October 2010

Bio Energy for Rural Development and Poverty Alleviation

Prepared for

Global Network on Energy for Sustainable Development

Project Report No. 2008DG10

www.teriin.org

The Energy and Resources Institute

Suggested format for citation

T E R I. 2010
Bioenergy for rural development and poverty alleviation
New Delhi: The Energy and Resources Institute.
[Project Report No. 2008DG10]

For more information

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Executive Summary

India's energy demand is expected to be more than three to four times the current level in the next 25 years. Non-commercial energy sources, predominantly fuel wood, chips and dung cakes, currently contribute around 30% of the total primary energy consumed in the country. With huge urban-rural disparity in terms of access to commercial energy forms such as grid electricity and LPG, bioenergy (energy from bio-resources) has an important role to play in not only contributing to the supply to meet future demand but also in reducing the existing energy access in-equity. As biomass as a resource is more equitably distributed than other energy sources in India and also can be procured locally from a variety of sources, it addresses energy security concerns in a country like India which is already dependent on energy imports.

Bioenergy contributes to nearly 90% of energy used in rural households and about 40% of energy used in urban households use. Unfortunately, use of biomass as energy in India is characterized by low efficiency and environmental degradation. Unprocessed biomass is mostly used in traditional stoves and furnaces that have low efficiencies, of the order of 10% with serious indoor air pollution and negative health impacts.

This study focuses on two bioenergy technologies, biomass gasification for power and biogas for cooking with lessons incorporated from a case study each for the two technologies. Population having access to electricity for lighting and clean cooking energy enjoy multiple social benefits like facilitating education for children and economic opportunities arising from avoided health related expenditure. Further, on average, labour intensive biofuels would generate about 100 times more workers per joule of energy content produced in comparison to capital-intensive fossil fuel industry which contributes to livelihood augmentation of economically under-privileged sections of society. Though several government policies, programmes and civil society initiatives have taken place in the past, past achievements to promote bioenergy technologies on ground have not been able to tap India's bioenergy potential.

Life cycle analyses of biogas and biomass gasification technology are reported to outperform conventional fossil fuel based technologies for power generation in economic terms in some cases. Sustainability of bioenergy depends largely on how the risks associated with its development – especially pertaining to the land use and climate implications of large-scale feedstock production and potential social inequity- are managed on project to project basis. The report conclusively proves the role that bioenergy can contribute to rural development and poverty alleviation.

CHAPTER 1 Introduction

Context

Bio energy refers to renewable energy resources derived from organic matter, such as forest residues, agricultural crops and wastes, wood and wood wastes that are capable of being converted into modern energy carriers. The various conversion routes for bio-energy are presented in Figure 1.1. The solid biomass includes the use of trees, crop residues, household or industrial residues for direct combustion to provide heat. Biogas is obtained by anaerobic digestion of organic material such as cattle waste and leafy biomass. The liquid bio fuels, usually used in place of petroleum derived liquid fuels, is obtained by processing plants, plant seeds or fruits of different types such as sugarcane, oilseeds or nuts using various chemical or physical processes.

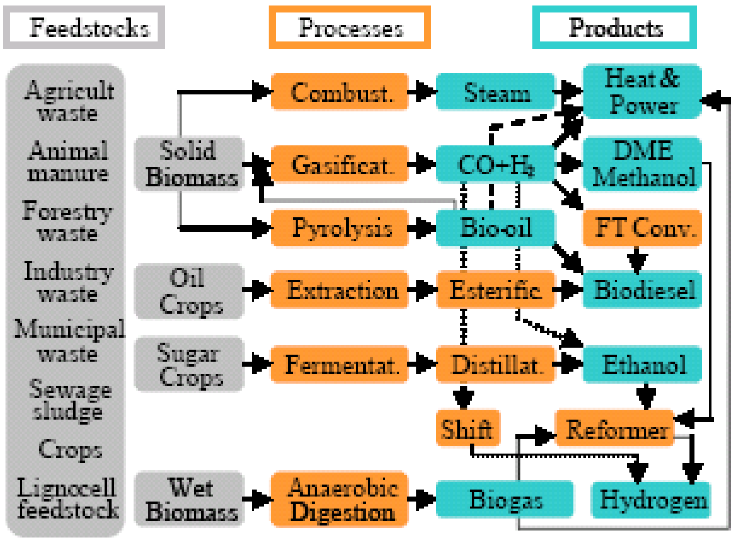

Figure 1.1: Biomass conversion routes

In the total energy mix of India, biomass fuels play a vital role especially in its rural economy, as it constitutes the major energy source to a large number of rural enterprises apart from majority of households in the rural and peri urban India. According to IEA (International Energy Agency) estimates, the number of people relying on biomass for cooking and heating in India during the year 2000 was about 585 million and this is projected to increase to 632 million during 2030. Among the various biomass fuels, fuelwood is the dominant fuel and its consumption is estimated to be in the range of 162 to 298 million tonnes followed by 37 to 156 million tonnes of crop residue and 64 to 114 million tonnes of cattle dung[1] (Table 1.1). Dependence on biomass is expected to continue in India, due to the projected increase in rural population in absolute terms and continued lack of access to commercial fuels in rural areas particularly for cooking.

Table 1.1 Current and expected future energy consumption in households

Source	Consumption 2003-2004 MTOE (%)	Projections 2031-2032 MTOE (%)
Fuelwood	92.57 (57.82)	106.39 (37.44)
Agro waste	17.12 (10.69)	-
Dung cake	22.62 (14.13)	40.47 (14.24)
Biogas	0.71 (0.44)	-
Kerosene	10.69 (6.68)	15.12 (5.32)
Electricity	7.72 (4.82)	69.72 (24.53)
LPG	8.68 (5.42)	52.49 (18.47)
Total	160.11	284.19

Source: Ravindranath N H and Balachandra P. Sustainable bioenergy for India: Technical, economic and policy analysis; Energy (2009). doi10.1016/jenergy.2008.12.012

Further, with greater pressure on the country to reduce the emission of green house gases and the rising oil prices there is an increased interest in using bio energy as a renewable source of energy. However, traditionally use of biomass as energy in India is characterized by low efficiency and environmental degradation. Modern bio-energy technologies such as biomass combustion and gasification for power, production of bio diesel and ethanol as liquid fuels and biogas as gaseous fuel provide opportunities for meeting energy needs sustainably, improving quality of life and protecting environment, including addressing climate change. It is expected that cleaner sources of bio energy will contribute to the sustainable development of the rural areas through agricultural modernisation, rural electrification, provision of cleaner cooking fuels, employment generation and opportunities for small entrepreneurial activities, etc.

As regard the liquid form of bio energy i.e biofuels, the current trend of business investment in large-scale monoculture of biofuels like Jatropha is fraught with sustainability challenges. Given the current state of knowledge gaps about the genetics, input responsiveness, agronomy and impacts of Jatropha plantations, it is a high risk venture (Achten et al., 2010). Critics claim that production of biodiesel can lead to seizure of common lands by corporate investors, putting livelihoods of small and marginal farmers at risk (Aruvian's R'search, 2010). Doubts have also been raised on whether the life-cycle carbon balance, that is, the net carbon effect, taking inputs, transports and other side effects into account, is really positive as it may

[1] N.H. Ravindranath, P. Deepak and Shamiyulla Najeem, 2007. Biomass for Energy - Resource Assessment in India; Development Benefits of Clean Energy in India

significantly vary with site conditions and other technology input parameters. Hence, given the controversial nature of biofuels as their production holds “significant economic (e.g., subsidies and protectionism), social (e.g., food security) and environmental risks (e.g., loss of biodiversity and water recharge, negative carbon balance)” (Achten et al., 2010), it was decided that the biofuels would be excluded from the review. Further, as the concept of in-situ usage of small scale community based biofuel initiatives is yet to be demonstrated successfully and sustainably, given the uncertainties of productivity it would have been pre-mature to project biofuels as a critical energy source at household/ community level. Hence, the study focuses on solid or gaseous form of bioenergy with focus on technologies (like biomass gasifier and biogas) which have non-technical bottlenecks (like institutional linkage and economics preventing its wide scale dissemination and adoption) have been reviewed in greater details.

With the above background, TERI under the theme of ‘Bio-energy’ aims to study the impact of bio-energy on rural development and poverty alleviation in India with support from GNESD.

Methodology

The study involves extensive survey of secondary literature to study the relevance and potential of bioenergy resources in India. Also, policy documents were reviewed extensively during the study to asses the regulatory, institutional, financial and policy framework of bioenergy sector in the country.

The study focuses on solid or gaseous form of bioenergy which assumes importance at household level in India. Two case studies covering modern and mature bioenergy technologies- biomass gasifier and biogas plant were studied. In this context, TERI studied Village Energy Security Programme (VESP) and Biogas program of SKG Sangha for woody biomass and biogas respectively. The relevant lessons were incorporated in the concerned chapters. The case studies are detailed in the annexure of the main report. The key question addressed through case studies, is whether rural communities have benefited, as envisaged, from bio-energy programme. The case studies have analyze reasons for lacunae and suggested steps and policies that need to be in place to ensure that such bio-energy programmes can contribute to rural development.

Structure of Report

The report is divided into 8 chapters. Chapter 1 defines the context of the study. Chapter 2 presents the linkages of bioenergy with other sectoral policies in the country followed by the relevance of bioenergy in India’s energy matrix in the next chapter. Chapter 4 details the bioenergy resource potential in India. Chapter 5 describes the strategies adopted for promotion of bioenergy for rural development followed by chapter 6 which describes the opportunities/constraints to rural development in this regard. Chapter 7 presents the regulatory, institutional and financial framework. Chapter 8 finally presents the recommendations and conclusion to the study.

CHAPTER 2 Review of policies related to bioenergy sources

India has a long history of bio energy planning and programme interventions. The national biomass policy originated in the decade of 1970's, as a component of rural and renewable energy policies. The rural energy crisis called for a national policy response to find economically viable and sustainable energy resources to meet growing rural energy needs. To reduce the increasing oil import burden and to diffuse the rural energy crisis, RET (renewable energy technology) programmes were initiated in late 1970s. Biomass, being a local, widely accessible and renewable resource, was potentially the most suitable to alleviate macro and micro concerns raised by the rural energy crisis.

The biomass policy followed a multi-pronged strategy: i) improving efficiency of the traditional biomass use (e.g. improved cook-stove programme), ii) improving the supply of biomass (e.g. social forestry, wasteland development), iii) technologies for improving the quality of biomass use (e.g. biogas, improved cook-stoves), iv) introduction of biomass based technologies (wood gasifiers for irrigation and biomass electricity generation) to deliver services provided by conventional energy sources, and v) establishing institutional support for programme formulation and implementation. The institutional response resulted in the establishment of DNES (Department of Non-Conventional Energy Sources) in 1982 and state level nodal energy agencies during the early 1980s decade.

The RET programme received the required support with the establishment of the DNES, which emphasized decentralized and direct use of RETs. The renewable energy resources were viewed primarily as the solution to rural and remote area energy needs, in locations and applications where the conventional technology was unavailable or as stop gap supply options where commercial energy could not be supplied. Direct subsidy to the user and supply orientation were the major element of the renewable energy programme. Though the RET program achievements are noteworthy in India, two deficiencies in policy perspectives contributed to the slow progress in the penetration of biomass technology. Firstly, the biomass was viewed solely as a traditional fuel for meeting rural energy needs. Secondly, the policies primarily focused on the supply-side push with market instruments having little role in biomass policies[2]. Under the circumstance, neither the modern plantation practices for augmenting the biomass supply nor the growing pool of

[2] Shukla P R; Biomass Energy In India: Transition From Traditional To Modern; The Social Engineer, Vol. 6, No. 2; < http://www.e2analytics.com>

advanced biomass energy conversion technologies could penetrate the Indian energy market.

Currently, the new perspective views biomass as a competitive energy resource, which can be pulled through energy markets. The timing of the change in the perspective coincided with the development of several advanced biomass technologies. As a result, the Ministry of New and Renewable Energy (MNRE, erstwhile DNES) policy shift towards market based incentives and institutional support has led to introduction of modern biomass technologies such as bagasse-based co-generation and large-scale gasification and combustion technologies for electricity generation using a variety of biomass. The current bio energy programs and policies in India with respect to modern usage of bioenergy (solid and gaseous forms) are described below.

Direct combustion and cogeneration

Biomass power and cogeneration program is being implemented in the country with the objective to promote technologies for optimum use of country's biomass resources for power generation. MNRE has been supporting the promotion of biomass power /co-generation programme since the mid nineties. It has been estimated by MNRE that surplus agricultural residues can generate about 16,000 MW of grid quality power with the present available technologies. The biomass power projects in the country are all private sector driven. In the cogeneration projects, which largely exist in sugar industries, the generated power is used in the sugar mill and the balance is exported to the grid.

Central Financial Assistance (CFA) in the form of capital subsidy and or interest subsidy has always been instrumental in building promoters' interest for bringing investments in the sector. Besides the CFA, fiscal incentives such as 80% accelerated depreciation, concessional import duty and excise duty exception on equipments, tax holiday etc are also available for biomass power projects. At the state sector, different State Governments have also taken initiatives and declared their policies for attracting private investment in biomass power projects. Preferential feed in tariffs along with renewable purchase obligation declared by the State Electricity Regulatory Commissions is also assisting the growth of the sector.

Biomass Gasifier

MNRE is promoting the biomass gasifier programme with the following key objectives:

- To deploy biomass gasifier systems for meeting unmet demand of electricity in villages;
- To take up demonstration projects for 100% producer gas engine, coupled with gasifier for off grid and grid power

operation;

- To meet electricity needs for water pumping and other electrical applications on decentralized basis from various types of woody and non-woody biomass available in villages

The biomass gasifier projects can be taken up by village level organization, Panchayats, institution, private entrepreneurs and industries, in rural areas. The programme is implemented through the state nodal agencies with the involvement of energy service companies (ESCOs), co-operative, panchayats, NGOs, and manufactures or entrepreneurs etc. The total installed capacity of biomass gasifier systems as of Jan 2009 is nearly 160.31 Mweq[3]

Biogas based distributed/ grid power

In addition to the biomass combustion and gasifier program, MNRE also started a scheme called biogas based distributed/ grid power generation programme from 2005-06 onwards with a view to promote biogas based power generation, specially in the small capacity range, based on the availability of large quantity of animal wastes and wastes from forestry, rural based industries (agro / food processing), kitchen wastes, etc. Under the program, MNRE provides CFA to a maximum of Rs.30000 to 40000 per kW depending upon capacity of the power generating projects in the range of 3 kW to 250 kW of different rating limited to 40% of the plant cost. The projects could be taken up by any village level organization, institution, private entrepreneurs etc in rural areas.

Village Energy Security Programme

The Village Energy Security Programme (VESP) was started by the MNRE in 10^{nth} five-year plan with an objective beyond electrification to provide total energy requirement of villages including lighting, cooking, and motive power with the involvement of local community. VESP aims to transform the locally available biomass energy use in rural remote areas from traditional biomass that is currently in use, mostly in unsustainable manner to innovative modern biomass energy use in sustained manner. Clear emphasis of VESP is thus on energy security; with a further thrust on productive micro enterprise development linked to existing rural credit facilities and local employment generation to enhance the income of rural households. The program is quite innovative and novel as it tries to solve an emerging 3E-trilemma of maintaining Energy resources; sustaining Economic development and preventing Environment degradation through a pragmatic approach.

[3] www.mnes.nic.in

Test projects on village energy security are being taken up to demonstrate the techno-economic parameters, provide operational experience, mobilize local communities and firm up the institutional arrangements to operate and maintain the energy production system. The energy production systems comprises of improved cookstoves, biogas plants based on dung/ oil cakes or leafy biomass; biomass gasifiers coupled with 100% producer gas engines; and, biofuel based engines running on 100% straight vegetable oils.

Under the program 90% of capital cost is provided as grant by MNRE and remaining 10 % is mobilised by the community/ Project Implementation Agency (PIA) and or SNA (State Nodal Agencies). Further, support is also provided towards professional charges to implementing agencies and administrative charges to SNA towards operation and maintenance charges.

The World Bank under its Policy and Human Resource Development Fund (PHRD) grant project on 'Biomass for Sustainable Development' is also supporting the pilot phase of VESP for the period of 2006 -2009 . The purpose of the grant is to identify and test scaleable models for designing and implementing community-driven programs for meeting comprehensive village energy needs. The focus is on business models for small-scale biomass based applications that can meet energy needs related to productive uses, cooking and lighting. A total of 95 test projects, including 56 ongoing projects and 39 new projects in 8 States are covered under this World Bank supported program.

Improved Cook stoves

The NPIC was launched in 1983 with the aim to disseminate improved mud cookstoves, equipped with chimneys, and portable metallic stoves to increase the fuel use efficiency and to reduce indoor air pollution. Under NPIC, three types of IC were promoted, which included fixed-type cookstoves, portable cookstoves and high-altitude metallic cookstoves, with an efficiency of over 20% for fixed cookstoves and over 25% for portable ones. The aggregate number of IC disseminated by 2003 was around 35.2 million[12]. However, the NPIC was found to be ineffective over the long term and MNRE discontinued the programme since 2002. Currently, the responsibility of promoting IC lies on state and local governance institutions and NGOs. However, with the lack of central government support and limited funding the success rates are negligible.

National Project on Biogas Development (NPBD)

The national biogas program, which mainly caters to setting up of family type biogas plants, has been under implementation since 1981-82. The NPBD was broadened and rechristened as National Biogas and Manure Management Program. The key objectives of the programme are:

- To provide fuel for cooking purposes and organic manure to rural households through family type biogas plants;
- To mitigate drudgery of rural women, reduce pressure on forests and accentuate social benefits;
- To improve sanitation in villages by linking sanitary toilets with biogas plants.

The programme is implemented by the SNAs, Khadi and Village Industries Commission (KVIC) and NGOs. MNRE provides central subsidy in fixed amounts, turn-key job fee linked with three years' free maintenance warranty; financial support for repair of old-non functional plants; training of users, masons, entrepreneurs, etc. At the household level, the cumulative number of biogas plants built from 1982 to 2006 is estimated to be 4.09 million against a potential of 12 million[12]. Some selected NGOs such as SKG Sangha, Gram Vikas etc has attained good success in implementing the biogas program in India.

There is also brief discussion on policies and current experience related to liquid form of bioenergy i.e biofuels in Box 2.

Biofuel activities in India stand out against other parts of the world because it is mostly based on the use of non-edible oils derived from oil-bearing trees that can grow on less fertile land (Altenberg et al., 2009). In other words, biofuel development in India centers almost "exclusively" around cultivation of Jatropha and to some extent for Pongamia. As Jatropha is projected as the "wonder crop" which reclaims wasteland (no competition with food crops or high carbon stocks unlike sugarcane ethanol or palm oil corn) while promoting socio-economic development (Achten et al., 2010), it has been the "most politically and morally acceptable choice amongst India's present biofuel options" (Mutha, 2010).

Policy Aspect: In September 2008, the Government of India adopted a National Biofuels Policy which aims at substituting 5% of transport (fossil fuel) diesel with bio-disesel by 2012, 10% by 2017 and 20% beyond 2017, thereby establishing demand-side incentives in form of an assured market for blending apart from scrapping taxes and duties on bio-diesel (Altenberg et al., 2009).

In the process, the Government has mandated that bio-diesel comes from non-edible oil seeds and be grown on waste, degraded or marginal lands. Government has already identified 400, 000 sq. km (98 million acres) of such land to achieve this amibitious target (Mutha, 2010). It is important to actually ascertain whether this land is "waste/ idle" as it has been reported that even unsuitable degraded land is still often used illegally by the economically disadvantaged for subsistence agricultural production or – even more commonly – for cattle husbandry (Altenberg et al., 2009). The policy also advocated for greater research and development, while aiding plantations, processing and production technologies including cellulosic biofuels.

There has been certain gaps between the policy planning and its implementation. Based on Planning Commission of India's Integrated Energy Policy (2003), Government of India had mandated 5% blending of ethanol that would have been raised to 10% by 2007-08. To meet the targets for 5% blending with ethanol in 2006-07, about 0.50 million tons of ethanol was required, while about 1.01 million tons would have been required to meet the target of 10% blending. Ethanol in India is primarily produced by the fermentation of molasses, a by-product in the manufacture of sugar from sugarcane. Molasses is traditionally used for the production of alcohol. The availability of molasses depends on sugar production and unfortunately there was low sugar production. Such fluctuation in price of molasses (fluctuated considerably over the 2001- 2006 to range between Rs 50/ton to Rs 2,000/ton) led to lack of economic uncertainties over ethanol production. Hence the first phase of the project (5% blending in selected states) had to be abandoned. The project was reinstated in September 2006 and it was estimated that 0.2 million tons of ethanol was blended against the target of 0.43 million tons in 2006-07 (Rao and Bantilan, 2007).

The three primary categories of biofuel value chain which is currently being implemented in India is described below:

- Government-centred cultivation which is characterised by cultivation on government (forest and/or revenue) and community land. In this scenario, government plays the role of an investor and promotes employment generation for the rural poor with co-benefits for increasing the national forest cover, and protection of the soil from further degradation
- Farmer-centred cultivation which is characterised by cultivation on private land. It involves tripartite or shared risk arrangement between government, farmer and private processing companies to protect interest of small/ marginal farmers.
- Corporate-centred large scale mono-culture which is characterised by large-scale cultivation where private oil companies act as the main investor (risk-taker), and the objective of achieving high returns on investment.

While the union government policy has only recently been approved, several state governments took the lead and established their own biofuel policies, each setting its own priorities and employing particular policy mixes. Major states promoting bio-diesel include Andhra Pradesh, Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu and Uttaranchal.

CHAPTER 3 India's energy profile

India's energy profile

With a population of about 1.2 billion growing at about 1.5% annually, and an economy recording growth of over 9% p.a. in 2006-2008 and over 6% at the time of global recession. In concurrence with GDP growth, India's energy demand is also rising rapidly. India's energy demand is expected to be more than three to four times the current level in another 25 years (Ravindranath and Balachandra, 2009). Analysis of the latest data available from US Energy Information Administration (EIA) website , per capita energy consumption in India has risen by 28.25% in the period 1997-2007 in India, compared to the world average of 11.08%. Yet, in comparison to world average of 73.11 million Btu, per capita energy consumption in India is only 16.98 million Btu in 2007.

Coal dominates the Indian commercial energy basket followed by oil and gas. India's import dependence for commercial fossil fuels is demonstrated below. In Table 3.1 below, import dependence of major fossil fuel types are provides as percentage of its Total Primary Energy Supply (TPES) in India in 2007.

