Sustainable Energy Handbook

Module 4.3
Introduction to Bioenergy

Published in February 2016

1 General Introduction

Bioenergy can be defined as energy derived from biomass[1] and is the most widely used renewable energy worldwide. In turn, bioenergy can be classified as:

- **Traditional bioenergy**, such as wood fuels, charcoal or animal dung used mainly in developing countries,
- **Modern energy**, such as biofuels, bioelectricity, pellets and wood chips.

Biomass demand continued to grow steadily in the heat, power, and transport sectors. Global primary energy consumption of biomass reached approximately 57 EJ[2] in 2013, of which almost 60% was traditional biomass, and the remainder was modern bioenergy (solid, gaseous, and liquid fuels) (REN21 2014). This corresponds to around 10% of total energy demand and can represent more than 90% of energy supply in certain countries.

Around 2.5 billion people still don't have access to modern fuels (Practical Action 2012) and only in West Africa about three-quarters of the estimated 350 million population rely on traditional biomass as the main source of energy (ECREEE, 2013). Moreover in certain regions, the heavy dependence on traditional wood and charcoal has resulted in a massive depletion of the forest resources, magnified by the increased population, with devastating economic, social and health consequences for the rural populations and the poor. UNEP (2014) estimates that about 3.4 million hectares are deforested annually in Africa and wood fuels for cooking are a major driver of **deforestation** and, even more importantly, of forest degradation. This is associated with the release of large amounts of Greenhouse Gases (GHGs), contributing to climate change and to the reduction of other ecosystem services provided by forests at the benefit of poor population (water regulation, medicines…).

Moreover, WHO (2012) reports that **indoor pollution** from traditional biomass fuels kills more people than malaria – about 1.5 million people per year.

Deforestation is obliging the poor rural population to increasing difficulties to gather or afford wood and charcoal and to cover much longer distances to collect the required wood, while the penetration of modern energy services (electricity, biogas, LPG, bioethanol and improved stoves) is still low.

Recent global trends in promoting modern bioenergy in some countries, in the wake of very high oil prices in 2007-2008 and the rush to liquid biofuel production and blending mandates, resulted in unsustainable farming practices (e.g. the introduction of alien or invasive plant species).

The development of sound policies to foster sustainable bioenergy development in developing countries is not primarily linked to the need of mitigating GHG emissions, like in most developed countries, but rather:

1 Biomass is the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste (EU Directive on Renewable Energy)

2 1 Exajoule (EJ) corresponds to one quintillion (1018) joules, or to 23.884 Mtoe or to 277.77 TWh

- To anticipate and reverse negative impacts;
- To foster the adoption of modern bioenergy technologies;
- To meet set targets for renewable energy and energy efficiency, including modern bioenergy.

Main benefits (and challenges) of bioenergy development

Bioenergy, including bioelectricity, biogas and heat through different mature and proven technologies, has the potential to meet the following development objectives:

- Provide an immediate available and cost-effective manner to reduce **GHG emissions** by substituting fossil fuels,
- Contribute towards the increase of the **renewable energy** uptake hence reducing the dependency of an economy on fossil fuels and its volatile market.

Particularly in developing countries:

- Provide energy services to the poor;
- Develop agro-industrial activities and create jobs;
- Decrease health diseases and improve gender implications;
- Attract investments to agriculture and improve agricultural productivity;
- Improve food security;
- Improve government budgets, balance of payment and energy security;
- Maintain or improve biodiversity and natural resource management.

The use of fuel-wood and charcoal in Sub Saharan Africa (SSA) (South Africa excluded) has very important and specific impacts: (i) on health and on social behaviours, namely for women; (ii) on the time spent for collecting fuel-wood (according to recent surveys, the average in SSA is of 1.5 hours per day and Niger and Ethiopia have the highest rates with a record of 4 and 3 hours per day respectively).

Biomass has the following potential advantages:

- Can be used for heat, power and combined heat and power (CHP);
- Can produce firm energy, and therefore does not have intermittency problems (like those associated with wind and solar);
- Can be stored. It is therefore also dispatchable to meet demand, making possible to provide large amounts of energy only when needed.

2 General principles and uses of biomass

The use of biomass for energy production is primarily an agricultural and natural resources management issue. The main objective should aim at maximising the economic usage of the resources while guaranteeing the system sustainability and food security.

A **bioenergy system** is characterized by the cultivation, production, gathering and transport of feedstock, and its conversion to yield an energy carrier which delivers an **energy service** to an end user. Examples of some of these energy services are heating, lighting, mechanical power or transport.

The suitability of a particular system in a particular context depends on several aspects and no "best" technology route exists. The choice of route will vary with the type and volume of available (or sustainably feasible) feedstock, type of energy service(s) needed, investment possibilities and

technological readiness of the region. An overview of the main conversion pathways is given in section 4.

Biomass can be used for:

- **Industrial heat and electricity production**: Small industries can make use of low-grade heat, mechanical energy and off-grid electricity. Large industries will need continuous electricity supply and may require high-pressure steam.
- **Cooking and heat at household level:** Biogas can be produced easily and cheaply at the household, thus providing a reliable and cheap energy source to be used in improved cooking stoves.
- **Transport fuel production:** This includes various options with respect to technical specifications (fuel vehicle compatibility) and marketability. Currently, main transportation biofuels are ethanol and biodiesel.

Definition of modern bioenergy and improved cooking stoves

Building upon the definition of the Global Bioenergy Partnership (GBEP 2011), a **modern bioenergy service** can be defined as that *"modern energy service that relies on biomass and includes usage of improved cook-stoves*". These stoves:

1. *Make an energy efficient use of the biomass resource (considering the energy stored in the biomass resource and the energy actually made available for the specific service);*
2. *Do not release harmful flue gases or at least the flue gases do not have a negative direct impact on human health.*

Modern bioenergy services include electricity delivered to the final user through a grid from biomass power plants; district heating; district cooling; improved cook stoves (including such stoves used for heating) at the household and business level; stand-alone or grid-connected generation systems for household or businesses; domestic and industrial biomass heating systems; domestic and industrial biomass cooling systems, biomass-powered machinery for agricultural activities or businesses; biofuel-powered tractors and other vehicles, grinding and milling machinery.

Modern bioenergy services do not include biomass used for cooking or heating purposes in open stoves or fires with no chimney or hood or any other energy system that release indoors dangerous flue gases for human health, irrespective of the feedstock or biofuel employed.

3 Bioenergy feedstock and feedstock production

Bioenergy feedstock

Bioenergy feedstock can be divided into three main following categories:

1. *Waste and residues*. These bioenergy feedstock do not directly compete with food production for land, water or inputs, or with biodiversity and carbon sinks for land use, and can provide significant GHG savings, as long as they are collected and used in a sustainable manner. Due to costly collection/conversion, waste/residues tend to be more suited for conversion into heat, electricity or biogas.

   Agricultural residues and wastes are defined as the by-products of the agricultural system and can be split into two types, dry and wet. Wet residues can be used in bio-digesters (biogas). Dry residues consist of parts of arable crops that are not used for the primary

production of food or fibre. Included in dry residues are straw, poultry litter, rice and coffee husks, corn stover, etc.

Commercial and industrial residues, wastes or co-products, of organic origin, can be potentially used or converted to biomass fuel. These residues, wastes and co-products arise from commercial and industrial process and manufacturing operations. The wastes produced by commerce and industry can be split into two categories, woody materials and non-woody materials. Most of them can be burned for heating, power or Combined Heat and Power (CHP) or can be gasified. For wet residues, it is more convenient to get methane (biogas) than direct combustion.

