRC cogen	164	Biomethane from short-rotation coppice in gas-turbine cogeneration plant (energy allocation)
bio-SNG SRC CC	128	Biomethane from short-rotation coppice in gas combined-cycle powerplant

Source: own computation with GEMIS 4.8

Table 2 Data for land use from bioenergy production in the EU, year 2030

bioenergy feedstock	bioenergy output	land productivity GJ_{bio}/ha
rapeseed	1G biodiesel	87
palm	1G biodiesel	154
palm-degraded	1G biodiesel	118
SRC poplar	2G biodiesel	116
switchgrass degraded	2G biodiesel	45
switchgrass pasture	2G biodiesel	75
wheat	1G EtOH	128
switchgrass degraded	2G EtOH	50
switchgrass pasture	2G EtOH	80
SRC poplar	pellets	183
switchgrass	pellets	198
SRC poplar	biomethane	126
switchgrass	biomethane	126

Table 3 Biofuel life-cycle land use productivity for EtOH settings

				$GJ_{biofuel}$/ha	
Country	**Feedstock**	**input level**	**cultivation**	**2010**	**2020**
BR	sugarcane	intermediate	mechanised	131	
BR	sugarcane	high	manual	197	
MZ	sugarcane	intermediate	manual	147	
MZ	sugarcane	high	manual	193	
BR	sugarcane	intermediate	mechanised		138
BR	sugarcane	high	mechanised		207
MZ	sugarcane	intermediate	mechanised		131
MZ	sugarcane	high	mechanised		230
TH	Cassava	low	smallholders		102
TH	Cassava	intermediate	smallholders		108
TH	Cassava	high	plantation		140

Source: own computation with GEMIS 4.8

Table 4 Biofuel life-cycle land use productivity for biodiesel settings

				$GJ_{biofuel}$/ha	
Country	**Feedstock**	**input level**	**cultivation**	**2010**	**2020**
ID	palmoil	intermediate	smallholder	113	
ID	palmoil	High	plantation	120	
CO	palmoil	intermediate	smallholder	133	
MY	palmoil	High	plantation	140	
ID	palmoil	High	plantation		150
MY	palmoil	High	plantation		150
TZ	Jatropha	High	plantation	22	
TZ	Jatropha	Intermediate	plantation	19	
TZ	Jatropha	High	plantation		36
TZ	Jatropha	Intermediate	plantation		31

Source: own computation with GEMIS 4.8

Table 5 Biofuel life-cycle secondary resource use efficiency

			Conversion efficiency*	
Country/Region	**Feedstock**	**Product**	**2020**	**2030**
EU	tallow, waste oil	1G biodiesel	91%	92%
EU	wheat straw	2G EtOH	50%	55%
EU	forest residues	2G biodiesel	55%	60%
EU	organic residues	biomethane	67%	70%
EU	forest residues	biomethane	65%	67%
CN	rice straw	2G EtOH	49%	50%
UA	wheat straw	2G EtOH	50%	51%

*Source: own calculation with GEMIS 4.8; * = expressed as* $GJ_{biofuel}/GJ_{residue}$