Sustainable Energy Handbook

Module 4.5

Industrial heat and electricity produced by biomass

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1 General Introduction

The demand for biomass for heat and electricity is growing steadily worldwide. Total primary energy consumption of biomass reached approximately 57 Exajoule (EJ)[1] in 2013, of which around40% was modern bioenergy mainly for heat and electricity generation (GSR 2014). Heating accounted for the majority of biomass use, with modern biomass heat capacity rising about 1% per year to an estimated296 GW_{th}. Global bio-power capacity (bioelectricity & heat) was up to 88 GW and generation in 2013 exceeded400 TWh (including power generated in combined heat and power plants). Demand for modern biomass is driving increased international trade in solid biofuels, including wood pellets (GSR 2014). In the EU, around 5% of final energy consumption is from bioenergy (EC 2010), including solid, liquid and gaseous fuels.

Bioenergy is sometimes the cheapest sources of energy. Especially local resources such as residues and waste (e.g. straw, rice husks, corn stoves, stalk, nut shells, etc.) can be mobilised from the agricultural fields and processing centres and converted locally into biogas, bioelectricity and heat using simple technologies. Thus biomass for power has the potential to improve livelihoods through involving small farmers as direct producers or out-growers enabling them to generate new income, opening up employment opportunities, and thereby alleviating poverty and boosting rural incomes.

The use of slurry (a residue of biogas production) and ash (a residue of combustion and gasification processes) can improve soil quality and ultimately agriculture yields. Modern bioenergy strengthens equally commercial farming as it provides extra revenues for the farmers, can improve the environment and supply organic fertilizers to the market.

If sustainably managed, the production of the bioenergy feedstock can maintain or improve biodiversity and natural resource management. In fact, sustainable bioenergy production implies e.g. the ban of slash and burn practices as a way to clear land, which destroys biodiversity and contribute to soil erosion (and can attract the additional investments needed to implement such more sustainable practices).

Biomass has several potential advantages when compared to other renewable energy resources. For example it can be used for heat, power and combined heat and power (CHP), also in existing power plants (i.e. biomass co-firing, which usually need just minor technical adjustments to the plant), as well as being able to produce continuous energy, and therefore avoiding intermittency problems, like those associated with wind and solar. It can be stored and the energy generation can be adjusted to some extent to meet demand.

Some biomass sources require fuel processing activities, for example gathering, harvesting, drying and chipping in the case of woodchips. Therefore when compared to other renewable energy sources there is a greater potential for creating jobs and stimulating rural development.

[1] 1 Exajoule is equivalent to 1018 J (1 billion of billion Joule)

2 General principles

The suitability of a biopower system in a particular context depends on several aspects and no ideal technology exists as it depends mainly on the sustainability and economic viability of the available feedstocks, the type of energy service needed (e.g. electricity for lighting, space heating, etc), investment capacity and technological readiness. Diversity helps mitigate economic and climate related risk, but comes with a trade off in terms of economies of scale due to constraints of limited investment capital.

Biomass for heat and power can be provided at different scales: small industries can make use of low-grade heat, mechanical energy and off-grid electricity; large industries who need continuous electricity supply and may require high-pressure steam.

The biomass feedstock for heat and electricity can be originated from waste/residues, dedicated energy crops and plantations, or biomass harvested from natural resources. The potential for these different types of feedstock vary significantly between areas and within areas, as do the production, collection and conversion costs and the market value of end products. Each source has its specific advantages and disadvantages and the type of feedstock should be chosen in consideration of national objectives (see the "Bioenergy Overview" section for more details).

Planted forests are particularly relevant as they are becoming increasingly common, and their products traded, also internationally, as pellets or used locally often as wood chips provided that this is the most economically way to exploit them.

Agriculture, commercial and industrial organic residues, waste or co-products can be potentially used or converted to electricity and/or heat. Residues and wastes are particularly relevant for developing countries as there are important amounts that could be easily mobilized, and this is usually a low impact option. Residues can be split into two types: dry and wet. Wet residues can be used in bio-digesters (biogas). Dry residues usually consist of wood or parts of 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, stem cotton, etc. Dry residues can be either burned for heating, power, CHP or gasified.