Municipal Solid Waste (MSW) refers to a combination of domestic, light industrial and demolition solid wastes, generated within a community. At present there are three main ways of treating MSW; disposal in landfills, combustion and disposal in anaerobic digesters. Incineration of waste can be problematic as the composition of the waste is varied and may release pollutants such as dioxins, heavy metals, acidic gases, nitrogen oxides and particulates. These can have an effect on health and impact upon the environment when emitted during incineration.

2. *Dedicated energy crops are crops grown for energy purposes*. Energy crops can be divided into the four groups of sugar crops, starch crops, oil crops and lignocellulosic crops. The theoretical potential for energy crops in many regions is large, but can be limited by land and water availability as well as competition for other uses (food, feed, fibre). The potential environmental and social impacts from the production of dedicated energy crops differ depending on the choice of crop and management system.

3. *Biomass harvested from natural resources is another form of bioenergy feedstock*. These include forest, woodland, grassland or aquatic resources. Some areas might have the potential to harvest naturally growing biomass for local needs; however, the potential is often low and generally not able to supply large-scale bioenergy systems. Nevertheless, good practices such as modern forestry practices, agroforestry, integrated agricultural and forestry management systems can significantly increase wood productivity. Agroforestry for example has been an integral part of many traditional farming systems for a long time and includes both crop and/or animal farms to produce food, feed, fuels, fibre and building materials. It can either be by spatial arrangements (i.e. intercropping of trees and crops) or by temporal sequence (trees included in crop rotations). Agroforestry, and especially multiple cropping systems and crop rotation have the main objective of crop intensification in space and/or time, along with a number of other co-benefits such as resistance to pests and pathogens, improved soil quality, agrobiodiversity, and incomes. On the other hand, these practices demand specific awareness and education, as well as input and labour requirements. A detailed compendium of modern practices that could be put in place to increase productivity, along with their co-benefits and challenges is available on the FAO's website at http://www.fao.org/energy/befs/gpenv/en/.

Wood is the most common form of biomass and has been burned for thousands of years for cooking and water heating. The term 'wood' includes products such as wood, sawdust and bark that has not been chemically treated or finished. This 'wood' can be obtained from a number of sources such as forestry, saw mills and timber merchants. When buying wood for fuel, the physical forms it can be bought in are logs, sawdust, woodchips, wood pellets and briquettes. The lower the moisture content the better the calorific value of the wood product as a fuel. The major issue in wood harvesting is sustainability. Unsustainable wood harvesting conducts to deforestation.

Good environmental practices

Bioenergy feedstock production can have positive or negative effects on the agriculture sector as well as on food security and this ultimately depends on how the bioenergy sector is managed.

The FAO for example has been analysing the effects of bioenergy production on food security in several cases and concluded that the same production pathway can have positive effects in one context and negative in another one.

However, a number of good environmental practices have been identified by FAO which are summarised in the table below.

MAIN POTENTIAL DIRECT BENEFITS	SUSTAINABLE AGRICULTURAL MANAGEMENT APPROACHES	Conservation Agriculture	The Ecosystem Approach and Sustainable Crop Production Intensification, Agro-ecology and Eco-agriculture	Organic Agriculture	SUSTAINABLE INTEGRATED AGRICULTURAL AND FORESTRY MANAGEMENT SYSTEMS	Agroforestry	Integrated Food-Energy Systems	Multiple Cropping Systems and Crop Rotation	SUSTAINABLE FIELD-LEVEL AGRICULTURAL AND FORESTRY PRACTICES	Alternatives to Slash-and-Burn	Community-Based Forest Management	Conservation and Sustainable use of Plant Genetic Resources and Seeds	Forest Buffer Zone	Integrated Pest Management (IPM)	Integrated Plant Nutrient Management (IPNM)	No- or Minimum Tillage	Pollination Management	Precision Agriculture	Rainwater Harvesting and Management	Rehabilitation of Degraded Lands	Soil Cover	Sustainable Forest Harvest	Sustainable Irrigation	Wild Biodiversity Management at Farm Level
ENVIRONMENTAL																								
Soil quality		√		√			√			√			√	√	√	√		√	√	√	√	√	√	√
Water availability and quality		√	√	√			√			√	√		√	√	√	√		√	√	√	√	√	√	√
Biodiversity			√	√			√			√	√	√	√	√			√			√		√		√
Agrobiodiversity		√	√	√			√					√		√			√				√			√
Climate change mitigation		√	√	√			√			√					√	√		√		√		√		
SOCIO-ECONOMIC																								
Productivity/Income		√	√	√			√			√	√	√	√	√	√	√	√	√	√	√	√	√		√
Availability of inputs		√	√				√																	√
Access to energy							√			√	√		√								√	√		√

Figure - Main potential direct benefits of good approaches, systems and practices to bioenergy feedstock production (FAO, 2012)

4 Technology overview

The main sources and technologies of bioenergy are summarised in the table below.

	Feedstock	Conversion process	Energy vector	End use	Typical scale range
Solid Biomass	Woody biomass (including pellets and briquettes) Crop residues/ agro-processing residues	Combustion in improved cooking stoves	Heat	domestic / community	1-10 kW_{th}[a]
		Torrefaction[3] / carbonisation	Solid biofuels (heat) Charcoal	domestic / community	2,000-200,000 GJ/year
		Gasification into syngas	Heat	Industry, farms or public grids	5-100 kW_{th}
			Electricity		10-1,000 kW[b]
		Direct Combustion	Heat	Industry, farms or public grids	10-10,000 kW_{th}
			Electricity		500-50,000 kW

[3] Torrefaction is a thermal process that involves heating the biomass to temperatures between 250 and 300 degrees Celsius in an inert atmosphere. In doing so, the moisture evaporates and various low-calorific components contained in the biomass are driven out. Torrefaction changes biomass properties to provide a better fuel quality for combustion and gasification applications, resulting in a char-like product.

	Feedstock	Conversion process	Energy vector	End use	Typical scale range
Biogas	Animal waste / digestible organic wastes / wastewater	Anaerobic digestion	Heat	Industry, farms or domestic	1-1,000 kW_{th}
			Electricity		5-5,000 kW
			Mechanical power		5-100 kW
Biofuel	Sugar/starch	Fermentation and/or distillation	Fuel (Ethanol)	Automotive	>30,000 GJ/year
			Heat fuel (Ethanol)	Domestic	1-10 kW_{th}
	Vegetable oils / animal fats	Extraction	SVO[c] (electricity)	Industry, farms or domestic	5-100 kW
			SVO[c] (mechanical power)		5-100 kW
		Extraction / transesterification	Biodiesel	Automotive	>100,000 GJ/year

[a] kW thermal; [b] based on 100-10,000 t/year and 2,000-4,000 h/year; [c]Straight Vegetable Oil