Table 3.1 Contribution and import dependence of major fossil fuel types in India

Energy Source	TPES (ktoe)	Import Dependence
Coal and Peat	242488	14.11%
Crude Oil	163450	76.07%
Natural Gas	33370	28.88%

Source: EIA Website

However, contribution of non-commercial bio-energy is significant in India's primary energy basket. Ravindranath and Balachandran (2009) have reported that non-commercial energy sources, predominantly fuel wood, chips and dung cakes, contribute around 30% of the total primary energy consumed in the country. It has been reported that 46% of households using firewood and chips in rural India obtain these fuels through 'free' collection; about 21.14% of households depend on home grown stock; and 23.7 per cent make cash purchase. In comparison, two-thirds of urban households using fire wood need to purchase the same. Yet, bioenergy does not figure in most energy analyses as they are confined to "commercial" energy. Given that most of the biomass used in households is not transacted on the market, bioenergy data is "inadequate and not up-to-date (FAO, 2007). What is clear though – based on studies by TERI and others (NSSO, 2008) is that biomass delivers nearly 90% of energy used in rural households and about 40% of energy used in urban households use.

FAO (2007) reported that in 2005, contribution of bioenergy was 29.4% of India's TPES. Analysis of India's Energy Balance (IEA, 2009) also substantiates the role of biomass based energy in India's energy basket. Table 3.2 below provides the breakup by energy carrier type for India's Total Final energy Consumption (TFC) in 2007 indicating the prominent played by biomass based energy in India's energy basket.

Table 3.2 Contribution of energy (by type) in India's energy usage

Energy Type	Contribution to TFC
Coal and Peat	11.9%
Petroleum Products	30.2%
Gas	4.5%
Electricity	12.4%
Combustible renewables and waste[4] (CRW)	40.9%

Source: EIA Website

The existing pattern of usage of Combustible and Renewables (CRW) detailed in Table 3.3 based on IEA energy balance estimates shows that almost 80% of CRW is used for residential energy purposes.

Table 3.3 Break up of sector wise usage of Combustible and Renewables in India

Sector	Usage Pattern
Residential	78.7%
Industry	17.4%
Others	3.9%

Source: EIA Website

Most of CRW is for use in the residential sector is consumed for cooking, water heating and space conditioning needs and is produced locally. However, traditionally use of biomass as energy in India is characterized by low efficiency and environmental degradation. Unprocessed biomass is mostly used in traditional stoves and furnaces that have low efficiencies, of the order of 10% (Ravindranath and Balachandra, 2009).

There are also other concerns associated with the use of biomass in this way. Most important among the ill-effects of

4 97% of which is biomass-both commercial and non-commercial

Source: www.iea.org/papers/2006/renewable_factsheet.pdf use of traditional biomass for cooking are the health effects of indoor air pollution (Box 3.1).

Box 3.1 Concerns associated with traditional biomass as a cooking fuel

Concerns posed by the high and persistent dependence on traditional biomass for cooking are now well-known. The smoke emitted by the combustion of biomass fuels in traditional cook stoves contains several hazardous pollutants including particulate matter, carbon monoxide, nitrogen dioxide, formaldehyde and polycyclic organic matter including carcinogens like benzopyrene. The problem worsens when these stoves are not vented to the outside, producing, pollution levels often 10-30 times those recommended by the health agencies. In the last few years, there have been several studies that have focused on the health impacts of IAP and its association with household energy use in India. Usage of solid bio-fuels is characterized by burning in traditional unimproved, open stoves causes emission of substantial amounts of harmful pollutants, such as particulate matter (PM), carbon monoxide, and nitrogen and sulfur oxides. Further, as mostly such burning occurs inside poorly ventilated kitchens (Deasi et al, 2004), Indoor air pollution (IAP) levels in rural households are often much higher than outdoor air pollution in cities. For instance, typical levels of PM10 in rural households range from 300 to 3 000 micrograms per cubic metre (μg/m3) (WHO 2002), whereas even in the most polluted cities rarely exceed 150 μg/m3. Globally, indoor air pollution from solid fuel use is responsible for 1.6 million deaths, with the overall disease burden (in Disability-Adjusted Life Years or DALYs, a measure combining years of life lost due to disability and death) exceeding the burden from outdoor air pollution by five times.

WHO has reported that almost 40% of acute respiratory infections (ALRI), more than 20% of chronic obstructive pulmonary disease (COPD), and almost 3% of DALYs are caused by IAP from burning of solid fuels (Arcenas et al, 2010). This makes IAP the second most important environmental risk factor after water, sanitation, and hygiene (WHO, 2002). Further, in 2000, indoor air pollution was responsible for more than 1.5 million deaths worldwide making reliance on solid bio-fuels “as one of the ten most important threats to public health”. Also, indoor air pollution from the burning of traditional biomass fuels increases the risk of chronic obstructive pulmonary disease, acute respiratory infections among children, cataract, adverse pregnancy outcomes, pulmonary tuberculosis, asthma and cancer in women[5].

Also, contrary to the general view that biomass use is carbon-neutral, the dependence on traditional devices for burning unprocessed biomass has adverse effects from the carbon point of view as well. This stems from inefficiencies at two ends: (1) in unsustainable harvesting of firewood and (2) in inefficient combustion of firewood.

Among the various biomass fuels, fuel wood is the dominant fuel and its consumption is estimated to be in the range of 162 to 298 million tonnes followed by 37 to 156 million tonnes of crop residue and 64 to 114 million tonnes of cattle dung (Ravindranath et al, 2007).

Within the residential sector, there is a wide disparity in quality and access to energy services between urban and rural households. NSSO (2008) estimates 160,868,100 rural households and 57,843,400 urban households in India. According to IEA (International Energy Agency) estimates, the number of people relying on biomass for cooking and heating in India during the year 2000 was about 585 million and this is projected to increase to 632 million during 2030. Table 3.4

[5] http://www.who.int/mediacentre/factsheets/fs292/en/index.html

demonstrates the dependence of rural population on bioenergy sources for cooking needs. The major cooking fuels in India are firewood and chips, dung, kerosene and LPG and it is evident that firewood and chips is the primary cooking fuel in most rural households. It has also been reported that among rural LPG- consuming households, only 2.7 per cent were using it as the only cooking fuel and the rest were multiple fuel users with dependence on biomass. Yet, in spite of lack of access to quality energy, rural households spend about 10% of total household expenditure on energy for cooking and lighting compared to 9% for urban households.

Table 3.4 Primary energy source for cooking

Primary Cooking Primary Energy Source for cooking	Percentage of Rural households	Percentage of Urban households
Firewood and chips	75.4%	22.1%
LPG	8.9%	59.2%
Dung Cake	9.1%	1.7%
Kerosene	0.8%	7.5%

.Source: NSSO, 2008

The above discussion conforms to the view that rural energy scenario is characterized by inadequate, poor and unreliable supply of energy services and large dependence on traditional biomass fuels (Ravindranath and Balachandra, 2009).

Biomass fuels play a vital role especially in its rural economy, as it constitutes the major energy source to a large number of rural enterprises apart from majority of households in the rural and peri urban India.

Dependence on biomass is expected to continue in India, due to the projected increase in rural population in absolute terms and continued lack of access to commercial fuels in rural areas particularly for cooking. Planning Commission (2006) has estimated that share of bioenergy in total household energy consumption would be over 50% in 2031-32. The table 3.5 below indicates the continued relevance of bioenergy in the foreseeable future (Ravindranath and Balachandra, 2009).

Table 3.5: Present and Future projections on importance of bioenergy in household

Source	Consumption 2003-2004 MTOE (%)	Projections 2031-2032 MTOE (%)
Fuelwood	92.57 (57.82)	106.39 (37.44)
Agro waste	17.12 (10.69)	-
Dung cake	22.62 (14.13)	40.47 (14.24)
Biogas	0.71 (0.44)	-
Kerosene	10.69 (6.68)	15.12 (5.32)
Electricity	7.72 (4.82)	69.72 (24.53)
LPG	8.68 (5.42)	52.49 (18.47)
Total	160.11	284.19

Source: NSSO, 2008

Further, with greater pressure on the country to reduce the emission of green house gases and the rising oil prices there is an increased interest in using bio energy as a renewable source of energy. Multiple government programmes have been launched in the past to tap into the huge potential of bioenergy such as National Biogas Programme. The National Mission on Decentralised Biomass Energy encapsulates much of the Government of India’s vision in employing biomass to address both the energy and the development needs of rural communities. The programmes on improved cook stoves and promotion of LPG as a cooking fuel were also rooted in such a perspective. However, not only were these initiatives fraught with gaps, such a view also failed to tap bio-energy as a strategic energy option (Box 3.2 below)

Box 3.2: Improved cookstoves, LPG and biogas: as alternatives to traditional biomass

Improved biomass stoves

The Indian government initiated the National Programme on Improved Cookstoves NPIC in 1983 in response to concerns associated with the use of biomass in traditional stoves. Improved biomass stoves typically seek to improve combustion efficiency (thereby reducing the need for fuel the collection of which entails a lot of effort and time) and reduce emissions (which is associated with significant adverse health effects). The NPIC was implemented by the Ministry of New and Renewable Energy in cooperation with regional, district, and state government offices. Under the original program, the NPIC provided a subsidy of at least 50% for households purchasing an improved cookstove. From 1983 to 2000, approximately 35 million ICS of various types were distributed; however, the NPIC has not been effective or successful over the long term in promoting a fundamental change-over to improved stoves in India. The programme being target-driven rather than needs-driven, was sometimes mistakenly focused on areas that there was no history of cash spending on stove and fuel. Also minimal interactions among designer, producer and user led to designs that were not suited for user requirements / expectations. Also, decentralised production of stoves and stove parts has resulted in high cost of production. Eventually, in 2002 the responsibility for the dissemination of improved cookstoves was transferred to the states. Since this time, a handful of state governments and NGOs have continued ICS and related projects. Government of India is planning re-launch a national level cook stove programme in near future in the backdrop of new technological innovations in the technology like forced draft stoves and entry of commercial private players.

LPG[6] as a cooking fuel

LPG has been positioned as a transition fuel for many decades and this has been the rationale for a continued subsidy on the fuel. Over the years, household energy transition from traditional biomass to LPG is evident though this is confined to urban households, particularly middle and higher income classes. As a result, the LPG subsidy – meant to spur access to clean cooking energy among poor households – has been skewed in its being enjoyed more by the rich than the poor. The persistent use of firewood in rural households, even by those with LPG connections[7] is an indicator of gaps with LPG as a transition fuel. And these gaps reportedly range from unreliable supplies and higher cost compared with biomass.

Likewise, most programmes to promote bioenergy technologies have not been able to achieve its goals as demonstrated by their cumulative performance in Table 3.6 (Ravindranath and Balachandra, 2009).

Table 3.6 Bioenergy potential in India

Item	Power generation/ Energy Potential	Cumulative Achievements (as of 30-Sep-2006)
Power generation from wasteland cultivation	45000 MW	0
Power generation from Surplus biomass	16000 MW	466.5 MW
Power generation from sugar cogeneration	5000 MW	571.83 MW
Waste to Energy	7000 MW	34.95 MW
Bioenergy from Cattle dung	17.8 billion m3/year	1.12 billion m3/year
Ethanol for transport	10 MTOE/year	> 1 MTOE/year

Recent advances in modern bio-energy technologies (BETs) such as biomass combustion and gasification for power, production of bio diesel and ethanol as liquid fuels and biogas as gaseous fuel provide opportunities for meeting energy needs sustainably, improving quality of life and protecting environment, including addressing climate change.

Modern BETs should be tapped into for greater efficiency in utilizing India's vast bio-energy resources and partially replacing the share of fossil fuel based energy economy of India.

[6] LPG is typically a mix of two hydrocarbons propane and butane – is a by-product of the natural gas and petroleum industries. These gases have an usual property of being liquid at room temperature if moderately compressed and reverting to gases when the pressure is sufficiently reduced

CHAPTER 4 Biomass availability in India for energy usage

Biomass is defined as renewable organic matter derived from trees, plants, crops or from human, animal, municipal and industrial wastes. Biomass can be classified into two types, woody and non-woody. Woody biomass is derived from forests, plantations and forestry residues. Agricultural and agro-industrial residues, and animal, municipal and industrial wastes can be categorized as non-woody biomass (Ravindranath and Balachandra, 2009).

Biomass as a resource is more equitably distributed than other energy sources in India and also can be procured from a variety of sources, such as through extraction of biomass from natural forests, forestry residues, and wastes from processing of timber; agricultural residues; and dedicated energy plantations. It also has numerous applications and a wide array of biomass conversion technologies are also commercially available or under development. This chapter focuses on the estimation of the availability of biomass quantities from each of the above-mentioned sources for energy production.

In the subsequent sections, the problem of identification and estimation of exploitable biomass potential from agriculture wastes, available potential from forest and Trees of Forests (TOF) and dedicated energy plantations (in degraded lands and wastelands). Although energy crops would be analysed from a feedstock perspective, the potential of agriculture residues has not been ignored from a similar analysis, contrary to the view that 'energy crops are considered the main contributor for energy production in the near future'. As a result, in this section due consideration would be given to all forms of biomass that may be finally utilised for production of carbon neutral alternative to conventional diesel, kerosene and gasoline. However, the requirement of biomass for production of biofuels, primarily driven by energy security and climate change concerns, is a complex function of multiple variables such as the land availability for production of biomass sans the land requirement for current and projected demands for food; the requirement of biomass for alternative uses viz fuel[8] and inputs for wood based industries (timber processing units, paper industries etc.); the productivity/ yield of biomass; the efficiency of biomass conversion process and lastly the cost of production of bio-fuels from biomass as compared to the prevailing costs of substitutes (in this case fossil fuels).

[8] An estimated 668 million households in India (in 2005) were dependent on fuelwood, dung and agricultural residue for cooking and heating.

This chapter delves into the details of all the above-mentioned factors sans the factors related to efficiency of conversion process and related costs of biomass based biofuel. As a starting point an analysis of land availability has been undertaken. Subsequently, the available potential of biomass from forests, agricultural lands and wastelands has been analysed. This has been undertaken at the state-level.

Land use in India

India is the seventh largest country in the world, with a total land area of 3,287,263 sq. km. (1,269,219 sq. miles). It measures 3,214 km (1,997 miles) from North to South and 2,993 km (1,860 miles) from East to West. It has a land frontier of 15,200 km (9,445 miles) and a coastline of 7,517 km (4,671 miles). Ever-growing population and urbanization are two important factors affecting the land availability under forests and agriculture. Although India occupies only 2.4 per cent of the world's total land area, it supports over 16.7 per cent of the entire global population. Of the total geographical area of 328.73 Mha (table 4.1), 306 Mha comprise the reporting area of which 69.8 Mha are under forests (contributing 2.3% of the world's forest stock), 141.9 Mha is under agriculture, and 93.6 Mha of land is under various other uses including area under non agricultural uses, barren and uncultivable land, land under pastures, cultivable wastelands and fallow lands. Further, MoEF in its State of Environment report (2009) have estimated almost 146.2 Mha of land as degraded land suffering from various forms of degradation due to water and wind erosion and other complex problems like alkalinity/salinity and soil acidity due to water logging.

The subsequent section provides details on the various land uses prevalent in the country:

Table 4.1 Land use pattern in India

Sl. No.		Classification	2001-02		2002-03		2003-04		2004-05		2005-06	
			Area	Percent	Area	Percent	Area	Percent	Area	Percent	Area	Percent
1		Geographical Area	328.7		328.7		328.7		328.7		328.7	
2		Reporting Area for Land	305.1		305.3		305.4		305.3		305.3	
3		Forest	69.6	22.8%	69.7	22.8%	69.7	22.8%	69.7	22.8%	69.8	22.9%
4		Not Available for cultivation (a+b)	41.8	13.7%	42.1	13.8%	42.2	13.8%	42.3	13.9%	42.5	13.9%
	a	Area Under Non-Agri. Uses	24.1	7.9%	24.3	7.9%	24.7	8.1%	24.8	8.1%	25.0	8.2%
	b	Barren & Un-Culturable Land	17.7	5.8%	17.8	5.8%	17.6	5.8%	17.6	5.8%	17.5	5.7%
5		Other Uncultivated Land excluding fallow land (A+B+C)	27.4	9.0%	27.4	9.0%	27.0	8.8%	27.0	8.8%	26.9	8.8%
	a	Permanent Pastures & other grazing lands	10.6	3.5%	10.5	3.4%	10.4	3.4%	10.4	3.4%	10.4	3.4%
	b	Land Under Misc.Tree crops & groves not included in Net Sown area	3.4	1.1%	3.4	1.1%	3.4	1.1%	3.4	1.1%	3.4	1.1%
	c	Culturable Waste Land	13.4	4.4%	13.5	4.4%	13.1	4.3%	13.2	4.3%	13.1	4.3%
6		Fallow Lands (a+b)	25.0	8.2%	33.5	11.0%	25.5	8.3%	25.1	8.2%	24.2	7.9%
	a	Fallow Lands Other Than current fallows	10.3	3.4%	11.8	3.9%	11.2	3.7%	10.7	3.5%	10.5	3.4%
	b	Current Fallows	14.6	4.8%	21.7	7.1%	14.3	4.7%	14.4	4.7%	13.7	4.5%
7		Net Area Sown (a-b)	141.5	46.4%	132.7	43.5%	141.0	46.2%	141.1	46.2%	141.9	46.5%
	a	Total Cropped Area	189.7	62.2%	175.6	57.5%	190.2	62.3%	190.4	62.4%	192.8	63.2%
	b	Area Sown More than Once	48.3	15.8%	42.9	14.1%	49.2	16.1%	49.3	16.1%	50.9	16.7%
8		Other agriculture related parameters										
	a	Cropping Intensity*	-	134.1%	-	132.4%	-	134.9%	-	134.9%	-	135.9%
	b	Net Irrigated Area	56.7		53.8		56.6		58.9		60.2	
	c	Gross Irrigated Area	78.7		73.5		78.0		80.0		82.6	

P: Provisional

*Cropping Intensity is percentage of the gross cropped area to the net area sown.

Note: The decline in net area sown in 2002-03 reflects the impact of the severe drought of 2002-03 on agriculture operations.

Cropland: The land use pattern figures for India, for the years 2000 - 2005, are given in Table 4.1.The net sown area of India increased from 119 Mha in 1950 to 140 Mha in 1970–71, and has remained more or less stable at 142 Mha in the tenth 5-year plan period (2002 - 2007). Cropping intensity has increased from 134% in 1996–97 to 136% in 2005–06, and is further expected to increase to 150% in 2010 - 11[9].

- Forestland: The area under forests in India has remained stable, at around 69 Mha (table 8.1) since 2000, an increase of approximately 5 Mha over area under forest in 1980's.

[9] Sustainable biomass production for energy in India; P. Sudha, H.I. Somashekhar, Sandhya Rao, N.H. Ravindranath; Biomass and Bioenergy 25 (2003) 501 – 515; Science direct

The broad land use categories in India, other than cropland and forest, are as follows:

i. Non-agricultural area: accounts for about 25.0 Mha. This land is under settlement, buildings, road, railways, water bodies and other land uses and thus not available for agriculture.

ii. Tree crops and groves: Area under Casuarina trees, thatching grass, bamboo bushes and other tree groves which are not included under orchards, is under this category. This land category is in a degraded state.

iii. Culturable fallow: Includes lands available for cultivation but not taken up for cultivation or taken up for cultivation once but not cultivated during the current year and the last 5 years or more in succession. Such land may either be fallow or covered with shrubs.

iv. Permanent pastures and grazing land: These cover all grazing lands and meadows including village common lands and permanent pastures.

v. Fallow land other than current fallow: All lands which were taken up for cultivation but are temporarily out of cultivation for a period of 1–5 years, and left fallow.

vi. Barren unculturable land: covers all barren and unculturable land, which cannot be brought under cultivation except at a high investment cost.

vii. Current fallow: includes cropped areas that are kept fallow during the current year.

Woody biomass, can be obtained by

- clear felling of natural forests,
- sustainable extraction from forests,
- collecting residues of the timber processing industry
- dedicated plantations

Hence, the categories ii–vii can be brought under forestry options to produce biomass to meet various demands for fuel wood, industrial wood, and sawn wood and biomass for production of biofuels. This land accounts for 68.6 Mha.

Theoretical sources of biomass

Biomass from forests

Area under forests

India ranks 10th in the list of most forested nations in the world with 76.87 million ha of forest and tree cover. Like other forests of the world, forests in India also provide critical ecosystem goods and services. Forest biomass is an important commodity as it provides for fodder, feed and fuel[10], of which biomass for fuel wood has a dominant share. Fuel wood consumption for households in India has been estimated at 311 MT[11] in 2006, of which 42% is extracted from forests (Sudha et al). As a result, the forests (especially in case of developing countries like India where biomass is utilised for cooking and heating purposes, characterised by low efficiency of use) are under constant pressure to provide for the needs of the population vis-à-vis what they can supply as a matter of sustained productivity.

The present study, however aims at estimating the quantum of biomass available from various sources for use as an input to bio fuel production, of which the forest may act as a potential source. India's forest and tree cover accounts for about 23.6% of the total geographical area of the country. The forest cover consisting of 67.71 Mha (20.5% of total geographical area) comprises of very dense forests (5.46 Mha.), moderately dense forests (33.26 Mha) and open forests (28.99 million ha including 0.44 million ha of mangroves). The Forest conservation act provides a ban on extraction of biomass from very dense and moderately dense forests; hence the options for utilising forest resources for biomass are limited. The data procured from Forest Survey of India (2005) projecting woody biomass resources has been provided in table 4.2.