3 Technology overview

Feedstock	Conversion process	Energy vector	End use	Typical scale range
Woody biomass / Crop residues / Agro-processing residues	Gasification into syngas	Heat	Industry, farms or public grids	5-100 kW_{th}[a]
		Electricity		10-1,000 kW[b]
	Combustion	Heat	Industry, farms or public grids	10-10,000 kW_{th}
		Electricity		500-50,000 kW
Animal waste / digestible organic wastes / wastewater	Anaerobic digestion	Heat	Industry, farms or domestic	1-1,000 kW_{th}
		Electricity		5-5,000 kW

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

Table: Relevant bioenergy technologies for heat and electricity

Gasification

Gasification is a thermochemical process that converts solid fuels into a combustible gas (or syngas). Syngas is a mixture of carbon monoxide (CO), hydrogen (H_2), methane (CH_4), carbon dioxide (CO_2) water vapour (H_2O) and nitrogen (N_2). It is a low calorific gas that has a net calorific value of approx. 4-6 MJ/N m^3, which is much lower than natural gas (34 MJ/N m^3). Nonetheless, the gas can be used in gas engines, diesel engines, and (industrial) thermal processes such as heating and drying.

The gasification process takes place in a gasifier. There are several types of gasifier; most commonly used type for small scale power applications is (downdraft) fixed bed gasifier which is suitable for a range of biomass sources. In the gasifier, the solid fuel reacts at elevated temperatures with a limited amount of oxygen, decomposing into gas, char, and ash. The raw gas is very hot and contains contaminants (tar and ash); it needs to be cooled down and cleaned before it can be used.

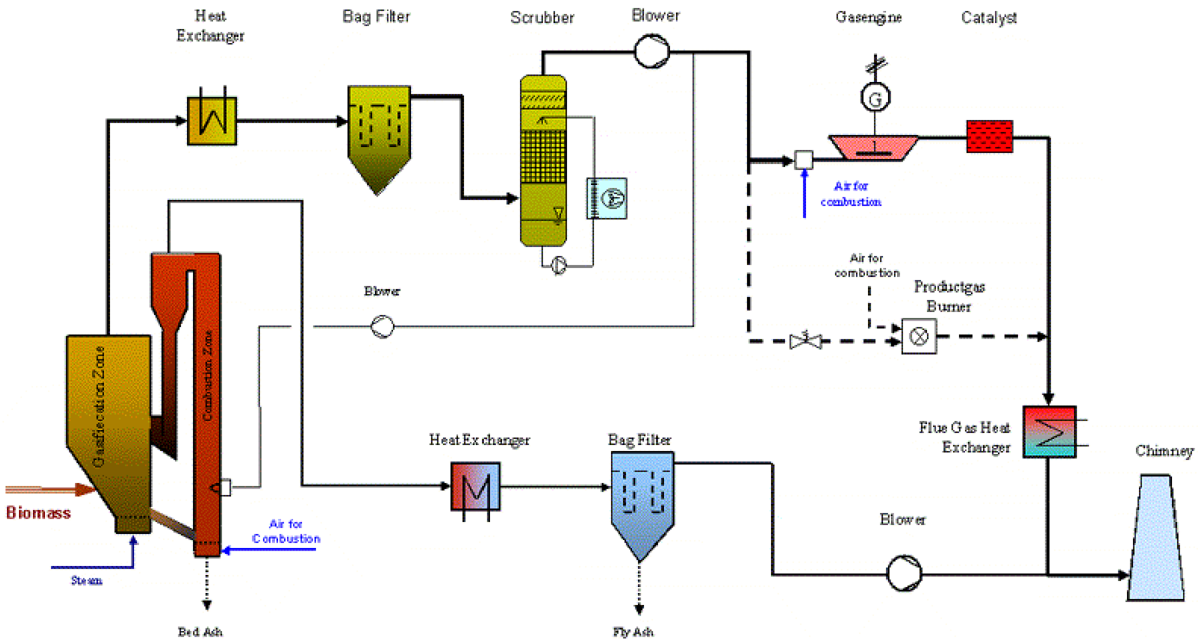


Figure - Biomass gasification plant scheme producing electricity and heat2

A large range of feedstocks is suitable for gasification, including wood chips, nut shells, corn cobs, and rice husk. Note that most gasifiers are sensitive to fuel quality (particle size, moisture content, ash content) and fuel management is a major challenge in gasification projects.