Table: Relevant bioenergy technologies and fuels

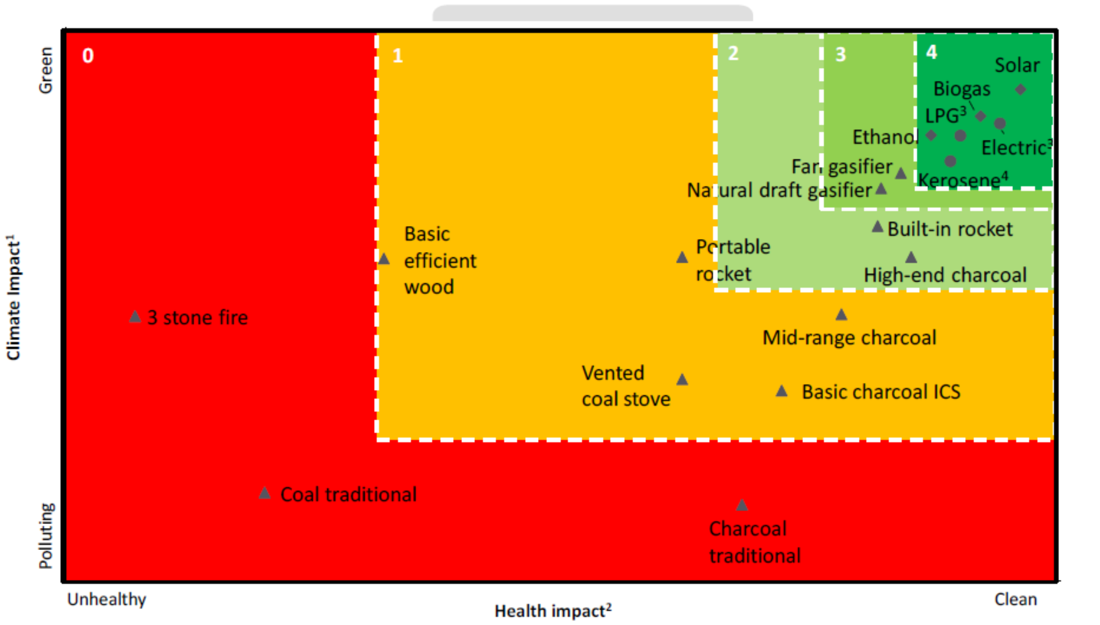
Improved Cook Stoves (ICS) are capable of wood savings of 60% or more (in addition to the health benefits mentioned above) compared to the basic stoves in use today (see table below). Natural draft gasifier and fan or forced-draft gasifiers have substantially better performances, and can potentially perform close to those of kerosene or LPG stoves.

The International Standards Organisation identified four performance tiers for cook stoves depending on their efficiency, environmental and health impacts: Tier 0 includes unimproved traditional cooking methods; Tier 1 relates to measurable improvements; Tier 2 substantial improvements; Tier 3 currently achievable technology for biomass stoves; Tier 4 stretch goals for targeting ambitious health and environmental outcomes.

Proposed ISO Tier	Illustrative stove type	Efficiency	Energy savings relative to Tier 0
Tier 0	3-stone fire	<15%	0%
Tier 1	ICS	>15%	23%
Tier 2	Rocket stove	>25%	>40%
Tier 3	Forced draft	>35%	>57%
Tier 4	LPG / advanced biomass	>45%	>67%

Table – Cook stove efficiency ratings for proposed ISO Tiers
Source: World Bank ACCES project

The above classification proposed by the World Bank ACCES project includes not just energy criteria, but also health criteria as illustrated schematically below, which shows typical performance of different types of cook stove.



1 Index on scale of 1-10 based on stove emissions of tons of GHG $CO_{2\text{-eq}}$ including all particles from fuel combustion and charcoal production weighted at GWC_{100}; assumes fNRB of 0.5
2 Index on scale of 1-10 of daily PM 2.5 intake per person and CO concentration, weighted 80/20 to reflect the more deleterious effects of particulate emissions relative to CO
3 Climate impact of electric and LPG stoves only includes CO and particulate emissions at point of fuel consumption; production of these fuels may have significantly negative climate effects, e.g., in the case of electricity production from coal combustion, but such climate costs vary across countries and are difficult to estimate
4 Kerosene stove results reflect measured PM and CO emissions and do not incorporate potential kerosene carcinogen effects
Note: The ISO tiers indicated in red correspond roughly to the ISO IWA Tiers for emissions.
Source: Berkeley Air Monitoring Stove Performance Inventory Report (October 2012); Grieshop et al (2011); Dalberg stove database; Dalberg analysis

Figure - Performance of different cook stoves against energy and health impacts criteria. Higher performing (Tier 2- 4) stoves marked in green

Source: World Bank "Clean and Improved Cooking in SSA"

The various bio-energy technologies are described in specific modules based on the energy service they provide (clean cooking systems and biogas, industrial heat and electricity produced by biomass, biofuel production).

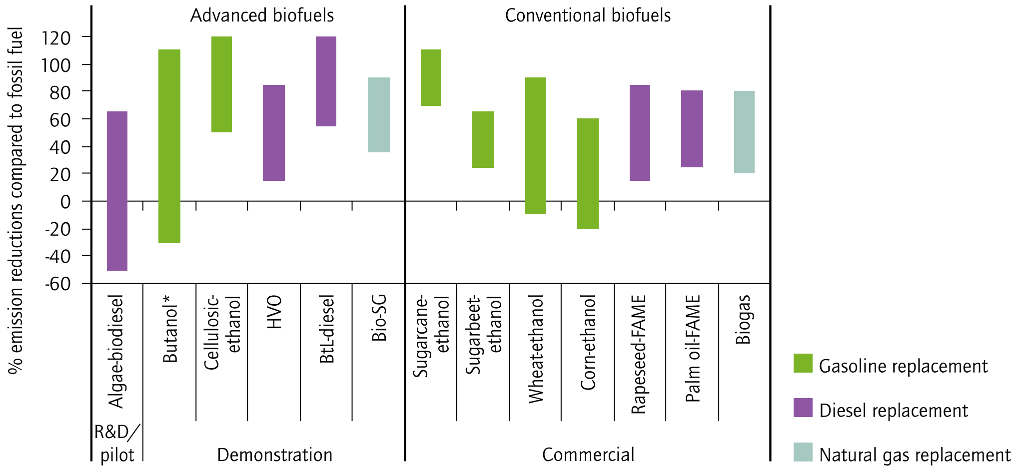
5 Greenhouse gas emission abatement

The GHG emissions released when bioenergy products are burned are similar to those of the fossil fuels they replace (during combustion). However, the amount of CO_2 originating from the biomass when burnt is similar to the amount of CO_2 that was removed from the atmosphere during biomass growth. This can lead to the simplistic understanding that bioenergy is CO_2 neutral since it releases, during its use, the same amount of CO_2 absorbed during biomass growth. In reality, the real emissions associated with bioenergy should be considered from a life-cycle analysis (LCA) perspective, considering all inputs needed during biomass growth, the emissions associated with change in land use, indirect deforestation, processing of the biomass into the final product, etc. In doing so, it would become clear that bioenergy emit lower GHG than the fossil energy it replaces, but cannot be considered carbon neutral and actually, in a few cases (e.g. when energy crops are grown on organic soils), the overall emissions could be even higher than fossil fuels.

Some analyses assume that people can harvest trees as "carbon-free" sources of energy so long as they only harvest the annual growth of that forest. The thinking is that as long as the forest's carbon stock remains stable, the harvest for bioenergy has not added carbon dioxide to the atmosphere. But this theory ignores the fact that any forest that has such annual growth already would have added biomass and have stored additional carbon if it had not been harvested for bioenergy (WRI 2015).

In general, bioenergy production and use emit less than fossil fuels, however the actual emission reduction must be assessed on a case-by-case basis using LCA. At the same time, for a proper comparison with fossil fuels, also the latter should be addressed from an LCA perspective (e.g. in the case of transport fuels: "from well to wheel").

Especially for liquid biofuels, GHG reduction can vary significantly depending on the specific production pathway, the desired end product and, even more importantly, on where (on which land and using which agricultural practice) the bioenergy feedstock was produced. The two graphs below compare some key advanced and conventional biofuels as well as key (forest based) solid biomass pathways with their respective fossil fuel replacement.



Note: The assessments exclude emissions from indirect land-use change. Emission savings of more than 100% are possible through use of co-products. Bio-SG = bio-synthetic gas; BtL = biomass-to-liquids; FAME = fatty acid methyl esthers; HVO = hydrotreated vegetable oil.