[10] Growing stock-based forest biomass estimate for India; Biomass and Bioenergy 22 (2002) 187 – 194; Abha Chhabra, S. Palria, V.K. Dadhwal
[11] UN estimates fuel wood consumption by households in India at 353 million cubic meters (http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AFW%3BtrID%3ABR) which when considered at 40% moisture (multiplier of 0.88; http://www.fao.org/docrep/Q1085E/q1085e0c.htm#1.%20fuelwood) is equivalent to 311 MT

Table 4. 2 Woody biomass from forests

State/UT	Geographic Area (km^2)	Recorded Forest Area (UF), Km^2	Tree cover Area (km^2)	Blocks of Forest Cover (> 1 ha) outside Recorded Forest Area, Km^2	Growing Stock (Volume in m.cum) in TOF
Andhra Pradesh	275,069	977	7,640	3,172	179.0
Arunachal Pradesh	83,743	31,466	446	15,668	77.6
Assam	78,438	8,968	1,484	6,114	25.2
Bihar	94,163	1	2,522	2,296	32.9
Chhattisgarh	135,191	9,954	4,492	3,300	63.2
Delhi	1,483	987	107	85	1.1
Goa	3,702	4,199	268	931	6.7
Gujarat	196,022	152	7,621	5,817	140.4
Haryana	44,212	2,094	1,565	834	15.4
Himachal Pradesh	55,673	36	709	1,085	12.4
Jammu & Kashmir	222,236	33	5,633	11,717	88.8
Jharkhand	79,714	5,663	3,080	2,740	48.2
Karnataka	191,791	--	5,467	4,921	131.1
Kerala	38,863	1,705	2,632	4,346	51.8
Madhya Pradesh	308,245	4,518	6,267	2,834	99.8
Maharashtra	307,713	11,780	8,978	7,279	144.6
Manipur	22,327	8,372	142	1,947	4.3
Meghalaya	22,429	5,240	405	5,130	11.3
Mizoram	21,081	8,628	122	1,840	3.7
Nagaland	16,579	16,282	238	3,153	7.0
Orissa	155,707	1,903	4,589	4,848	90.6
Punjab	50,362	2,976	1,823	865	17.9
Rajasthan	342,239	--	8,379	3,398	121.9
Sikkim	7,096	1,306	27	73	0.5
Tamil Nadu	130,058	2,117	5,621	6,675	107.7
Tripura	10,486	3,450	134	1,663	3.7
Uttar Pradesh	240,928	131	8,203	4,068	87.1
Uttarakhand	53,483	1,053	658	1,054	12.0
West Bengal	88,752	--	2,269	4,520	44.0
Andaman & Nicobar	8,249	2	53	87	1.1
Chandigarh	114	--	9	2	0.1
Dadra & Nagar Haveli	491	--	28	46	0.7
Daman & Diu	112	--	9	11	0.1
Lakshadweep	32	--	4	5	0.1
Pondicherry	480	--	42	45	0.5
Total	3,287,263	133,993	91,666	112,569	1632.3

Growing stock in forests

The growing stock of the country for the year 2005 is 6,218 million cubic meter comprising 4,602 million cubic meter corresponding to the forest cover and 1,616 million cubic meter corresponding to the tree cover. There has been a decrease of approximately 195 million cubic meter of overall growing stock as compared to 2003. In 2003, the growing stock under tree cover was 1,632 million cubic meter and for forest cover was 4,781 million cubic meter. In 2005, average growing stock in the recorded forest area per hectare is 59.79 cubic meter.

The proportion of growing stock for tree cover as compared to that for forest cover is 35.12% and 34.14% in 2005 and 2003 respectively (FSI, 2005, 2008). Kishwan et. al. (2009) have estimated the adjusted mean biomass expansion factor, ratio between below and above round biomass, mean density, and ratio between other forest floor biomass to the tree biomass. The total biomass from forests has been quantified at 8823 MT (Table 4.3). The calculation uses conversion of commercial wood volume (growing stock) into total biomass using average adjusted wood density and expansion factors and ratios as also suggested by Brown, Gillespie and Lugo, 1991.

Table 4.3 Biomass from forests

Sl. No.	Parameter	Symbol	Factor	1995	2005
1	Growing stock of country in Mm^3	GS		5842.32	6218.28
2	Mean biomass expansion factor	EF	1.575		
3	Ratio (Below to above ground biomass)	RBA	0.266		
4	Above ground biomass (volume)	AGB = GS X EF		9201.65	9793.79
5	Below ground biomass (voume)	BGB = AGB X RBA		2447.64	2605.15
6	Total biomass (volume)	TB = AGB + BGB		11649.29	12398.94
7	Mean density	MD	0.7116		
8	Biomass in Mt	GS X MD		8289.63	8823.09

Source: Technical paper; India's forest and tree cover, 2009

Availability of biomass from forests

The three major sources of woody biomass from forests are extraction of biomass from forests, sustainable harvesting and lastly biomass from dedicated energy plantations in degraded forest land. Each of the above has been analysed below for their potential provision of biomass.

Firstly, extraction of biomass from natural forests is not desirable as primary forests must be conserved for their environmental role as discussed in preceding section. So, clear felling of primary forests cannot be considered as a source of woody biomass for energy. Secondly, sustainable harvesting from forests defined as the quantum of biomass harvest equivalent to but not exceeding the annual increment of forests, is also limited by present knowledge on the modes of sustainable extraction in different forest ecosystems. Further, natural regeneration of desired species is difficult to achieve. Thus sustainable extraction may not be feasible. Moreover, forests are already subjected to non-sustainable extraction; hence any further extraction might lead to various environmental problems such as soil erosion, emission of carbon dioxide, loss of rich ecosystems and of biodiversity and the loss of livelihood of forest-dwelling communities.

In case of timber processing waste, due to a scarcity of fuel wood in rural areas, these residues are generally sold in the local market or left to be collected freely by the local communities for use as cooking fuel. Thus, the only potential option for biomass supply is dedicated plantation forestry. However, it should be noted that any incremental biomass demand for fuel wood, industrial wood and sawn wood has to be met through these dedicated plantations and only the surplus should be considered for production of bio fuels.

Given the above context, biomass from dedicated plantations may be an important potential source of biomass for production of bio fuels. However, several issues such as availability of suitable land, ownership status, government policies towards utilisation of such land, opportunity costs involved, suitability of plantation species and potential yield of plantations, and potential costs and benefits merits further detailed evaluation.

Biomass from agricultural residues

For assessing the crop residues for energy potential it is imperative to understand the area under agricultural crops, cropping patterns and utilization of crop residues. The following sections discuss the details of above-mentioned issues in India.

Area under agricultural crops and cropping pattern

In India, out of the total geographic area of 328 million hectare (Mha), the net cropped area accounts for about 43% and it is estimated that the net cropped area has stabilized at around 140 Mha since 1970. However, the gross cropped area has increased from 152.8Mha in 1960 to about 192.8 Mha in 2005-06. In India there are two main cropping seasons, namely Kharif (based on southwest monsoon) and Rabi (north-east monsoon). Gross cropped area includes land areas subjected to multiple cropping (normally double cropping) in irrigated land. Net irrigated area has increased substantially from 24 Mha during 1960–61 to 60.2 Mha by 2005-06.

Table 4. 4 Normal (average of 2002-03 to 2006-07) Area, Production and yield of major crops in India (Area in million hectares; Production in million tonnes; yield in Kg/hectare)

Crop / Group of Crops		Season	Area	Production	Yield
I. Foodgrains					
	Rice	Kharif	38.91	74.47	1914
		Rabi	3.72	11.25	3027
		Total	42.63	85.72	2011
	Wheat	Rabi	26.53	70.34	2651
	Jowar	Kharif	4.06	4.18	1029
		Rabi	4.91	2.96	604
		Total	8.97	7.14	796
	Bajra	Kharif	9.33	8.17	876
	Maize	Kharif	6.58	11.44	1740
		Rabi	0.80	2.58	3220
		Total	7.38	14.02	1901
	Total Coarse Cereals	Kharif	22.55	26.18	1161
		Rabi	6.36	6.84	1075
		Total	28.91	33.02	1142
	Tur	Kharif	3.51	2.39	681
	Gram	Rabi	6.82	5.47	803
	Total Pulses	Kharif	10.86	4.94	455
		Rabi	11.60	8.41	725
		Total	22.46	13.35	594
	Total Foodgrains	Kharif	72.33	105.60	1460
		Rabi	48.21	96.84	2009
		Total	120.54	202.44	1679
II .Oilseeds					
	Groundnut	Total	6.18	6.38	1031
	Rapeseed & Mustard	Rabi	6.27	6.67	1063
	Soyabean	Kharif	7.25	7.29	1006
	Sunflower	Total	2.06	1.13	549
	Nine Oilseeds	Total	25.41	23.33	918
III . Other Cash Crops					
	Sugarcane	Total	4.29	279.01	64969
	Cotton @	Total	8.38	15.98	324
	Jute & Mesta$	Total	0.96	10.97	2063
	Potato	Total	1.37	23.19	16962
	Onion	Total	0.55	6.54	11987
Note : ' Normal' is worked out as simple average of estimates for 5 years, i.e. 2002-03 to 2006-07					
@ : Production in million bales of 170 kg. each.					
$: Production in million bales of 180 kg. each.					

Rice and wheat are the dominant crops, together accounting for 36% of cropped area, while pulses, oil seeds and other commercial crops account for 13.8%, 15.9% and 10.2%, respectively. Cereals dominate the agricultural crops as shown in Table 4.4 and account for 60% of cropped area, followed by pulses, cotton and sugarcane. Out of 140 Mha of net-cropped area, approximately 50% is estimated to become irrigated by 2010. It has been observed that the adoption of irrigation practices results in expansion of crops such as rice, wheat, cotton and sugarcane. It is estimated that expansion of irrigation by 2010 may result in increase of area under the above said crops by 6% to 86.7 Mha[12] at the cost of coarse

[12] Assessment of sustainable non-plantation biomass resources potential for energy in India; N.H Ravindranath, H.I Somashekar, M.S Nagaraja, P.

cereals and millets. These changes would also influence production of crop residues in the future.

Table 4. 5 Area under major crops and their respective residue production

Crop	Economic produce	Gross cropped area	Total economic production	Total residue production	Residue to total economic produce ratio	Type of residue	Moisture %	
		Mha	MT	MT (air dry)			At harvest	At use
Rice	Food grain	42.6	85.7	154.3	1.8	Straw+Husk	30	10
Wheat	Food grain	26.5	70.3	112.5	1.6	Straw	30	10
Jowar	Food grain	9.0	7.1	14.3	2.0	Stalk	30	10
Bajra	Food grain	9.3	8.2	16.3	2.0	Stalk + cobs	30	10
Maize	Food grain	7.4	14.0	35.1	2.5	Straw	30	10
Other Cereals	Food grain	3.2	3.7	7.4	2.0	Stalk	30	10
Red Gram	Food grain	3.5	2.4	12.0	5.0	Waste	20	10
Gram	Food grain	6.8	5.5	8.8	1.6	Waste	20	10
Other pulses	Food grain	12.1	5.5	15.9	2.9	Shell + waste	20	10
Ground nut	Oil seed	6.2	6.4	14.7	2.3	Waste	30	10
Rapeseed and Mustard	Oil seed	6.3	6.7	13.3	2.0	Waste	20	10
Other oil seeds	Oil seed	16.1	14.9	29.8	2.0	Waste	20	10
Cotton	Fiber	8.4	16.0	55.9	3.5	Seeds + waste	20	10
Jute	Fiber	1.0	11.0	17.6	1.6	Waste	30	10
Sugarcane	Sugar	4.3	279.0	111.6	0.4	Bagasse + leaves	30	30
Total		162.7		619.4				

Source: Ministry of Agriculture; Sudha et al

Agricultural crop residue production

The residue production varies from crop to crop. The data on the residue to product ratio (RPR) are given in Table 4.5. The straw to grain ratio of the cereals varies from 2.5 for maize to 1.6 for wheat. Straw, a low-density residue, is the dominant residue. Rice husk, a by-product of rice milling, accounts for 20% of paddy. Unlike the cereals, crops such as red gram, cotton, rapeseed, mustard and plantation crops produce woody (ligneous) residues. Residue production level for sugarcane were estimated based on secondary sources and Biomass Atlas published by Ministry of New and Renewable Energy (MNRE). The total crop residue production in India during 2005-06 is estimated to be 619 Mt of air dry weight (Table 4.5). The dominant residues are those of rice, wheat and sugarcane accounting for 61% of the total residue production. Rice, Wheat and Sugarcane residue production is 154.3, 112.6 and 111.4 MT, respectively (table 4.5)

Current use of crop residue

The use of crop residues varies from region to region and depends on their calorific values, lignin content, density, palatability and nutritive value. The proximate analysis of some of the commonly available biomass is provided in Annexure C. Residues of most of the cereals and pulses have fodder value.

Sudha, G. Sangeetha, S.C Bhattacharya, P. Abdul Salam; Biomass and Bioenergy 29 (2005) 178-190; Elsevier

However, woody nature of residues of a few crops restricts their use to fuel purpose only. The dominant end uses of crop residues in India are as fodder for cattle, fuel for cooking and thatch material for housing. India has a large cattle population of 294 million. Even though India has 67 Mha[13] of grazing land, grass productivity is low due to land degradation, leading to near total dependence of cattle on crop residues of cereals and pulses.

The estimated total residues utilized as fodder was 301 Mt in 1996–97 and is projected to be 300Mt for 2009, accounting for about 47% of total residues generation (Table 4.6). Use of some crop residues as fodder is the priority in rural areas and only ligneous residues are likely to be available for use as an energy source. In India, dung use as fuel is wholly restricted to the domestic sector, while crop residues are used as fuel in both domestic and industrial sectors. Ligneous and hardy crop residues namely, rice (husk), maize (cobs) and stalks of redgram, cotton, mulberry, coconut fronds and shells are mainly used for fuel purpose. About 44 Mt of sugarcane bagasse is used as fuel in sugar mills, and in small scale crude rural sugar producing units. The total residue use as a fuel in India during 2009–10, (Table 4.6), is estimated to be 214MT and the projected value is expected to rise with the growing population of cattle and a growth of industries. Reported estimates of different types of biomass used as fuel is given in Table 4.6.

In addition to use of crop residues as fuel and fodder, the residue of some crops are used for thatching, composting, mulching, etc. Rice and wheat straw, and coconut fronds are used to a small extent for thatching in the rural areas. Non-woody leguminous crop residues are normally put into the composting pit after the harvest of the main produce. The leafy residue of sugarcane is burnt in the field. The total crop residue used for other purposes is estimated around 105 MT in 2009–10 and is projected to rise in subsequent years.

[13] As estimated by Ravindranath et al

Table 4.6 Current use of agricultural residue as fuel and fodder (MT)

Crop	Economic produce	Gross cropped area	Total economic production
		Mha	MT
Rice	Food grain	42.6	85.7
Wheat	Food grain	26.5	70.3
Jowar	Food grain	9.0	7.1
Bajra	Food grain	9.3	8.2
Maize	Food grain	7.4	14.0
Other Cereals	Food grain	3.2	3.7
Red Gram	Food grain	3.5	2.4
Gram	Food grain	6.8	5.5
Other pulses	Food grain	12.1	5.5
Ground nut	Oil seed	6.2	6.4
Rapeseed and Mustard	Oil seed	6.3	6.7
Other oil seeds	Oil seed	16.1	14.9
Cotton	Fiber	8.4	16.0
Jute	Fiber	1.0	11.0
Sugarcane	Sugar	4.3	279.0
Total		162.7	

Source: Author, conversion figures were adapted from Sudha et al

Availability of crop residue for biomass energy

Crop residues, which are used as fodder, will not be available as feedstock for energy. The total potential of non-fodder crop residues available for energy is currently estimated to be 319 MT for 2009-10.

Table 4. 7 Availability of agricultural residue purposes other than fodder

Crop	2010	
	MT	PJ
Rice	29.6	383.6
Wheat	15.3	198.5
Jowar	0.0	0.0
Bajra	1.7	21.5
Maize	6.7	86.0
Other Cereals	0.0	0.0
Red Gram	12.0	154.7
Gram	8.8	114.1
Other pulses	15.4	200.2
Ground nut	14.7	200.5
Rapeseed and Mustard	13.3	182.7
Other oil seeds	29.8	34.1
Cotton	55.9	838.4
Jute	17.6	261.8
Sugarcane	98.4	1553.7
Total	319.0	4229.8

However, it must be noted that only the woody (ligneous) crop residues, rice husk and bagasse are considered for energy. This is primarily due to the physical, chemical, and thermal properties of biomass and its constituents, which are critical for selecting and designing any subsequent thermo-conversion process.

Biomass from wastelands

Area under wastelands

Wastelands are defined as “degraded lands which can be brought under vegetative cover with reasonable efforts and which are currently underutilized, and also the land which is deteriorating for lack of appropriate water & soil management or on account of natural causes” (Ministry of Rural Development, 2004). Wastelands can result from inherent/imposed disabilities such as by location, environment, chemical and physical properties of the soil or financial or management constraints.

These degraded lands form a substantial part of India’s land cover, and if managed prudently (in terms of soil and water management, silviculture practices and appropriate investments), it offers the potential for being utilised for a variety of purposes. In the context of the study, wastelands have been considered as potential lands where captive and dedicated energy plantations could be undertaken for the production of biomass. However, in the Indian context, wastelands are characterised by a variety of planning, technical and investment related constraints. First and foremost being an unambiguous estimation of extent of land suffering from degradation. Though, there are several estimates available for the extent of wastelands, they vary considerably from 42.6 million hectares (as estimated by Sudha et al) to 130 million hectares (degraded land quoted in Planning commission). Hence, in order to have the precise spatial distribution of the wastelands, a study on the “Identification of Wastelands in India” was commissioned in collaboration with the National Remote Sensing Agency (NRSA), Department of Space, Hyderabad. As a result, the Wastelands Atlas of India 2000 was developed, containing maps on a 1:50,000 scale for 28 different categories of wastelands.

Table 4.8: 28 categories of wastelands classified according to their suitability for land conversion

SL. No	Category of wasteland	Suitability
1	Gullied and/or ravenous land (Shallow)	suitable
2	Land with scrub	suitable
3	Land without scrub	suitable
4	Land affected by salinity/alkalinity (Slight)	suitable
5	Shifting cultivation area (Abandoned Jhum)	suitable
6	Shifting cultivation area (Current Jhum)	suitable
7	Under utilized/degraded notified forest land	suitable
8	Under utilized/degraded notified forest land (Agri.)	suitable
9	Degraded pastures/grazing land	suitable
10	Degraded land under plantation crop	suitable
11	Gullied and/or ravenous land (Medium)	moderately suitable
12	Waterlogged and Marshy land (Seasonal)	moderately suitable
13	Land affected by salinity/alkalinity (Strong)	moderately suitable
14	Land affected by salinity/alkalinity (Moderate)	moderately suitable
15	Sands-(Levees)	moderately suitable
16	Sands-(Coastal Sand)	moderately suitable
17	Sands-(Semi Stab.-Stab.>40m)	moderately suitable
18	Sands-(Semi Stab.-Stab Moder. High 15-40m)	moderately suitable
19	Sands-(Semi Stab.-Stab. Low<15m)	moderately suitable
20	Sands-(Closely Spaced Inter-Dune Area)	moderately suitable
21	Mining wastelands	moderately suitable
22	Industrial Wastelands	moderately suitable
23	Gullied and/or ravenous land (Deep)	unsuitable
24	Waterlogged and Marshy land (Permanent)	unsuitable
25	Sands-(Flood Plain)	unsuitable
26	Barren Rocky/Stone Waste/Sheet Rock Area	unsuitable
27	Steep Sloping Area	unsuitable
28	Snow covered and/or Glacial Area	unsuitable

The 28 categories as mentioned above, have evolved from the base 13 classes of wasteland viz., Gullied and/or ravenous land, Land with or without scrub, Waterlogged and Marshy land, Land affected by salinity/Alkalinity, Shifting Cultivation, Under Utilized/Degraded Notified Forest land, Degraded pastures/Grazing land, Degraded land Under Plantation Crop, Sands, Mining/Industrial Wasteland, Barren Rocky area, Steep sloping area and Snow Covered and/or Glacial area. The various categories have been tabulated (Table 4.8), further classified into their suitability for land conversion based on physical inaccessibility and indicative costs for restoration .

However, for the purpose of the study, the total area considered available in India under wastelands has been taken as 49.6 Mha as estimated by Department of Land Resources (DOLR). Of the total land estimated under wastelands, almost 66% fall in the classification of wasteland which are suitable for land conversion (Table 4.9). Amongst the land suitable for land conversion almost 40% (12.96 Mha) land fall under the categories of under-utilised/ degraded notified forest land, degraded pastures and degraded land under plantation crop. These offer the highest potential of being converted into land for dedicated energy plantations.

Table 4.9: Area under various categories of wastelands

Classification of wasteland	Area (in Mha)
Wastelands suitable for land conversion	32.6
Wastelands moderately suitable for land conversion	5.0
Wastelands unsuitable for land conversion	12.0
Total wasteland available in India	49.6

Wastelands are classified as generally unsuitable for any cultivation when lands require substantial investments for conversion and as a result would not provide the required level of returns especially for any commercial venture. Apart from the above there are other four major categories which are unsuitable for cultivation purposes, primarily due to their inaccessibility. These are barren rocky areas, steep sloping areas, snow covered areas and glacial areas.

The area under waste land categories which have potential for energy planatations are degraded forest lands, degraded grazing lands and degraded land are mentioned in Table 4.10.

Table 4.10: Area under various degraded forests, degraded grazing lands and degraded land under plantation crops

Category of wasteland	Area (in Ha.)
Under utilized/degraded notified forest land	9,455,589
Under utilized/degraded notified forest land (Agri.)	1,504,394
Degraded pastures/grazing land	1,794,783
Degraded land under plantation crop	206,492
Total	12,961,258

Source: Department of land resources

CHAPTER 5 Bio energy strategies for rural development

Traditional biomass (firewood, animal wastes, crop residue) continues to be the major source of energy fuels in Indian households especially among the rural areas. Figure 5.1 indicates the primary source of energy used for cooking activity in both rural and urban activities.

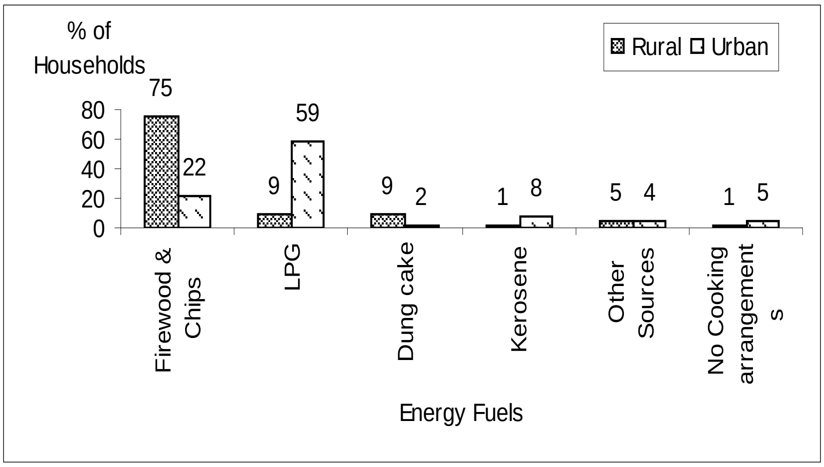

Figure 5.1 Energy Fuels for Cooking Activity

Source: NSSO 2007

Figure 5.1 highlights that among the all households, dependence on traditional fuels is significantly higher among rural households wherein about 85% of rural households depend on traditional biomass as compared to just 25% of household in urban areas. This makes the rural households more vulnerable to the negative heath impacts of using traditional un-processed biomass in energy in-efficient devices. More so indoor air pollution caused by burning of traditional biomass have large negative impact on the health of household members especially women and children. Also, women in rural areas end up spending a substantial time and effort in collection of biomass which hampers their economic development.