Advantages

- Gasification offers the possibility of converting solid biomass (residues) into power and heat over a large capacity range (10-1000 kW_e and higher) with a relatively high efficiency
- Investment costs of systems from Asia (India, China) are limited
- Especially in larger systems, electricity production costs are low

Disadvantages

- Gasifiers are relatively complicated to operate; they are typically sensitive to fuel quality and load variations, and prone to breakdown. Gasification is as such regarded by some as immature technology. They are often best operated in an industrial environment with skilled technical staff and readily available feedstock. Intensive operator training is required
- Gasifiers are less suitable for supplying small loads (in relation to their capacity) and highly varying loads
- Gas cleaning systems may cause local pollution of soil and groundwater

[2] This specificschemereferstothe CHP gasifierofGuessing in Austria - http://www.ficfb.at/renet_d.htm

- Operating costs for small systems (10-20 kW) may be relatively high

Gasification can efficiently convert solid biomass into electricity and fuel on a smaller scale (i.e. below the range where steam cycle systems are relevant).

Combustion

Combustion of biomass with conventional steam cycle for the production of electricity and / or process heat is well proven and commercially available technology. There are many examples of such systems in industry (sugar mills, palm oil mills, saw mills etc) and as stand-alone units for grid supply. Systems typically consist of a boiler plant in which the hot flue gases from biomass combustion produce high pressure, high temperature steam. The steam passes through a turbine, which in turn drives a generator. The expanded steam is either used for process heat or condensed. Particularly at larger scales (upward from several MW_e), fuel-to-energy efficiencies are considerable and specific investment costs go down.

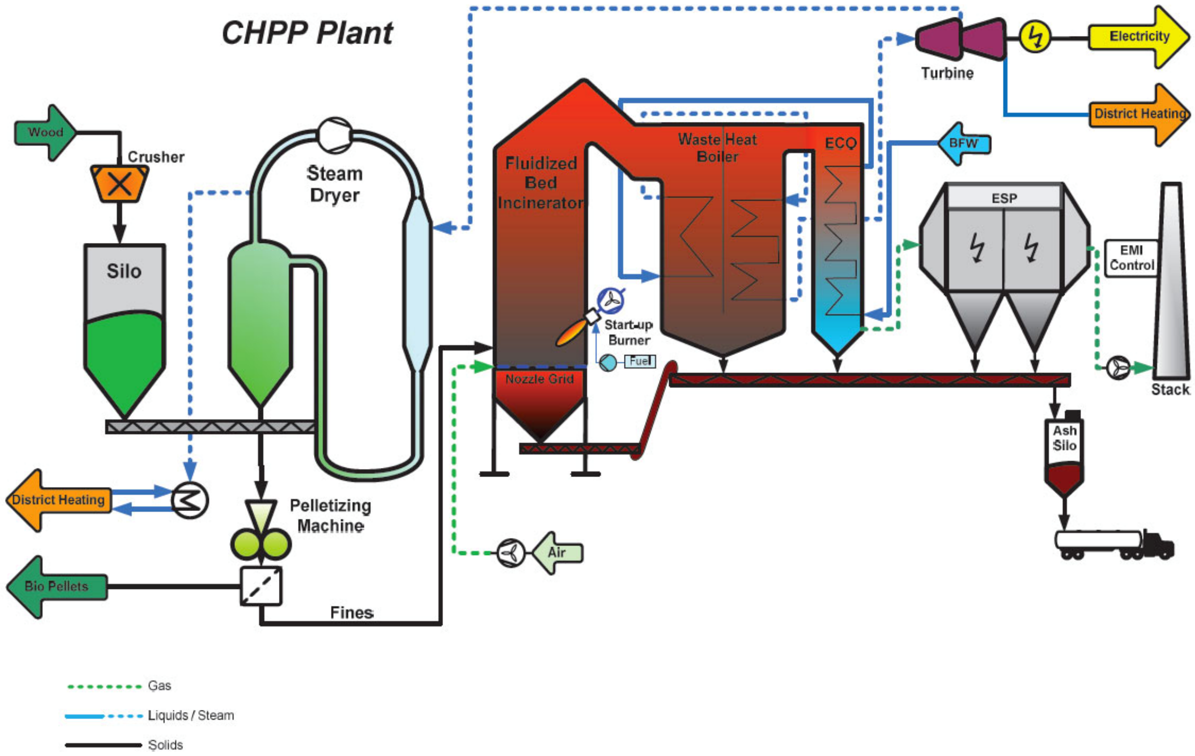


Figure - Biomass combustion plant scheme producing electricity, heat and wood pellets

Many types of (dry) biomass can be used, including wood, bagasse, empty palm fruit bunches, stalks, shells, husks etc. Ash (melting behaviour) can be a limiting point. The biomass should preferably be available year-round, in order for the power plant to operate at high availability. In general, the dryer the biomass, the better.

