RETD
IEA - RENEWABLE ENERGY TECHNOLOGY DEPLOYMENT

IEA Bioenergy

Better Use of Biomass for Energy

Position Paper of
IEA RETD and IEA Bioenergy
December 2009

Lead Author: **Uwe R. Fritsche, Oeko-Institut**
Contributing Authors: **Bettina Kampman, CE Delft**
Geert Bergsma, CE Delft

Better Use of Biomass for Energy

Position Paper of IEA RETD and IEA Bioenergy

December 2009

Lead Author: **Uwe R. Fritsche, Oeko-Institut**

Contributing Authors: **Bettina Kampman/Geert Bergsma, CE Delft**

Contents

Better Use of Biomass for Energy: Key Messages

IEA RETD and IEA Bioenergy present key findings from a joint project on "Better Use of Biomass for Energy" which identifies opportunities

- **of bioenergy for better greenhouse-gas reduction, and**
- **of climate policies for better bioenergy development.**

"Good" biomass for energy could diversify energy supply at reasonable cost, improve trade balances, and provide rural income and employment. Bioenergy could help reduce greenhouse-gas (GHG) emissions from fossil fuels.

Biomass for energy could be **"bad"** if no safeguards are placed against GHG emissions and biodiversity loss from land use change, food insecurity, overuse of water, and mismanagement of soils.

"Better" biomass for energy is needed to increase sustainable energy in all countries, taking into account costs and efficiency.

There is a variety of **substantial options for better** use of biomass for energy **both** on the supply side of biomass, and for its conversion – from electricity and heat generation to providing transport fuels, and biochemicals or biomaterials.

- All countries significantly **underuse** their potentials of sustainable bioenergy, and could use it more **efficiently** in terms of costs, GHG reduction and social impacts. The global potential of biomass for energy **without** degrading biodiversity, soils, and water resources, taking into account growing population and demand, is estimated to be between 25% and 33% of global energy supply by 2050.
- Direct GHG emissions from land use changes (LUC) from expansion of biomass cultivation can **be high** if carbon-rich land is converted, but this can be **controlled** through certification systems, wherever biomass is grown. Technology progress in remote sensing will make monitoring of direct LUC more reliable and cost-effective.
- **Indirect** LUC emissions can be high as well, and are far more difficult to quantify. Indirect effects of bioenergy are, however, direct effects of changes in agriculture, leading to e.g. more deforestation.

  An effective and financially viable scheme for reduced emissions from deforestation and degradation (REDD) would reduce risks of ILUC emissions from bioenergy and improve its overall GHG balance.

Better Use of Biomass for Energy: Key Messages – cont'd

- **Additional options** to minimize ILUC effects are: using residues and wastes; favoring high-efficient bioenergy conversion; using land "set free" through yield increases; using abandoned or degraded land not in competition with food, feed or fiber production. To implement those options, **incentives** need to be considered.
- Multi-year crops, multiple cropping schemes (agroforestry) and land-based algae are critical in shifting towards sustainable production, but depend on **further RT&D successes** to reduce costs and improve overall performance.
- **All** negative effects of biomass for energy production are reduced by implementing **more efficient** conversion systems, especially combined heat & power (CHP), next-generation biofuels, and integrated biorefineries.
- **"Better"** depends on which sector or end-use combination will use biomass. As countries and regions differ in supply mixes for electricity, heat, and transport, **generic indicators** to measure and assess "better" are suggested.
- Better use of biomass for bioenergy will **change over time**: future pathways depend on achieving technology development goals through learning which is subject to rising market shares, which in turn depend on successful RT&D efforts.
- In coupling conversion systems with Carbon Capture & Storage (**CCS**), sustainable bioenergy could be a **key long-term option to reduce atmospheric CO_2 levels**
- Given the different situations in countries, "better" needs to be considered along **road maps** depicting possible routes into national bioenergy futures.
- There are **critical milestones** of better use of biomass for energy which call for flexibility to avoid potential lock-ins:
    - In **most** countries, the near-and medium-term "best" use of biomass for energy is in electricity and heat production, and less for transport fuels.
    - Up to 2050, stringent climate policy targets might require **coupling bioenergy with CCS** to reduce CO_2 in the atmosphere, and **shifting** biomass use to road, ship and aviation fuels.
    - Biomass for energy cultivation of perennial crops on low-carbon land could help sequester atmospheric carbon in soils, and could reduce deforestation pressures through economic development alternatives, and through providing access to modern energy.
    - For this, strong efforts in bi- and multilateral collaboration, and private sector involvement are crucial and must be combined with careful evaluation of "better" use from national and international perspectives, taking into account economic and social tradeoffs.
- Better bioenergy should receive policy support for substituting fossil fuels to the extent that reducing **net** GHG emissions, maintaining biodiversity, energy security, and low social tradeoffs can be **demonstrated**.
- **Performance-based policies** seem suitable to provide incentives proportional to the benefits delivered.

