Ashden India
Renewable Energy Collective

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Briefing Paper Series on Decentralised Renewable Energy for Sustainable Energy Access

# Mainstreaming Bio-Energy for Heat and Power: Systematically Tapping Opportunities

Biomass resources provide nearly 30% of India's energy needs. Traditional biomass is also a major energy resource in nearly 70% of Indian households. Much of this energy is in the form of agricultural waste, forest residue, and dung gathered from nearby areas and used as fuel for cookstoves. In recent decades, biomass-based energy has evolved from being a locally and freely available cooking fuel of poor rural households to a fuel for agriculture-based industries such as jaggery making and turmeric boiling, and a commercial fuel used in boilers and furnaces in industries such as textiles and tea-drying, as well as for power generation.

This evolution has resulted in the gradual 'monetisation' of biomass-based energy. This energy monetisation is characterised by all or some of the following: formal or informal markets for unprocessed biomass; formal and informal arrangements for collection of biomass; facilities for storage and processing; markets for aggregated and/or processed biomass; and informal and formal pricing of processed (and in some cases, unprocessed) biomass.

Some see this monetisation as an outcome of the need to expand India's energy mix, as well as an enormous opportunity for biomass to transition into a mainstream fuel to meet India's growing energy needs. There is little doubt about the energy potential of India's biomass resources. However, to optimally harness this potential, many issues need to be probed, much caution is to be exercised, and many questions must be answered.

## Bio-energy: potential and opportunities

Biomass, as a source of renewable energy, is considerably more flexible than other renewable energy forms. Globally, bio-energy is one of the largest sources of renewable energy and can provide heat, electricity, and transport fuels (IEA, 2012). This paper focuses on bio-energy use for heat and power.

There are various technologies used to derive thermal and electrical energy from biomass resources. Bio-energy can be provided in solid, gaseous, or liquid forms. Most importantly, it can be stored and can therefore be dispatched or used at times (of the day or year) and in places where energy is needed. Bio-energy can therefore play a complementary role in the provision of variable renewable electricity from wind and solar in the power system.

Harnessing bio-energy has significant potential for employment and income generation during the various stages from cultivation to harvest, processing, and conversion into energy. Biomass fuel sources are readily available in most rural areas. Bio-energy is considered to be low carbon or carbon-neutral (albeit under certain conditions of harvesting and use), and because it is an indigenous resource it can strengthen energy security. Rising coal and oil prices and mounting global pressure to reduce energy-related carbon emissions have also increased the demand for bio-energy, globally and in developing countries such as India.

## Bio-energy for heat and power: technology options

A wide range of biomass feedstocks can be used for heat or power generation. These include organic wastes such as agriculture and forestry residues, purpose-grown energy crops, sewage sludge, animal wastes, and organic liquid effluents as well as the organic component of municipal

## >> Highlights

- Biomass is a major energy source in India, but most of it is free traditional biomass used in rural households.
- Modern biomass has enormous potential for industrial uses and electrical power generation.
- Modern applications of bio-mass require it to be commer-cialised, or monetised.
- Industrial and power applica-tions require biomass to be processed for efficient han-dling, storage, and utilisation.
- Jobs will be created in the bio-mass supply chain, and com-mercial markets will emerge.
- Regulation and certification of biomass will ensure its sustainable cultivation and harvest.

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| | Basic and applied R&D | Demonstration | Early commercial | Commercial |
|---|---|---|---|---|
| **Biomass pre-treatment** | Hydrothermal treatment | Torrefaction | Pyrolysis | Pelletisation/ briquetting |
| Anaerobic digestion | Microbial fuel cells | | 2-stage digestion<br>Biogas upgrading | 1-stage digestion<br>Landfill gas<br>Sewage gas |
| **Biomass for heating** | | | **Small scale gasification** | **Combustion in boilers and stoves** |
| **Biomass for power generation** | | | | |
| Combustion | | Stiring engine | Combustion with organic rankine cycle | Combustion and steam cycle |
| Co-firing | | Indirect co-firing | Parallel co-firing | Direct co-firing |
| Gasification | Gasification with fuel cells | Biomass internal combustion gas turbine<br>Biomass internal gasification combined cycle | Gasification with engine | Gasification with steam cycle |

**Source**: Modified from Bauen *et al.*, 2009 as cited in IEA 2012

**Figure 1**. Globally available biomass technologies at various stages of development

solid waste. Most commercial biomass receives some form of treatment before it is converted to energy; pelletisation and briquetting are the most common. Figure 1 shows the various bio-energy technologies at various stages of development. The technologies used for bio-energy conversion in India include the following:

- As fuel in traditional cookstoves (most common);
- Heating through combustion, largely after processing (such as drying, chopping, pelletisation or briquetting) in improved or larger stoves, and in industrial boilers;
- Through anaerobic digestion, wet biomass such as animal dung or land-fill waste is used to produce biogas;
- Biomass for power generation takes various forms, including combustion and steam cycle, direct co-firing, and gasification with steam cycle.