Advantages

- Steam cycles are efficient at high power: indicative 25% at 5 MW, 30% at 10 MW, 35% at 50 MW because of the characteristics of steam cycles and the fact that in large-scale combustion sophisticated measurement and control systems are available. Lack of cost-effective sensors and automation sets hard limits to small-scale combustion control.
- Highly reliable technology that can reach high availability rates, when properly operated and maintained, continuous fuel supply is secured and energy demand is sufficient

- Modern boiler systems are relatively flexible in terms of fuel properties (moisture and particle size)

Disadvantages

- Large quantities of biomass are required for larger systems (in the order of 1.5 tons of wood per MW_{el}), which complicates fuel logistics
- High investment costs for individual plants
- CHP plants require high availability for financial feasibility; this in turn requires a national grid able to absorb the power generated continuously throughout the year
- Especially with large systems, useful applications for waste heat are difficult to find
- The power generated can be adjusted within a very limited range, making biomass combustion more apt for base load power generation rather than to respond to a variable power demand

Large scale biomass combustion could play a role in strengthening the national grids and diversification of the fuel mix. There might be opportunities in large agro-industries that typically produce excess biomass (e.g. sugar, palm oil) or consume a lot of heat (e.g. brewery, cement, tea and coffee process industry).

Biogas

Biogas is a versatile fuel that is suitable for fuelling stationary engine applications. It can be used in dedicated (spark plug) gas engines and as a co-fuel in diesel engines, making it a practical fuel for stand-alone generators used in off-grid electricity supply and mechanical power applications (e.g. grain mills, rice decorticators, motorised water pumps). It can also be used as a fuel for (industrial) thermal processes, including heating, drying and singeing.

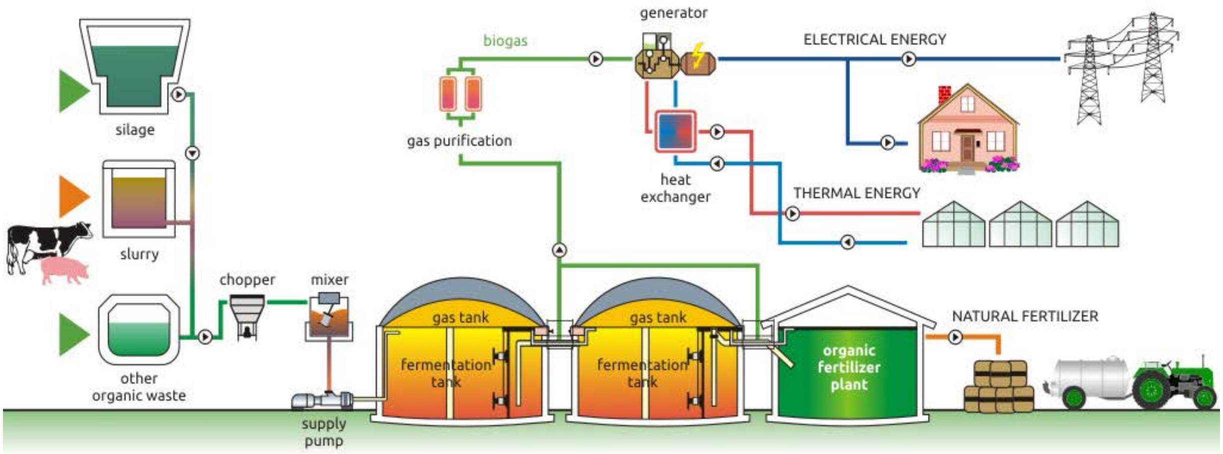


Figure - Biogas plant scheme producing heat and electricity

Biogas can be produced in a range of system types, including (stirred/unstirred) tank reactors, plug flow systems, and lagoon type systems. Simpler systems have no stirring and heating devices installed, but these are generally less versatile with respect to feedstock. In some cases, biogas conditioning (dewatering, desulphurisation) is needed in order to avoid damaging engines. Applicable system scale depends on the power/energy requirements, but typically ranges from 10-1000 m^3/day of biogas for power systems being able to produce 5-200 kW of electricity.