Bioenergy: the Good, the Bad, and the Better

All countries need options to solve energy security and environmental challenges arising in the coming decades, with food security being a special challenge for developing countries. In all of that, bioenergy can play a **major role** (see Box 1):

- Biomass for energy could be **"good"** to diversify energy supply at reasonable cost, and to improve trade balances[1]. If produced and used right, it will also help reducing greenhouse-gas (GHG) emissions.
- On the other hand, it could be **"bad"** if the challenges of producing biomass sustainably – i.e., managing GHG emissions and biodiversity impacts from land use change, avoiding negative food security effects and overuse of water resources – are not adequately addressed.

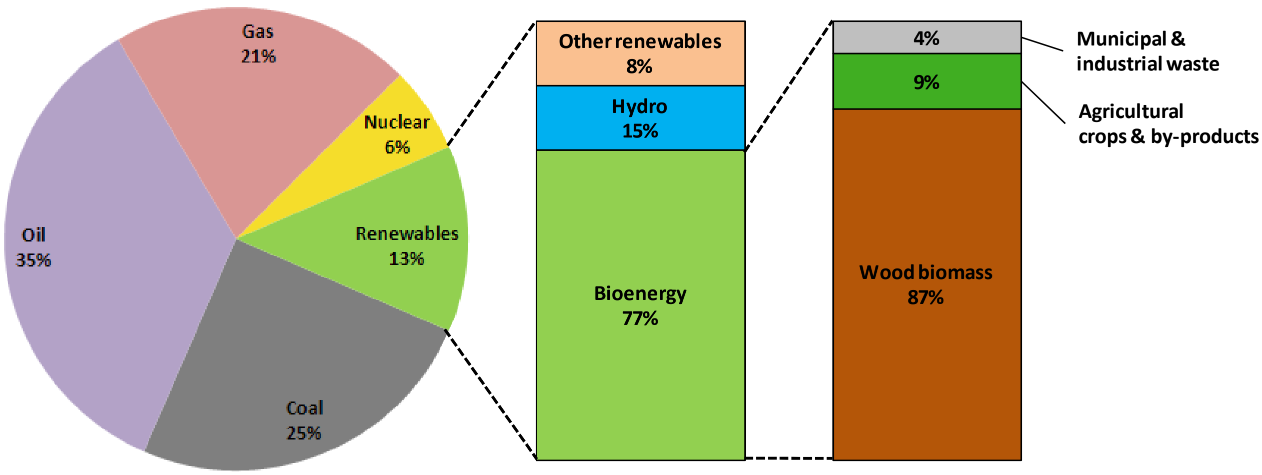
Establishing national and global policies to foster sustainable markets for bioenergy is needed, taking into account both the risks of currently uncontrolled bioenergy production and deployment, and the opportunities arising from future RT&D efforts.

This paper presents options for **better** use of biomass for energy both on the supply side of biomass, and for its conversion – from electricity and heat generation to providing transport fuels, and chemicals[2].

Biomass Today – and Tomorrow

Currently, biomass provides more than ¾ of all renewable energy, mainly from woody biomass – the global shares are detailed in Figure 1 below.

Figure 1 Share of Bioenergy in the World Primary Energy Mix



Source: Bioenergy – a Sustainable and Reliable Energy Source. IEA Bioenergy ExCo:2009:05

---

1 The focus of this paper is bioenergy in OECD countries, although production is considered globally due to (rising) bioenergy and biofuel trade. For developing countries, better use of biomass for energy is also an issue of increasing access to modern energy supply. It should be further noted that **all** sources of energy – non-renewable or renewable - have environmental and socio-economic impacts along their life cycles.

2 More details and examples (brief case studies) are given in the background report for this position paper.

Box 1 - Brief Facts on Bioenergy

Today, biomass provides approx. 13% of global energy supply, and the majority of all renewable energy (see Figure 1). In OECD countries, the bioenergy share is 3% on average, mainly used for electricity and heat generation, but its use for transport fuels is rising.