Figure - Life-cycle GHG balance of different conventional and advanced biofuels, and current state of technology

Source: IEA, 2012

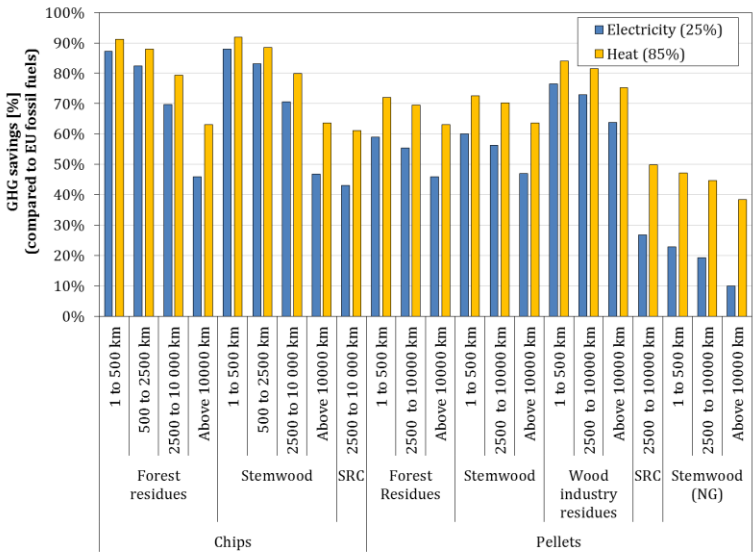


Figure - GHG savings for the most representative forest-based solid biomass pathways. SRC = Short Rotation Coppice. The calculations are based on GHG data from eucalyptus cultivation in tropical areas. Stemwood (NG) = pellets produced using natural gas as process fuel, all the other pathways are based on wood as process fuel

Source: JRC, 2014

6 Sustainable biomass regulation

Indicators of environmental, social and economic sustainability

A long-term successful bioenergy development strategy needs to take into account sustainability issues. The sustainability of bioenergy in its social, environmental and economic aspects should be thoroughly addressed with the participation of all relevant stakeholders.

The Global Bioenergy Partnership (GBEP) released in 2012 a set of 24 environmental, economic and social indicators for sustainable bioenergy with the purpose of providing relevant, practical, science-based, voluntary guides for any analysis of bioenergy that may be undertaken at the national level. These indicators, intended to be applied at the national level and to different country conditions, could be adapted to the specific needs.

PILLARS GBEP's work on sustainability indicators was developed under the following three pillars, noting interlinkages between them:		
Environmental	**Social**	**Economic**
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under this pillar:		
Greenhouse gas emissions, Productive capacity of the land and ecosystems, Air quality, Water availability, use efficiency and quality, Biological diversity, Land-use change, including indirect effects.	Price and supply of a national food basket, Access to land, water and other natural resources, Labour conditions, Rural and social development, Access to energy, Human health and safety.	Resource availability and use efficiencies in bioenergy production, conversion, distribution and end-use, Economic development, Economic viability and competitiveness of bioenergy, Access to technology and technological capabilities, Energy security/Diversification of sources and supply, Energy security/Infrastructure and logistics for distribution and use.
INDICATORS		
1. Life-cycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and re-qualification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

Table: Environmental, social and economic GBEP Indicators for Sustainable Bioenergy

Source: GBEP 2011

Methodology sheets explaining how to calculate each indicator are available in GBEP 2011 www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf.

Certification and regulation

Certification and the development of a tracking or chain of custody system for bioenergy feedstock and products can be a natural next step for regulators.

In **certification schemes**, companies are required to demonstrate with certificates that they are complying with the standards. It is critical to enforce only sustainability schemes that are credible, i.e. that are comprehensively addressing sustainability, and which have been developed in a multi-stakeholder and transparent manner, and are supported by third part auditing.

Since any certification comes with a cost associated, it is important to ensure that smallholders do not need to bear a too high compliance cost. Sustainability schemes must not cut out small farmers and small businesses. Therefore, it is essential to simplify the sustainability requirements where necessary, or by enabling group certification. It is possible to build upon experiences gained in certified food markets, such as the market of fair trade products or organic products.

At the same time policies and regulation should monitor and address macro effects, such as shifts in land use, which have consequences in terms of GHG emissions, biodiversity, competition with food, etc.

A number of international organizations have developed tools that can help countries to develop a sustainable bioenergy sector, at different stages of development. A comprehensive approach to domestic bioenergy development requires (FAO 2013):

- An in-depth understanding of the situation and of the related opportunities, risks, synergies and trade-offs;
- An enabling policy and institutional environment, with sound and flexible policies and effective means to implement these;
- Implementation of good practices by investors and producers in order to reduce risks and increase opportunities; and appropriate policy instruments to promote these good practices; and
- Proper impact monitoring, evaluation and response.

In order to promote this sound and integrated approach, FAO, partly in collaboration with partners, has developed the FAO Support Package to Decision-Making for Sustainable Bioenergy. The support package includes different elements which can be used independently or together at different stages within the decision making and monitoring processes of bioenergy development. For more information: http://www.fao.org/energy/82318/en/

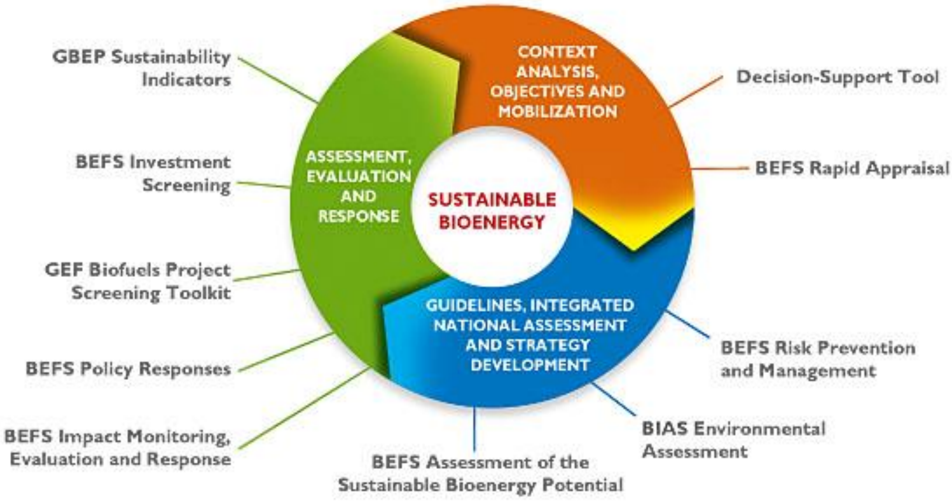


Figure - Overview of the FAO Support Package to Decision-Making for Sustainable Bioenergy

Examples of policies and regulation on sustainable bioenergy enforced in different parts of the world include:

- In the **US**, the Environmental Protection Agency (EPA) is responsible for the Renewable Fuel Standard II programme, which sets the annual volume requirements for renewable fuels. These regulatory requirements apply to domestic and foreign producers and importers of renewable fuel used in the US. Advanced biofuels and cellulosic biofuels must meet minimum GHG reduction standards of 50% and 60% respectively, based on a life-cycle assessment in comparison with the petroleum fuels they displace.
- In **Switzerland**, the Federal Act on Mineral Oil mandates a 40% GHG reduction of biofuels in order to qualify for tax benefits. In addition, feedstock must not be grown on land that was recently deforested or that is important for maintaining biodiversity. Biofuel producers must also comply with social standards in the countries in which feedstock production and biofuel conversion take place.
- For the **EU**, under the Renewable Energy Directive (2009/28/EC, http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32009L0028), criteria are set for biofuels to be eligible to contribute to the binding national targets that each member state must attain by 2020 (EC 2009). In order to be eligible, biofuels must provide e.g. 35% GHG emissions saving compared to fossil fuels.