Although there is large quantum of available biomass in rural areas, its usage in traditional forms causes negative social and economic impact on rural households. In such a scenario, putting the available biomass to productive use would prove to be a good strategy for sustainable development of rural areas.

Biomass could be productively be used to produce cleaner and efficient form of energy or what is called as bio energy. Bioenergy could be used in various forms and may include the following:

Biomass may be used to produce electricity using biomass gasifiers wherein biomass of low heat value is converted into combustible gas which is then fed into generator for electricity generation.

- Biomass could be used to produce a clean fuel i.e biogas which is used for cooking and lighting purposes. Biogas is a mixture of methane and carbon dioxide produced by bacterial degradation of organic matter and used as a fuel. Biomass or organic waste is put into a sealed tank called a digester (or bioreactor). In the absence of oxygen, anaerobic bacteria consume the organic matter to multiply and produce biogas. When cattle dung is a major constituent of fermentation, the resulting gas will be between 55-66% CH_4, 40-45% CO_2, plus a negligible amount of H_2S and H_2 (KVIC, 1993). Biogas has the advantage of a potential thermal efficiency, given proper equipment and aeration, of 60%, compared to wood and dung that have a very low thermal efficiency of 17% and 11% respectively (KVIC, 1993).

The usage of above mentioned forms of bioenergy contributes to the availability of the clean energy fuels among the rural households. This has a positive impact on the social development of the rural households. It is expected that cleaner sources of bio energy will contribute to the sustainable development of the rural areas through agricultural modernisation, rural electrification, provision of cleaner cooking fuels, employment generation and opportunities for small entrepreneurial activities, etc.

Taking example of the various biomass gasifiers and biogas plants installed in the country, it is interesting to analyse their impact on rural development. This section describes impact of the cleaner sources of bioenergy on the following social economic factors.

Modernization in agriculture

The usage of different forms of bioenergy contributes positively towards agricultural modernisation in many ways. For the agricultural purpose, water is regarded as the prime input. With rising uncertainties in rainfall pattern, the farmers tend to use ground water supply for meeting the water requirements of agricultural farms. However, lack of electricity acts as a hindrance to running of irrigation water pump sets which is needed for release of ground water. In this regard, setting up of biomass based power plant within the rural area and providing its connection to the pump sets prove beneficial for the farmers. With the proper and reliable electricity connection farmers are able to use agricultural water pumps and are thus able to use better irrigation methods. This results in improvements in their agricultural yield and subsequently improvements in their income level of farmers. Box 5.1 quotes an example of farmers in a village in south India who experienced improved living with the help of biomass gasifiers[14].

Box 5.1 Impact of biomass gasifier on agriculture

In an effort to provide decentralised power to rural areas in an environmentally clean manner, the United Nations Development Programme (UNDP) through its Biomass Energy for Rural India project inaugurated a biomass based gasifier power plant in a Tumkur district's Koratagere cluster nearly 100 km from Bangalore .Prior to setting of biomass gasifiers a farmer could grow just one crop on a piece of land due to lack of irrigation facilities. However, with setting up of biomass gasifiers, farmers are able to grow at least three crops in a year. Also, farmers are able to cultivate crops that would have been impossible to cultivate without the improved irrigation techniques. For instance, with the help of drip irrigation farmers in the village are able to grow tomatoes on their fields and are also able to grow vegetables and flowers that are not rain-dependent like the Ragi and groundnut. Setting up the biomass gasifiers at the village also contributes to overall social development of the village. With provision of clean energy source, people feel a sense of security for lighting and water need and are saved from lot of drudgery. Having seeing the positive impact of the gasifiers, there are plans to replicate the same model in other villages as well.

In addition to improved water supply facility, bioenergy also contributes to agricultural modernisation through improvements in soil conditions. Biogas technology fits well with agricultural systems. The slurry from the biogas plants are used as farm manure which could improve soil conditions and enrich it with organic matter and nitrogen as anaerobic digestion of the cellulose biomass materials prevents loss of nitrogen. This in turn decreases the use of chemical fertilisers. It also enhances the agricultural production and conserves soil from erosion losses. Also, the anaerobic digestion process and the gestation period in the digester kills pathogens and weed seeds which when used as manure has an added advantage to farmers (Ravindranath and Balachandra 2009)

Rural Electrification

Provision of electricity is regarded as a key input to development of rural areas. It is an important infrastructural requirement for agricultural, industrial and socio-economic development and also for employment generation in rural and remote areas. Electricity is an input to the production of goods and services that contribute directly to households well being. Positive effects of provision of electricity could be felt by rural households in forms of basic activities such as pumping water for drinking and irrigation, lighting for increasing working hours in the evening and carrying out operations in small-scale rural industry. Such activities have spiral up impacts in terms of improvements in economic conditions of rural households. Efficient provision of electricity contributes to poverty reduction

[14] http://southasia.oneworld.net/fromthegrassroots/biomass-energy-benefits-villagers-in-south-india/

by spurring economic growth and fulfilling human needs of health and education.

Providing electricity access in rural and remote areas was regarded as synonymous with rural electrification through extension of grid. However provision of electricity through extension of grid to the remote inaccessible areas is plagued with several inherent problems. These may include high transmission and distribution (T&D) losses, frequent disruption in supply of grid power, practical difficulties and financial un-viability of extending grid to remote and inaccessible areas, dispersed population in small villages resulting in low peak loads in rural and remote areas, poor financial health of the state electricity boards, etc.

Centre and state governments are regarding rural electrification as their priority for development process. There are policy directives regarding rural electrification. Section 6 of the Electricity Act regards the supply of power to all areas including rural areas as one of its key development objective of power sector. In this regard, National Electricity Plan (NEP) which was announced in February 2005 highlights the importance of determined efforts to be made to ensure that the task of rural electrification for securing electricity access to all households and also ensuring that electricity reaches poor and marginal sections of the society at reasonable rates is completed by 2010. For creation of reliable rural electrification system, NEP stresses the importance of creating Rural Electrification Distribution Backbone (REDB) with at least one 33/11 kv (or 66/11 kv) substation in every Block. Supply feeders and one distribution transformer should be set up in every village settlement wherein each household may be connected to distribution transformer on demand. However due to problems associated with extension of grid to rural areas, wherever extension of grid is not feasible (it is neither cost effective nor the optimal solution to provide grid connectivity) decentralized distributed generation facilities together with local distribution network would be provided so that every household gets access to electricity. This could be done either through conventional or non-conventional (renewable sources of energy) methods of electricity generation whichever is more suitable and economical.

Biomass gasifiers are regarded as an ideal option for decentralized applications of power generation in rural areas as there is adequate availability of biomass, which acts as a feedstock for running of biomass gasifiers. The technology of biomass gasification is a standard and mature technology. It needs to be operated by skilled and semi-skilled operators.

However, consumers or beneficiaries do not need any technical expertise to benefit from it. The biomass based decentralised power generation is promoted by various policies and programmes. MNRE provides subsidies for the installation of biomass gasifier systems. Financial incentives worthRs 1.5 million per 100 kWe are provided for 100% producer gas engines with biomass gasifier systems for village-level electrical application, as well as for both off-grid and grid-interactive applications. Financial assistance under different schemes is given as per the specific guidelines set under each scheme (TEDDY2009). In recent years, several biomass gasifier systems have been installed with the support of district rural development agencies and village panchayats. As on 31 March 2008, the total installed capacity of biomass gasifier in the country was approximately 100.11 MW.

To quote as an example, a 500 KW biomass gasifiers (5* 100kW) rural electrification system has been installed at Gosaba in Sunderbans (West Bengal). Box 5.2 provides the details about this gasifiers and highlights how with the provision of electricity thorough gasifiers lead to overall development of the region.

Box 5.2 Impact of provision of electricity through biomass gasifiers

About 2 million out of three million people inhabiting the Delta Region of Sunderbans, West Bengal State do not have access to electricity prior to setting up of a 500 kW (5 x 100 kW) biomass gasifier duel fuel power generation system (70% biomass + 30% diesel) at Gosaba Island, Sunderbans in June, 1997. At the time of its initiation, there were only 16 customers but realizing the benefits of electrification, the customer base increased very to about 1150 households. The plant operates at 15 hours a day (10:00 am to 1:00 am next day) and charges about Rs 5.6/Kwh from the domestic consumers. The cost of the fuel is about Rs. 35 ($0.78) / 40 kg half dry wood (one container) and the fuel efficiency is about 90 cc diesel + 850-900 g of wood / kWh. With the setting up of biomass gasifier the region has witnessed overall social and economic development. Commercial shops and hotels set up now which attracts people from nearby village for shopping purposes. This led to spiral up effect on other economic activities such as setting up of banks, improvements in telecommunication systems, internet facility etc. Also, the electricity is used for public purposes such as street lights, school lighting, drinking water supply and irrigation. The project provides employment to about 22 laborers for its operation and maintenance (Hitofumi 2005)

Substitution for cooking energy sources

Use of biogas as an alternative cooking fuel also proves beneficial for the rural development. Biogas (a mixture of methane and carbon-dioxide) is produced through the anaerobic fermentation of biomass such as cow dung, human waste and other organic wastes in the absence of oxygen in cylindrical digesters (fixed dome and floating drum). Biogas, thus produced, is taken from the outlet and used for cooking and other purposes. Biogas has advantage of being clean fuel posing no health hazard to the household members and thus leading to improved quality of life. Use of biogas makes the house smoke free and less black walls. Also the utensils used for cooking with biogas are not damaged with black layer deposit as in case of cooking with fuel wood. This in turn reduces the water consumption for cleaning the utensils. Usage of biogas also promotes optimal utilization of the natural resources of dung (energy produced is three times more useful than that produced by direct burning). Also, raw material for biogas production i.e cow dung is easily and freely available at the rural areas.

Considering biogas as an alternative and efficient option as energy fuel for cooking, the National Project on Biogas Development (NPBD) was launched by MNRE during 1981-82 for the promotion of family type biogas plants to provide clean and convenient fuel for cooking and lighting in rural areas, enriched organic manure for use in conjunction with chemical fertilizers in agricultural fields, to improve sanitation and hygiene by linking toilets with biogas plants and to reduce the drudgery of women. The project is implemented through multiple agencies. Up to 2008/09, over 4.12 million biogas plants have been supported under NPBD realising 34% of the total potential of 12 million. It was estimated that by adding 1.02 lakh family type biogas plants would result in an estimated saving of about 1.2 lakh tonnes of fuel wood and production of about 12 lakh tonnes of organic manure. Setting up of biogas plants also results in additional advantages in terms of generation of employment. It is estimated that with construction of 1.02 lakh biogas plants during the year generates about 3.65 million person-days of employment for skilled and unskilled workers in rural areas (MNRE 2009). A case study of biogas plants operated by SKG Sangha highlighting the benefits of biogas plant has been detailed out in Annexure A.

It is observed that the success of any governmental programs for introduction of newer products/technology such as improved cookstoves or biogas, is based on the participation of the targeted population. It is important to develop community based planning and management wherein the people from different household voluntarily sees benefit in adoption of product/technology. Box 5.3 describes a case of the village which poses as an example of how with the usage of biogas was promoted through community based participation and how it has led to overall rural development[15].

Box 5.3 Community Participation for Biogas Plants

A group of villages, Pichhaura, Dudapar, Ranipar and Asthuala Block Gagha, are situated about 42kms away from the south of distt. Headquarter Gorakhpur (U.P.) . The vilagaes were facing social problems such as greater poverty, poor health conditions, ecological degradation, waste disposal problem etc. Agriculture and its allied activities are

15 http://www.wesnetindia.org/fileadmin/newsletter_pdf/Dec06/An_Initiative_of_Promoting_Bio_gas.pdf

the main occupation of the people. However, few years ago, there has been depletion in various orchards of fruit trees like Mango, Mahuwa, Jamun & Neem as they were being cut slowly to meet the fuelwood requirement for cooking and heating purpose. A NGO called Sarvangeen Vikas Samiti,initaiated a project titled "Promotion of Sustainable Agricultural Activities through Demonstration of Bio-gas Plants and Others Allied Activities" in the year 2002 with the support of UNDP-SGP/GEF through Centre for Environment. The project aims to pilot a community initiative through the participatory approach to address these issues with alternate fuels. Majority of rural community were skeptical in the beginning about the proper functionality of biogas plants.

However, when the NGO started interventions for blending local knowledge and technical expertise, the certain women group were convinced about the benefits of biogas slowly adopted biogas technology along with other allied activities for better sustainable livelihoods. Participatory rural appraisals (PRAs) exercises led to negotiate many potential beneficiaries for functionality of biogas plants. Through community organization process, people developed confidence in the working of NGO. An example could be quoted of one of the women resident in the village who adopted biogas as cooking fuel. Comparing her social condition pre and post adoption of biogas, with setting up of biogas plants she saves lot of time and effort as she is freed from duty of collection of fuel wood, crop reside etc which involved lot of drudgery and loss of time. Also, usage of biogas results in monetary saving. Prior using biogas, she spends around costs Rs 3900 to 4800 per annum, (nearly 80 t0 110 USD) on crop residue, dung cake and fuel wood. However with usage of biogas, she saves all this which significantly contributes to her annual income of 500 USD and also nearly saves three hours of her time used for collection of water and fuel wood. Setting as an good example of benefits incurred with usage of biogas, she is propagating the idea to her fellow household people and is encouraging them towards the required change.

As the concept of the biogas technology has been successful, further advancement of technology is being carried out by various institutions. ARTI has developed a compact biogas plant which uses waste food rather than dung/manure as feedstock, to supply biogas for cooking. There are about 2000 biogas plants currently in use – both in urban and rural households in Maharashtra. It requires 2 kg of feedstock to produce about 500 g of methane, and the reaction is completed with 24 hours. In comparison, a conventional biogas system (using cattle dung, sewerage, etc) use about 40 kg feedstock to produce the same quantity of methane and requires about 40 days for completion of reaction. Also, the capital investment required for ARTI biogas system is Rs 10,000 which is half the investment for conventional biogas plants and the running expense per meal is very nominal of Rs 0-5 as compared to Rs 25 for conventional biogas system[16].

To sum up, there is growing awareness/usage of biogas and there has been technological advancement for the same to bring about further improvements in biogas systems which contributes positively to the rural development.

Job Creation

Biomass related technologies are labour intensive in nature and creates significant employment opportunities. The job creation impacts of a bioenergy plants are substantially greater than the people employed directly at the plant. Usually, for the operation and maintenance of the plant more than one person is required

[16] http://www.arti-india.org/content/view/45/52/

to take into account the safety and health requirement and for the emergency purposes. Full time jobs are also created in agricultural sector growing crops related to the plant which may involve job creation for preparing the land, growing and harvesting the energy crops. Full time transportation jobs are also created for transportation of the relevant feedstock to the plant. There are additional job creations in the supply chain wherein people get employed during the development and construction of bioenergy plant, though this job is created for a limited time period. Also, there is job creation during the manufacturing of wood processing plant or boilers. As per one of the study, taking the above mentioned job creation opportunities into account, it is expected that the typically 1.27 man years/GWhe is a reasonable estimate of total jobs created from bioenergy plants (Thornley, Rogers and Huang 2008).

In other words, the job creation potential from use of bioenergy could be classified into following three categories[17]:

- Direct employment: Employment from operation, construction and production such as labour necessary for crop production, construction, operation and maintenance of conversion plant and for transporting biomass.

- Indirect employment: Employment generated within the economy as a result of expenditures related to the fuel cycles. Indirect employment results from all activities connected, but not directly related, like supporting industries, services and similar.

- Induced Employment: Increased earnings from direct and indirect jobs lead to higher purchasing power. This in turns create opportunities for newer jobs. This is termed as induced employment.

It is important to note that the job creation from the bioenergy plant would depend and varies with the scale of production (large scale plantations, or medium and small scale operations) and on the degree of mechanisation. Also it is important to note that the additional income from new jobs is likely to have a multiplier effect when spent locally, which can further spur economic development. A case study of biogas plants operated by SKG Sangha highlighting the positive impact of biogas plants on the job creation has been detailed out in annexure A. Box 5.4

[17] http://www.abengoa.com/sites/abengoa/resources/pdf/biofuels/Agricultural_development/fuente2.pdf

cities another example of the job creation activities from a biomass based gasifier in one of the Indian village[18].

[18] http://www.cdmgoldstandard.org/fileadmin/editors/files/4_GS-stories/project-case-studies/Collections/Case_Studies.pdf

Box 5.4 Impact of biomass gasifier on job creation

Two companies namely Plant Pvt Ltd. and South Pole Ltd., worked in cooperation with the Swiss-based MyClimate Foundation to develop and execute the Malavalli Power Plant Project in Mysore, India. The Malavalli Power Plant consists of a 4.5 MW (gross) capacity grid connected biomass based power plant with high-pressure steam turbine configuration. Over a 7-year period the plant generates about 193 GWh by using lowdensity crop residues (70%) and other biomass fuels found in the local area. Agricultural residues used include sugar cane trash, coconut fronds, corn cobs, and toppings of plantation wood. The project has contributed well to the rural entrepreneurial development. About 450 new jobs have been created in the crop residues supply chain and about 200 jobs at the Biomass Power Plant and Organic Fertilizer O&M have been created for local residents. The project's contributes approximately Rs. 45 million to the rural economy through the biomass supply chain.

Opportunities for SMEs

Biogas could find its application in various industries such as mineral processing industries for brick, lime, roofing tiles, pottery etc., textile industries for dying, silk reeling etc., agriculture/plantation product processing industries for tobacco curing, cardamom drying, tea drying etc. and food processing industries for bakeries, khoya making, gur, puffed rice, sweets. Following paragraphs explains how the biomass could be used in some of the small scale enterprises.

India is the largest producer of large cardamom with a 54% share in world production, followed by Nepal and Bhutan. For storing the cardamom for a longer period of time, the moisture content in the capsules needs to be reduced from about 70-80% to below 10%. Traditionally, an inefficient smoking method is employed, using a bhatti (oven) system which is made-up of locally available construction materials wherein it takes about 30-50 hours to dry the cardamom. An example of usage of biogas in cardamom industry I quoted in box 5.5

Box 5.5: Usage of biogas in SMEs- Cardamom Industry

TERI has developed an appropriate gasifier-based large-cardamom dryer system to suit local conditions. It uses locally available material and can be easily transported into remote forested areas where cardamom plantations are found. More than 150 systems have been installed in the Sikkim in collaboration with the state Horticulture Department and these systems have also been pilot tested in Nagaland state in India, as well as in Nepal and Bhutan. The Gasifier resulted in more than 62% fuelwood saving and improvement in the quality of the product, as the dried cardamom retained 35% more volatile oils and natural reddish colour. The improved quality of cardamom has spiral impact on the increased income of farmers and also provides opportunities for new industries for large-cardamom by way of extracting its oil (Palit, Mande 2007)

Biomass also finds an application in cleaner form in silk industry. India is the largest producer of silk. Most of the silk produced here is reeled in charkha and cottage based oven which consume large amount of firewood. Annual fuel consumption of cottage basin ovens is estimated at 120,000 tons of fuelwood, while charkhas consume 105,000 tons of locally available biomass, such as groundnut shells, tamarind and rice husks and coffee beans. However, the consumption of these fuels by the silk industry is only 11.7 to 15.3 per cent efficient. To address this issue, TERI developed a cocoon cooking oven with gasifiers as its main component which is marketed under the name of SERI-2000. Two manufacturers—2M Industries (Mumbai) and Silktex Industries (Kannakpura)—were selected for commercialization. The technology has been transferred to both the manufacturers through a licensee agreement. The successful development and demonstration of a gasifier-based system for thermal applications in the silk industry has had spin-off effects in many other industries that need to generate heat. To date, about 35 gasifier-based systems have been installed in the silk industry for reeling and dyeing. Long-term testing of these systems has found that their use leads to savings of 745 rupees a day: 90 rupees from reduced wood consumption, 455 rupees from increased silk production and 200 rupees from improved silk quality. Overall, the systems are saving about 822 tons of fuel wood a year and generating an extra 2,490 Kilograms of silk. In addition, pollution and water requirements have also been reduced considerably [19]

The above discussion highlights the strategies to use bioenergy for rural development.In the situation of scarce energy resources, it is important to put the available biomass to its best use to produce clean fuel. Access to clean energy fuels in form of electricity of biogas has far reaching positive social and economic impact on rural development. For facilitating introduction of clean fuels among the rural areas, it is important to have policy framework for promotion of such activity. For instance, strong policy directives towards rural electrification, through Electricity Act and National Electricity Plan have resulted improvement in this regard. Also, for facilitating acceptance of newer technology among rural households, it is important to involve people from community in the process of technology application. For instance, involvement of people for setting up of biogas plants and sharing of information by technical experts with them helps in easier convincing the household members about the benefits to using biogas. Also, as the people in rural community are closely knit to each other, a successful experience of newer technology by any one household spreads to other households through word of mouth promotion.

[19] http://tcdc.undp.org/sie/experiences/vol8/India1.pdf

CHAPTER 6 Opportunities and constraints related to leveraging bio-energy for rural development

Accelerated growth in the production and use of bioenergy in recent past has generated interest of policy makers and investors across the world (UN, 2007). Hence, it is important to examine inter-linkage and balance between key social, economic and ecological sustainability concerns related to small and large applications of modern biomass energy technologies (BETs) for heat and power generation needs to be explored in the context of rising concerns regarding sustainable development in energy sector (Demirbas, 2009). In the chapter, opportunities and challenges of two BETs-namely biomass gasification systems for power generation and biogas for cooking purpose will be explored from Indian context.

Opportunities

Promotion of energy security

Exposure of Indian economy to increasingly unstable international energy markets is high. In some instances, recent advances in BETs are expected to provide locally produced bio-energy for local agriculture, industrial and household usage at less than the cost of fossil fuels (UN, 2007). Instead of directing scarce resources to foreign countries to pay for oil, it makes business sense to invest in local agriculture and manufacturing sectors with additional benefits of strengthening local economies and rise in livelihood opportunities. In terms of the plant capacity the potential of biomass gasification projects could reach 31 GW that can generate more than 67 TWh electricity annually (Purohit, 2009) which would directly contribute to energy self-sufficiency.

Economic Cost competitiveness: Biomass gasifier is reported to outperform conventional fossil fuel (mostly coal) based grid power for electricity generation in economic terms (Ravindranath and Balachandra, 2009). LCA- life cycle cost analysis (Table 6.1) of power generation in Indian condition clearly indicates that though biomass gasification technology is marginally more costly compared to grid based power generation, it is environmentally benign and creates local livelihood opportunities.