In many developing countries, bioenergy is a key source for cooking, and contributes on average 22% of all energy use, but with up to 90% in some countries.

The global **potential** of biomass for energy which could be grown **without** degrading biodiversity, soils, and water resources depends on agricultural and forest developments and is estimated as 250 to 500 EJ, representing 50 to 100% of the current global energy use. By 2050, with growing population and demand, bioenergy could contribute between 25% and up to 33% of global supply (see Figure 2)[3].

Biomass is a **versatile** energy source – it can be stored and converted in practically any form of energy carrier and also into biochemicals and biomaterials from which, once they have been used, the energy content can be recovered to generate electricity, heat, or transport fuels.

Although bioenergy is the oldest renewable energy used by humanity, there are substantial opportunities for further technological improvements – **both** in producing and using biomass.

Better Supply: Domestic Biomass and Global Trade

Currently, all countries significantly **underuse** their domestic potential of sustainable bioenergy (see Box 2), and could use it more **efficiently** in terms of costs, GHG reduction and social impacts. Furthermore, international trade of bioenergy is in its early stage of development[4].

Box 2 - Sources of Bioenergy

Bioenergy can be derived from domestic sources, such as agricultural and forest residues, and industrial or residential organic wastes as well as from energy crops, including aquatic biomass.

The potential for extracting biomass residues and wastes in OECD countries considering biodiversity needs and soil sustainability is typically around 5-10% of the current overall energy supply, mainly depending on the share and structure of the agricultural/forest and food processing sectors, and the waste handling.

The potential for domestic bioenergy crops is determined by available land, while for aquatic biomass, water resources and coastal sea access are restrictions.

Better Biomass Supply: Future Opportunities

Domestic supply of bioenergy from residues and wastes can be increased substantially with improved management systems for manure and organic wastes to produce biogas, and for cereal straw and woody residues to produce solid feedstocks for electricity, heat and next generation biofuels such as lignocellulosic ethanol and synthetic biodiesel.

There is also opportunity to sustainably **grow** biomass for energy on land which is underused or not used for other purposes (e.g., nature protection, recreation) – for that, the productivity and selection of cropping systems are key (Box 3 and Figure 2).

---

3 Bioenergy – a Sustainable and Reliable Energy Source. A review of status and prospects. IEA Bioenergy; ExCo:2009:05 http://www.ieabioenergy.com/MediaItem.aspx?id=6360

4 see IEA Bioenergy Task 40: Sustainable Bioenergy Trade http://www.bioenergytrade.org

