# Sensitization Workshop Manual on Sub-Megawatt Scale Biomass Power Generation

Under the project

"Removal of Barriers to Biomass Power Generation in India"

Supported by

United Nations Development Programme, New Delhi

Prepared by

The Energy and Resources Institute, New Delhi

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The University of Petroleum and Energy Studies, Dehradun

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# Preface

The power sector in India had an installed capacity of 236.38 gigawatt (GW) as of March 2012, which is an increase of 14% from 2011. An additional 36.5 GW is generated through captive power plants. Out of the installed capacity, thermal power plants constitute 66%, hydroelectric about 19%, and rest being a combination of wind, small hydro-plants, biomass, waste-to-electricity plants, and nuclear energy.

The biomass-based power generation installed capacities are around 3,600 MW in June 2013 as per data from the Ministry of New and Renewable Energy (MNRE) while India has the potential of generating 17,000 MW from biomass residues and 5,000 MW additional through biomass cogeneration. According to EAI (Energy Alternatives India) estimates, the total installed capacity of biomass gasification based power is only about 140 MW out of 2,600 MW, the rest is constituted by bagasse-based power generation (about 1,400 MW), followed by combustion-based biomass power production (about 875 MW). Therefore, there are a lot of opportunities available in terms of biomass gasifier based power generation in India.

In recent years, many companies have implemented biomass gasification plants in different parts of the country but large-scale dissemination of the technology still faces many barriers. In this report, the existing business models and successful case studies for biomass gasification projects are detailed, focusing on various stages of implementation such as access to finance, viability, tariff etc. These case studies essentially promoted local socio-economic development as an integral component of the project, while simultaneously demonstrating their financial viability.

But, in the current scenario, baseline for the prevailing biomass gasification technology is diesel. Therefore, the emphasis is on the restructuring of tariff by central and state government. There are some concerns of entrepreneurs about financing of power projects, technology customization, biomass resource management, tariff structure and lack of government policies on biomass.

Therefore to promote biomass-based power generation, conducive policies are required at state and central levels. Based on the MNRE annual report 2012–13, 17 states have policies for promotion of biomass power while Rajasthan has an exclusive policy for promotion of biomass power, announced in 2010. Also, the Government of India provides fiscal incentives such as accelerated depreciation, Concessional custom duty, excise duty exemption, income tax exemption on projects for power generation for 10 years, electricity duty exemption, etc., for promoting biomass power projects. The report also addresses the tariff details and fiscal incentives as MNRE for biomass gasifier based power projects.

In addition to all these steps, MNRE has plans to promote biomass gasification based power generation for large scale projects. It becomes very important to develop the skills and awareness of different stakeholders in biomass gasification so that large scale biomass based power generation can be promoted. Therefore organizations like UNDP, GEF and MNRE have come forward to enhance the skills of the stakeholders of biomass gasification sector especially entrepreneurs, operators and technicians. UNDP, GEP and MNRE have funded this project which includes the study of available business model, sensitization program of entrepreneurs and technicians, initiating development of detailed project reports etc. As per the given objectives, this project has conducted two workshops for the entrepreneurs and about 40 entrepreneurs were invited from North India.

Apart from the above, the broader aim of the study is to develop a comprehensive document which will illustrate to entrepreneurs the various facets of these projects. This project has made an attempt to remove the barriers of biomass gasification based power generation by providing skills as well as training programs of the various stakeholders involved in value chain of biomass gasification. It has also helped the entrepreneurs to initiate DPRs for financing the more than 1 MW biomass gasification based power generation. The document begins with the technological know-how of gasification-based biomass power plants, followed by a discussion on successful case studies from different parts of the country. Each project is different in its way of implementation, financing structure, revenue generation, etc. It is very important for an entrepreneur to decide about the implementation model before setting a gasifier-based power plant. In addition, the report mentions the current tariff rates and incentives that are provided by state and central governments to motivate the entrepreneurs.

# Acknowledgements

We wish to acknowledge UNDP–GEF–MNRE for supporting the project to conduct a 'Skilln Enhancement and Laboratory Exposure Training' on sub-megawatt-scale biomass power generation. We would like to thank Dr S N Srinivas, Ms Chitra Narayanswamy, and other reviewers from UNDP for their valuable suggestions. We are also grateful to Dr V K Jain, MNRE, for his guidance and support. We are also thankful for the support of UPES team and TERI Press and secretarial staff.

# Abbreviations

| | |
|---|---|
| BERI | Biomass Energy Rural India |
| BESCOM | Bangalore Electricity Supply Company Limited |
| BM | Built and Maintain (Business model of HPS) |
| BOM | Built, Own and Maintain (Business model of HPS) |
| BOOM | Built, Own, Operate and Maintain (Business model of HPS) |
| CERC | Central Electricity Regulatory Commission |
| BOVSS | Baharbari Odhyogik Vikash Sahkari Samiti |
| CFA | Central Financial Assistance |
| $CH_4$ | Methane |
| $CO_2$ | Carbon dioxide |
| DESI | Decentralized Energy Systems Private Limited |
| GEDA | Gujarat Energy Development Agency |
| GEF | Global Environment Facility |
| GoI | Government of India |
| GoK | Government of Karnataka |
| $H_2$ | Hydrogen |
| HPS | Husk Power Systems |
| ICEF | India – Canadian Environment Facility |
| IRPPs | Integrated Rural Power Producers |
| kWh | Kilo-Watt-hour |
| LSP | Local Service Provider |
| MNRE | Ministry of New and Renewable Energy |
| MW | Mega Watt |
| $N_2$ | Nitrogen |
| NGOs | Non-Governmental Organizations |
| $O_2$ | Oxygen |
| PMU | Power Management Unit |
| PSC | Project Steering Committee |
| RECs | Renewable Energy Certificates |
| SRE | Saran Renewable Energy |
| UNDP | United Nations Development Programme |
| UPCL | Uttarakhand Power Corporation Limited |
| WBREDA | West Bengal Renewable Energy Development Agency |
| WBSEB | West Bengal State Electricity Board |

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# Executive Summary

The Ministry of New and Renewable Energy, Government of India, is implementing a MNRE - UNDP/ GEF assisted Project on "Removal of Barriers to Biomass Power Generation in India." The aim of the Project is to accelerate the adoption of environmentally sustainable biomass power technologies by removing the barriers identified, thereby laying the foundation for the large scale commercialization of biomass power through increased access to financing. The focus of the project is the removal of barriers related to Technology, Size and Sustainability and would like to provide financial support to the grid interactive projects based on biomass combustion technology.