Several types of genset can be used to transform the biogas into electricity and heat using internal combustion engines. Possibly the biogas should be filtered and/or upgraded removing corrosive gas and increasing its heat value before being combusted. Small diesel and gasoline genset (1-5 KW) can be easily be adapted to run also with biogas. Often small gasoline genset can be start with gasoline and can subsequently be fuelled with biogas adjusting the amount of air in the combustion chamber.

One important limitation of biogas systems is that they require a fairly constant power demand. Usually digesters can act as buffer but only for slight temporary changes in biogas demand. As an alternative, it is also possible to add a biogas storage to the system, although this is a not very common solution. Gas storage can vary from 50 m^3 to over 5000 m^3 over usable volume.

Biomass feedstocks include:

- Animal dung
- Slaughterhouse waste, waste from food processing (fruit/vegetable, oil seedcakes, starch residues, brewery wastes, market waste, organic fraction of municipal solid waste (MSW), municipal liquid waste and aquatic weeds (e.g. water hyacinth)
- There is also a range of fast-growing energy plants that can be grown for biogas production (e.g. euphorbia tirucalli, elephant grass)
- Ligno-cellulosic feedstocks (wood, rice husk) are unsuitable
- A reliable source of feedstock at low or no costs is a prerequisite of most biogas projects.

Advantages

- Biogas is potentially very profitable when diesel power is the only practical alternative, and biogas feedstock is readily available
- It can be very profitable for (industrial) thermal applications that are otherwise fuelled with fossil fuels
- It is suitable for powering mini grids, either solely or in combination with other (renewable) energy technologies such as solar PV
- The waste from the digester or slurry, can improve nutrient recycling and productivity in agriculture
- Fermentation of the feedstock helps to decrease the possibility that diseases spread from animal waste which is not properly disposed of.

Disadvantages

- Biogas for power is often not competitive with electricity from the national grid[3] and, with PV system prices dropping, solar power is becoming more competitive per unit of KWh produced.
- The required quantities of feedstock can be considerable; due to the high water content, transportation is often unpractical and/or expensive.
- Water consumption for some feedstocks can be considerable
- More complicated feedstocks require more complex technology, which can be challenging to manage.

Biogas is one of the few options for powering heavier loads, such as those often found in productive systems. It can be used directly in virtually any diesel engine, reducing fuel consumption of existing diesel systems that are used extensively in off-grid areas. Especially uncomplicated biogas systems are relatively affordable and easy to manage.

[3] As a reference, a 250 KW biogas plant using ad-hoc grown crops can generate electricity at a cost (LCOE) of around 0.2 USD/KWh.

4 Technology Benchmarks

The tables below summarize the current costs of the main technologies for heat and electricity from biomass for commercial purposes, associated and depending on their characteristics. Certain technologies can make use of residues and waste, and should therefore be prioritized, while others cannot.

BIO-ELECTRICITY					
Technologies and feedstock	**Typical plant size**	**Conversion efficiency**	**Capacity factor**	**Capital costs (USD/kW)**	**Energy costs (LCOE[4] US cents/kWh)**
Bio-power from gasification	0.03–40 MW	30–40%	40–80%	2,050–5,500 (Global)	6–24 (Global)
Bio-power from anaerobic digestion	0.075–20 MW	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 and organic MSW)	0.5–200 MW	25–35%	25–95%	800–4,500 (Global) 200–800 (Co-fire, Global) Up to 1,000 (China and India)	3–22 (Global) 4–12 (Co-fire, Global) 14 (Europe) 5-6 (China)

DISTRIBUTED RENEWABLE ENERGY IN DEVELOPING COUNTRIES		
Technology	**Typical characteristics**	**Energy costs (LCOE USD/kW_{el} 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	8–12 (Global) 4 (Bangladesh)

HOT WATER / HEATING / COOLING					
Technology	**Plant size**	**Capacity factor**	**Conversion efficiency**	**Capital costs (USD/kW)**	**Typical energy costs (LCOE US cents/kWh)**
Biomass heat plant	0.1–15 MW_{th}	~50–90%	80–90%	400–1,500	4.7–29
Wood pellet heater	5-100 kW_{th}	15-30%	80-95%	360-1,400	6.5-36
Biomass CHP[5]	0.5–100 kW_{th}	~60–80%	70–80% for heat and power	600–6,000	4.3–12.6

Tables - Status of bioenergy technologies for heat and electricity at commercial scale: characteristics and costs (adapted from REN21, Renewables 2015 Global Status Report)

5 Economic and environmental impact

Biomass for heat and/or electricity has the potential to play a significant contribution to the future world energy mix and is an untapped resource in most of the developing world. However, the huge technical and economic potential of bioenergy, can be significantly limited by environmental and socio-economic (mainly food security) sustainability constraints. One of the key preconditions

[4] LCOE=Levelised cost of energy.