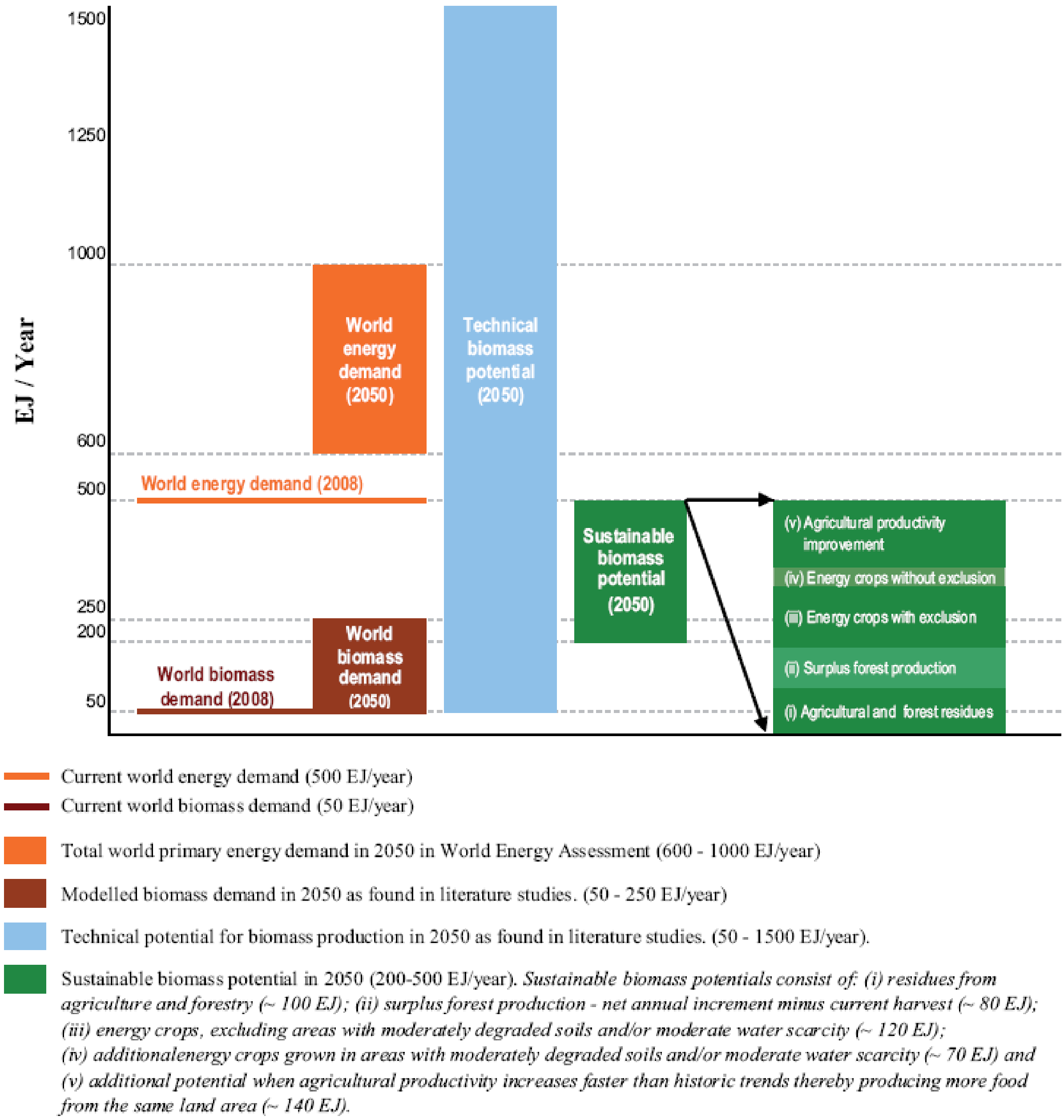
Box 3 - Sustainable Bioenergy Crops

The major potential to improve the sustainability of biomass for energy production is shifting to **multi-year** (perennial) plants and to multiple cropping systems and agroforestry. These systems have high energy yield, need less agrochemical inputs and offer biodiversity gains compared to annual single cropping. Their integration into agricultural landscapes can lead to improved water productivity and reduced soil erosion.

A variety of oil-bearing and lignocellulose plants such as Jatropha, switchgrass and short-rotation coppice can be grown on lands **unfit** for agricultural use, delivering biomass feedstocks not in competition with food or feed production.

Algae grown in land-based ponds and photobioreactors could contribute also, depending on further RT&D successes to reduce costs and improve overall performance. Seaweeds from coastal regions are another potential, but their cultivation and harvest face not only competition for other uses, but also biodiversity and nature protection concerns.

Figure 2 Global Primary Energy Potentials from Sustainable Biomass



Source: Bioenergy – a Sustainable and Reliable Energy Source. IEA Bioenergy ExCo:2009:05

Better Biomass Production: GHG and Land Use Changes

The availability of land is a key issue for all countries, but especially for those which export biomass and biofuels. Land availability and land use are affected not only by bioenergy development, but also by national and global agricultural, food, forest, and trade policies.

Land use change (LUC) from increased biomass production has implications for the GHG emission balance of bioenergy: If existing vegetation such as tropical forests or savannah is cleared to establish plantations, resulting carbon emissions can be higher than GHG savings from replacing fossil fuels with bioenergy.

On the other hand, cultivating multi-year (perennial) instead of annual crops for bioenergy on arable land or introducing agroforestry systems will increase the soil carbon content, resulting in additional GHG **savings** (see Figure 3).

The GHG balances of producing biomass for energy depend on previous land use, cropping and cultivation systems used to produce bioenergy, and the considered time horizon.

The **direct** LUC effects of bioenergy production can, in principle, be **controlled** through certification systems, wherever biomass is grown. Procedures for this are being implemented in the EU, and the US. If exporting countries participate in such systems, net GHG emission savings from imported bioenergy can be assured, and respective negative direct impacts on biodiversity can be avoided.

With technology progress in remote sensing and more available data for geographical information systems, monitoring of direct LUC will become more reliable and cost-effective.