BOX - The EU and Bioenergy Sustainability

The EU's Renewable energy directive (2009/28/EC) sets a binding target of 20% final energy consumption from renewable sources by 2020. To achieve this, EU countries are also required to have at least 10% of their transport fuels come from renewable sources by 2020. All EU countries have adopted national renewable energy action plans showing what actions they intend to take to meet their renewables targets. These plans include sectorial targets for electricity, heating and cooling, and transport; planned policy measures; the different mix of renewables technologies they expect to employ; and the planned use of cooperation mechanisms.

The Renewable Energy Directive (2009/28/EC) also introduced sustainability requirements for biofuels and bioliquids, and announced that the European Commission would suggest requirements for a sustainability scheme for other energy uses of biomass as well. For liquid biofuels for transport, the directive sets minimum GHG savings and certification schemes that must be met by biofuels which contribute towards the renewable energy quota.

The other directive relevant for bioenergy and specifically liquid biofuels is the Fuel Quality Directive (2009/30/EC) which sets biofuel blending targets.

The European Commission has proposed amending the current legislation on biofuels, specifically the Renewable Energy Directive and the Fuel Quality Directive, making sustainability requirements more stringent (including land use change safeguards. See http://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/land-use-change for more info).

Regarding solid biomass (for heat and power) the situation is less clear as regulations are still in the making (see http://ec.europa.eu/energy/en/topics/renewable-energy/biomass for more info).

In February 2010, the Commission adopted a report on requirements for a sustainability scheme for solid and gaseous biomass used for generating electricity, heating and cooling (COM(2010)11), hereafter called the '2010 Biomass Report'. No binding criteria were suggested at the European level. Nevertheless, the Commission formulated recommendations for Member States developing sustainability schemes (VITO 2012). In the report the Commission recommends member states that either have or plan to introduce national sustainability criteria for solid and gaseous biomass used in electricity, heating and cooling, ensure that these in almost all respects are the same as those laid down for biofuels in the Renewable Energy Directive (2009/28/EC). These non-binding sustainability criteria include:

- a general prohibition on the use of biomass from land converted from forest, other high carbon stock areas and highly biodiversity areas;
- a common GHG calculation methodology which could be used to ensure that minimum greenhouse gas savings from biomass are at least 35% (rising to 50% in 2017 and 60% in 2018 for new installations) compared to the EU's fossil energy mix; the EU GHG methodology includes emissions from the conversion of the biomass fuel into electricity, heating and cooling.

It is also recommended not to apply sustainability criteria to wastes, as these must already fulfil environmental rules in accordance with waste legislation at national and at European level, and that the sustainability requirements should apply to energy producers larger than 1 MW thermal or 1 MW electrical capacity. In addition, the Commission recommended to:

- differentiate national support schemes in favour of installations that achieve high energy conversion efficiencies, and
- monitor the origin of biomass.

Only UK has introduced regulations specifically referring to the biodiversity and carbon stock criteria laid down in the 2010 Biomass Report. In several countries biodiversity protection is indirectly covered in energy legislation through the requirement of Sustainable Forest Management (SFM) certification (FSC or PEFC[4]) of woody biomass. In 2009, 45% of the forest area in Europe was certified by either PEFC (58 Mha) or FSC (188 Mha) (Martikainen and van Dam, 2010). On a country level, certified forest areas ranges from 0.6% in Greece to 100% in Austria in 2009. Countries that include only PEFC-certified areas are Austria, Finland and Norway (harvest) and countries that include only FSC certified areas are Hungary, Ireland, Poland, the Baltic states, the Netherlands, Slovenia, Romania and the UK (Martikainen and van Dam, 2010). Wood fuels as such are not defined in the international FSC standard or PEFC Terms and

[4] The Forest Stewardship Council (FSC) is an international not for-profit, multi-stakeholder organization established in 1993 to promote responsible management of the world's forests. Its main tools for achieving this are standard setting, certification and labelling of forest products. The main competing forest certification system is the Programme for the Endorsement of Forest Certification (PEFC).The PEFC is an international, non-profit, non-governmental organization which promotes sustainable forest management through independent third party certification. It is considered the certification system of choice for small forest owners. PEFC was established by a number of stakeholders, including associations of the forest industry, pulp-and-paper production and forest owners in response to the creation and increasing popularity of FSC. Both certification schemes received criticisms over the years. For example the PEFC has been criticized for having little influence from local people or environmental organizations, lack of transparency and non-objective requirements.

Definitions and also on a national level, wood fuels are rarely defined in forestry standards (Stupak *et al* 2011). However, the revised Finnish Forest Certification System (FFCS), recognised by PEFC, now covers questions on energy wood harvesting (van Dam *et al* 2010).

Only 8% of all forests were certified in the world in 2010, compared to almost 45% in the EU (COWI 2010).

	Country / regulation	Aspects of environmental sustainability
Energy legislation		
BE	Minimum requirements for wood pellets (PelletNorm)	SFM precondition
BE	Green certificate granting system in the Walloon Region (Wall_CV)	Request of reporting if the wood is produced under SFM
FI	National renewable energy plan (NREAP)	Link to Forest Act to maintain biological diversity of the forests
FR	Fonds "Chaleur renouvelable" (BCIAT)	'Good practice guide' related to forest residues to be followed; advantage in project evaluation if SFM wood is used.
HU	Feed-in Tariff (FIT)	SFM precondition for electricity from wood biomass
PT	Feed-in Tariff (FIT)	Reference to forest management (to avoid fires)
SI	Support for CHP (EECHP)	Higher subsidies for CHPs using SFM wood
SI	Support for renewable electricity (EERES)	Higher subsidies for electricity from SFM wood
UK	Renewables Obligation Order, update 2011 (ROO2011)	Reference to Renewable Energy Directive land use requirements (high biodiversity value, high carbon stock land)
UK	Renewable Heat Incentive (RHI)	Reference to Renewable Energy Directive land use requirements (high biodiversity value, high carbon stock land)
Forestry regulations		
FI	Act on the Financing of Sustainable Forestry (Sust. Forestry)	Promotion of felling of young stands for energy use in view of maintaining the biological diversity of forests.
Agriculture legislation		
DK	Order on special support to farmers for the establishment of perennial energy crops (PEC)	Land restrictions for perennial energy crop support
IE	Bioenergy Scheme for production of non-food crops (BES)	Land restrictions for non-food crop support
UK	Energy Crops Scheme (ECS)	Land restrictions for energy crop support
NL	Decree on the use of manure (FERTI)	Co-digestate from digestors on 'waste' biomass not allowed as fertiliser for soil quality reasons
Waste legislation		
NL	National Waste Management Plan (LAP)	Criteria on whether biomass is considered waste and for which stricter emission requirements apply

Table: Regulations with reference to sustainable biomass production (VITO, 2012)

Most EU countries rely on their existing agricultural and forestry regulations to address the sustainability of biomass production and harvesting, as far as domestic production is concerned, but issues related to biomass produced outside the EU are not addressed by these regulations.

7 Technology Benchmarks

Bioenergy management is first an issue of food security and sustainable management of natural resources, but the efficiency of the conversion technologies plays also an important factor as it is important to make out the most from the available biomass resources.

The goal of sustainable bioenergy should be always the best and sustainable use and valorisation of the natural resources with a positive impact on local population.

Certain technologies can make use of residues and waste, and should therefore be prioritized, while others cannot.

The four tables below summarize the current costs of the main bioenergy technologies, associated and depending on their characteristics.