## Heat and power from bio-energy: large potential yet to be achieved

The Ministry of New and Renewable Energy (MNRE) estimates the annual biomass-based electricity potential at 18 GW, generated by 120–150 million tonnes of biomass. This estimate is in addition to about 5 GW of power possible from bagasse-based cogeneration in sugar mills. While the potential is high, results have been lagging. MNRE estimates indicate that just half of the 2013/14 targets have been met for biomass-based grid-interactive power capacity. While 4 GW of installed capacity was expected, just 2.1 GW is installed. The results have been similar (a little over 50% of targets) for off-grid biomass-based systems. The key issues are with agro-residues such as rice husk, cotton stalk, coconut shells, soya husk, coffee waste, and sawdust. The concerns are the availability, collection, processing, and pricing of these biomass feedstocks.

Biomass energy for thermal applications, especially cooking, is by far the most common use of biomass and is the single largest energy-use category in India, albeit largely non-commercial and therefore unrecorded. Biomass-based cooking solutions also include improved biomass cookstoves and biogas, which have been promoted by programmes of the MNRE. Unfortunately, initiatives have met with mixed results for a variety of reasons, including poor understanding of user priorities and weak feedstock arrangements. Biogas plants also continue to under-perform, with installations accounting for just half of the targeted 1 lakh plants in 2013/14. The Ministry's programme for improved cookstoves has now been revised and is discussed in another paper in this series.

## Expanding bio-energy: challenges

While managing biomass feedstocks is a serious challenge for bio-energy projects, there are other concerns. In the 1980s and through the 1990s, concerns were raised about the growing practice of head-loading[1] of firewood to cater to urban firewood needs in small towns and large cities that have flourishing firewood markets. As firewood markets become an important source of livelihood and income, the question arises if there will be a tendency to exploit the biomass resources unsustainably and even illegally. There were reports of women in some rural areas having to walk even greater distances than usual to collect firewood, or having to switch to inferior fuels such as shrubs, roots, weeds, or crop residue in loose form (Ramana *et al*., 1997).

[1] Women and girls carrying large and heavy bundles of firewood on their heads is a common sight around villages. This is typically firewood collected from forest or forest fringe areas being taken for sale to informal markets.

Early signs suggest that the expansion of commercial biomass energy poses a genuine danger of biomass becoming unaffordable or unavailable for basic activities like cooking and water heating in poor rural households.

Such issues are not to be seen as negative aspects of biomass energy, but as concerns that must be carefully analysed and resolved as we move ahead in the process of adopting biomass as a broader, mainstream source of energy.

## Biomass availability and allocation

### *Gaps in biomass availability assessment*

The Biomass Resource Atlas of India (http://lab.cgpl.iisc.ernet.in/Atlas/) provides a survey of biomass availability, especially for its use in power generation. The atlas takes into account present uses in traditional practices and socially essential uses such as fodder, domestic fuel, thatching, and manure. Data updates on crop residue are based largely on published secondary data for assorted crops. However, surveys are not being conducted to update consumption and price figures. There also appears to be no effort to capture the rapidly growing use of biomass for industrial applications, or to incorporate such information in planning for availability and price of biomass residue for other uses (Ocampo, 2011). In the absence of reliable data that adequately captures the dynamics of demand and supply of biomass resources, questions remain about their sustainability.

### *Arrangements for biomass collection, processing, storage, and distribution*

To date, biomass-based power projects have used surplus agriculture and forestry residues, but their availability and collection have proven to be a challenge. Biomass processing and distribution among various categories of biomass feedstocks is complex. Planning for bio-energy projects must include institutional arrangements, pricing mechanisms, and physical infrastructure for collection, processing, and distribution of feedstocks. Standards and regulations applied to feedstock quality, and transparent mechanisms for fuel pricing are also imperative.