Under the project, UNDP–GEF has awarded a joint project to TERI and UPES on conducting a 'Sensitization workshop and skill development training on sub-megawatt-scale biomass power generation' in north India.

In India, there are several key issues related to biomass based power generation such as technology customization, biomass resource management, tariff structure and lack of government policies on biomass. The sensitization manual is prepared as a reference guide for potential investors manufacturers, entrepreneurs, local service providers (LSPs), non-government organizations (NGOs), etc., who would be interested to enter in the business of biomass based power generation. This booklet has been prepared with a focus on the following aspects of the biomass gasification project — technology, available business models, tariff, incentives, and financial feasibility. The report contains four chapters. In Chapter 1, the basics of biomass gasification technology is discussed in- detail, focused on the chemistry of biomass gasification, types of gasifiers, and the benefits of gasification.

Chapter 2 presents successful business model for biomass gasifier based power projects in India. Several case studies are discussed in this chapter which provides descriptive information on project cost, financing, implementation strategies, tariffs and related barriers. The case studies are categorized on the basis (i) Off Grid, (ii) Grid-Connected, and (iii) Captive.

Chapter 3 provides information about tariff related to small-scale biomass power projects in India. Also, fiscal incentives and the Central Financial Assistance (CFA) scheme given by the Ministry of New and Renewable Energy (MNRE) to the biomass gasification based power project implementers are mentioned.

Chapter 4 gives an overview of the financial feasibility of a 1 MW biomass gasifier based power project. This section has been included to give an idea about the cost-benefit analysis of such projects, and also outlines the main parameters and assumptions that need to be followed while designing and implementing a megawatt-scale plant.

It is believed that the manual will provide an easy to understand information to the users. Besides, it will be useful for new entrepreneurs to understand the technology, tariff and incentive structure related to biomass based power generation.

# Chapter 1
# Gasification Technology

The term 'biomass' generally refers to renewable organic matter generated by plants through photosynthesis, is a process in which solar energy combines with $CO_2$ and moisture to form carbohydrates and oxygen. Materials having combustible organic matter are referred to as biomass. It generally contains high levels of moisture and volatile matter and a low-bulk density and calorific value.

## 1.1 Classification of Biomass

Biomass can be of various types, and can be of plant or animal origin. Classification of biomass resources on the basis of their origin is presented in Figure 1.1.

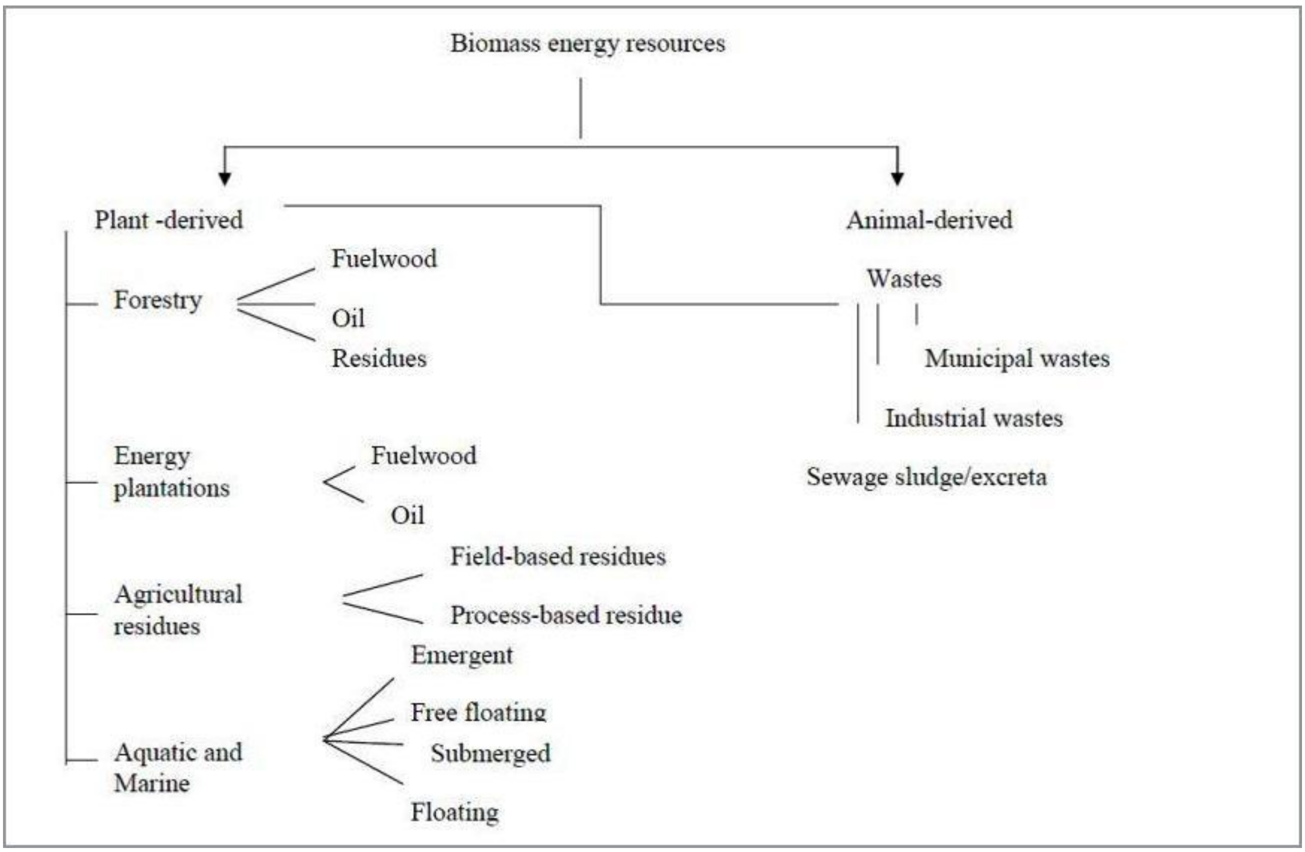



**Figure 1.1**: Classification of biomass

Figure 1.1, it can be noted that biomass can be obtained from forestry residues, energy plantations, agricultural residues, industrial waste, aquatic plants, etc. For thermochemical-based technologies, wood received from forests, energy plantation, agro industrial residues, and agro residues are the most important because their physical and chemical properties are suitable for combustion.