BIOMASS POWER for electricity production					
Technologies and feedstock	Typical plant size	Conversion efficiency[5]	Capacity factor[6]	Capital costs (USD/kW)	Energy costs (US cents/kWh)
Bio-power from gasification	1–40 MW_{el}	30–40%	40–80%	2,050–5,500	6–24
Bio-power from anaerobic digestion (biogas)	1–20 MW_{el}	25–40%	50–90%	500–6,500 (Biogas) 1,900–2,200 (Landfill gas)	6–19 (Biogas) 4–6.5 (Landfill gas)
Bio-power from solid biomass (including co-firing[7] and organic MSW)	1–200 MW	25–35%	50–90%	800 – 4,500 200 – 800 (Co-fire)	4 – 20 4 – 12 (Co-fire)

DISTRIBUTED RENEWABLE ENERGY IN DEVELOPING COUNTRIES		
Technology	Typical characteristics	Installed costs or LCOE[8](USD / kW or US cents / kWh)
Biogas digester	Digester size: 6–8 m^3	USD 612 / unit (Asia); USD 886 / unit (Africa)
Biomass gasifier	Size: 20–5,000 kW	LCOE: 8–12 USD cents/kWh?

HOT WATER / HEATING / COOLING			
Technology	**Typical characteristics**	**Capital costs (USD / kW_{th})**	**Typical energy costs (LCOE/H[9] – US cents / kWh_{th})**
Biomass heat plant	Plant size: 0.1–15 MW_{th} Capacity factor: ~50–90% Conversion efficiency: 80–90%	400–1,500	4.7–29
Domestic pellet heater	Plant size: 5–100 MW_{th} Capacity factor: 15–30% Conversion efficiency: 80–95%	360–1,400	6.5–36
Biomass Combined	Plant size: 0.5–100 kW_{th}	600–6,000	4.3–12.6

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5 Conversion efficiency refers to the efficiency of converting energy stored in biomass into the final useful energy carrier (electricity and/or heat).

6 The capacity factor of a power plant is the ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at full nameplate capacity continuously over the same period of time.

7 Co-firing is the combustion of two different types of materials at the same time, typically biomass and coal. One of the advantages of co-firing is that an existing plant can be used to burn biomass with minor adaptations, which may be cheaper or more environmentally friendly.

8 LCOE = Levelised cost of energy

9 LCOE/H = Levelised cost of energy/heat

Heat and Power (CHP)	Capacity factor: ~60–80% Conversion efficiency: 70–80% for heat and power		
TRANSPORT FUELS			
Technology	**Feedstock**	**Feedstock characteristics**	**Estimated production costs (US cents / litre)[10]**
Biodiesel	Soy, rapeseed, mustard seed, palm, jatropha, waste vegetable oils, animal fats	Range of feedstock with different crop yields per hectare; hence, production costs vary widely among countries. Co-products include high-protein meal.	Soybean oil: 56–72 (Argentina); 100–120 (Global average) Palm oil: 100–130 (Indonesia, Malaysia, and other) Rapeseed oil: 105–130 (EU)
Ethanol	Sugar cane, sugar beets, corn, cassava, sorghum, wheat (and cellulose in the future)	Range of feedstock with wide yield and cost variations. Co-products include animal feed, heat and power from bagasse residues. Advanced biofuels are not yet fully commercial and have higher costs.	Sugar cane: 82–93 (Brazil) Corn (dry mill): 85–128 (United States)

Tables - Status of bioenergy technologies: characteristics and costs (adapted from REN21, 2014)

To the extent possible, costs provided are indicative economic costs, levelised, and exclusive of subsidies or policy incentives. Several components determine the levelised costs of energy/heat (LCOE/H), including: resource quality, equipment cost and performance, balance of system/project costs (including labour), operations and maintenance costs, biomass costs, the cost of capital, and productive lifetime of the project.

8 What is the environmental and social impact

Water and land resources will be increasingly under pressure in the future, as these are limited resources that should be used to satisfy a number of human needs and to provide a number of environmental services. A sound water-energy-food nexus assessment is needed when dealing with such a cross-cutting issue like bioenergy. There are however pathways which are safer than others, and the safest include relying on agricultural residues and wastes.

Countries with an important production of cocoa, cassava, coffee, groundnuts, shea nuts, rice, millet, sorghum, cashew nuts, palm oil, and coconuts, can surely already mobilize a large amount of bioenergy feedstock just hindering on the residues of these production chains. These crops produce large amount of wastes and residues that are usually burned on the production fields or dumped on land or in rivers. In addition, municipal wastes, slaughterhouses, aquatic plants offer substantial opportunities to turn waste into valuable energy resources.

The utilization of these wastes will resolve most of the waste disposal and environmental constraints. It will increase hygiene, reduce health risks, and avoid the depletion of soils; and of course it would promote gender equality and provide modern energy services to the population.

[10]Litre of diesel of gasoline equivalent

As a rule of thumb, the table below separates this feedstock that require dedicated land and those that don't and which are therefore advisable to be used.

FEEDSTOCK THAT REQUIRE DEDICATED USE OF LAND (UNADVISABLE)	FEEDSTOCK THAT DO NOT MAKE DEDICATED USE OF LAND (ADVISABLE)
• Food crops • Fast-growing trees or grasses purposely grown on land dedicated to bioenergy • Harvests of standing wood from existing forests	• Some forest slash left behind after harvest • Black liquor from paper making • Unused sawdust • Municipal organic waste • Landfill methane • Urban wood waste • Crop residues that are otherwise not used, are not needed to replenish soil fertility, do not add substantial carbon to the soil, or the soil functions of which are replaced by additional cover crops • Cover crops that would not otherwise be grown • Unused manure • Wood from agroforestry systems that also boost crop or pasture production • Intercropped grasses or shrubs for bioenergy between trees in timber plantations in ways that maintain timber yields • Tree growth or bioenergy crop production that has higher yields and is more efficiently burned than traditional fuel wood and charcoal (and that replaces these traditional fuels in societies that continue to rely on them)

Table - Bioenergy feedstock that require and do not require dedicated use of land

Source: WRI, 2015

The relationship between biofuel production and **deforestation** is very complex and difficult to quantify (CIFOR, 2011): no global deforestation data and global biofuel feedstock plantation data are available of sufficient resolution. However there are very recent models able to assess the renewable and non-renewable biomass fraction, based on remote sensing and GIS[11].

It is generally accepted that bioenergy has the potential of either increasing or reducing **food security** (especially for smallholder farmers) depending on the policy behind its development and the characteristics of the local agricultural sector.

Most land acquisitions are linked with free access to **water sources** and sometime exclusive control over the water resources, when the increasing scarcity of water must be recognized. Besides the high water requirements for the cultivation and processing, the supposed free water use by biofuel investors leads to inappropriate water footprint (inefficiency, waste and pollution).

The principal critique relative to agricultural investment in developing countries deals with the concerns and relevance of treatment of **"unused" or "marginal" lands**. In most cases, land is already being used or claimed – yet existing land uses and claims go unrecognised because land users are marginalised from formal land rights and access to the law and institutions.

However there are several instruments that aim to encourage **Corporate Social Responsibility** (CSR) among companies. In terms of relevance to conventional biofuel production, the most relevant ones can be found within commodity specific instruments, as well as general CSR

[11] See for example a recent article on the application of WISDOM to assess the carbon footprint of traditional woodfuels by the Yale University and the National Autonomous University of Mexico: http://www.nature.com/nclimate/journal/v5/n3/full/nclimate2491.html

instruments. Compliance with such instruments or commodity certification schemes is voluntary and they usually lack remedy mechanisms.

The main environmental impacts of feedstock production for energy crops are caused by **intensive farming systems**, cultivating crops with high input levels, which are both natural (land, soil, water, native vegetation) and agrochemical. Large scale systems used for food crops production may be more efficient but not always sustainable.