Table 6.1 LCA estimates bioenergy technologies for power generation

Power generation technology	Total life cycle cost (Rs./kW)	Unit Cost of Energy (Rs./kWh)
Grid Electricity (coal based)	174310	3.25
Biomass Gasifier	149150	4.17

Source: Ravindranath and Balachandra, 2009

Comparison of life cycle analysis of traditional fuel wood technology with improved stove and biogas for cooking has been compared in Table 6.2 indicate the efficacy of improved cooking stoves. Though unit cost of biogas is slightly higher it has significant environmental and health benefits for which monetization is difficult.

Table 6. 2 LCA estimates bioenergy technologies for cooking energy

Technology details	Total life cycle cost (Rs./GJ of heat output)	Unit Cost of Energy (Rs./GJ of heat output)
Traditional fuel wood stove	674.27	271.13
Efficient fuel wood stove	713.78	163.89
Dung based biogas	3572.4	393.56

Source: Ravindranath and Balachandra, 2009

However, as bioenergy production costs can vary widely by feedstock, conversion process, scale of production and region(Demirbas, 2009), the life cycle and unit energy cost can significantly vary with project location and management efficiency.

Livelihood benefits

As it any development project, the essence of sustainability of bioenergy projects lies on how the community benefits from the project activity. The primary driving force for acceptance of such project activity from community point of view will most probably be employment or job creation, contribution to regional economy and income improvement Other "big issues" such as carbon emissions, environment protection, security of energy supply on a national level are "added bonus" (Domac et al., 2005).

Bioenergy related employment opportunities include direct employment, comprising jobs involved in fuel or crop production, in the construction, operation and maintenance of conversion plants and in the transport of biomass; and indirect employment, comprising jobs generated within the economy as a result of expenditures related to biofuel cycles (Faaij, 1997). Please refer to chapter 5 for more details of type of job creation from bio-energy sector.

Bioenergy is possibly the most labour intensive energy source and there is little doubt that bioenergy development will bring about significant job creation in unskilled and semi-skilled labour in India depending on the scale of production (large scale plantations, or medium and small scale operations) and on the degree of mechanisation – new employment opportunities arise for unskilled workers (FAO, 2007). On average, labour intensive biofuels would generate about 100 times more workers per joule of energy content produced in comparison to capital-intensive fossil fuel industry (UNDP, 2009).

However, actual direct and indirect employment opportunities for biomass gasification and biogas vary considerably due to local factors such as physical infrastructure, density of plants, feedstock type, soil quality etc. For example, TERI experience suggests that installation of a 2 m^3 biogas plant requires 10 skilled and 40 semi-skilled person days. However, the job generation for servicing and maintenance will vary depending on the number of biogas plants installed in adjoining areas. Say, if 10 biogas plants are installed, 10 skilled person days will be generated for periodic visits to the installed plants every week. However, presence of 100 plants would lead to a full time direct employment for 1 skilled worker deputed for service and maintenance. In the case of biomass gasifier technology, there is potential of regular employment generation. One skilled and one semi-skilled personnel is required for daily maintenance and operation for 20 kWe biomass gasification system. Job creation for fabrication of one plant is difficult to calculate. Staff on permanent payroll of company deal with fabrication and person days/unit of plant would depend on the number of orders executed by the company in a month.

The potential for generating employment opportunities in modern bioenergy applications among developing countries is a topic worthy of serious study and a country and technology specific study should be commissioned to understand the direct, indirect and induced benefits from selected case studies.

Climate Change Benefits:

In the era of increasing climate change awareness, environmental benefits produce a strong case for bioenergy (Demirbas, 2009). Table 6.3 below details the theoretical possibility of greenhouse gas abatement through bioenergy technologies (Ravindranath and Balachandra, 2009).

Table 6.3 BETs greenhouse gas reduction potential in India

BET detail	Technical Potential	Annual abatement (million TC/year)
Biogas	17 million	5
Community Biogas	150,000	10.8
Improved stove	120 million	4
Biomass based power generation	57000 MW	89

Sustainability challenges in Bio-energy value chain:

The sustainability of bioenergy depends largely on how the risks associated with its development – especially pertaining to the land use and climate implications of large-scale feedstock production and potential social inequity- are managed. Hence, while the much touted positive impacts related to bioenergy activities is well accepted, it is also important to be cautious about safeguard mechanism against possible negative impacts which are described below with special focus on the two selected technologies- biomass gasification and biogas.

Carbon neutrality:

Feedstock production is arguably the most important factor in determining the sustainability of bioenergy production. Hence, potential impacts of efficient (often translated to “intensive”) land usage will have direct impact on biodiversity impacts, greenhouse gas emission, and degradation of soil and water bodies (WWF, 2007). Land usage has very high impact on GHG emissions. Conversion of forest land, pastures and or savannah type land for bioenergy cultivation can cause higher GHG emission than what is abated by GHG emissions (WWF, 2007).

It is sometimes perceived that burning biomass merely returns the CO_2 that was absorbed as the plants grew and as long as the cycle of growth and harvest is sustained, biomass burning is carbon-neutral (Ravindranath and Balachandra, 2009). But this is not applicable as an universal truth for all forms of bioenergy and its varied production and usage mechanisms. Schubert and Blasch (2010) list several factors which determine the carbon-neutrality (or otherwise) of bioenergy vis-à-vis the fossil fuel which is purported to be replaced. The life-cycle carbon balance critically depends on the choice of feedstock, the management of land resources when growing the feedstock, the kind of land-use changes induced by cultivation, conversion and processing methods used in bioenergy production, the type of fossil energy carrier which is replaced by biomass and the efficiency of energy end-use. The efficiency in harvesting and combustion – both play a role in determining the carbon implications of biomass burning. For example, 40% of fuel wood usage in India is from unsustainable extraction (Ravindranath and Balachandra, 2009).

Food security: FAO (2007) has raised concern that rapid biofuel growth, mono-cropping practices and assured buyback of preferred energy crop varieties may lead to a reduction in agricultural biodiversity with negative repercussions on food security. While globally there is sufficient food production but unequal access, local bioenergy production and usage can be a means of alleviating poverty and improving food security through income generation (WWF, 2007). However, Lewandowski and Faaij (2006)[20] have expressed concern are that biomass production could compete with food production on a local/ regional scale and lead to regional food supply shortage in developing countries.

There are growing doubts on the efficacy of biofuels in reducing carbon emissions, largely because of the impacts of large-scale land use change particularly relevant for large-scale commercial biofuel production, which tends to take place on lands that would be suitable for food production (FAO, 2008). Even the concept of "biofuel cultivation in wasteland" has been questioned in India because of the heavy reliance of rural people on these lands for collecting fuelwood, food, fodder, timber and thatch (Rajagopal, 2007). However, in the context of biogas and biomass gasifier technology dissemination such concerns are not applicable.

Loss of Biodiversity: Depending on land type, cultivation forms (rotation scheme, plantation management plan etc.) there are threats of biodiversity loss. Conversion of forest land for bio-energy usage would lead to severe loss of biodiversity (WWF, 2007). Apart from strict land use policy there should also be more stress on perennial bioenergy plantations rather than annual rotation harvests as it may create more favourable habitats for biodiversity compared to conventional crop production (FAO, 2007).

Competing local usage of bio-resources: Local level production of agri-residue based processed solid fuel (briquettes/pellets) is likely to spike the demand for agricultural residues which are currently used for cattle fodder and manure. Poor population runs the risk of compromising on usage of agricultural residue for short term monetary gains. Such competition with local bioenergy system may in the long run negative impact cattle rearing and soil quality for villagers without access (due to disparity between purchasing power and

[20] Steps towards the development of a certification system for sustainable bio-energy trade; I. Lewandowski, A.P.C. Faaij; Biomass and Bioenergy 30 84 (2006) 83–104

cost) to commercial alternatives. Hence, detailed, location specific and participatory resource assessment should be carried out before executing BETs based on local biomass resources.

Monetization of local biomass: Often, economic constraints (disposable surplus cash) force population to rely on (often) non-monetized fuel from own land, public/open access lands or engage in informally traded fuel. There is a risk of monetization of hitherto un-monetized fuel depriving access of existing fuel to the poor. If the bio-energy alternative is unaffordable, introduction of bio-energy systems locally can cause grave impact on access to energy for the economically underprivileged. Hence, introduction of any BETs should consider the access issues related to local population.

Institutional financing mechanism: In has been reported that financial institutions in developing countries have less favourable risk rating for small scale BETs compared to better established energy technologies like grid access and solar power (UN, 2007). This risk perception should be addressed by sensitizing concerned stakeholders through policy initiatives such as crop insurance and technological measures like demonstration projects and access to best cropping technologies and knowledge for the farmers engaged in bioenergy feedstock. Financial instruments such a price support mechanism, micro-credit, tax breaks etc. are often necessary for commercial viability of BETs till they reach economies of scale.

Conclusion:

The chapter clearly demonstrates that biogas and biomass gasification system have significant benefits from energy security and green house gas (GHG) mitigation potential. However, for all practical purposes, it is vital to clearly define land usage policies categorically mentioning amount and type of land (with clearing mentioning soil quality, water access indicators) which will be followed by potential investors to ensure restriction of bio-energy cultivation to areas that are not in competition with other uses like agriculture, biodiversity etc. Also, during GHG calculations of bioenergy, fossil fuel/fertilizer inputs in bioenergy production and downstream processing should also be taken into account like GHG benefits from by-product utilization which varies significantly with local conditions. At project approval stage, a relatively simple yet verifiable estimation of GHG life cycle crops must be submitted before appropriate authorities which can indicate reduction vis-à-vis life cycle GHG emission of unprocessed crude oil combustion of approximately 90 kg/GJ (WWF, 2007).

CHAPTER 7 Regulatory, Institutional and Financial Framework

This chapter summarizes the regulatory and various institutional and financial frameworks existing for two forms of bio energy i.e. solid biomass and biogas.

Regulatory framework

The electricity sector is regulated by the Central Electricity Regulatory Commission (CERC) at central level and by State Electricity Regulatory Commission (SERCs) at state level. These electricity regulatory commissions are governed by the Electricity Act 2003 and have mandate to regulate generation, transmission and distribution of electricity including power generated through renewable sources of energy. Regulation in this sector is mainly concerned with tariff regulation.

Forms of bio-energy i.e. solid biomass and bio gas are also subject to tariff regulation by these agencies at central and state level. CERC in September 2009 enacted the "Terms and Conditions for tariff determination from renewable energy sources Regulations 2009". The regulations specify the various general and specific conditions for determining tariff for grid connected renewable energy technologies including biomass such as life of projects, control period for tariff, benchmark capital costs, efficiency factors, etc. In case of grid connected biomass, only those projects would be eligible for tariff determination based on these regulations which have new plant and machinery based on rankine cycle technology and use biomass fuel sources. The regulations provide for higher return on equity (pre-tax) – 19% for first 10 years and 24% from 11 year onwards, through higher tariff for renewable energy power producers. Notably, this new RE tariff regulations provide significantly higher returns on investments in comparison with the conventional sources of power generation (14%). The tariff permitted to these projects is valid for 13 years after considering the normative debt of 10 years. The levelised tariff specified by CERC for biomass power for various Indian states depending on the type of biomass available and their costs is summarised in table 7.1.

Table 7.1 Levelised tariff for biomass projects for 2010/11

States	Levelised tariff (Rs/kWh)
Andhra Pradesh	4.15
Haryana	5.52
Maharashtra	4.76
Madhya Pradesh	3.93
Punjab	5.49
Rajasthan	4.73
Uttar Pradesh	4.47
Tamil Nadu	5.08
Other states	4.88

Other than the tariff regulation, in order to promote generation from renewable energy sources, renewable purchase obligations (RPO) is also mandated by SERCs. Under the RPO, the appropriate electricity regulatory commission mandates a certain minimum percentage of total consumption in the state to come from renewable sources. Most of the SERCs have mandated such obligation. Further to ensure compliance with RPO, CERC recently (January 2010) notified the “Terms and Conditions for recognition and issuance of renewable energy certificate (REC) for renewable energy generation, Regulations 2010”. These regulations involve setting up of a central agency at national level for issuance, transfer, monitoring and surrendering of RECs. This would help in addressing the problem of non-uniform distribution of RE potential in various Indian states. While the RECs would be traded in market through power exchanges and their price would be determined through the exchange only, the associated power would be sold to the local grid at a price not exceeding the pooled cost of power purchase of utility. Such regulatory initiatives have provided impetus to growth of RE in India.

Institutional framework

Various types of institutional models exist for providing energy access to rural areas through various forms of bio energy. While biomass based energy can either be grid connected or off-grid models, the biogas based energy is usually in decentralized mode. Institutional mechanisms for following projects are detailed out below:

1. Grid connected projects – biomass
2. Off-grid projects – biomass and biogas
3. Other – mini grid models, etc

Grid connected projects – biomass

Biomass power projects in the country are all private sector driven. The state renewable energy development agency allots prospective districts/talukas for setting up biomass power projects based on the resource availability. The power generated is usually utilized for captive consumption, sale to third party or sale to utility depending upon the policy of the respective states. In case of Independent Power producer, the state utility purchases electricity at pre-determined rate as per the tariff order declared by the respective state electricity regulatory commission. Further financial support for such project developers is mostly in form of grants; of late mainstream financial institutions have started financing biomass power projects. Most projects have been financed by a handful of financial entities, namely, the Indian Renewable Energy Development Agency, Industrial Development Bank of India (IDBI), and Industrial Credit and Investment Corporation of India (ICICI).

Off-grid projects – biomass and biogas

These projects are either based on PPP model or government subsidy driven. In case of PPP models, project developer jointly with local partners sets up power plants in villages. The power plant is integrated with energy services and with a number of micro enterprises, largely engaged in agro-processing work. It is managed by the village community, members of whom are trained by project developers. The local partner organization ensures the supply of the biomass and the purchase of the generated electricity at agreed prices.

Various projects have been implemented based on this institutional or service delivery model. For example DESI Power, a biomass project developer, has successfully implemented projects in TARAGram Orcha in Madhya Pradesh, Baharbari and Gayari villages in Bihar based on this model. At Baharabari and Gayari, DESI Power facilitated the formation of a local cooperative and has jointly implemented the rural electricity related activities in the villages. DESI Power is acting as an Independent Rural Power Producer (IRPP) with the local partner assuming the responsibility of arranging biomass, distribution of power and bill collection. DESI Power also acts as an intermediary to promote small and micro enterprises in the village by providing power from the power plant, train the people and standing as a guarantee to repay the loan by the small industries. A local group manages the supply of biomass with whom DESI Power enters into biomass supply agreement. For financing, DESI Power has successfully sourced funds from ICICI bank for fuelling power requirements in rural areas.

In case of subsidy driven models in the off grid village electrification by various implementing agencies in India involves formation of a Village Energy Committee (VEC), with representation from villagers and local governance body (panchayat). The VEC plays the role of stand-alone power producer, distributor and supplier of electricity, manages the revenues through collection of payments for the electricity used from consumers and dispute resolution in case of power supply disruption (Fig 7.1).

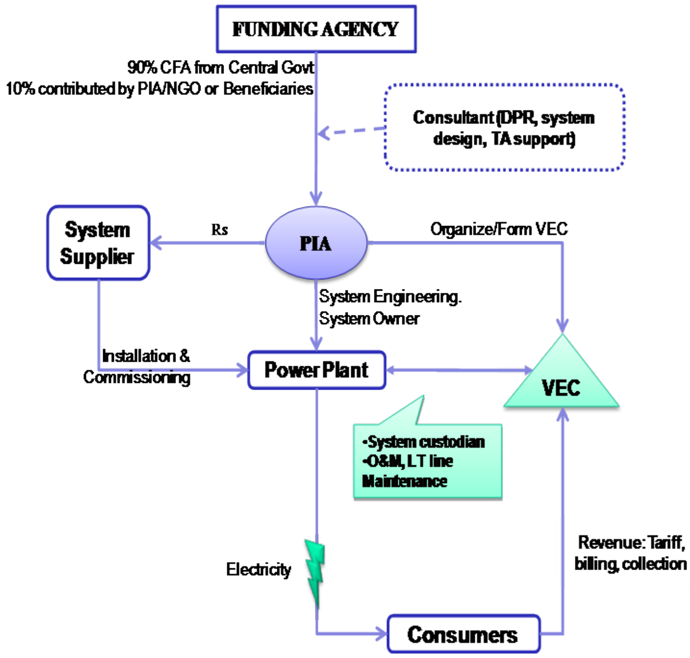

Figure 7.1 The VEC Model

Usually for decentralized systems, the electricity generated from the gasifier system is distributed to the consumers through a local mini-grid. As most of such projects are subsidy driven, the tariff is set by the VEC in consultation with the PIA (Project Implementation Agency) in such a way that it takes care of the fuel and the O&M costs. Experience from many such projects shows that the tariff is set at a flat rate based on the ability and willingness to pay of the local community, ranging between Rs 10- 20 per light point per month and Rs 50 per socket point per month for a 4-5 hours of supply, equivalent to Rs 3-6/kWh.

NTPC, the largest power generation company in the country has been setting up distributed generation projects for village electrification based on VEC model. NTPC provides the technical back up support and does the social engineering in the project area either directly or involving a NGO or a consultant agency. Till now about 10 projects in off grid mode have been commissioned, of which 9 projects are based on small capacity biomass gasifiers (10-30 KW). The VEC acts as the project custodian and responsibility of revenue collection and O&M also remains with the VEC. Local youths from the village are trained to operate the systems. The tariff is based on flat rate and is usually @Rs 30 per light point.

Further, door-to-door delivery models also exist in case of off-grid bio gas plants for household needs for cooking and lighting. For example SKG Sangha has been installing biogas plants for domestic use in various parts of the country. In Karnataka, biogas plants are installed with the support of the Ministry of New and Renewable Energy Resources (MNRE), Government of India and Ministry of Rural Development Panchayati Raj Institute (RDPR), Government of Karnataka. The local NGOs, Gram Panchayats (GP) and Self Help Groups (SHGs) are also supporting the SKG Sangha to identify beneficiaries and act as facilitators for installation of biogas plants in their respective area. Once the local NGO's or elected representatives identify beneficiaries, experienced masons construct the biogas plant under the supervision of SKG Sangha.

Other – mini grid models, etc

Another institutional model for delivery of energy through such projects is by development of a local mini-grid. For instance, the West Bengal Renewable Energy Development Agency (WBREDA) is looking at electrifying remote villages in Sunderban area through creation of local mini grid. Both 11 kV and LT grid network is created by WBREDA depending on the capacity of the power plant and evacuation of power from the plant. To maximize the PLF, WBREDA establishes the plant near the load centre and creates a 2-4 km of mini grid in the area for supply. The mini grids are operated by cooperative societies formed by the local people (Fig 7.2). The responsibilities of the societies includes selection of consumers, planning for the distribution networks, tariff setting in consultation with WBREDA, revenue collection from consumers and passing them to WBREDA and consumer grievance redressal.

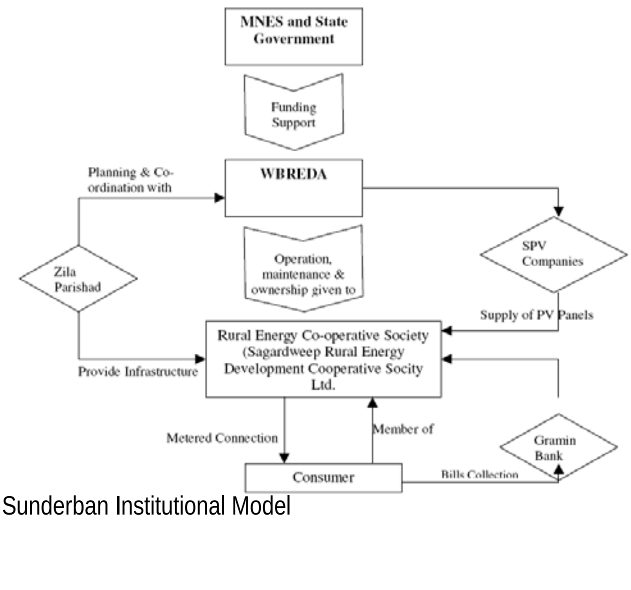

Figure 7. 2 The Sunderban Institutional Model

Financial models

Most of the projects, in grid connected or off grid mode, are subsidy driven. At central level, Central Financial Assistance (CFA) is extended to these projects in form of capital subsidy and/or interest subsidy. CFA has always been instrumental in building promoters' interest for bringing investments in the sector (Table 7.2 and Table 7.3). Besides CFA, fiscal incentives such as 80% accelerated depreciation, concessional import duty and excise duty exception on equipments and tax holiday are also available. At the state level, biomass power and cogeneration are promoted through pricing and wheeling/banking policies stipulated by respective state electricity regulatory commissions and/or the new tariff guidelines brought out by CERC.

Table 7.2 Capital subsidy for biomass/cogeneration projects (Rs million)

	Special category states	*Other States*
Biomass power	$2.5(C)^{0.646}$	$2(C)^{0.646}$
Bagasse cogeneration	$1.8(C)^{0.646}$	$1.5(C)^{0.646}$
Bagasse cogeneration by cooperative/public/joint sector (per MW)		
40 bar and above	4*	4*
60 bar and above	5	5
80 bar and above	6	6
	Maximum support Rs 80 million per project	Maximum support Rs 80 million per project
Biomass power using advanced technologies	$12(C)^{0.646}$	$10(C)^{0.646}$

* For new sugar mills (that are yet to start production and sugar mills employing back pressure route/seasonal/incidental cogeneration), subsidies will be half of the level mentioned above.
C: Capacity in MW

SOURCE Ministry of New and Renewable Energy
Note: C = Capacity in MW

Table 7.3 Interest subsidy for bagasse-based and biomass cogeneration

Schemes	Pressure configuration	Interest subsidy (%)
Projects by cooperative/ public/joint sector sugar mills	40 bar and above	3
	60 bar and above	4
	80 bar and above	5
Projects in IPP mode in cooperative/public sector sugar mills	60 bar and above	2
	80 bar and above	3
Projects by private sector sugar mills	60 bar and above	2
	80 bar and above	3
Biomass cogeneration		
Commercial projects	60 bar and above	2
	80 bar and above	3

Source Ministry of New and Renewable Energy

While capital subsidy has allowed implementation of several projects, in many cases it has been inadequate for ensuring long-term sustainability & replicability of the models developed. External financing is also being sought by many project developers. Of late mainstream financial institutions have started financing biomass power projects. Most projects have been financed by a handful of financial entities, namely, the Indian Renewable Energy Development Agency, Industrial Development Bank of India (IDBI), and Industrial Credit and Investment Corporation of India (ICICI). The financial mechanism for SKG Sangha is also subsidy driven and is summarised in box below.