## 1.2 Biomass Gasification

In a thermochemical conversion, heat is the dominant mechanism to convert biomass into another chemical form. Combustion and gasification are the two main processes. With respect to sub-megawatt power generation, gasification can be considered the most suitable process.

Biomass gasification involves the partial combustion of biomass under controlled air supply, leading to the generation of producer gas. It is a thermo-chemical (chemical and heat) process in which solid biomass (wood, charcoal, rice husk, etc.) is converted into a gaseous fuel by a series of processes including drying, pyrolysis, oxidation, and reduction.

### *Gasification Reactions*

In a gasifier, biomass is progressively heated from the ambient temperature to a temperature of around 1100°C. The main reactions which take place in a gasifier are:

- Drying: Biomass fuels usually contain moisture in the range of 10–35%. When the biomass is heated to around 100˚C, the moisture gets converted into steam.
- Pyrolysis: After drying, as the biomass is heated, it undergoes pyrolysis. Pyrolysis is the thermal decomposition of biomass fuels in the absence of oxygen. Biomass decomposes into solid charcoal, liquid tars,
- Oxidation: Air is introduced in a gasifier in the oxidation zone. During oxidation which takes place at about 700–1400°C, the solid carbonized fuel reacts with oxygen in the air, and produces carbon dioxide and releases heat.

$C + O_2 \rightarrow CO_2 + 406$ kJ/g.mol

- Reduction: At higher temperatures and under reducing conditions, the following reactions take place resulting in formation of $CO$, $H_2$, and $CH_4$ and gases.

$CO_2 + C \rightarrow 2\,CO$ -172.6 kJ/g.mol

$C + H_2O \rightarrow CO + H_2$ -131.4 kJ/g.mol

$CO_2 + H_2 \rightarrow CO + H_2O$ -41.2 kJ/g.mol

$C + 2\,H_2 \rightarrow CH_4$ +75 kJ/g.mol

The producer gas will consist mainly of carbon monoxide (CO), hydrogen ($H_2$), methane ($CH_4$), nitrogen ($N_2$), and carbon dioxide ($CO_2$). The first three of these are combustible gases.

The calorific value (energy per unit mass) of the producer gas is about 1000–1200 kilocalories/ ($Nm^3$).[1] Approximately 2.5$Nm^3$ of producer gas is obtained from the gasification of 1 kg of woody biomass using atmospheric air as gasifying agent.

Producer gas can be used for the generation of motive power either in dual fuel engines (where gas and diesel are mixed and combusted together in the engine) or in diesel engines that have undergone some modification. Engines operating on a spark-ignition system (e.g. petrol engines) can be made to run entirely on producer gas, whereas those using compression ignition (CI) systems (e.g., diesel engines) can be made to operate with about 60–80% diesel replacement by the gas. A rough performance ratio for electricity produced from gasifier-based systems is:

1 The unit Nm3 stands for normal cubic meter. When measuring gas volumes, the N means the gas is at normal temperature and pressure, usually taken to be 20°C and 1.01 bar (one atmosphere).

- ~ 0.9–1.1 kg of biomass/kWh in the dual fuel mode of operation

- ~ 1.5–1.8 kg of biomass/kWh in 100% producer gas engine operation

Producer gas can also be burnt directly in air, much like LPG gas, and therefore finds useful applications in cooking, water boiling, steam production, and food and materials drying. In general, the fuel-to-electricity efficiencies of thermo-chemical processes such as gasification are much higher than those of direct combustion. Where gasification converts approximately 35-45% of embodied energy, combustion converts only 10–20%.

## 1.3 Types of Gasifiers

In all gasifiers, the gasification of solid fuels containing carbon, such as wood, takes place in an air-sealed chamber, under a slight vacuum or pressure. The fuel column is ignited at one point and exposed to a continuous air blast during operation, with the producer gas being drawn off at another location. Depending upon the positions of the air inlet and gas withdrawal, three broad types of gasifiers have been designed and operated till date:

(i) downdraft; (ii) updraft; and (iii) cross-draft gasifiers.

**Downdraft or co-current gasifier:** The most common gasifier is the downdraft gasifier, or co-current type. In this gasifier, the pyrolysis zone is above the combustion zone, and the reduction zone is below the combustion zone. Fuel is fed at the top. The flow of air is downward through the combustion and reduction zones (Figure 1.2).