A key factor in the analysis of the impacts of biofuels development is the **type of production system**: large-scale plantations; small-scale liquid biofuel farms (contract farming); small-scale local energy farms for local energy power needs; hybrid model (a mix of plantation and out-grower).There is no "best" scheme because the conditions must be considered on a case-by-case basis.

The FAO BEFSCI project identified a number of **good socio-economic practices** in modern bioenergy production, which can minimize risks and increase opportunities for food security (BEFS, 2011). They include:

- Access to Land for Local Communities (Consultation; Mapping of customary land rights; Fair compensation to landowners/users; Conflict resolution mechanisms; Inclusion of smallholders in bioenergy supply chain);
- Decent Work (Adherence to: ILO Declaration on Fundamental Principles and Rights at Work and related Conventions, ISO 26000 - Social Responsibility, Social Accountability (SA); Living wage)
- Income Generation and Inclusion of Smallholders (Contracts with local goods and service providers; Freedom of association and collective bargaining; Access to credit; Fair and transparent pricing; Profit sharing; resolution mechanisms)
- Local Food Security (Integrated Food and Energy Systems; Subsistence plots; Provision of improved agricultural inputs and/or equipment; Trainings on good agricultural practices; Provision of food; Improved cook stoves)
- Community Development (Development or improvement of local infrastructure; Training and education programmes; Health and safety equipment/devices and information; Micro lending and financial support mechanisms)
- Energy Security and Local Access to Energy (Development or improvement of energy infrastructure; Provision of energy for local and/or domestic use; Improved cook stoves)
- Gender Equity (Gender-sensitive corporate conduct; Gender-related corporate policies and programmes; Women in leadership positions)

Associated with these good practices, the project compiled specific **policy instruments** which could be put in place to promote such good practices (see BEFS, 2012 "Policy Instruments to Promote Good Practices in Bioenergy Feedstock Production" for more info).

An important positive impact of increasing access to modern energy is that it directly displaces fuels sold in **informal wood fuel** (mainly charcoal) markets. Informal biomass trade and wood fuel collection is an important phenomenon in several developing countries. It is difficult to assess its scale in each country; however, FAO calculated that it is responsible for more than three quarters of all removed wood from forests (FAO, 2010). This illegal wood removal is at the same time an economic, environmental and health problem. It is directly responsible for deforestation in the

region (globally around 13 million hectares of forest were lost each year between 2000 and 2010) and is commercialized at a price that does not take into account the ecosystem loss that it causes [12] . It is important to move to cleaner fuels for cooking but at the same time the transition should be smooth, and the new fuel (and stoves) should be made economically competitive with the traditional ones. Successful experiences exist where traded charcoal was taxed and at the same time the cleaner fuel (i.e. LPG) was subsidized. The cost of fuel, particularly in urban areas is relatively high, creating the potential for cleaner and more efficient stoves to have a positive economic benefit.

9 Major studies required and areas of intervention

Because of its cross-cutting dimension, a policy on sustainable bioenergy should deal with various issues related to food and energy security, land and environmental governance, gender equity, public health, rural economy development, etc. In this respect, it offers potential opportunities in the social (job creation), technological (industrial and SME development), micro-economic (reduction of oil imports), micro economic (creation of SME), environmental (reduction of pressure on forest, climate change) and energy security areas (production of solid and liquid fuels, production of electricity). A thorough socio-economic assessment of the implications is always needed for the specific situation.

On the other hand, the use of biomass for energy production may potentially lead to conflicts and unwanted effects. To mention a few: the primary use of good agricultural land, use of foodstuff for energy purposes (food-versus-fuel debate), loss of biodiversity due to unsustainable wood collection and/or plantation extension, neglected land tenure rights and loss of income for small holders in countries with weak tenure rights, virtual export of natural resources (QUINVITA, 2014). For these reasons the use of bioenergy should be well regulated and assessed.

National and international legislation usually require an Environmental Impact Assessment (EIA) or Environmental and Social Impact Assessment (ESIA) to be conducted before any implementation works begin. Even if some examples demonstrate the interest and the positive effects of an EIA undertaken under a business-as-usual approach, in the majority of cases reviewed, the EIA is considered as an administrative burden. A Strategic Environmental Assessment (SEA) for bioenergy development would constitute an important step to undertake, even if examples of this were not identified during the study (AETS Consortium, 2013).

The major studies required for the **development of a bioenergy sector** (in a development context) revolve around the following issues:

- The suitable business models for the local context and the practical regulatory steps to put in place to immediately start an energy transition to new and more sustainable models;
- The need to articulate the supply side and demand side for bioenergy for the sustainable supply of different (domestic) energy sources to the population;
- The practical steps for the implementation of financial incentives and mechanisms;
- The development of markets for new bioenergy products and the establishment of new regulation or a mechanism that facilitates access to equipment and fuel to reach a larger number of end-users, especially at the bottom of the pyramid;

[12] Charcoal, which is in high demand especially in urban areas, comes predominantly from felled trees, while the wood collected by rural women for their own use is mainly dead wood taken from trees (therefore more sustainable, as they wish to conserve the tree for the future).

- The most suitable good practices in producing bioenergy feedstock and technologies to convert this feedstock into the most useful final energy product, given the local conditions;
- Quantification of the actual GHG emission reduction compared with the business-as-usual (the use of fossil fuels) from an LCA perspective.

In addition to the above, factors that need to be investigated before embarking in any **bioenergy intervention**, include:

- Existing regulatory mechanisms in place which encourage private investment in the sector;
- Local knowledge management in the field of bioenergy;
- Mapping stakeholders involved in bioenergy, existing national and international partnerships, between governments or different actors to promote bioenergy development;
- Professional skills locally available, especially among operators who produce and market improved stoves, biogas, etc. often dominated by the informal sector;
- Mechanisms in place for systematic collection of data on bioenergy (official statistical surveys, census, etc.);
- The involvement of financial institutions, including microfinance institutions in the renewable energy sector;
- Existence of local standardisation of feedstock and biofuels;
- For the agricultural and forestry sectors:
    - the potential productivity improvement,
    - the availability of agricultural and forest land, and
    - the access to primary residues.
- For other feedstock, such as residues from wood processing and municipal solid waste:
    - mobilisation and responsible use of wastage.
- The local capacity for monitoring land-use;
- Awareness of agro-ecological zoning (AEZ), GIS tool, and availability of satellite data/remote sensing tools.

10 What are the key questions?

At policy level:

1. <u>Environment and natural resources: potential impacts to ecosystems, biodiversity, water, forest resources and products, soil, GHG balances, and air quality</u>
    - Will bioenergy production directly affect any rare or threatened ecosystems or habitat types through conversion, habitat loss or fragmentation?
    - Will bioenergy production lead to a reduction in soil productivity?
    - Will bioenergy production result in the introduction of non-endemic invasive species?

- To what extent will bioenergy production adversely impact water availability and/or quality both for downstream ecosystem processes and services and for downstream human activities and domestic uses (both current and projected)?
- Will the GHG balance be positive or negative compared to traditional fuels?
- Are sufficient land and water resources available?
- Which are the most suitable crops and the most adequate modes of cultivation?

2. Socio-economic effects: land tenure and displacement risk, income generation, potential exclusion of certain groups/individuals, employment, labour conditions, increased energy access, local governance
    - To what extent will bioenergy production lead to the displacement of local communities or of certain groups/individuals (particularly vulnerable groups such as indigenous communities and women) within them?
    - Will the opportunities associated with bioenergy production be equally distributed across groups and individuals?
    - Will bioenergy production generate more jobs than it will replace?
    - To what extent will the bioenergy produced (or part of it) be used to meet the local demand for energy?
    - Is bioenergy production profitable without explicit and implicit subsidies? In the short, medium and long run?
    - What action can the local population take in case of bad performance of local government/local line agencies/economic operators?