## Equality and resource security issues

### *Potential impacts on energy inequality*

Bio-energy has traditionally been the fuel of the poor. It was collected without cost, processed minimally, and used as an important source of thermal energy or as a soil nutrient. With the practice of aggregation and processing, biomass becomes a value-added resource. However, as indicated above, this value addition and associated monetisation allows large industrial users of biomass briquettes and pellets to acquire large quantities of high-quality biomass.

Large industrial customers are more attractive than scattered rural users because of their greater ability to pay and lower transaction costs. This has resulted in higher prices, especially for processed biomass.

Biomass briquettes typically have a calorific value similar to Indian coal (at around 4000 kcal/kg) but with a much lower ash content (just 1%–10% compared to an average of 35% for Indian coal). Given that biomass briquettes compare favourably with coal, their price has skyrocketed to nearly that of coal. The knock-on effects have been dramatic for biomass fuels such as rice husk or sugarcane bagasse that were available to villagers without cost just a few years ago.

This rise in biomass prices has also adversely affected the viability of biomass plants, especially larger units whose tariffs were based on old prices. A few small plants with strong customer support and willingness to pay have managed to stay afloat, but it has been a struggle.

How this process has affected the poor is a matter of serious concern and requires extensive study. Anecdotal evidence indicates that the poor, in the face of dwindling fuelwood supplies, are switching to inferior fuels such as leafs and twigs. At the same time, fuel gathering has become a more arduous and time-consuming task, a pattern seen two decades ago.

### *Competing uses of biomass and land resources*

Bio-energy programmes have often been embroiled in the 'food versus fuel' debate, exemplified by the controversy over corn used for biofuels production in North and South America. The debate was whether the corn should be used for food or fuel. Competing uses of biomass resources for fuel, food, feed (for livestock), or manure have to be acknowledged.

One option for harvesting biomass feedstocks is to develop energy plantations. Bio-energy projects associated with plantations are considered to have good potential. A study[2] is now under way to explore dedicated energy plantations on part of India's estimated 467 lakh hectares of wasteland. It is important to investigate the productivity of these wastelands, their potential alternative uses, and the requirement of other inputs such as water and fertiliser.

[2] Part of the MNRE–UNDP/GEF-assisted project 'Removal of Barriers to Biomass Power Generation in India' as cited in Biopower India January–March 2014, Volume I, Issue I, an MNRE–UNDP quarterly magazine on biomass energy.

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Bio-energy plantations can also compete for productive land, as alleged by critics of waste-to-energy projects that use forest residue or agricultural waste. These critics argue that so-called 'waste' in the forestry or agricultural sector has often traditionally been used as farm manure or livestock feed, and therefore the land should be considered productive. Resolving such arguments is important in the valuation of bio-energy resources.

### Climate and environmental issues

With biomass monetisation, incomes of those in the biomass harvesting, processing, and distribution industries are dependent on biomass resources. Consequently, the likelihood of over-harvesting of biomass increases.

#### *Carbon-neutrality not clear*

Early sustainability issues around biomass harvesting focussed on the alleged carbon neutrality of biomass. In reality, this debate hinges on the methods used to characterise the carbon and greenhouse gas (GHG) impacts associated with using biomass. The discussion is complicated by differing definitions of the term carbon neutrality, and different options that may be used to characterise carbon neutrality.

There are many carbon accounting methods in use and they are useful for different purposes. The most common applications for carbon accounting are GHG inventories, product carbon foot-prints, company carbon footprints, and policy studies. It is important to use carbon accounting methods that are appropriate for the issue being examined. In addition, how the choices made in applying these methods can affect the results of studies of feedstock carbon and other products. The use of biomass energy for avoiding carbon emissions, however, continues to be misunderstood. But the focus has now shifted to environmental sustainability around principles for sustainable harvesting of biomass as discussed below.

#### *Other environmental issues*

Harvesting leaves and twigs may not seem harmful, but it robs the soil of rich organic matter. Similarly, reducing standing vegetation could increase soil erosion and water run-off. Emissions associated with biomass combustion also need to be monitored closely.

### Way forward: requisite checks and balances

It is clear that there are many questions about biomass in terms of environmental and social issues. As biomass is main-streamed as an energy source, several of these issues will only magnify unless effective steps are taken to systematically address them. While some of these concerns are intrinsic to bio-energy, others are a manifestation of poor policies or inaction.

### Multi-criteria impact assessment of biomass monetisation

It is sometimes assumed that biomass monetisation and the use of processed biomass represents a comprehensive transition to improved forms of energy. This is not always the case, as when the use of processed biomass in one sector results in the use of inferior fuels by marginalised groups. There are also instances of biomass pellets being exported, potentially compromising the country's energy security. In countries without surplus biomass, a ban on exports must be legislated.