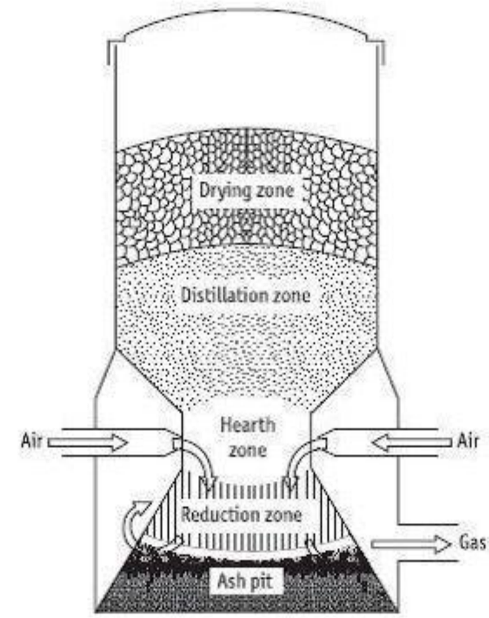
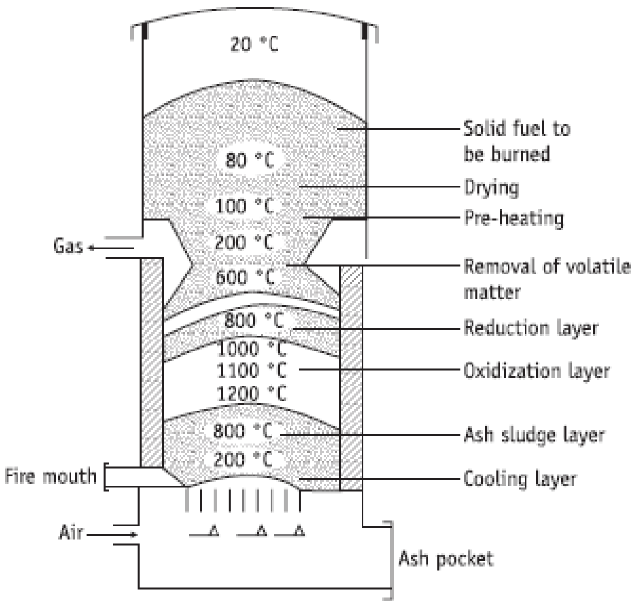



**Figure 1.2**: Downdraft gasifier

The term co-current refers to the fact that the movement of air is in the same direction as that of the fuel. The essential characteristics of the downdraft gasifier is that it is designed so that the tars given off in the pyrolysis zone travels through the combustion zone, where it is broken down or burnt (provided the gasifier is working properly). As a result, energy is released, and the mixture of gases in the exit stream is relatively clean. The arrangement of combustion zone is thus a critical element in the downdraft gasifier. Hence, the main advantage of a downdraft gasifier is production of a gas with low tar content suitable for engines.

**Updraft or counter-current gasifier**: In the counter-current moving bed reactor, also called the updraft gasifier, the air flows counter to the downward fuel flow and enters into the gasifier from below the grate and flows in the upward direction within the gasifier within the gasifier (Figure 1.3). An updraft gasifier has distinctly defined zones for partial combustion, reduction, and distillation/ devolatilization. The gas produced in the reduction zone leaves the




gasifier reactor together with the pyrolysis products and the steam from the drying zone.

**Figure 1.3**: Updraft gasifier

The resulting combustible producer gas is rich in hydrocarbons (tars) and, therefore, has a relatively higher calorific value. Therefore, the updraft gasifier is more suitable for thermal applications, such as direct heating in industrial furnaces, as it gives higher operating thermal efficiencies. If it is to be used for electricity generation by internal combustion engines, it has to be cleaned thoroughly.

**Cross-draft gasifier**: In a cross-draft gasifier, air enters from one side of the gasifier reactor and leaves from the other side (Figure 1.4). Cross-draft gasifiers have very few applications and have a distinct advantage other than good permeability of the bed.

**Cross-draft gasifier**: In a cross-draft gasifier, air

- *Feasibility of installation in any location or village:* While the deployment of large-scale thermal power plants as well as solar- and wind-based units is very location specific,

enters from one side of the gasifier reactor and leaves from the other side (Figure 1.4). Cross-draft gasifiers currently have very limited usage for both power and thermal applications.

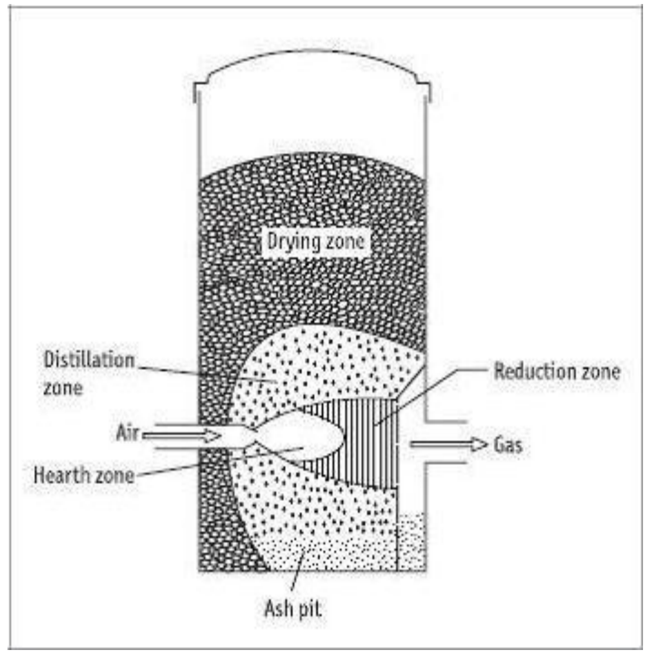



**Figure 1.4**: Cross-draft gasifier of the bed.

### *Benefits of Biomass Gasification Technologies*

- *Technology maturity:* Biomass gasifier technology is mature with several designs and manufacturers who undertake planning and commissioning of small-scale biomass power systems and also provide performance guarantee.
- *Availability in different capacity scales:* Biomass gasifiers are available in different capacities for decentralized applications from 5kW, 20 kW, 100kW to 500 kW in India.
- *Feasibility of operating at different hours and periods*: A gasifier-based system, unlike other renewable energy technologies such as solar and wind, can generate electricity as per the end-users' requirements and schedules.

biomass gasifier based systems can be located in almost any place or village, where biomass feedstock is available.

- *Indigenous availability of technology and back-*

*up systems:* There are numerous gasifier manufacturers in the country, and the technology has also been deployed in numerous locations over the years. Repair and maintenance of these systems can also be carried out at local level easily.
- *Economic viability:* For small-scale systems, the cost of power generation is much more reasonable than other comparable systems such as diesel-based power generation, solar power systems, wind-based power, etc.
- *Socio-economic benefits*: Biomass gasifier based systems require a pool of people including operators, technicians as well as manpower associated with managing the biomass supply chain. This would help in generating employment to local people and enhance their living conditions too.
- *Land reclamation*: In the biomass project, for continuous supply of biomass one can reclaim the wasteland for energy purposes. This would be important, especially for large plants which require a continuous supply of biomass.
- *Climate change mitigation*: Biomass is a $CO_2$ neutral fuel, and therefore, unlike fossil fuels like diesel, the use of biomass for power generation does not result in net $CO_2$ emissions. Therefore, biomass-based power generation systems are an important tool for climate change mitigations.