Box 1 Financial mechanism for SKG Sangha case study

Each beneficiary, i.e. household requiring bio gas plants, places an order with SKG Sangha for setting a plant at site. SKG Sangha obtains a letter of authority from each beneficiary which authorises the Sangha to collect the subsidy amount from MNRE on their behalf. In return, the Sangha provides materials such as cement, iron, stove, pipe and other fitting accessories for biogas plant construction including mason charges. This amount is borne through micro finance which they take through other Micro Financing Institutions (MFIs) or other revolving fund of the Sangha. The beneficiaries contribute sand, bricks, stone chips, pit digging charges and labour charges for constructing biogas plants. The Sangha expressed that they have not been able to receive subsidy from the Government for the past four-five years due to lack of funds as stated by the concerned departments. To mitigate this problem, the Sangha is looking forward to mobilise funds from other sources with focus on CDM so that they can continue their efforts in disseminating the biogas plants.

As regards tariff and viability of projects, most of the biomass projects are seen to be viable at the prevailing tariff of Rs.3.93-5.52 per kWh. While the distributed generation based biogas projects have usually flat tariff and are viable at Rs 30-50 per household (for 1-2 light points) equivalent to Rs 3-6 per kWh.

Another innovative way of financing these projects is through implementing these projects under the Clean Development Mechanism (CDM) and Voluntary Emission Reduction (VER). The main principles behind these projects are to utilise the reduced carbon emissions acquired through switch to a cleaner fuel and technology of biogas or biomass plants. For instance in the case of biogas based power generation by SKG Sangha, CDM and VER are being explored as opportunities for future financing. Exploring alternative sources of funding to meet the growing demand for biogas plants, SKG Sangha is now developing and is in the process of implementing quality projects under CDM and VER. Many Gold Standard VER projects and few Gold Standard CDM projects are in the pipeline and looking for investors.

Need for research and development (R&D)

Use of bio energy for power generation either through combustion or gasification has been widely used. However the efficiency of these technologies have been relatively low and thus there is a need for dedicated R&D for developing more efficient technologies for generation of power from bio energy. A technology-specific R&D need assessment is given below.

1. Combustion technology used to generate power from biomass is commercialised, efficiencies can be improved through focused research in following areas:
    a. Technology development for co-combustion of biomass in coal plants – this will provide a low cost solution to cut carbon dioxide, sulphur and nitrogen oxide emissions.
    b. Developing combustion technology with improved efficiency and ability to handle various fuels of different heating values – such innovation would increase capacity factor of plant.
    c. Improvements in overall efficiency of biomass based combustion technology through advancements in i) refractory materials for furnace walls that will result in better thermal insulation leading to increased thermal efficiency; and ii) reactor design and fuel processing methods for more complete combustion.

2. Biomass gasification is an old technology for power generation through biomass, but lack of adequate R&D has restricted its further development. Major R&D challenges for this technology are as follows:
    a. Biomass gasification is not significantly commercialized; hence it has higher costs than the combustion based technology.
    b. Development of materials and technology for the producer gas to remove contaminants that damage IC engines and turbines.
    c. Focused research to develop new technologies such as oxygen gasification or catalytic gasification can increase the efficiency of the plant.

Thus for further deployment of bio energy (biomass and gaseous form), improvements in both technologies through focused R&D and policy and regulatory framework is essential. Also innovative financial schemes may be promoted for ease in investments in this sector.

CHAPTER 8 Conclusion

In India, at the level of policy, multi-pronged strategy for leveraging bio-energy for poverty alleviation and rural development was adopted : i) improving efficiency of the traditional biomass use (e.g. improved cook-stove programme), ii) improving the supply of biomass (e.g. social forestry, wasteland development), iii) technologies for improving the quality of biomass use (e.g. biogas, improved cook-stoves), iv) introduction of biomass based technologies for heat and electricity generation (Village Energy Security Programme) to deliver services provided by conventional energy sources, and v) establishing institutional support for programme formulation and implementation (formation of separate government wing to exclusively deal with non conventional energy sources).

In the past, biomass was viewed solely as a traditional fuel for meeting rural energy needs. Also, the policies primarily focused on the supply-side push with market instruments having little role in biomass policies. Only recently, biomass has been recognized as a competitive energy resource vis-à-vis fossil fuel in some cases, which can be introduced in commercial energy markets.

Rural energy programmes should be dovetailed with forestry-poverty projects like REDD (Reducing Emissions for Deforestation and Degradation) so that rural energy and employment can emerge as significant co-benefits of carbon-based forest financing. Further, it is desirable that the government while framing its policy directions for promotion of clean fuels should create environment (by providing incentives, tax rebates etc.) for facilitating investments from private sector in this sector. Involvement of private sector in setting of biomass gasifier in rural and remote areas has proved beneficial in popularising the technology.

Rural energy scenario in India is characterized by inadequate, poor and unreliable supply of energy services and large dependence on traditional biomass fuels. However, traditionally use of biomass as energy in India is characterized by low efficiency and environmental degradation. Unprocessed biomass is mostly used in traditional stoves and furnaces that have low efficiencies, of the order of 10% with serious indoor air pollution and negative health impacts. This builds a strong case for research and policy focus on improving efficiencies of local biomass usage. Achievements from past programmes to promote bioenergy technologies on ground have not been able to tap India's bioenergy potential. It requires new programme interventions for cook stoves, biogas and biomass gasification systems which has a bottom up approach. Also, for facilitating acceptance of newer technology among rural households, it is important to involve people from community in the process of technology application. For instance, involvement of people for setting up of biogas plants and sharing of information by technical experts with them helps in easier convincing the household members about the benefits to using biogas. Also, as the people in rural community are closely knit to each other, a successful experience of newer technology by any one household spreads to other households through word of mouth promotion. The focus should be on quality delivery services (with convenient and affordable post-dissemination service facilities) rather than merely meeting programme targets.

Extraction of biomass for serving energy needs from natural forests is not desirable from ecology and biodiversity perspective. Sustainable harvesting from forests is also limited by present knowledge on the modes of sustainable extraction in different forest ecosystems. Further, natural regeneration of desired species is difficult to achieve. Hence, as sustainable extraction from forests may not be feasible the focus should be on sustainable extraction of biomass from trees outside forests (TOF) and energy plantations especially species like Propocis Juliflora on wastelands.

Life cycle analysis of modern BETs are reported to outperform conventional fossil fuel based technologies for power generation in economic terms in some cases. The cost advantage depends on bioenergy production costs which can vary widely by feedstock, conversion process, scale of production and region. However, inmost cases, the upfront cost of BETs is more than conventional technologies thereby creating a practical barrier to adoption. Suitable micro-finance mechanism would result in greater penetration of these technologies into economically under-privileged communities of rural areas in an economically sustainable manner.

Specific Policy Recommendations

Use of bio energy for power generation either through

1. Promotion of Biofuels:
    a. While there is National wasteland Atlas (based on satellite data), it is prudent to engage in a resource intensive process of field level waste land survey- whether it is actually lying barren or whether it has current uses, soil conditions, whether it is contiguous in nature which needs to be documented as a master dataset.

b. Based on the findings, research should be carried out to:
    i. Identify a set of most applicable species and its germplasm for particular site conditions
    ii. State governments with inputs from Central government will explore value chain mechanism depending on site and socio-economic condition. For example, large investors would prefer large contiguous area
c. Establish clear national and state level legislations (not draft policy or draft guidelines as current trend suggests) related to tax waivers, land lease pricing, MSP of seed/oil, buyback agreement format etc. to reduce economic uncertainties
d. Any bio-fuel investment (government or private) above a specific land usage limit must go through a responsible authority with sufficient technical background to make a realistic assessment of the project DPR specially assessing the risks involved with mono-culture. It will mollify the accusation against large investors who are allegedly engaged in “land grabbing” in the garb of biofuel investment.
e. Encourage small-scale community based Jatropha initiatives like agro-forestry with Jatropha intercropping for insitu usage like lighting fuel or as fuel for running water pumps. Such mechanism will reduce dependence on fossil fuels like diesel and kerosene. Further Jatropha produces woody by-products, which can be used as cooking fuel.
f. Set up a national bio-energy technical review committee with a mandate to carry out rigorous technical analysis of available bio-energy technologies like gasifiers across the world. Such analysis would enable setting up quality standards for these technologies (including for post deployment service) preventing the current trend of ad-hoc design and claims of functionality.
g. The existing technologies have high capital expenditure and are targeted at rural population with lower purchasing power. This paradox can be addressed by mandating that all bank branches must have targets of financing installation of bio-energy technologies.

h. A dedicated institution for bioenergy research, development and promotion should be carved out of the existing institutional maze of multiplicity of institutions and overlapping of roles. Such step would encourage private investment into this sector. A market approach can promote technology transfers on a self-sustained basis rather that remaining dependent on “one time” grants.
i. Create linkage between existing programmes reclamation and bioenergy technologies. For example, biomass gasification is ideally suited in sites where wasteland reclamation/ afforestation programmes are being implemented, as it would ensure steady sustainable fuel supply. Further, dairy development programmes can be tied up with biogas programmes. Such creative interlinkages would ensure that the existing opportunities and infrastructure is tapped to achieve resource efficiency.

In conclusion, sustainability and contribution of bioenergy depends largely on how the risks associated with its development – especially pertaining to the land use and climate implications of large-scale feedstock production and potential social inequity- are managed on project to project basis. Sufficient flexibility for adjustment to account for local factors must be institutionalized in any bio-energy project even whendirected and coordinated at a national scale.

References

Demirbas, 2009
Political, economic and environmental impacts of bio-fuels: A review. Applied Energy 86, 5108-5117

FAO, 2007
A review of the current state of bioenergy development in G8 +5 countries
Food and Agriculture Organization of the United Nations (FAO), 2007

Ravindranath and Balachandra, 2009
Ravindranath, N.H., Balachandra, P., 2009. Sustainable bioenergy for India: Technical, economic and policy analysis. Energy 34, 1003–1013

UN, 2007
Sustainable Bioenergy: A framework for decision makers. United Nations Energy. 2007.

WWF, 2007
Sustainability Standards for Bioenergy
World Wildlife Fund for Nature, Germany, 2006

MNRE 2004
Annual report 2003/04, Ministry of New and Renewable Energy, Government of India

MNRE 2009
Annual report 2008/09, Ministry of New and Renewable Energy, Government of India

Ravindranath, Balachandra 2009
Sustainable bioenergy for India: Technical, economic and policy analysis, N.H. Ravindranath, P. Balachandra, Energy Policy 34 (2009) pg 1003–1013

Nouni,Mullick, Kandpal 2008
Providing electricity access to remote areas in India:
An approach towards identifying potential areas for decentralized electricity supply, Science Direct, M.R. Nouni, S.C. Mullick , T.C. Kandpal, Renewable and Sustainable Energy Reviews, 12 (2008) pg 1187–1220

Sinha 2002
Bhaskar Sinha, The Indian stove programme: an insider's view – the role of society, politics, economics and education, Boiling Point 48, pg 23.

TEDDY 2009
The Energy Data Directory Yearbook, 2008/09, The Energy and Resources Institute, New Delhi, India

ESMAP 2004
Clean Household energy for India: Reducing the Risks to Health 2004, UNDP Energy Sector Management Assistance Programme

Thornley, Rogers and Huang 2008
Quantification of employment from biomass power plants Patricia Thornley,John Rogers, Ye Huang, Science Direct, Renewable Energy 33 (2008) Pg 1922–1927

Palit, Mande 2007
Biomass Gasifi er Systems for Thermal Applications in Rural Areas, Debajit Palit and Sanjay Mande; Boiling Point No 53 2007 Pg 17-19

Hitofumi 2005
Summary of Biomass Power Generation in India, Abe Hitofumi, Japan International Cooperation Agency

Desai, 2004
The World Health Organization, Indoor smoke from solid fuels Environmental Burden of Disease Series, No. 4 Assessing the environmental burden of disease at national and local levels
http://www.who.int/entity/quantifying_ehimpacts/publications/en/Indoorsmoke.pdf

FAO, 2007
A review of the current state of bioenergy development in G8 +5 countries
Food and Agriculture Organization of the United Nations (FAO), 2007

IEA, 2009
World/India Energy Balanc
http://www.iea.org/stats/balancetable.asp?COUNTRY_CODE=29
Accessed on 17 February, 2010

MNRE 2009
Annual Report 2008/09
Ministry of New and Renewable Energy
Government of India

NSSO, 2008
National Sample Survey Organisation, 2008. NSS 63rd Round Household Consumer Expenditure in India, 2006-07. Report

No. 527 (63/1.0/1); Ministry of Statistics and Programme Implementation, Government of India, New Delhi.

Palit Mande 2007
Biomass Gasifier Systems for Thermal Applications in Rural Areas
Debajit Palit and Sanjay Mande
The Energy and Resources Institute

Planning Commission, 2006
Integrated Energy Policy. Report of the Expert Committee. Government of India. Planning Commission. New Delhi. August 2006

Ravindranath and Balachandra, 2009
Ravindranath, N.H., Balachandra, P., 2009. Sustainable bioenergy for India: Technical, economic and policy analysis. Energy 34, 1003–1013

WHO 2002
The World Health Report 2002: Reducing Risks, Promoting Healthy Life World Health Organization , Geneva

Singh K D. 2008a
Forests, farms and trees: recent trends and future prospects
International Forestry Review **Vol 10** (2) : 103-115

Singh K D. 2008b
Balancing fuelwood production and consumption in India
International Forestry Review **Vol 10** (2) : 190-200

Verma M. 2008
Framework for forest resource accounting: factoring in the intangibles
International Forestry Review **Vol 10** (2) : 362-375

Annexure A: Biogas Program of SKG Sangha

SKG Sangha is a non profit voluntary organization, engaged in a variety of economic, agricultural, social and environmental empowerment activities in rural India. Founded in 1993, the organisation's core focus areas include Sustainable Energy, Sustainable Agriculture, Rural Industrialization, Solid Waste Management and optimizing natural resources.[21] The group has developed a unique and sustainable model for using bio-gas plants (BGPs) as a source for meeting cooking and lighting loads in rural households. At present it has its presence in 4 southern states including Karnataka, Andhra Pradesh, Tamil Nadu and Kerela and other states include West Bengal, Meghalaya and Manipur. Further it is also implementing similar initiatives outside India in countries such as Nepal and Africa (particularly Kenya, Uganda and Ghana) and is considering working in Sudan, Morocco, Liberia and Tanzania.

The following case study discusses in detail the business model used for setting up biogas plants (BGPs), the objective of program, the beneficiaries identified, implementation strategy and modes of finance used in detail. It also summarises the achievements and benefits accrued by the project so far.

Background

In India, almost 95% of rural households are dependent on biomass for cooking and lighting. Different forms of biomass are used for this purpose including fuel wood, cow dung and agricultural waste. Women and children spend almost 2-3 hours per day, several days a week collecting fuel wood, and this activity becomes increasingly arduous with depleting forests. Further, burning of biomass through traditional inefficient cook stoves (only 10% efficiency) causes Indoor Air Pollution (IAP) which causes negative health impacts such as respiratory and eye infections.

In order to overcome the drawbacks of traditional use of biomass, one of the means is to promote the diffusion of anaerobic digesters in the form of BGPs. India has a huge potential for generating biogas sufficient to meet the cooking needs of approximately 87.45 million households.[22] The manure

[21] http://www.skgsangha.org/index01.html
[22] As per the Directorate of Non-Conventional Energy – Department of Biogas, annual production of cattle dung in India is approx. 980 MT. This can generate approx. 36,260

generated from the residue of the bio-gas plants can further supply organic manure to the tune of 114 MT (million tonnes), sufficing for 4.56 million hectares of agricultural land assuming manure consumption at the rate of 25 tonnes per hectare.[23]

Policy framework

The Ministry of New and Renewable Energy (MNRE), Government of India (GoI) has been involved in promoting use of biomass through the biogas technology renewable energy devices in the country with the objective of utilising locally available renewable sources. The ministry launched the National Project on Biogas Development (NPBD), which is one of the largest programmes being implemented, for development of biogas plants for meeting rural energy and cooking needs. Box A-1 provides a chronology of the development of biogas technology in India.

Box A-1 Chronological history of development of biogas technology in India

- 1987 – Biogas used for lighting at Matunga asylum, Bombay
- 1946 – First family size biogas plant designed at IARI, Delhi
- 1952 – Development of floating drum biogas model – Gramalaxmi III
- 1981 – Launching of NPBD
- 1982 – Inclusion of biogas 1 PM's 20 points programme

National Project on Biogas Development (NPBD)

NPBD was initiated in India more than two decades ago in 1982-83. The main objectives of the program were to provide clean and cheap source of energy in rural areas; reduce drudgery of women and children; and create rural employment. Under NPBD, the Central Government provides various facilities for promotion and extension of biogas programme. These supports provided by the Central Government include:

- Central Subsidy – in accordance with size of plant
- Training programme – users, turn-key workers, masons etc.
- Turn key job fee – a rate for every biogas plant constructed
- Incentive for saving diesel from biogas – for large size biogas plants (6-10 cu. m per day) for dual fuel engines
- Technical support – through Regional Biogas Development and Training Centres (RBDTCs)
- Communication and publicity – two-fold publicity campaign involving both the Central Government and State Implementing Departments/Agencies

million cubic meter of gas through the gasification process used in Biogas plants, which is sufficient to meet the cooking needs of approximately 87.45 million households.

23 Biogas–Retrospect and Prospects; Directorate of Non-Conventional Energy - Department of Biogas; Khadi and Village Industries Commission

Under NPBD, over 2 million biogas plants have been installed in India over the last two decades. In Karnataka in Southern India, "Anila Yojane" program was launched in 1992-93 to complement the NPBD. Under this scheme, an additional subsidy is provided apart from the Central subsidy[24].

Potential and achievement

In India there is huge potential for biogas plants. Table A-1 illustrates the estimated potential for biogas plants and the untapped potential within India and the State of Karnataka.

Table A-1 Potential of Biogas plants in India and Karnataka

Statistic	India	Karnataka
Potential for biogas plant*	24,000,000	700,000
No. of biogas plants installed so far*	3,370,000	270,000
Investment required for achieving full potential (in £)	3,403,950,000	70,950,000
Potential for vermi-compost units**	25,000,000	800,000

SOURCE Adapted from Ashden Awards for sustainable energy, 2007

*2001 Census of India

**MNRE, 2002 data

SKG Sangha – Biogas business model

After testing various other biogas business models, SKG Sangha Biogas model was established in 1992-93. It was based on the The Deenbandhu (DB) model in brick masonry developed by AFPRO – Action for Food Production, New Delhi. Adopted by the NPBD, this model is cheaper than all the earlier models.[25]

Objective of project

The broad goals of SKG Sangha's project maybe summarized as:

- Removal of indoor air pollution – environmental and health benefits
- Conservation of forests
- Employment generation and additional income (with additional time and income sources)
- Soil fertility (from organic manure) and sustainable agriculture
- Women empowerment

The target beneficiaries for SKG Sangha's initiative are rural women who own cattle and have sufficient space for the installation of the biogas plant unit. Secondary beneficiaries are

[24] Evaluation of NPBD, NPIC and IREP programmes in Karnataka, TERI, 2001

[25] A Construction manual for the Deen Bandhu In-situ model, Ferrocement Biogas Plant, Sustainable Development Agency (SDA), 2000.

the entire families including children and other family members.

Implementation Strategy

SKG Sangha uses the bottom-up approach, giving priority to the needs of the community and beneficiary family. When a customer orders a biogas plant, SKG Sangha technicians co-ordinate the work, arrange for materials to be delivered, organise training of the owners and check the quality of the construction. The supervisor for that area will help the new user to become familiar with the plant operation, and gives each user a maintenance manual.

Further, in their implementation strategy they have carefully sought solutions to address the main identified reasons for BGP failures in past projects by the Government. Learning from these past experiences, they have incorporated in their system methods such as local level supervisors, adequate training of implementing staff, prompt problem-rectification, awareness and capacity building of beneficiaries etc. to reduce the occurrence of factors leading to failures of the BGP programs. Incorporating these factors in their implementation strategy has resulted in their **success rate of 95% functionality after 5 years of operation**[26]. This maybe compared to the National Average functionality rate of only 42%.

Biogas Plant (BGP) model

A BGP is a device for conversion of fermentable organic matter, in particular cattle dung, into combustible gas and fully matured organic manure. This is achieved by subjecting the material to anaerobic fermentation.27The Biogas produced is a combination of Methane and Carbon dioxide in a ratio of about 60:40 and it contains traces of gases like Hydrogen Sulphide, Nitrogen, etc. The calorific value varies from 20–25 MJ/m3.28

The DB model was selected after researching available options. This model was chosen on parameters such as reliability, cost (cheapest alternative), good local network for construction and maintenance, and suitability. To illustrate, the DB model plants costs about 30% less than the Janata biogas plants and about 45% less than the KVIC biogas plants of comparable sizes. Further, the DB is also about 15-30% cheaper than the other three new models of comparable hydraulic retention times (HRTs).

26 Validation report - "Bagepalli CDM biogas programme" project in Kolar, India; report no. 2005-9058, revision no. 01- Det Norske Veritas, 2005.

27 Biogas – Retrospect and Prospects – Directorate of Non-Conventional Energy, Department of Bio-gas; Khadi and Village Industries Commission (No date of publication mentioned on booklet)

28 http://www.skgsangha.org/index01.html

Achievement

On SKG Sangha's entrance in Karnataka, they were able to install only 34 BGPs in the first year. This was due to the many failures of previously installed BGPs in the State. On seeing the functionality and service for the 34 BGPs installed by SKG, the numbers rose to 800 BGP installations in the second year29. Between 1994 and 2007, SKG Sangha installed over 40,000 BGPs. As on 31st December 2008, the number of BGPs installed is approximately 65,000 (table A-2).

Table A-2 State-wise BGPs installed by SKG Sangha as on 31st December 2008

S.No.	State	Biogas Plants (BGPs)
1.	Karnataka	54505
2.	Andhra Pradesh	6325
3.	Tamil Nadu	3120
4.	Kerela	92
	Total	64042

SOURCE SKG Sangha, 2009

Modes of finance

The DB model of biogas plant costs between Rs.18,000 – 19,000 for the 2 cubic meter sized plant, the size that is generally installed by SKG Sangha. Table A-3 provides a clear description of the costs of various materials required in construction of the DB plant. This break up of the various costs is most useful to provide an overview of the contributions of government subsidy and beneficiary contributions.