3. Food security impacts: food availability, access, stability and utilization
    - What is the status of food insecurity (chronic and transitory)?
    - What are the main staple foods in the diet of the country's poor and vulnerable populations?
    - To what extent will bioenergy production affect the availability of the key staple crops - now, throughout the year, and in years to come?
    - To what extent will increased demand for agricultural commodities for bioenergy production affect the prices of key staple foods? At the national level? In the local area?
    - How will increased use of agricultural inputs for feedstock production affect input availability for food production? Now, and in the future?
    - Do safety nets exist to protect against temporary food insecurity?

4. Legal, institutional and enabling environment.
    - How are local tenure rights managed?
    - Is there a regulatory frameworks for feeding/selling power to the grid?

- Is there enforcement of laws governing waste discharge which creates a barrier to the uptake of bioenergy technologies for the treatment of waste?
- Are R&D efforts supported towards the development of the sector?
- Are specialised skills available?
- Is corruption an issue and is local governance transparent enough?
- Are the appropriate bioenergy technologies and services locally available?
- Is it possible to sell power to the local grid?
- What is the local level of awareness and knowledge among private actors and governments of bioenergy solutions?
- What is the amount of biomass resources which can be made practically and economically (not just technically) available per year?
- Are there fossil fuel or electricity subsidies that make traditional energy sources artificially cheap?
- Is there a market for bioenergy by-products (e.g. organic fertilizers, glycerine, char, waste heat)?
- Which sustainability requirements should the bioenergy produced comply with and what is the associated compliance cost?

At intervention/investment level:

Stand-point organization

- What is the current heating/power system in place, does it need to be replaced due to age, environmental policy or high running costs?
- Is there a support for using biomass, is the resource clearly defined and sustainable?
- What budget is available for the system including plantation and/or reforestation?
- Previous experience and needs for external assistance?

Biomass demand requirements

- What is the electricity to heat demand ratio?
- The potential energy demand reduction (efficiency and saving)?
- The climatic and seasonal characteristics for the project site?
- Any need for a back-up system?

Potential biomass supply assessment within the local area

- What suitable type of biomass (chips/ pellets/ briquettes/ slurry/ energy crops, etc.) can be used, hence what type of technology is required?
- Who are the potential biomass suppliers?
- What are the biomass/fuel costs?
- Quality and quantity that can be guaranteed and secured for the next 10, 15 or 20 years?

- How much store is needed?

Available/suitable technologies and financial analysis

- What are the maintenance requirements, fuel requirements, system performance and operating parameters (times, temperatures, flow rates, etc.) associated?
- What are the capital costs and running costs associated to the fuel purchase and maintenance?
- How do they compare with existing plant and/or alternative fossil fuel systems now and considering forecasts of price trends for each technology and fuel in the future?
- What is the payback period and net present value (NPV) of the investment?

Relevant legislation

- What are the regulations relating to solid wastes?
- Is the project compliant with legislation and management of waste products?

Available funding and financing

- Which funding or financing sources are locally available? Is there any public support available?
- What is the amount of GHGs that could be saved?

Impact assessments

- Who are the current users of this land, and are their rights fully respected in the process of development of agro fuels?
- What is the current state of local food insecurity and how dependent is the community/region/country on food imports, particularly for staple foods?
- Shall the expansion of energy crops increase dependence on imports, and potentially worsen local food insecurity?
- Can the local resources in question (land, water) be better used to service local food needs?
- What modes of agriculture will be favoured in the production of agro fuels and what will the impacts be for local smallholders?
- Can smallholders benefit from the expansion of energy crops and can opportunities be found to increase the incomes of smallholders and their position in local value chains?
- What is the state of local energy provision, and will the energy yielded be used for local electrification?

(Recommendations from Office of the High Commissioner on Human Rights and Special Rapporteur on the Right to Food and AETS Consortium 2013)

11 Useful information

Good environmental, and socio-economic practices for bioenergy feedstock production

AETS Consortium, 2013.Assessing the impact of biofuels production on developing countries from the point of view of Policy Coherence for Development. http://ec.europa.eu/europeaid/sites/devco/files/study-impact-assesment-biofuels-production-on-development-pcd-201302_en_2.pdf

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FAO, 2010.Making Integrated Food-Energy Systems Work for People and Climate. http://www.fao.org/docrep/013/i2044e/i2044e00.htm

PREDAS, 2004.Aménagement Participatif et Gestion Décentralisée des Forêts Naturelles pour la production de bois-énergie: Capitalisation de l'expérience nigérienne

Sustainable bioenergy tools

FAO BEFS Rapid Appraisal Tools:

- Country Status: http://www.fao.org/energy/befs/86186/en/
- Natural Resources - Biomass Potential Assessment (including Land Suitability Maps): http://www.fao.org/energy/befs/86187/en/
- Energy End-use Options - Techno-economic and Socio-economic Analyses: http://www.fao.org/energy/befs/86188/en/

FAO/IIASA. Global Agro-Ecological Zones (GAEZ) tool: http://www.fao.org/nr/gaez/en/

FAO/UNEP, 2012.A Decision Support Tool for Sustainable Bioenergy.http://www.bioenergydecisiontool.org/overview/Overview_content_web.pdf

FAO Water-Energy-Food Nexus Tool: http://www.fao.org/energy/81320/en/

GBEP, 2011.The Global Bioenergy Partnership Sustainability Indicators for Bioenergy, First edition – Executive Summary. www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/GBEP_Report_Indicators_Executive_Summary.pdf

IFEU, ENZO2 Greenhouse gas calculator for biofuels and bioliquids.https://www.ifeu.de/english/index.php?bereich=nac&seite=ENZO2

References on cookstove standards: http://cleancookstoves.org/technology-and-fuels/standards/index.html

The FAO Support Package to Decision-Making for Sustainable Bioenergy: http://www.fao.org/energy/82318/en/ including: the Decision Support Tool for Sustainable Bioenergy (DST), Bioenergy and Food Security (BEFS) Approach, the Bioenergy Environmental Impact Assessment Framework (BIAS), the GEF biofuels project screening toolkit, the BEFS Operator Level Tool.

A comprehensive repository of tools that can be used to assess bioenergy sustainability: http://www.globalbioenergy.org/toolkit/analytical-tools/en/ (updated 2011)

EU policy and implementation

COWI Consortium, 2009.Technical Assistance for an evaluation of international schemes to promote biomass sustainability

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EC, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

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Enabling policy environment

African Union and UNECA, 2014.Africa Bioenergy Policy Framework and Guidelines - Towards Harmonizing Sustainable Bioenergy Development in Africa

EUEI PDF and GIZ, 2014.Biomass Energy Sector Planning Guide

Netherlands Enterprise Agency, 2014. Sustainable Biomass Production and Use – Lessons learned from the Netherlands Programme Sustainable Biomass (NPSB). http://english.rvo.nl/sites/default/files/2014/06/Sustainable%20biomass%20production%20and%20use%20-%20Lessons%20learned%20from%20the%20Netherlands%20Programme%20Sustainable%20Biomass%202009-2013.pdf

Environmental impact assessment

European Commission, 2009. Commission Impact Assessment Guidelines. http://ec.europa.eu/smart-regulation/impact/commission_guidelines/commission_guidelines_en.htm

FAO, 2012.Environmental impact assessment – Guidelines for FAO field projects. http://www.fao.org/docrep/016/i2802e/i2802e.pdf

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Financing sources for bioenergy projects

A comprehensive repository of financing options for sustainable bioenergy projects and programmes: http://www.globalbioenergy.org/toolkit/financing-options-for-bioenergy/en/ (updated 2011)

Further Reading

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