## 1.4 Biomass gasifier-based systems

### *Thermal Systems*

A biomass gasifier for heat application is simple in construction. It consists of a biomass gasifier, a blower, and a burner with a furnace. For heat applications, any of the aforementioned three types of biomass gasifiers can be used. The producer gas released from the gasifier can be efficiently used with a good degree of control to meet heat demands in ovens/burners, boilers or kilns for thermal applications.

### *Power-generation systems*

A general scheme of a biomass gasifier based power system is shown in Figure 1.5. The system consists of component 1, a biomass gasifier reactor that converts the solid fuel into combustible gas, a cleaning-cooling system that removes impurities such as dust particles and tar vapours present in the raw gas coming out of the gasifier, and an internal combustion engine for power generation. The different items that can be seen in the figure are described in the following paragraphs.

The component 2 is the Heat Exchanger, in that energy is transferred from the hot fluid (producer gas) to the cold fluid (air). This helps in increasing the efficiency of the system, by enabling utilization of the thermal energy of the producer gas that would otherwise have been discarded in the cooling system.

The contaminated gas stream is passed into a cylindrical chamber, component 3, called the Cyclone Separator where dust is swung to the wall by the centrifugal force, after which the dust is carried off through the bottom. The purified gas leaves the component 3 at the top, and enters the component 4, Venturi Scrubber, which consists of a converged neck (the narrowest part of the venturi tube), a diverging expansion chamber and beyond that a drip precipitator. The dust/ gas mixture streams into the component 4 and reaches high speeds in the neck. Then the mixture reaches the expansion chamber where the speed diminishes. The cleansing liquid (water) is added to the gas just before or inside the neck. Due to the high speed attained by the gas and liquid, the water scatters into small drops resulting in an intense contact between the gas and liquid phases.

The gas stream, which is moisture laden following its passage through the Component 4, is next passed through component 5, chillers to condense the moisture and bring down the gas temperature to a value suitable for passage into the component 6, Fabric Filter. The producer gas is lead through the component 6 and the dust particles are separated. The dust is periodically removed from the filter and collected in a funnel (hopper) placed below the filtering installation. Finally, gas is passed through the component 7, a Paper Filter, which is used as a safety filter to ensure that clean gas with permissible levels of tar and particulates is supplied to the engine.

The gas–air mixture is in turn supplied to component 8, a natural gas engine, which converts the chemical energy in the gas to mechanical energy by rotating a shaft. The engine shaft is in turn coupled to the shaft of an alternator that converts the mechanical energy into electrical energy. The electrical energy so produced by the alternator is distributed through electrical conductors to the connected load to power the bulbs, motors, and other electrical appliances.

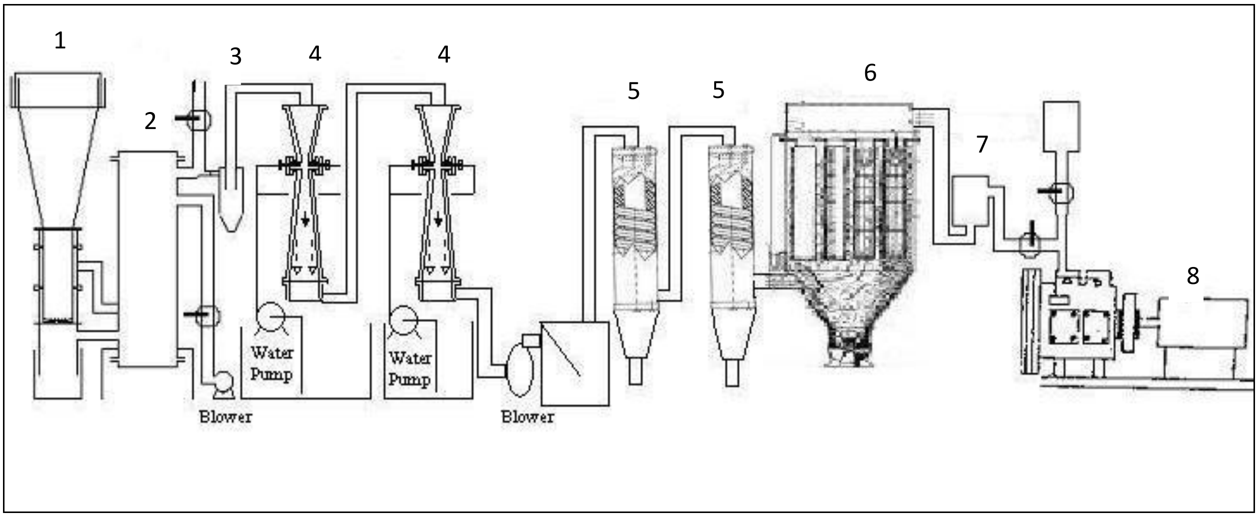



**Figure 1.5** General Scheme of biomass gasifier based power

| Legend | Component |
|---|---|
| 1 | Gasifier |
| 2 | Heat Exchanger |
| 3 | Cyclone |
| 4 | Venturi Scrubber |
| 5 | Chillers |
| 6 | Fabric Filter |
| 7 | Paper Filter |
| 8 | Engine |

# Chapter 2

# Case Studies

This chapter includes some successful case studies on small-scale biomass power projects in India. The case studies have been characterized on the basis of whether they are Off -Grid, Grid Connected, or Captive in nature.