Still, increased biomass for energy production could also cause **indirect** LUC effects (see Box 4) and imply price impacts on agricultural commodities which might affect the food security of vulnerable populations.

Box 4 – Emissions from indirect Land Use Changes (ILUC)

Recent research indicated a further source of emissions from increased biomass for energy production: if bioenergy cropping occurs on land **previously used** for food, feed or fiber production, it **displaces** the previous production of food, feed or fiber.

As demands for displaced production remain, it will be produced somewhere else, which might result in converting other land (and respective carbon emissions) to producing the respective amounts of food, feed, or fiber. These emissions from **indirect** land use changes are caused by the displacing bioenergy production and can, in the net balance, negate any positive effects of replacing fossil fuels (Figure 3).

The extent to which ILUC might occur and to which it could cause GHG emissions is under debate[5].

Biomass for energy is **only one** option for land use among others, and markets for bioenergy feedstocks and agricultural commodities are closely linked. Thus, LUC effects which are "indirect" to bioenergy are "direct" effects of changes in agriculture (food, feed), and forestry (fiber, wood products).

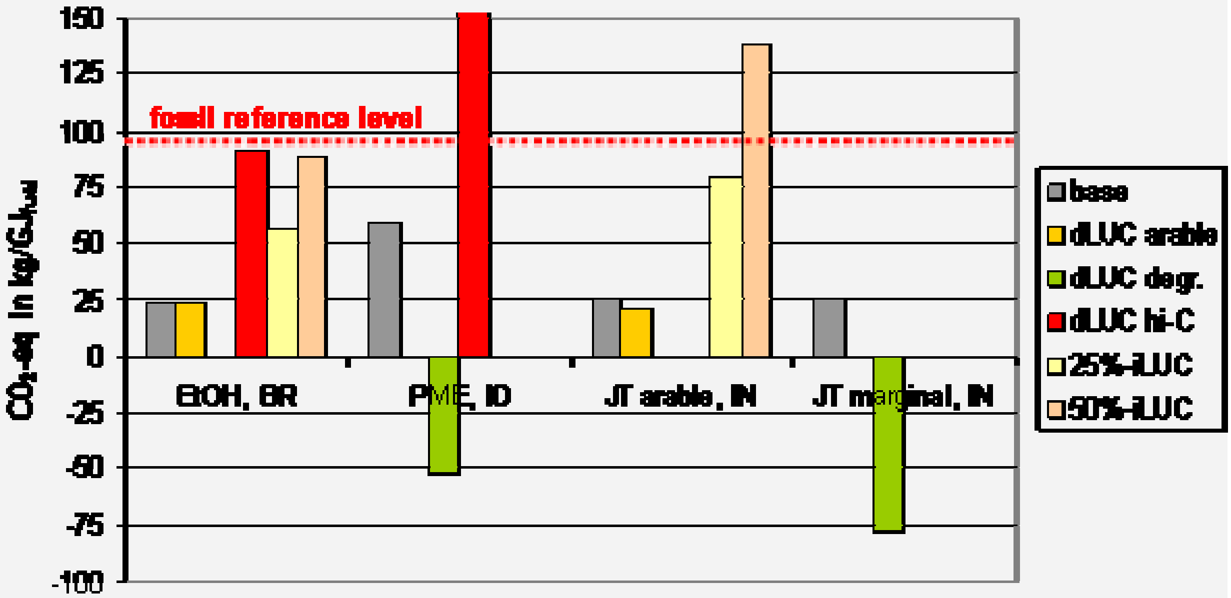
---

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

Box 4 …cont'd

They can be dealt with only within an overall **framework of sustainable land use**, and in the context of **overall** food and fiber policies and respective markets[6]

Figure 3 Sensitivity of Biofuel GHG Balances with regard to direct and indirect LUC



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

To reduce ILUC effects of bioenergy, several options and strategies are discussed:

In the **short-term,** potential indirect LUC effects from bioenergy can be minimized through

- using residues and wastes (see Box 2)
- favoring of high-efficient systems which have low land demands
- cultivating biomass for energy on land "set free" through yield increases, and
- using abandoned or degraded land not in competition with food, feed or fiber production, nor implying negative biodiversity or social impacts (Box 3).

In the **medium-term**, GHG emissions from indirect LUC could be reduced through the so-called REDD mechanism (see Box 5).