[5] CHP= Combined heat and power.

before setting-up large industrial biomass chains is the good governance of the natural resources as well as their sustainability.

In this context, the safest pathways include relying on agricultural residues and wastes. Countries with an important production of cocoa, cassava, coffee, groundnuts, sheanuts, rice, millet, sorghum, cashewnuts, palm oil, and coconuts, can surely already mobilize a large amount of bioenergy feedstock just making use of 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 can also resolve most of the waste disposal and environmental constraints. It will increase hygiene, reduce health risks, and avoid the depletion of soils.

Key **environmental concerns** include the overuse of natural resources through deforestation or increased extraction rates of forest biomass, with negative impact on soil quality, carbon stocks and biodiversity. For agricultural biomass, the issues include unsustainable intensification associated with excessive residue removal, excessive use of fertiliser and pesticides, and overuse of irrigation water. Most of these issues can be addressed by sound land-use planning, strict application of good management practices, and the use of well-adapted indigenous energy crops (e.g. use of perennial instead of annual species). Social and economic impacts are also important factors in the overall impact of bioenergy production. Bioenergy deployment has considerable potential to create employment in the agricultural and forestry sector and along the supply chain, and thus to benefit rural communities (IEA 2012).

Serious impacts on health can arise due to **fine particles** (<2.5 micro meter diameter) from biomass combustion. The filters and scrubbers that remove particulate matter and are commonly installed in utility-scale power plants are rarely applied to smaller scale biomass combustion units. However, small scale particle removal technologies are becoming available, and electrostatic precipitators seem to be quite suitable for this purpose, but of course require a source of electricity (IEA Bioenergy Task 32, 2011).

A considerable number of **certification schemes** that deal specifically with the sustainability of biofuels for transport exist but few schemes include biomass used for heat and power generation, which reflects the lack of specific legislation. However, there are several well established schemes that certify forestry and agricultural products, and these could provide a basis for certification schemes for bioenergy for heat and electricity (see 'References' for more details).

Many **policies and strategies** are implemented at regional and national as well as local levels in order to improve sustainable access to bioenergy. In the development context, they are often focused on reforestation, decentralisation and increased participatory forest management approaches involving local communities. For example the empowerment of rural actors in the management of forest resources on their land, as part of the Household Energy Strategy (HES), an approach that links energy to forest management, has appeared to be a power tools for poverty reduction. The outcomes include:

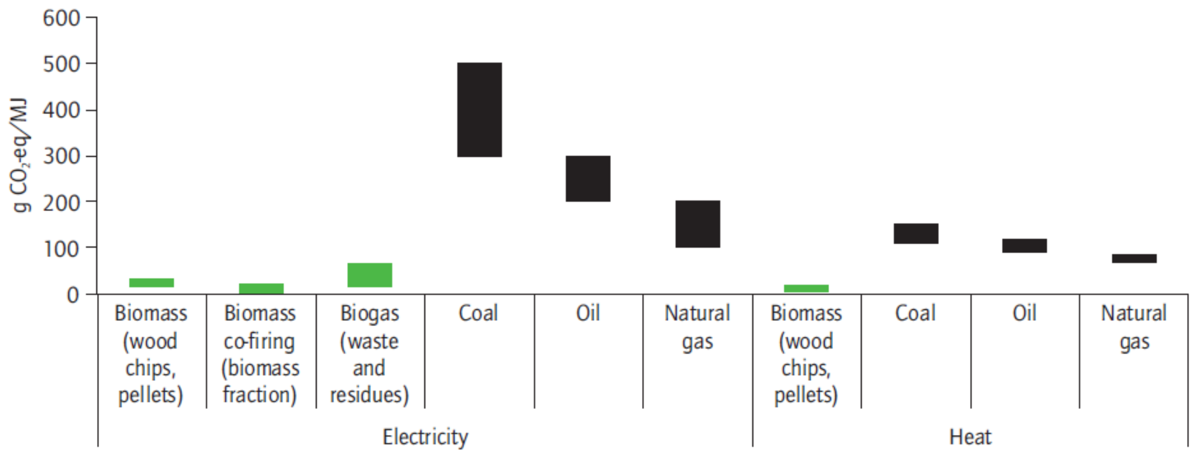
- Development of simplified methods of forest management and / or village forest management;
- Development of methods to manage woody formations in agricultural areas;
- The ownership of the operational approach to local forest management by local actors;
- The effective transfer of technical and / or scientific innovations to local actors;
- Change of approach from the forestry staff in charge of assisting the local management of forest formations;