## 2.1 Sub-Mega Watt Gasifier Projects (OFF-GRID)

### *2.1.1 Husk Power Systems in Bihar*

**Figure 2.1***:* Husk power biomass gasifier plant

**Address**
Husk Power Systems Pvt.
Ltd. Opp. Shiv Mandir
Near National Seed Corporation
Shastri Nagar Market
cSheikhpura
Patna - 800014, Bihar, India
Website: http://www.huskpowersystems.com

**About the Company:** Husk Power Systems (HPS) is a private organization run by Gyanesh Pandey, Ratnesh Yadav, and Manoj Sinha. HPS provides electricity to about 2,00,000 people, across 300 villages in Bihar. The company uses rice husk as the main raw material to produce electricity and has installed around 80 plants. Most of the plants are 25–100 kWe in capacity. Each of these biomass gasification plants uses about 330 kg/day or 50– 60kg/hr of rice husk to generate power for six hours a day.

**Financing**: HPS was established with the help of international agencies and government subsidies. The initial capital funding came from the founders' savings and competition prize money. The other major source of capital includes strategic partners, such as Shell Foundation that helps the HPS both in its operations and financing.[2] They also get a subsidy of Rs 15/W + Rs 1 lakh per kilometre distribution (upto 3 kms) from the Ministry of New and Renewable Energy (MNRE).

The total landed cost of typical a 32 kW plant, including distribution system, is less than US $ 1000 per kW (approx. 32000US $ for a 32kW plant. HPS is paid a subsidy of up to Rs 320,000 (US$ 7,100) for each plant, by the MNRE.

2 IFC, Acumen Fund, Oasis Funds, LGT VP, DFJ, CISCO, Shell Foundation, MNRE were investors for HPS.

The remainder of the capital comes from investment and sales revenue.[3]

**Business Model**: HPS operates on several innovative aspects and mechanisms as part of their overall business model. As rice husk is a natural waste found in various parts of the count, the model is replicable elsewhere. Using an agro residue such as rice husk as a feed, helps achieve cost -effective monthly operations. The proprietors own the entire system, i.e., from generation to revenue collection with virtually no dependence on government or outside support. HPS also promotes energy efficiency by encouraging rural customers to use energy-efficient CFL bulbs. As a by- product, they sell the ash residue and rice husk char to incense stick manufacturers and other customers.

HPS has three business models commonly referred as BOOM, BOM, and BM. These models are characterized on the basis of responsibility of HPS for any system.

- *BOOM (Build, Own, Operate, and Maintain)*: Under this model, HPS builds, owns, operates and maintains the power generation and distribution systems, with revenues coming from subscriber fees.

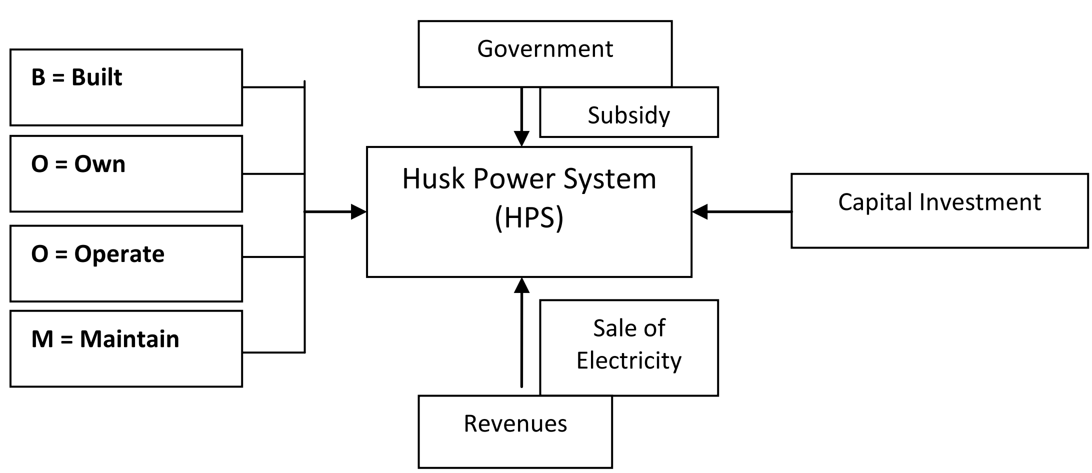



**Figure 2.2***:* BOOM business model of HPS

HPS has 100% ownership of the plant. Additional revenue streams come from the sales of silica and husk ash (to be mixed in cement or used to produce incense sticks). HPS also does carbon offsets, in 2012.

- *BOM (Build, Own, and Maintain):* Under BOM model, HPS still has 100% ownership of the plant. HPS installs the plant and provides regular maintenance during its six-year contract period. The plant is operated by a local entrepreneur who has to pay a maintenance fee of Rs 15,000 per month for six years. After completion of the contract period, the plant will be owned by the local entrepreneur. In order to start this plant, the local entrepreneur has to deposit a non-refundable fee of Rs 2 lakh.

- *BM (Build and Maintain):* This latest business model is suitable for rapid scaling up. HPS installs the plant and provides maintenance service of the plant. The plant is fully owned and operated by the local entrepreneur who invests all the capital cost. Any financial assistance/subsidy on plant gets transferred to the local entrepreneur.