6 See IEA Bioenergy Position Paper on Bioenergy and Land Use (forthcoming)

In the **longer-term**, two options are discussed which both would **eliminate ILUC:**

- Introducing a global GHG cap within the UN Framework Convention on Climate Change which includes emissions from **all** LUC in all countries, subject to effective monitoring, would cover all causes of LUC. Negotiating and implementing such a system would take time, though, and might be developed only step by step.
- An alternative approach is to develop a global certification system which requires all biomass uses to meet GHG emission standards, including emissions from direct LUC.

Both options are similar in substance, but differ in governance and implementation.

Box 5 – Biomass in the Climate Negotiations: REDD

Rewarding reduced emissions from deforestation and degradation (REDD) is a mechanism considered for the post-2012 climate regime. Various studies and workshops on REDD concluded that cost effective systems for estimating and monitoring deforestation and changes in carbon stocks can be designed and implemented, and improvements on remote sensing will reduce costs.

At COP15 in Copenhagen, parties will decide on REDD – with a positive outcome and a viable financial mechanism, the global extent of deforestation could be reduced significantly in the coming years.

Thus, REDD could be an **important driver** for future sustainable bioenergy, and – if effectively implemented - would reduce (but not avoid) risks of GHG emissions from indirect LUC (Box 4).

Better Use of Biomass for Energy: Efficient Conversion and Use

The second pillar of better using biomass for energy is **more efficient conversion** of biomass into usable forms of energy and its use in efficient end-use applications. Both contribute to reduce burdens from feedstock supply, but have different implications for costs and emissions.

For heat and power generation, several biomass technologies are in the market or early commercialization stage, but they need further deployment, especially high-efficient systems using integrated gasification/combined-cycles, and fuel cells[7].

For liquid and gaseous transport fuels, improved "next generation" technologies are expected to deliver near-commercial biofuels in the next decade[8].

Biomass can also be converted into bio-based (raw) materials and bioproducts which could replace fossil carbon – e.g., chemicals, fibers, pharmaceuticals and plastics. **Biorefineries** are means to integrate those products while delivering (some) energy output in parallel[9].

7 Bioenergy – a Sustainable and Reliable Energy Source. A review of status and prospects. IEA Bioenergy; ExCo:2009:05 http://www.ieabioenergy.com/MediaItem.aspx?id=6360

8 From 1st- to 2nd-Generation Biofuel Technologies: An overview of current industry and RD&D activities (A joint Task 39 and IEAHQ Report), Paris 2008 http://www.ieabioenergy.com/MediaItem.aspx?id=6060

9 For more information, see IEA Bioenergy Task 42 http://www.biorefinery.nl/ieabioenergy-task42

Biomaterials do not necessarily imply competition with biomass for energy, as once bio-based products spent their usefulness and become wastes, their energy content can be recovered to generate electricity, heat, or transport fuels.

Thus, a challenge for better use of biomass is to establish waste collection, management and conversion systems which allow "cascading" use of biomass while taking into account economic constraints.

Better Use of Biomass for Energy: Key to Climate Change Mitigation

The climate change negotiations and the better use of biomass for energy share crucial challenges and, thus, could share mutual benefits in

- short-term direct reductions of GHG emissions from **both** land use changes, and fossil fuel use
- short- and medium-term improvements in access to modern energy, and broadening of socio-economic development options
- developing the longer-term option to reduce CO_2 levels in the atmosphere through coupling bioenergy conversion systems with carbon capture & storage (CCS).

Better use of biomass for energy offers opportunities to reduce sources of GHG **and** to enhance their sinks, at reasonable net costs, and with possible positive social development perspectives.

Stringent policies to mitigate climate change will drive better use of biomass for energy, and better use of biomass for energy could drive climate change mitigation.

Better Biomass Assessment: BUBE Indicators

The previous sections indicated that for "better" use of biomass for energy, various options already exist and will increase in the future if respective RT&D and policy efforts are made and prove successful. Each option and their combinations imply different positive or negative effects on key indicators such as GHG emissions, energy security and socio-economic development[10].

Thus, defining "better" depends on the energy supply mix for electricity, heat, and transport sectors of countries and regions which might value "better" using different indicators and respective weights.

Still, there are several overall indicators to assess "better" use of biomass for energy (Box 6) which can be applied in all countries.

---

[10] In the background report to this Position Paper, examples for this are given.