- Consideration of the ecological approach as a basis for sustainable management of village forests;
- The economic and ecological sustainability of local management of natural forest (PREDAS, 2004).

In addition to the revenue generated from the sale of marketed outputs, some forest owners may also receive income from **payments for environmental services** (PES). PES occur where resource owners or managers are paid for the production of environmental services such as watershed protection, carbon storage or habitat conservation. Such schemes can result in real economic costs and benefits if they bring about changes in management of the resource or increased net revenue for those making the payments. They are therefore relevant components of value added or income in the sector (FAO 2014).

One of the key issues for heat and power generated from biomass is the reduction of lifecycle GHG emissions compared to the use of fossil fuels, as this is one of the key drivers to promote bioenergy use. **GHG benefits** of bioenergy systems can be evaluated by comparing them with the energy system they replace through a lifecycle assessment (LCA) (see Bird et al., 2011 for more details). For bio-power the GHG reduction potential depends on the biomass feedstock, cultivation modalities, transport distance and mode as well as conversion technology and process efficiency among other factors. Good agricultural and forestry management practices ensure sustainable biomass extraction rates, reduce the use of energy-intensive fertilizers, and mitigate soil degradation (IEA, 2012. See 'References' for more info on good agricultural practices).

Bioenergy for heat and power can provide considerable emission reductions compared to coal, oil, and natural gas generated heat and power, when no additional GHG emissions from changes in land use occur. The lowest lifecycle GHG emissions can be achieved through use of residues and wastes on site.



Note: Based on current state of technologies. Ranges reflect variations in performance as reported in literature. Possible emissions from land-use change are not included here.

Figure - Lifecycle GHG emissions (excluding land use change) per unit of output for a range of bioenergy (green) and fossil (black) options (IEA, 2012)

Electricity generation technology	Ammonia emissions (g/kWh)	Life cycle NOx emissions (g/kWh)	Life cycle SOx emissions (g/kWh)
Hybrid poplar gasification combined cycle	0.04	0.65	0.4
Willow HP gasification	0.03	0.60	0.4
Willow LP gasification	0.03	0.70	1.0
Willow Direct combustion	0.04	0.30	1.0
Average coal	0.10	3.40	6.8
Natural gas	0.02	1.6	0.3
Large scale biogas from straw	-	0.60	0.02
Large scale biogas from liquid manure	-	0.50	0.02

Table - Comparison of non-GHG emissions from electricity generation from wood, straw, manure, coal and gas for selected technologies (adapted from Borjesson and Berglund, 2006 and Galbraith et al. 2006)

The **main challenges for the development of a biopower sector** in a development context revolve around the following issues:

- Governance of forest resources and natural resources, through the delegation of sustainable management of forest resources to local communities as part of the implementation of the decentralization policy in some countries.
- 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 that can address the concerns of an integrated, fair and inclusive development and restore social (gender), geographical (rural/urban) and green (sustainable forest management) equilibrium.
- The need to articulate the supply side and demand side for bioenergy for the sustainable supply of different (domestic) energy sources to the population. Experiences show the relevance of an approach combining both, the offer in terms of production of bioenergy (reforestation, participatory forest management) e.g. to enhance the availability of wood in rural and urban areas and, on the other hand, the demand by diversifying alternative fuels to reduce dependence on wood or kerosene through the dissemination of biogas, biodiesel, ethanol and LPG.
- The practical steps for the implementation of financial incentives and mechanisms, such as feed-in-tariffs (FiT), to promote the production of bioelectricity from anaerobic digestion, gasification, cogeneration and use of engines working with biofuel.
- Use of energy feedstock for grid power generation in multifunctional platforms, especially in rural areas where grid extension is still too expensive. Actually, growing bioenergy feedstock in a food-energy integrated system can not only stimulate production of local energy but also of food, feed and fibre crops (FAO, 2010).
- 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 a life-cycle perspective.