3 Husk Power Systems, India | Summary 2011 Ashden Award for Off-grid Generation

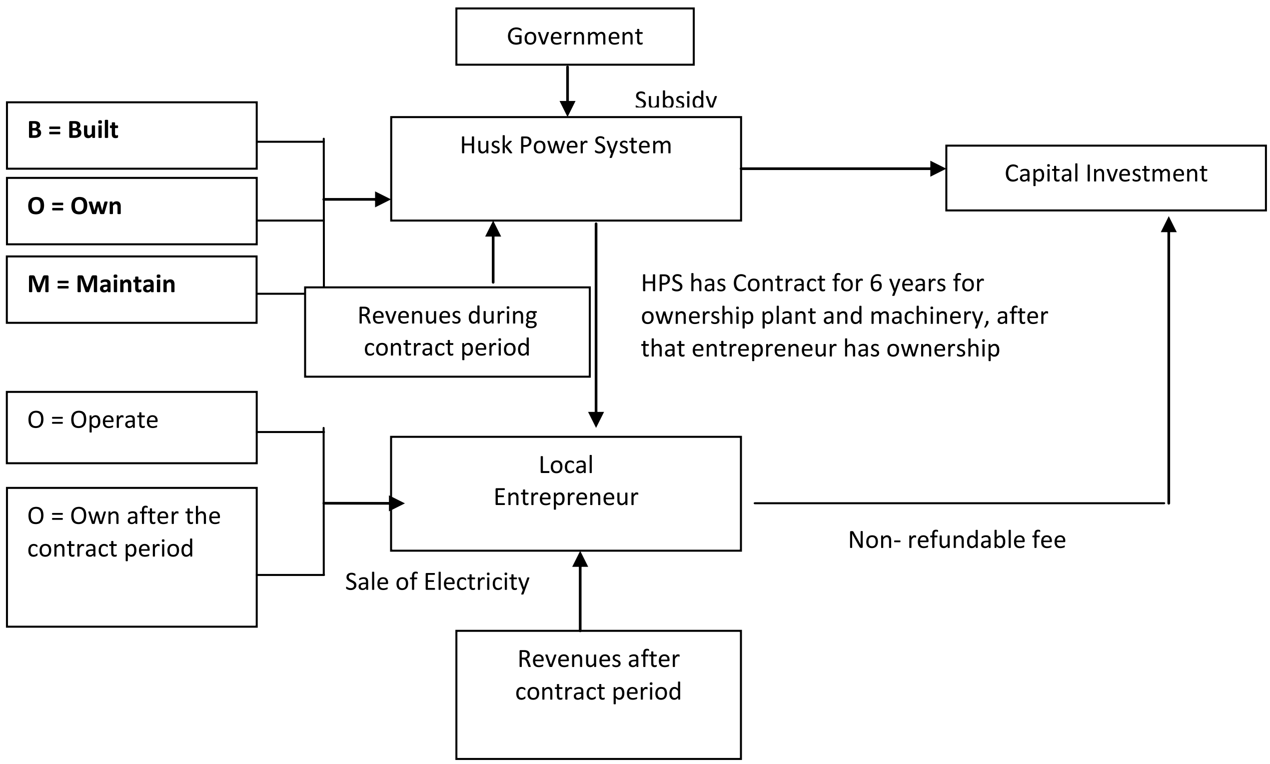



**Figure 2.3***:* BOM business model of HPS

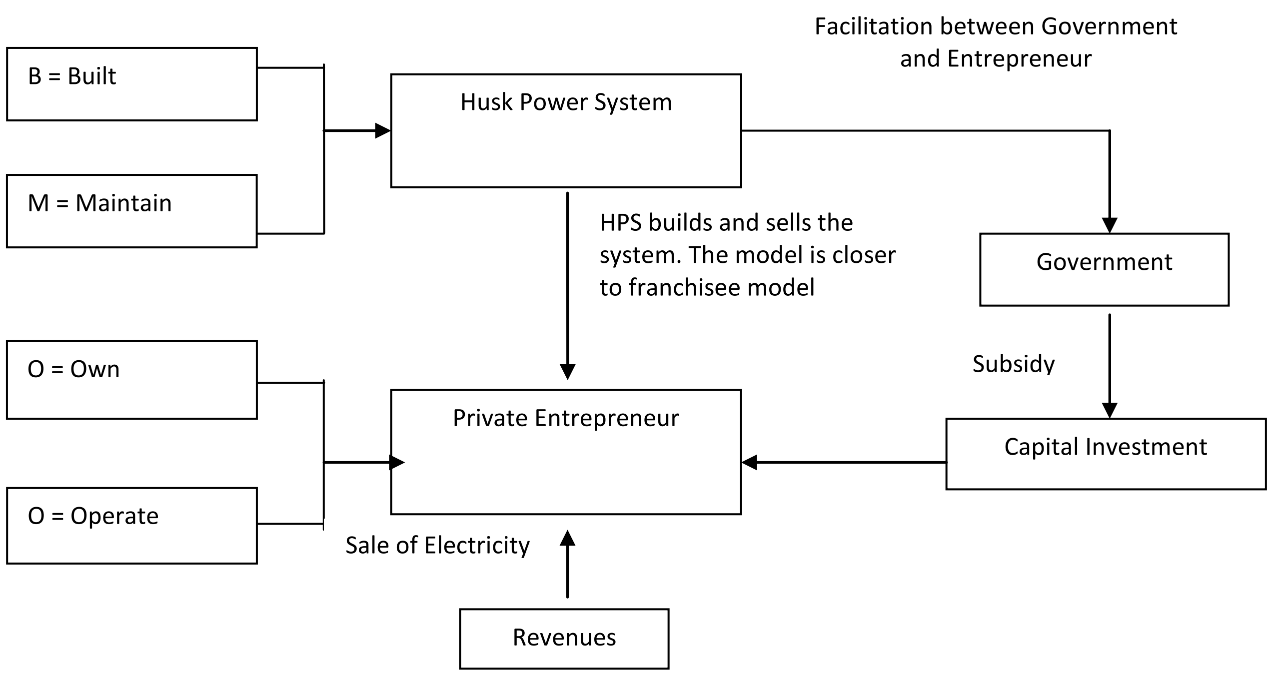



**Figure 2.4***:* BM business model of HPS

**Demand-driven business model**: HPS has adopted a demand-driven approach which ensures that only villages where people are eager to get the power connection can benefit from such a technology. At the outset, the HPS team surveys each household and estimates the potential demand in watt-hours. The households also pay a token installation charge of Rs 100 per household which not only ensures compliance by the users, but also covers a substantial cost of grid distribution. Overall, this reduces the fixed investment in infrastructure for the power plant shed and storage space, which is almost 5% of the total investment.

**O&M of the System**: The operators are trained by HPS in Patna (Bihar) for two months and then sent for on the job training in one of the operational plants. In addition, two more persons are associated with each plant — while one person handles husk buying, ensures a regular supply of raw material, and is involved in the revenue collection activities, the other is an electrician for the cluster of villages. In addition, HPS has cluster-level managers who look after the plants in the range of 20–25 km or about 5–7 plants.