Table A-3 Material requirements and cost of material for DB Biogas plant

S.No.	Material requirements	Plant Size (in cubic meters)					
		1		2		3	
		Qty	Amt (Rs)	Qty	Amt (Rs)	Qty	Amt (Rs)
1	Pit digging		500		600		750
2	Bricks (Nos)	1589	4449.2	2290	6412	2858	8002
3	Cement (bags)	15	3600	21	5040	27	6480
4	Sand (cu.m)	2.04	1500	2.9	1800	3.61	2000
5	Steel (kg)	40	1200	56	1680	70	2100
6	Tile (nos)	192	192	280	280	351	351
7	Wire mesh	5	200	8	320	10	400
8	Mason charge	6	700		900		950
9	Labour	6	540	7	630	8	720
10	Paint	1	170	1.5	255	2	340
11	Gas Pipe						
12	Valve	1	100	1	100	1	100
13	Stove		850		850		850
15	Total		14001		18867		23043

SOURCE TERI, 2001

Note: Materials as per the fixes dome biogas plants (A design, construction and operation manual)

29 Interview with Mr. K. Kiran Kumar, Secretary, SKG Sangha – 13th Oct 2009

The cost of the DB biogas plants, as mentioned above, is covered broadly through Central and State subsidy, while the balance amount is usually retrieved through beneficiary contribution (in cash or kind – labour, material etc.).

Beneficiary contribution

Beneficiary contribution has been important in the long run to ensure that the households involved have a stake in the success of the project. A sense of ownership will be instilled in the user only if they contribute towards the devices. Further, this increase in accountability also helps ensure that the biogas plants are functional and regularly repaired and maintained. Table A-4 provides an overview of the various contribution sources to the cost of the biogas plant, including the beneficiary contributions.

Table A-4 Description of Central and State subsidy and beneficiary contributions for different biogas plant sizes

Category	Central Subsidy		State Subsidy	Beneficiaries contributions
	2-6 cubic meter (fixed dome)	1 cubic meter	Same subsidy for all the domestic biogas plants (Karnataka)	In kind of materials and labour charges
Scheduled Caste, Scheduled Tribe, desert districts, small and marginal farmers, landless labourers, terai region of Uttaranchal, Western Ghats and other notified hilly areas.	Rs.3,500/- *	Rs.2,800/- *	3500/-*	Digging for pit, sand, stone chips, bricks and labour except mason charges for biogas constructions
All Others (General)	Rs.2,700/-	Rs.2,100/-		

Note: *SKG has providing cement, iron, biogas stove, pipe, nipple and charges for mason for construction of biogas plant instead providing subsidy amount to beneficiaries

Other sources of finance

The Government of Karnataka has allotted subsidy amount for implementation of biogas plants under *Anila Yojana* from 1992-93 to 2004-2005. Thereafter the subsidy was tapered for the biogas plants. Thus during the period 1993 to 2005, the NGO's and other implementing agencies implemented large number of biogas plants in Karnataka. Due to shrinking government subsidy after the year 2005, the implementation of biogas plants has drastically reduced.

According the SKG Sangha the demand for biogas plants is not being met by the limited number of plants accommodated under government subsidies. To address the growing demand of biogas plants, SKG Sangha is now exploring external funding for dissemination of biogas plants in rural communities. These alternatives include combining biogas plants with vermi-composting for additional government subsidy, and formulating CDM and VER projects.

CDM and VER

Exploring alternative sources of funding to meet the growing demand for biogas plants, SKG Sangha is now developing and is in the process of implementing quality projects under Clean Development Mechanism and Voluntary Emission Reduction. Many Gold Standard VER projects and few Gold Standard CDM projects are in the pipeline and looking for investors.

The main principles behind these projects are to utilise the reduced carbon emissions acquired through switch to a cleaner fuel and technology of biogas plants.

SKG Sangha has a policy to involve mainly women in the process of vermi-composting. Further, they ensure that of the total compost produced; only half is sold in the market while the other half is used by the beneficiary in their fields. The market price of this high quality is around Rs90 (approx. £1) for a 30kg bag. On an average a household with a biogas plant size 2m3 produces around 200 such bags of vermiculture manure a year, and sell half this amount. This sale generates a revenue of about Rs.16,000 per year. This is almost the same as the average annual income of a household in the region. With the women in the household bringing in a substantial amount of income to the family, the initiative also helps women empowerment.

Thus SKG Sangha fuses biogas and composting technologies, empowering women to earn money and live in healthier environments.

Project Benefits

The benefits derived from the biogas plants, with special reference to the SKG Sangha project, maybe summarised in the three pillars of sustainable development – mainly the economic, social and environmental aspects. Each of these has been elaborated below.

Economic benefits

Biogas plants do not have direct income generation benefits. However, the economic benefits arise indirectly through generation of employment, time saved from fuel wood collection which can be utilised for other activities, and by linking biogas with vermi-composting. Each has been explained below.

Employment generation

SKG Sangha emphasises on using and training locals in the building, installing and maintenance of the biogas plants. This ensures not only the long term reliability of the plants but also creates employment at the project villages. The selected persons are generally youth and from the beneficiary families. They are provided adequate training and capacity building to undertake the task. More than 1,000 masons have been trained so far and unemployed youth have been trained to become technicians or supervisors operating and maintaining the plants which prevent their migration to the cities. Both men and women are trained as maintenance technicians[30].

Income generation through vermi-composting

Although biogas plants alone do not generate direct income, linking them with vermi-composting units helps provide an avenue, especially for women, to earn income while at home. The average annual income from a 2m3 biogas unit is generally in the range of Rs.12,000 - 16,000 per vermi-compost unit[31].

Other Indirect benefits

There are many indirect economic benefits that need to be quantified for the SKG Sangha biogas project. However, even without their quantification, the mention of these benefits is essential. Women and children save in the range of **2-4 hours everyday** for fuel wood collection by installing a biogas plant in the selected SKG Sangha villages[32]. Further, due to the ease in cooking with the supply of gas, the women can also undertake other tasks while the food is put to cook on the stoves. This implies almost 4 hours of time saved everyday which can be used for other activities.

Further with the improvement in the indoor air quality, there are many health benefits that accrue to the women in the long run, which result in lesser expenditure on health. Also, the reduced expenditure on fuel wood and kerosene for cooking, all lead to indirect economic benefits to the beneficiary families. However, quantification of the same has not been done for the project initiative.

Environmental benefits

Reduction in fuel wood usage

In the project area of Kolar region Karnataka, studies reveal an estimated average consumption of fuel wood for a medium size

30 Interview with Mr. K. Kiran Kumar, Secretary, SKG Sangha – 13th Oct 2009

31 Interview with Mr. K. Kiran Kumar, Secretary, SKG Sangha – 13th Oct 2009

32 Clean cooking and income generation from biogas plants in Karnataka, The Ashden Awards for sustainable energy, 2007 family to be between 1300kg/year and 1700kg/year[33]. However, to be conservative, SKG Sangha has carried out separate surveys in the project region and determined that for a single household of five persons, the average consumption of firewood is 3.56 tonnes and 31.2 litres of kerosene per year. These are the baseline values used for calculation of reduction in use of fuel wood for cooking and other purposes by the project families by switching to biogas plants for their cooking needs[34].

Emissions reduction

Using the fuel wood and kerosene usage pattern of the project families (as mentioned above), the baseline emission factor for the project region is 2.85 tCO2e/household/year[35]. Further, with calculations applied under CDM and VER prescribed methods, SKG Sangha has determined that based on the 99% success rate of their biogas plants, emission reductions per household with installed 2m3 system, is expected to be 3.56 tCO2e and in the first seven year crediting period it is expected to amount to 136874 tCO2e reductions[36]. Thus at the time SKGS had installed 43,000 biogas plants, they had saved about 4 tonnes/year of CO2 and around 3.5 tonnes/year of fuel wood[37]. These emissions reduction are especially crucial with the growing concern of climate change.

Soil fertility

Each biogas unit of the size 2m3 generally produces between 30 to 60 tons of liquid spent slurry per year. The use of spent slurry from the biogas plants either in the form of liquid fertiliser or by processing the same with vermi-composting, the resulting organic manure helps improve the fertility of the soil. SKG Sangha shared that their organisation aimed at changing the situation of Indian agricultural soils from becoming saline and infertile because of indiscriminate use of chemical fertilizers; by bringing awareness in the farming community. They currently give training to farmers in a) modern compost pits, b) the spent slurry of biogas units, and c) vermi-composting[38].

Indoor Air Quality

Although quantitative figures are currently not available to substantiate the improvement in indoor air quality of the households using biogas plants in the SKG Sangha project villages, semi-structured interviews with women using biogas

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33 Validation report - "Bagepalli CDM biogas programme" project in Kolar, India; report no. 2005-9058, revision no. 01- Det Norske Veritas

34 Validation report - "Bagepalli CDM biogas programme" project in Kolar, India; report no. 2005-9058, revision no. 01- Det Norske Veritas

35 Validation report - "Bagepalli CDM biogas programme" project in Kolar, India; report no. 2005-9058, revision no. 01- Det Norske Veritas

36 Validation report - "Bagepalli CDM biogas programme" project in Kolar, India; report no. 2005-9058, revision no. 01- Det Norske Veritas

37 http://www.skgsangha.org/index01.html

38 http://www.skgsangha.org/index01.html revealed that they were satisfied to have kitchens without smoke, along with the improvement in health especially reduced eye irritation and coughing.

Social benefits

Capacity building of local manpower

SKG Sangha's initiative involves local manpower from among the beneficiary community as masons, supervisors and other grassroots manpower requirements. Apart from providing employment, they also provide key training and build capacities of the selected persons. Further, SKGS also conducts workshops for awareness generation among the beneficiaries and users of biogas plants. These activities help create opportunities for the rural communities and enhance their awareness, bringing social benefits in the region.

Reduced drudgery for women and children

A study reveals that one person in a family spends almost a month in a year for collection of firewood. As caretakers of the house, women must gather and carry heavy firewood long distances to cook over wood fires, straining their backs, and exposing them to large amounts of heavy smoke. It is estimated that women and children spend 2-4 hours travelling 2-3 kilometres a day to collect fire wood[39]. Not only will this, cooking with biogas stoves is faster than traditional biomass cook stoves. Installation of biogas thus reduces drudgery of women and children. The time saved in collection, as well as time saved during cooking can be utilised for other productive purposes.

Women empowerment

Apart from removing drudgery of women in the smoky kitchens, SKG Sangha is also trying to improve their economic status by promoting domestic vermi-composting units (see section above on vermi-composting). Additionally, SKGS promotes all the above activities through women's societies.

During TERI's interviews with key stakeholders, the experience of women earning Rs.12,000 a year, almost the same as an average income of a household, had repercussions on her social status. It was shared that the women's opinion was now sort for important household decisions, while also gaining respect within her family, especially the in-laws[40]. SKG Sangha stated that their aim was to empower women economically, to allow

[39] http://www.skgsangha.org/index01.html
40 Site visit to project villages - SKG Sangha – 13th Oct 2009

the benefits to trickle down to the entire family, especially the children.[41]

Key lessons learnt

There is huge potential for biogas plants in India with the estimated numbers at 24,000,000 BGPs[42]. SKG Sangha is one of the many organizations working towards covering this untapped potential of BGPs, especially in the Southern region of the country. Biogas plants have helped not only reduce the consumption of fuel wood for cooking, but also reduce indoor air pollution and drudgery of women and children by providing an alternative clean fuel and technology for cooking. This case study analyzed SKGS's initiative and the key learnings and features have been summarized in the table A-5 below.

Table A-5 Key features of SKG Sangha's biogas plant initiative

S.No.	Factors	SKG Sangha's Initiative
1	Type and size of biogas plants installed	• Deenbandhu model – cost effective, reliable, local network for construction and repair, and sustainability • Size – 2m3 – suitable for family size of 4-6 people, owning 3-4 cows (adequate for average family size in the project region)
2	Target beneficiaries	• Rural households, especially women, who own cattle and have sufficient space for the installation of the biogas plant unit
3	Implementation strategy	• Bottom up approach – priority to community needs • Employ grassroots level supervisors and masons (unemployed youth, both men and women) – key for adequate repair, maintenance and easily available to beneficiary users • Each supervisor provided with a mobile phone and vehicle (motor bike) – easily approachable by users • Prompt problem rectification – adequate training to local personal for rectification, easy accessibility and accountability • After sale services – 100% guarantee for all plants for 5 years; all service costs borne by SKGS for life of plant; 100% replacement for technical faults • Adequate training of implementation staff – skill development, linking with broader issues of environment and community development • Awareness and capacity building of beneficiaries (workshops at beginning of project, and after 6 months) – ensures proper utilization and maintenance of BGPs • Quality control – quality of material used (purchase material directly from factories – cheaper & better quality) • Demand driven approach (no marketing strategy) for replication – demonstration through successful BGPs
4	Functionality rate	• Functionality of 95% after 5 years of operation • National average in India – 42%
5	Financial aspects	• SKGS generally installs 2m3 size costing between

41 Interview with Mr. K. Kiran Kumar, Secretary, SKG Sangha – 13th Oct 2009

42 Census of India, 2001

		Rs.18,000-19,000 • Cost covered by contribution from Central subsidy, State subsidy and beneficiary contribution (in cash or kind) • Beneficiary contribution – households stake in success of project (labour or material costs) • Due to high demand for BGPs and shortage of government subsidy, alternative funding sought by SKGS– CDM, VER and vermin-composting
6	Innovation and linkages	• Linking vermin-composting with BGPs – more government subsidy, income generating opportunity especially for women, organic fertilizers to improve soil fertility • SKGS ensures that only half of compost produced is sold in the market, other half utilized on beneficiary fields – demonstrate benefits of organic fertilizers and enhance yields
7	Project benefits	Economic • Generation of employment – local youth (men and women) – supervisors, technicians and masons • Additional income from vermin-composting • Indirect benefits – time saved (3-4 hrs in fuel collection and cooking time), improvement in indoor air quality, reduction in expenditure on health, reduced expenditure on firewood and kerosene for cooking etc. These however need to be quantified in the project villages Environmental • Reduction in fuel wood consumption - 3.56 tonnes and 31.2 liters of kerosene per family per year • Emissions reduction – with SKGS installed $2m^3$ system, is expected to be 3.56 tCO_2e reductions per household • Improvement in soil fertility – organic fertilizers • Improvement in indoor air quality and reduced smoke in kitchens Social • Capacity building of local manpower especially youth • Reduced drudgery of women and children - 2-4 hours traveling 2-3 kilometres a day to collect fire wood • Women empowerment – income generation through vermin-composting, health benefits, awareness and capacity building
8	Awards and achievements	National and international recognition: • Mother Teresa Excellence Award - 2008 • International Ashden Award for Sustainable Energy – 2007 under Food Security Category • Social Entrepreneur Award - by Entrepreneurs forum • Sustainable Energy Association Award - 2006
9	Areas that need to be strengthened from documentation and research perspective	• Book keeping of problems faced by users needs to be emphasized • Possibly maintain a member card – date and type of problem faced, date and rectification measure, person undertaking rectification – help illustrate prompt problem rectification and analysis of types of problems faced in the SKGS biogas initiative

Thus it can be summarized that the SKGG biogas initiative has been successful in achieving its objectives, for which it has even received national and international recognition. Their initiative is now being replicated in other regions in India, and other countries especially the African continent.

References for the case study

1. A Construction manual for the Deen Bandhu In-situ model, Ferrocement Biogas Plant, Sustainable Development Agency (SDA), 2000
2. Biogas – A Rural Energy Source; Ministry of Non-conventional Energy Sources, Government of India, 1995
3. Biogas – Retrospect and Prospects – Directorate of Non-Conventional Energy, Department of Bio-gas; Khadi and Village Industries Commission
4. Clean cooking and income generation from biogas plants in Karnataka, The Ashden Awards for sustainable energy, 2007
5. Concurrent Monitoring of Biogas and Improved Chulha Programmes in Southern States of India – TERI, 2001
6. Evaluation of NPBD, NPIC and IREP programmes in Karnataka, TERI, 2001
7. http://www.actioncarbone.org/en/index.php (Accessed between 10th - 31st October, 2009)
8. http://www.ashdenawards.org/files/reports/SKG_Sangha_2007_Technical_report.pdf (Accessed between 10th - 31st October, 2009)
9. http://www.skgsangha.org/index01.html (Accessed between 10th - 31st October, 2009)
10. http://www.techawards.org/laureates/stories/index.php?id=199 (Accessed between 10th - 31st October, 2009)
11. Interview with Mr. K. Kiran Kumar, Secretary, SKG Sangha – 13th Oct 2009
12. TERI Site visit to project villages - SKG Sangha – 13th Oct 2009
13. TERI-OUTREACH-CLA's initiative for dissemination of energy devices; prepared for OUTREACH – Association of Volunteers for Rural Development, 2004
14. Validation report - "Bagepalli CDM biogas programme" project in Kolar, India; report no. 2005-9058, revision no. 01- Det Norske Veritas, 2005

ANNEXURE B: Small Capacity Biomass Gasifier system under VESP

This case study compiles the experience of small capacity biomass gasifier systems for village electrification implemented by Ministry of New and Renewable Energy (MNRE) in various Indian states under Village Energy Security Program (VESP), Remote Village Electrification and Gasifier Demonstration Program. In addition, it also takes into account the rural energy and socio economic aspects of the National Thermal Power Corporation (NTPC) and The Energy and Resources Institute's (TERI) project implemented in Jamera village of Korba district.

Background

A variety of biomass gasifier based power generation systems using woody and non-woody biomass and capacities varying in the range of 5 to 1000 kWe have been developed indigenously for electrical applications. The main objectives of such plants are:

- To deploy biomass gasifier systems for meeting the demand for electricity in households, cottage & small industries and village level institutions, etc.
- To take up demonstration projects for 100% producer gas engines, coupled with gasifiers for off-grid and grid power generation.

Most of the gasifier systems implemented in the country for village electrification by MNRE are in the off-grid mode. In addition, National Thermal Power Corporation (NTPC) has also developed power gasifiers for electrification of un-electrified villages in the periphery of their power plant as a part of their Corporate Social Responsibility. In addition, research institutes such as Indian Institute of Sciences, Bangalore, SPREI, Anand and TERI have set up gasifiers in remote villages mainly as pilots to test the system design. There are also other agencies such as DESIPower, BERI etc those have set up biomass power gasifiers in their areas of operation. Further, there are also few gasifiers that have been set-up in grid connected mode especially in Tamil Nadu and Gujarat. Many rice mills, especially in West Bengal and Chattisgarh, have set-up gasifier plants for utilization of surplus husk for power generation.

An aggregate capacity of 100 MWe of biomass gasifier systems (including both dual fuel and 100% producer gas mode systems) have been deployed in the country as on 31st August 2008 under various programmes of MNRE. The Ministry has also sanctioned 84 test projects under VESP in 12 states throughout the country. In addition, NTPC under its DDG program has implemented 8 projects in villages near to its thermal power plants especially in Chattisgarh, UP and Rajasthan. However, the technology suppliers in the country are limited with most of the suppliers unwilling to supply to small capacity gasifiers in remote areas because of higher transaction costs.

Biomass Gasifier system – business models

Biomass gasification technology

Biomass gasification is the process of conversion of a solid biomass feed material, through partial combustion, to combustible gas. The gas can be fed into an engine to operate either in a dual fuel mode or in a 100% producer gas mode to generate electricity. A biomass gasifier based power system usually consists of biomass preparation unit, the gasifier, gas cooling and cleaning train, an internal combustion engine and an electric generator for generation of electricity (Figure B-1). In dual fuel mode operation of engine, diesel or bio-diesel are used as pilot fuel and producer gas is used as the main fuel whereas in 100% producer gas mode appropriate provision is made for initiating combustion.

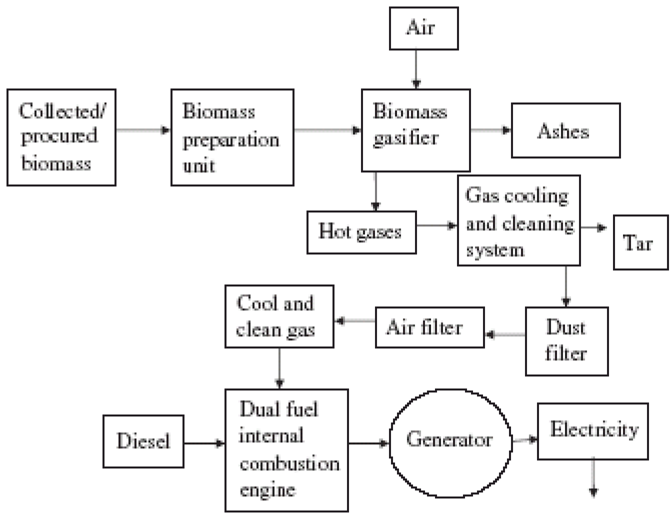


Figure B-1 Biomass gasifier power system

Most of the biomass gasification systems for electricity generation installed up to 2002-03 were based on dual fuel engine technology. With the advent of technology and some inherent problems with the dual fuel engines like lowering of the overall conversion efficiency as well as increase in cost per unit electricity (because of the use of diesel during startup as well as shut down of the engine), 100% producer gas engines came into usage. Currently, biomass gasifiers based on 100% producer gas engine are promoted for village electrification in the country.

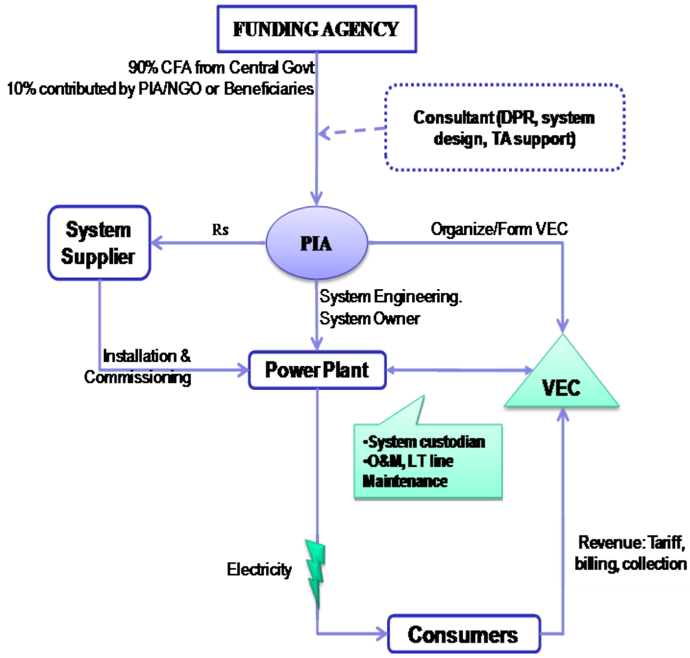
Electricity uptake

Usually for off-grid decentralized systems, electricity is generated from the gasifier system and is distributed to consumers through a local mini-grid. A mini-grid refers to which small power plants is connected to supply 415 volts 50 Hz three-phase AC electricity through low-tension distribution networks to households for domestic power, commercial (e.g. shops, rice mills etc) activities and community requirements such as drinking water supply and street lighting. In case of grid-connected decentralized systems, electricity is fed into 11 kV grid of the local distribution company. For grid interaction, dual fuel operation of gasifier for power generation is easier as diesel governor system takes care of fluctuating load to maintain the frequency.