Biomass monetisation can also threaten environmental sustainability and exacer-bate energy access inequities. Some of these issues may be addressed by systematically ensuring that production and processing of bio-energy feed-stocks create livelihood opportunities and economic benefits for poor rural households.

There is, therefore, a need to assess how processing of biomass and its use in clean and modern devices actually constitutes improvement. This assessment must be based on criteria that include energy security; energy access; energy efficiency; impact on natural resources such as water, forests, and land; reliability; and cost. Mechanisms to mitigate adverse effects must be identified.

### Research focus on biomass-based energy technologies

India, with its rich tradition of research and a bountiful biomass resource base, is well placed to become a global leader in biomass energy research. But this can happen only if there is a clear emphasis on biomass in leading technology research institutions, including Council of Scientific and Industrial Research laboratories. Several biomass fuels and energy technologies are mature, while many others need to be tested and demonstrated, especially waste-to-energy technologies.

Waste-to-energy projects based on agricultural residue and food waste hold enormous potential. Monetisation of feedstock based on such waste material can trigger efficient collection and processing of this material.

At the same time, opportunities exist but are not being tapped adequately, with biogas plants an example. Bricks and mortar plants are expensive, and non-masonry biogas plants offer an economic alternative. Flexible balloon digester-type plants are fabricated from special reinforced fabric, and the digester itself is a closed thin cylindrical pressure vessel (Kannor, 2011).

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## Policies on biomass energy allocation and pricing

Further research on biomass energy resources is needed, focusing initially on the availability of marketable surplus. Allocation of biomass must ensure that energy for the poorest households is not compromised, and studies of potential impact of biomass monetisation on energy access among the poorest households will guide policy.

There is also a need to analyse the price escalation and pricing principles (cost-plus, alternative use or opportunity cost, and replacement cost or price of substitutes) of diverse biomass feedstocks for various applications. Valuation and pricing of bio-energy is complex and, to be sustainable, biomass resources must be competitive, accessible, and used efficiently.

## Regulating the quality of biomass feedstocks

The uses of biomass are specifically designed to match feedstock properties, and often pre-treatment is necessary. Standards for different types of pre-treated biomass would help reduce technical challenges and the costs arising from conversion of biomass to energy (IEA, 2012). Grading of bio-energy feedstocks (as is done with coal) on the basis of calorific value, ash, and moisture content is essential if these feedstocks are monetised and are traded in significant quantities. Such grading will also raise awareness about quality aspects of the fuel.

## Regulation for environmental sustainability

Clear principles need to be articulated for harvesting of biomass from forest resources so that sustainability of the resource base is guaranteed. A recent IEA study on sustainability certification of bio-energy (IEA, 2013) highlights the need to set '… sustainability requirements for production, processing and trade of biofuels, bio-liquids and/or solid biomass, which must be fulfilled in order to meet present national targets and/or to be eligible for financial support.' As an example, the Renewable Energy Directive of the European Union provides numerous sustainability criteria, including the following:

- No raw material from land with high biodiversity value, such as primary forest, nature protection areas, or highly bio-diverse grasslands (unless it can be shown that biomass extraction is part of a management regime compatible with, or a requirement for, high biodiversity);
- No raw material obtained from land that had the status of continuously forested lands or wetlands until January 2008;
- Raw materials in European Union (EU) must be cultivated in accordance with the EU Common Agricultural Policy (with subsidies for producers for biofuels feedstocks).

India's dubious record of enforcement, especially on environmental issues, makes the promulgation and implementation of such stringent criteria for bio-energy harvesting or procurement unlikely in the near future. Biomass has historically been considered a free resource and regulating its harvesting may be viewed as an infringement of the basic rights of communities living in forest fringe areas. A two-pronged approach may be needed; local communities would be educated about the dangers of biomass over-harvesting (with the need to define the term), and regulatory provisions would keep a check on large-scale harvesting of forest resources for industrial and commercial applications.

## Comprehensive national bio-energy mission needed

For a country that has many missions, departments, and ministries, it is perplexing that there is no specific policy on bio-energy. The National Biofuels Policy focuses exclusively on liquid biofuels for transport, and has been a subject of much debate. A bio-energy policy that covers all forms of biomass-based energy is sorely needed. This paper raises major issues and suggests several important principles that such a policy should cover to ensure that India's bio-energy potential is tapped scientifically and systematically.

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