6 What are the key questions?

1. Environment and natural resources

- 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 used for heat and power?
- If the biomass is sourced locally, are sufficient land and water resources available?
- Which are the most suitable crops and the most adequate modes of cultivation?

2. Socio-economic effects

- 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?
- 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?
- 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?
- Are there regulatory mechanisms in place which encourage and empower private operators in making decision for investing in the production of modern bioenergy/bioelectricity and existing supervising public entities in sustainable land management?
- Who are the stakeholders involved in biopower generation? Are there existing national and international partnerships, between governments or different actors to promote bioenergy development?
- Is biomass (waste, wood, crops,…) to generate heat and electricity the best way to valorize this resource or are there other alternative uses?
- How much will biomass transportation and the logistics associated cost per unit of energy produced?

3. Legal, institutional and enabling environment

- How are local tenure rights managed?
- Is there a regulatory framework 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 specialized skills available?
- Is corruption an issue and is local governance transparent enough?

- Are the appropriate bioenergy technologies and services locally available?
- 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, char, waste heat)?
- Which sustainability requirements should the bioenergy produced comply with and what is the associated compliance cost?
- Is there good understanding of innovative and tested financing mechanisms in the region, on diffusion of business models, frameworks and best practices? In a context of poverty, demonstrated economic models can foster private investments to meet the local needs.
- Are there mechanisms in place for systematic collection of data on bioenergy (official statistical surveys, census, etc)?
- What is the local awareness of agro-ecological zoning (AEZ), GIS tool, and availability of satellite data/remote sensing tools for land-use related decisions?
- **Does local quality standardization of feedstocks exist?**

4. Technology suitability

- What suitable type of biomass (chips/pellets/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?
- 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?
- What is the electricity to heat demand ratio?
- Which are the climatic and seasonal characteristics for the project site?
- Is there any need for a back-up system?

7 Useful information

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

FAO, 2012. Good Environmental Practices in Bioenergy Feedstock Production - Making Bioenergy Work for Climate and Food Security. www.fao.org/3/a-i2596e.pdf

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

BEFS, 2012.Policy Instruments to Promote Good Practices in Bioenergy Feedstock Production.http://www.fao.org/uploads/media/1203_BEFSCI-FAO_Policy_instruments_to_promote_good_practices_in_bioenergy_feedstock_production.pdf

BEFS, 2011. Good Socio-economic Practices in modern Bioenergy Production. http://www.fao.org/docrep/015/i2507e/i2507e00.pdf

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

Some biogas system implementers

- Rota Guido (Italy) - http://rotaguido.it/
- FRI-EL Biogas (Italy) - http://www.fri-el.it/
- Snow Leopard (Germany) - http://www.snow-leopard-projects.com/
- Asja (Italy) -http://www.asja.biz/
- Rokim Group (Kenya) – www.rokimgroup.co.ke
- BDI –BioEnergy International (Austria) – www.bdi-bioenergy.com
- Sattler (Austria) – www.sattler-ag.com (biogas storage solutions)

Some biomass power plant implementers

- ICS Energietechnik Gesellschaft (Austria) – www.ics-austria.at
- KohlbachGruppe (Austria) – www.kohlback.at
- APL Apparatebau (Austria) – www.apl-apparatebau.at
- ETA Heiztechnik (Austria) – www.eta.co.at
- Lambion Energy Solutions (Germany) – www.lambion.de
- BioElectric Solutions (Sweden) - http://www.bioelectric.se/(financing of sustainable biomass power projects)

EU policy

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Sustainability schemes for biomass for heat and electricity

Some sustainability certification schemes include:

- The International Organization for Standardization (ISO) - www.iso.org
- International Sustainability and Carbon Certification System (ISCC) - www.iscc-system.org
- Roundtable on Sustainable Biomaterials (RSB) – www.rsb.org
- NTA 8080 - www.sustainable-biomass.org
- Forest Stewardship Council (FSC) - www.fsc.org
- Programme for the Endorsement of Forest Certification (PEFC) - www.pefc.org

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Further Reading

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FAO Bioenergy and Food Security (BEFS) Project: http://www.fao.org/energy/befs/en/

FAO Wood Energy Website: http://www.fao.org/forestry/energy/en

FAO, 2014. State of World's Forests 2014

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