Service delivery model

Small Scale Biomass Gasification Projects started with the use of dual fuel engines. Examples of this technology can be cited from IIS's experiments in Hosahalli and Hanumanthanagara villages in Karnataka where biomass gasifiers of 20 kW each were established. Since 2002-03, most gasifiers implemented for village electrification are based on 100% producer gas engines.

Almost similar service delivery models are being followed in the off grid village electrification by various implementing agencies in India (figure B-2). The decentralized energy projects are envisioned as community driven where the communities have direct control over key project decisions as well as management of investment funds. Thus for operation & maintenance of system, Village Energy Committee (VEC) is formed with representation from villagers and local governance body (Panchayat). A gram sabha is organized and the VEC is formed by adopting a resolution involving the representatives from each habitation in the village. The VEC acts as the custodian of the systems and is responsible for operation and management of the project. The VEC plays the role of stand-alone power producer, distributor and supplier of electricity, manages the revenues through collection of payments for the electricity used from the consumers and



dispute resolution in case of power supply disruption.

Figure B-2 Off-grid implementation model

A Village Energy Fund is created in the local bank under the provisions of State Panchayati Raj Act, initially with beneficiary contributions for sustained operation and management of the project. Subsequent monthly/annual user charges are deposited in this account, which is managed by the VEC. Two operators selected from the village are entrusted with the responsibility of operation of the system, biomass processing and also to collect the monthly electricity charges from the consumers. They are paid from the monthly revenue earned from the supply of electricity. The systems are in operation mainly during the evening hours from 5 to 10 pm. In case productive load is connected to the system, the system also runs during the daytime for few hours to cater to the load. The duration of operation depends critically on the availability of the biomass supply to the project.

The fuel procurement and day-to-day management and repair and maintenance of the energy system are also the responsibility of the VEC. However these projects have some limitations such as the supply of power from these projects being limited to village only and that there is no denial of lighting facility to those defaulting month after month or during limited periods. Recognizing the fact that VEC may lack technical and/or organizational skills to mange such a scheme, the Project Implementation Agency (PIA)'s supervises the project for sustainable O&M of the energy production system and also conducts capacity building of the VEC members and operators of the energy system.

Financial framework and subsidy availability

Under the VESP program, MNRE provided grant in the form of capital subsidy (upto 90% of the project cost) for such project, which includes formulation of Detailed Project Report (DPR), civil works, plant equipment & auxiliary systems, transmission and distribution (T&D) network including house wiring and energy plantation. The balance funding requirement is met either from community contribution or the NGOs. In some cases, consultants are also involved by the project implementation agencies for development of DPRs, training and capacity building and social engineering. After completion of project implementation, project is transferred to the VEC who acts as the custodian of the projects. The VEC reports to the PIA and shares the performance of project. For the NTPC supported projects and VESP projects, additional funds are also provided for entering into annual maintenance contract with the technology supplier.

In projects, developed by NTPC, the role of the PIA is taken over by NTPC (figure B-3). NTPC provides the technical back up support and does the social engineering in the project area either directly or involving a consultant agency. The income generation is also inbuilt in the NTPC projects and VESP so that any losses in selling of power to the villagers are offset by profits in other streams and ensure financial viability.

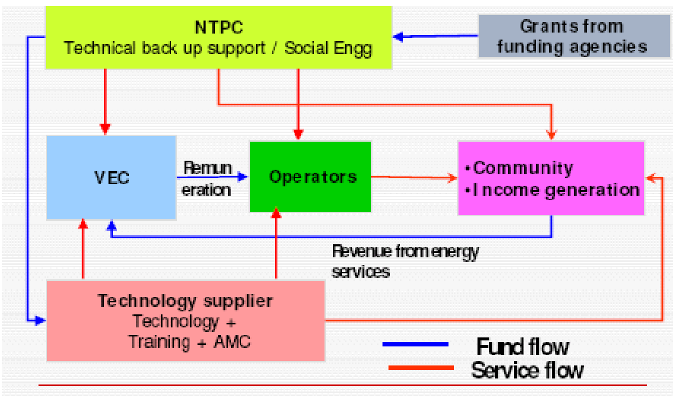


Figure B-3 Financing mechanism of NTPC off-grid gasification projects

Fuel Supply linkages

The fuel for biomass gasifier based power plant in off-grid projects is usually contributed by the households on a differential basis. The VEC is responsible for arranging the biomass. Energy plantation is also created in the village forestland or community land to ensure sustainable supply of biomass. Though theoretically, a project with 50 households and above can contribute sufficient biomass from the nearby forests or the energy plantation to run the gasifiers throughout the month, it has been observed that fuel supply mechanisms crumbled after few months of operation in many of the projects studied, especially the VESP projects and projects funded under MNRE program in Arunachal Pradesh. Successful projects, either DESIpower or MNRE funded, have created a strong fuel supply chain by involving self-help groups who collect the waste biomass from the nearby forests for the project. In such cases, biomass collectors are paid the collection charges in the range of Rs.0.5-1.0 per kg of biomass. The collected biomass is chopped and dried by the plant operators and subsequently used in the gasifier. Biomass supply may not be a big problem for small gasifiers if handled properly, but the collection mechanism and cost of delivered biomass are major issues for sustainable operation of the project.

Tariff setting

As most of these projects are subsidy driven, tariffs are set by VEC in consultation with the PIA in such a way that it takes care of the fuel cost, O&M costs and local administrative costs. Experience from many such projects shows that the tariff is set at a flat rate, based on the ability and willingness to pay of the local community, and usually ranges between Rs.10-20 per 40 watt light point/month and Rs.50 per socket point/month for 4-5 hours of supply which is equivalent to Rs.3-5 per unit. It is seen that one of the most important factor for successful implementation of such projects rests on the economic viability as well as an intelligent decision on the cost of service. The cost of generation per unit electricity ranges between Rs.2.5-7.5 per unit depending on the fuel management and plant load factor. Ensuring a high plant load factor helps in keeping the cost of generation low and within the reach of the local community. However, based on TERI's own experience in implementing biomass gasifier projects and experience from the VESP projects it can be said that any fall in collection efficiency below 60% and PLF less than 50% makes the project unsustainable. The following section discusses the impact assessment of biomass projects.

Overview of Gasification project in Jemara village by TERI

The village Jemara is situated about 23 km from Pali block office in the forest of district Korba. According to Census data of 1991, total households in Jemera village are 115 with a total population of 617. This village is spread over six hamlets. Before implementation of biomass gasifier, more than 90% of the population depended on agriculture for its livelihood.

As the village is located in the hilly areas, the terrain inside and around the village is undulating and no concrete road is available to reach the village. Village has one Primary school as well as a Panchayat Bhawan, Anganbadi kendra, Cooperative, Ration Shop & Kerosene Depot.

The village has no primary health center and therefore villagers have to visit nearby Lafa village PHC which is sixteen km away from the village. The nearest market is Pali, which is 23 km away from the village.

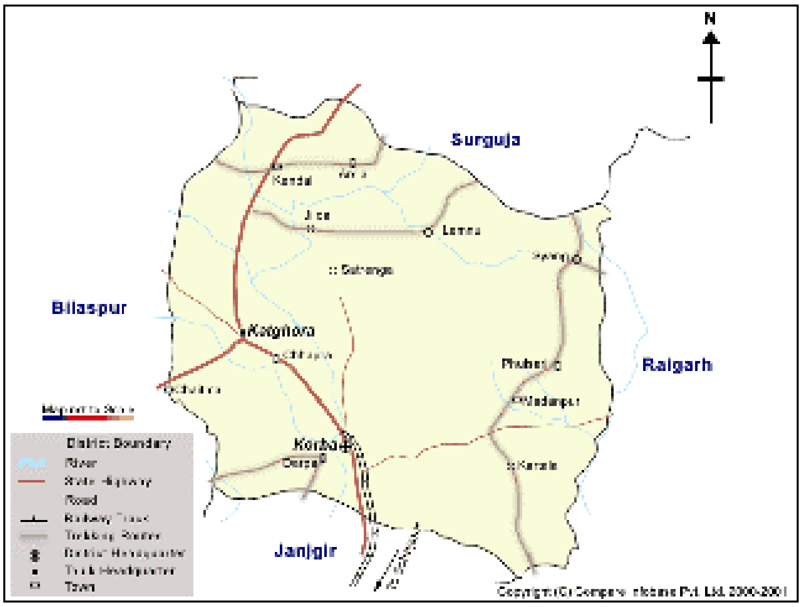


Figure B-4 Map of Jemara Village

The main crop grown in the village is Paddy; Maize, Arhar. Few vegetables are grown for their domestic uses. In the absence of irrigation facilities, the productivity per acre is low about 5 quintals per acre.

Firewood and kerosene were the main fuels used for cooking and lighting. For cooking, wood is available from the nearby forest, which belongs to the forest department. Villagers are conversant with the fact that they have to safeguard their forest. The socio-economic status of the village is given in Table B-1.

Table B-1 Socio-economic status of Village Jemara Pali Block, Korba District

Particulars	
Number of Hamlets	
Total Geographic area (in ha)	5274.78
Total cultivable area (in ha)	464.2
Total population	617
Scheduled tribes	99%
Male	47.97%
Female	52.03%
Number of households	115
Large farmer (>5 acre)	33
Medium farmer (< 5 acre)	32
Small farmer (<2.5 acre)	26
Marginal farmer (<1 acre)	45
Land less	4
Literacy rate	17.82%

To meet the lighting load requirement biomass gasifier system was installed by National Thermal Power Corporation (NTPC) in collaboration with TERI. Keeping in view the growth in load, high capacity gasifier and cooling cleaning system of 30 kg/h capacity along with biomass gasifier of 10 kW capacity was installed. The electricity produced at biomass based power plant is distributed to households through local grid network. For this arial bunched cable of 3 X 16 + 25 mm^2 size is used. The approximate length of the cable local distribution line is estimated to be about 2000 m, based on the location of power plant and households in the village.

The biomass gasifier plant supplies electricity to 100 households for lighting 2 points of 40 W each per household and it also supplies electricity to 5 street light points at a common place in the village. The plant operates from 6 - 10 PM in the evening for domestic lighting purposes and 2 hours in the morning to operate a small community rice huller and woodcutter is also be operated in order to cut the firewood of the required size. To implement the project capital subsidy of amount Rs 270,000 was provided by MNRE and remaining capital cost of project NTPC got financed at subsidised interest rate. Though the commercial rate of interest charged normally by financial institutions is 12% per annum. However, for the purpose of setting up DDG plant for village electrification development, finance was received at the rate 3%.

Electricity tariff was decided in consultation with the village community that each household would pay one time Rs 1000 towards connection charge. To support the low-income group households this amount was collected in instalments. In addition it has been agreed that each household would pay an amount of Rs 30/point/ month towards the electricity charges.

In addition to domestic and street lighting load, electricity is supplied to run commercial load in the morning hours to run a community based rice huller of 7.5 HP capacity. For this purposes, electricity charges of Rs 5 per unit is charged. The cost of setting up community based rice huller was about Rs 22,000 and the initial payment was provided by....

To extend the lighting facility to nearby village, the plant also charges batteries for village Bagdara households. About 40 batteries of 80 Ah is charged at a given time and it takes about 40-45 charging time. For that flat tariff of Rs 30 per battery is charged. The villagers use this battery for ..

Implementation and management of plant for first two years was undertaken through PIA [1] and thereafter through village committee. After two years of project implementation, village committee was formed which is responsible for project operation. *Project review committee meets once in every month to review the functioning of the system and other related matter. The representative of NTPC also acts as the authorized officer in the committee.*

Key lessons and benefits accrued from Gasifier models

- Experiences from various biomass gasifier based village electrification projects indicate that the uptime and PLF in most of the projects is poor. The low PLF and uptime initiates a vicious cycle leading to higher cost of generation, resulting in higher gap between income and expenditure and subsequently halting of operation because of inability on the part of the VEC to pay the operators. Some of the successful biomass gasifier projects have uptime in the range of 50-70% and PLF of more than 70%. However, the number of such projects is very low. Most of such successful projects are managed by NGOs having a very strong institutional set up.
- Maximizing the load comes out to be a crucial factor

for the financial viability. Field visits and interaction with PIAs/community, indicates that the capacity is under utilized in many remote villages, as domestic load is about one-third of the installed capacity without any productive load. In such case, the capacity utilization factor works out very low than breakeven to make it economically viable. Operational sustainability can be achieved either by maintaining high collection efficiency or exploring additional revenue options through introducing productive load with possibly higher tariffs depending on the enhanced profitability (figure B-5). Further, the load factor is largely dependent on organizational approaches to distribution and supply. Where organizational approaches lack the incentive to increase or maximize load, the viability of the project is threatened. Where measures are taken to help communities increase load through income generating activity or acquiring modern appliances, the project may succeed with increased benefit for local people. This is also very crucial as it can help in increasing income of local population and hence increasing their paying capacity or affordability of having electricity to further enhance their growth. However, in such cases, the creation of livelihood opportunities has to be linked with adequate capacity building and providing finances for livelihood opportunities as seen from the DESI power projects.

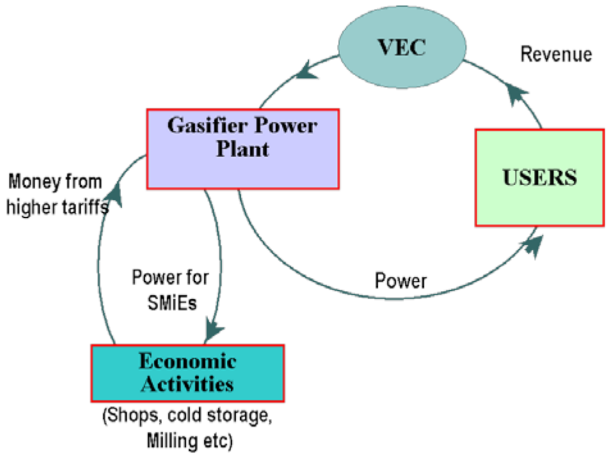


Figure B-5 Developing synergy with economic

- Field study of VESP projects indicate that the specific fuel consumption of small capacity gasifier projects under actual field operating conditions is much higher (the average is 1.6/kWh – 2.1/kWh) than the design parameter, thus requiring more biomass for electricity generation. This can be attributed to low PLF of the plant. The operator cost (varying between Rs 500 to Rs 2000/-per month) also becomes significant with prevailing low utilization factor due to low lighting load and negligible (or even sometimes absence of) productive load. The petty maintenance cost (lube oil, battery charging, filter changing, ignition fuel etc) also adds to the expense making the total expense much higher than what can be generated through user payment for such projects.

- The VEC more or less facilitate the flow of funds for regular upkeep of the system. However, the user contribution at times gets delayed because of poor paying capacity of the villagers in such remote villages thus affecting the revenue generation stream of the VEC. Further, it is also seen that VEC does not levy any penalty for non payment or the VEC does not want to enforce because of local compulsion. The payment cannot be entrusted to an entrepreneur also on commission basis because of the small size of such projects.
- Erratic biomass fuel supply is another concern that has been observed throughout in most of the biomass gasifier projects. Unorganized fuel supply chain, where each villager is required to contribute a share of the total biomass needed by the biomass gasifier leads to disinterest among the villagers after the initial months. Further, non-availability of fuel in the correct form and with appropriate moisture content also poses a hurdle in the successful operation of such projects.
- The number of small capacity gasifier suppliers in the country is also few. Added to this is the inadequate post installation maintenance network of the suppliers. As the projects are remotely located, the cost to provide after sales service is also high. It has also been observed in some VESP test projects that there is an absence of strong and effective post installation maintenance support network resulting in longer down time and causing decline in VEC's interest in managing the projects.
- Experience from VESP also indicates that because of the remoteness of location and community centric nature of the projects, the lead-time for implementation of the projects is very high. This not only defeats the concept of distributed generation, but also leads to a higher transaction cost on the part of the implementing agency.
- Currently, there are no standard designs and

performance oriented technical specifications of biomass gasifier systems optimised for rural energy projects to achieve lowest overall life cycle cost.

- Experience from the successful gasifier projects such as BERI, DESIpower or Bhalupani village indicate that electrification should focus first on those areas with high economic growth potential and lowest cost. Electrical supply systems should ideally be owned by those with the most important stake in their success. Such schemes may also be suitable for private development and operation particularly where there is potential for integration with the grid to ensure reliable supply of power. Community ownership may be most appropriate in the majority of villages, which are beyond the reach of the main grid and where the loads are poorly developed.

Annexure C: Proximate analysis and bulk density of selected biomass

Table: Proximate analysis and bulk density of selected biomass

Name	CV (Kcal/Kg)	Ash (%)	VM(%)	FC (%)	Total	Bulk Density (Kg/m3)	Reference
Woody Biomass							
ApricotTree Prunings	4971	0.2	80.4	19.3	99.9		
Arecanut shell	4750	0.9	78.3	20.8	100.0		Iyer, grover & Rao (2002)
Coconut Branch Waste	4380	5.6	75.2	19.2	100.0		Iyer, grover & Rao (2002)
Coconut Shell	3649	1.9	79.9	18.2	100.0	661	Iyer, grover & Rao (2002)
Coir Pith	4146	9.1	62.4	23.0	94.5	94	
Eucalyptus (wood)	4321	1.2	81.0	17.8	100.0		Iyer, grover & Rao (2002)
Eucalyptus Stalk		0.5	87.3	12.2	100.0		J.Parikh etal./ Fuel 84 (2005)
Eucalyptus Bark		19.0	65.7	15.3	100.0		Iyer, grover & Rao (2002)
G. Robusta	4674	2.0	38.4	27.4	100.0	739	
L. Ovvalifolia	4311	1.2	36.5	35.5	112.0	520	
L. Parviflora rqxburgii	3224	2.9	40.1	18.4	100.0	963	
Peach tree prunings	4500	1.0	79.1	19.9	100.0		
Poplar	4655	1.2	82.0	13.1	96.2		NREL
P. Wallichiana	4619	1.7	18.8	24.5	100.0	490	
Pongamia glabra	4571	3.9	27.1	22.1	53.1	560	
Quercus monogolica	4256	1.7					Young-jinsoo et al (2009)
Q. semecarpifolia	4562	2.0	31.1	28.6	100.0	799	
Rubber	4738	3.9	70.1	26.0	100.0		Iyer, grover & Rao (2002)
S. robusta	4675	1.7	21.1	28.5	99.7	925	
T. Arjuna	4499	2.0	36.3	16.9	100.0	739	
Subabul wood	4724	0.9	85.6	14.6	101.1	259	K Raveendran, Fuel 74
Agricultural crops							
Bajra Stalk	3850	17.5					
Coffee Spent	4300	1.8	83.7	14.5	100.0		A. Kumar et al./ Biomass & Bioenergy 22 (2002)
Coffee Husk	4212	10.8	71.9	20.0	102.7		Iyer, grover & Rao (2002)
Corn Cob	3738	2.8	85.4	12.4	100.6	188	K Raveendran, Fuel 74
Corn Stover	4323	4.8	76.0	13.2	93.9		NREL
Cotton Stalk	4278	6.4	67.4	18.5	92.3		L. cuiping etal./ Biomass and Bioenergy 27 (2004)
Cotton Stalk	3912	14.6	68.5	16.9	100.0		Iyer, grover & Rao (2002)
Cotton Stick	3300	13.5					
Cotton shells	4360	4.6	72.2	23.2	100.0		Iyer, grover & Rao (2002)
Cotton Shells (waste)	4235	4.7	73.2	22.1	100.0		Iyer, grover & Rao (2002)
Groundnut Shell	4680	2.3	77.9	19.8	100.0	299	Iyer, grover & Rao (2002)
Jowar Stalk (Sweet Sorghum)	4465	9.5	78.5	12.0	100.0		Iyer, grover & Rao (2002)
Jowar Stick (Sweet Sorghum)	4345	3.1	76.2	20.7	100.0		Iyer, grover & Rao (2002)
Maize Cobs		1.5					
Maize Stalk	4700	14.2					
Maize Starw	4013	5.3	75-80				N.El Bassam, Energy plant species
Millet Husk	4175	18.1	80.7		98.8	201	K Raveendran, Fuel 74
Mustard Stalk	4473	8.2	77.4	14.4	100.0		Iyer, grover & Rao (2002)
Olive residues	4765	6.6					
Paddy Straw	3469	15.5	72.7	11.8	100.0	259	Iyer, grover & Rao (2002)
Paddy Husk		14.1	68.5	17.4	100.0	617	Iyer, grover & Rao (2002)
Potato							
Peanut Stalk	3761	9.1	66.7	15.7	91.5		L.Cuiping
Ragi Straw	4060	8.4	77.4	14.2	100.0		Iyer, grover & Rao (2002)
Sugarcane Leaves	4390	9.4	75.0	15.6	100.0	167	Iyer, grover & Rao (2002)
Tea Plant (branch)	4200	7.0	76.2	16.8	100.0	100*	Iyer, grover & Rao (2002)
Tobacco leaf		17.2					Fuel vol 76
Wheat Stalk	3912	5.7	78.7	15.6	100.0	222*	Iyer, grover & Rao (2002)
Wheat Straw	4084	5.3	79.6		84.9	222	N.El Bassam, Energy plant species
Legumes							
Bean	4827	7.2	74.0	19.6	100.8		IEA site
Arhar Stalk	4206	5.3	77.0	17.7	100.0		
Gram Stalks	3600	11.0	72.0	17.0	100.0		Iyer, grover & Rao (2002)
Moong Husk	4106	7.6	79.8	12.6	100.0		Iyer, grover & Rao (2002)
Moong Straw	3820	12.6					
Oil Crops							
Castor Seed		3.2					
Castor Seed Shell	4180	9.0	71.9	19.1	100.0		Iyer, grover & Rao (2002)
Castor Seed Sticks	4315	5.4	76.5	18.1	100.0		Iyer, grover & Rao (2002)
Coconut Seed		0.4					
Groundnut Seed		2.8					
Seasame Stalk	3802	6.1	68.9	17.3	92.3		L Cuiping
Sunflower starw						204	
Sunflower Stalk	4467	1.9	76.5	21.6	100.0	91	Iyer, grover & Rao (2002)
Soyabean Stalk	3880	3.0	80.0	17.0	100.0	108	Iyer, grover & Rao (2002)