Box 6: Generic Indicators for Better Use of Biomass for Energy

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

- **Maximize the greenhouse gas reduction**
  - Demand minimum GHG reduction over bioenergy life cycles, including land use change emissions – measured in terms of CO_2eq reduced per ton of biomass in case of residues/waste, and CO_2eq reduced per hectare in case of biomass cultivation
  - Provide incentives for bioenergy routes that reduce more GHG emissions
  - Favor bioenergy applications in which waste and residues can be used
  - Prevent or at least limit use of arable and grassland for biomass cultivation for energy

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

- **Avoid competition with food, feed and fiber**
  - Promote cultivating biomass on agricultural land set free from significantly increasing agricultural yields
  - Promoting cascading use of residues and wastes from biomaterials for energy
  - Develop bioenergy strategies together with a strategy for global food security.

Better Orientation: Milestones for Biomass Futures

The “better” use of biomass for bioenergy will change over time – and the possible future pathways depend on achieving technology development goals through learning. Such learning is subject to rising market shares, though, which in turn depends on successful RT&D efforts.

Given the different country situations, “better” use of biomass for energy needs to be considered along national **road maps** depicting possible routes into bioenergy futures. Disregarding the variety of possible futures, there are **critical milestones** occurring in most scenarios so that they mark key “breakthroughs” needed to forward better use (see Box 7).

As the achievement of the future milestones is yet unknown, road mapping must also consider **flexibility** to avoid lock-in if expected developments over- or underperform.

Box 7: Milestones for Better Use of Biomass for Energy

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

- Harmonizing sustainability standards, criteria and indicators for biomass trade, especially for GHG emissions including LUC, biodiversity, and social impacts
- Supporting **shifts** towards advanced cropping systems, e.g. perennial oil-bearing and lignocellulosic plants which can be grown on degraded lands abandoned from agricultural use
- Adjusting waste extraction, collection and logistics to accommodate "cascading" use of biomaterial wastes for bioenergy, and
- Improving land use policies to integrate agricultural, energy and forestry as well as nature protection and social development needs.

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

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

- successful demonstration and commercialization of next generation biofuel technologies, and biorefineries,
- development and demonstration of carbon capture and storage (CCS) for larger bioenergy conversion plants as a **key longer-term option to reduce atmospheric CO_2 levels**
- cost reductions and lifetime improvements of electric vehicles which might use bioelectricity.

Achieving the medium-term milestones relies massively on RT&D activities on a scale which calls for international collaboration – mainly within the OECD, but also with other countries.

The **longer-term** milestones are

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

The long-term milestones require close interaction and collaboration on the multilateral level, and are subject to inclusive strategies which allow participation of all stakeholders.

Better Use of Biomass for Energy: Policies and Practices

In addition to prospects of better biomass supply, conversion technology, and RT&D, **better policy** is needed to establish and disseminate **better practices**.

To play its role in providing sustainable bioenergy, the biomass for energy **industry** will undergo rapid growth. The medium- to long-term development options for sustainable bioenergy require **substantial investments** in new biomass supply and conversion systems not only in the OECD, but also in countries with developing and emerging economies.

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

In that regard, providing bioenergy should receive **policy support** for substituting fossil energy to the extent that net reductions of GHG emissions, maintaining biodiversity, energy security, and low social tradeoffs (e.g. food security) can be **demonstrated**.

Performance-based policies seem suitable to provide incentives proportional to the benefits delivered.

With policies on better use of biomass for energy being implemented, the private sector in general and the bioenergy industry in particular will have the responsibility to **demonstrate better practice** in supply, conversion and use of biomass for energy.

Last but not least, there is a clear need for **complementary** policies which directly focus on problems going beyond biomass for energy, such as land- and water-efficient food and feed production, overall reduction of agricultural emissions, and the prevention of habitat loss from land clearing.

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

More information on BUBE

Details on the findings, recommendations and brief case studies are given in a background document prepared for IEA RETD and IEA Bioenergy by a research team consisting of CE Delft, Oeko-Institut, AidEnvironment and CIEP. The project was guided by a steering and editorial committee; Annette Schou and David de Jager from IEA RETD and Kyriakos Maniatis and Kees Kwant from IEA Bioenergy.

For more information, see **www.iea-retd.org** and **www.ieabioenergy.com**

This publication was produced by the Implementing Agreements on ‘Renewable Energy Technology Deployment (RETD)’ and ‘Bioenergy’, which form part of a programme of international energy technology collaboration undertaken under the auspices of the International Energy Agency.