**Biomass Supply**: As stated above, rice husk is the feedstock for the HPS power gasifiers. Accordingly, all HPS systems are located in the rice belt of northern India where rice husk is a plentiful agro residue. HPS procures the rice husk from the farmers and suppliers at competitive prices (approximately, Rs 1–2 per kilogram) and farmers have an incentive to supply them in order to ensure that electricity remains available in their villages. The typical plant can serve two to four villages, approximately 500 households within a radius of 1.5 km, depending on size and population. To ensure the viability of the plant, HPS follows demand-driven approach. Selection of the villages to be supplied is based on the village having a demand of at least 15 kW/month and falling within maximum radius of 3 km from the plant site. The husk collected from the suppliers is transported by tractors in parallel to about 7–8 plants in one cluster. HPS has plans to have one rice mill in each operational region to ensure sustained fuel supply at reasonable price.

**Services Offered**: The HPS model aims at not only providing electricity but empowering the village community by providing energy, employment opportunities, training, women's empowerment, and health care.

**Cost**: The cost of producing 32 kW of electricity per month is Rs 22,000, which includes cost of raw material, salaries, and maintenance. HPS loses only about 4% of revenue through default on payment or electricity theft, considerably lower than most power suppliers in India, who often lose 30%. HPS has set up its own distribution lines and each line has a fuse to so that no one draws power excess to what was informally agreed at the outset and to counter power theft. In general, the HPS model maximizes energy use and minimizes distribution and system losses by keeping an optimal mix of plant wattage and distance served.

**Tariff**: Generally, electricity is supplied to domestic and commercial consumers for a fixed 6–8 hours in a day. Basic connection supplies two 15 Watt CFL lights and mobile charging. Charge rates are US$ 2.20 per month (1US$ = Rs 45) for a 30-watt connection (2x15 Watt CFLs) and mobile recharge. Currently, in most of the cases, power supply is not metred and each customer is charged as per the number/wattage of equipment used in the daily supply. Monthly payment is collected in advance by HPS employees. However, a few low-cost pre-paid metres have also been installed that can efficiently regulate the flow of low-watt electricity and reduce electricity theft to less than 5 per cent.


**Figure 2.5**: Pre-paid metre at HPS

- *Management information system*: Unique in-house management information systems have been developed that are customized for distributed operations. It interfaces date through multiple input sources such as cell phones, monitoring hardware, and computers.

- *Employment to the local*: HPS hires local villagers for O&M of the power plants thereby ensuring that jobs are created for local communities. At each operating unit, at least three personnel are employed, which include an operator, a lineman/electrician - bill collector, and a husk loader.

- *Low-cost and low-skill incense stick manufacturing process:* An initiative that has also provided employment opportunities to thousands of rural women. It gives them training and raw material for the manufacture of incense sticks that can be made from the rice husk char, enabling them to earn up to Rs 1,000 per month. They also save money by the use of renewable electricity at Rs 80 instead of kerosene that had cost Rs 150.

### 2.1.2 Decentralized Energy Systems Pvt. Ltd (DESI Power)


**Figure 2.6**: Barbary Village Power Plant, North Bihar

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Website: http://www.desipower.com/

**About the Company:** DESI Power has an objective of providing power to rural society by means of renewable energy systems, and has built decentralized power stations for supplying electricity to industries and technical institutions. DESI Power has built 10 biomass gasification based plants and operates nine of them. The system capacity ranges from 20 to 120 kWe. DESI Power has successfully implemented biomass gasifier based power projects in TARA Gram, Orchha, in Madhya Pradesh, and in Baharbari and Gayari villages of Bihar based on a similar model. DESI Power first set up the plant and then created rural micro enterprises and energy services which provide demand for the plant. DESI Mantra and Baharbari Odhyogik Vikash Sahkari Samiti (BOVSS) are two sister organizations that promote and support micro-enterprises.

**Financing:** DESI Power model is also known as an 'Umbrella Model' because in their model, a rural enterprise gets partnered with many institutions. For example, DESI Power has four projects in Araria district in Bihar. The major sources of funding were subsidies from MNRE, a loan from ICICI Bank, promoter's equity, and revenue from sale of carbon credits.

**Business model:** The business model involves building and operating biomass gasification based power plants in direct association with local partners and later on transferring the plant to the partner under mutually agreed terms. The local partner may be an NGO, a Panchayat, a co-operative body or an industry, actively involved in these projects right from the beginning. The building of Interdependent Rural Power Producers (IRPPs) is integrated with the establishment of profitable local small scale industries, businesses and agro-forestry owned by the villagers. For commercial success, the power plant has to sell as much electricity as it can generate and the villagers have to produce and sell as much of their products as they can in the village and at neighboring market places. The mutual dependence is further strengthened through, on the one hand, the generation of additional income from the supply of agro-residues and other biomass to the power plant and, on the other, DESI power cluster trains villagers, especially women for capacity building.

**Biomass Supply**: DESI Power enters into a biomass supply agreement with a local group formed who in turn manages the supply of biomass. In Baharbari, DESI Power considers Ipomoea with hardwood as a feedstock. This was the second plant in the country using Ipomoea as feedstock. But, as the demand for electricity increased, search for an additional feedstock led to maize residue. To add additional substitutes, 'Dhaincha', a leguminous plant with low investment was identified as a possible raw material. The cost of feedstock ranges between Rs 0.40/kg – 0.75/kg (Ipomea) and Rs 1.4/kg – 1.6/kg for other residues.

Similarly, in Araria district, DESI Power has prepared a feedstock calendar for the entire year to ensure year-round supply. This reflects on the importance they attach to this vital link in the entire chain. The company is also thinking on the lines of captive forestry dedicated for the biomass production.

**Cost:** DESI Power came into being to supply electricity and energy services to two distinct decentralized electricity markets:

- Captive power plants for small-scale industries which depend on diesel generators (due to unreliable grid supply)
- Independent Rural Power Producers IRPPs) for villages and semi-urban areas

**Tariff**: Different slabs for load usage have been formed for varied usage. Domestic load is about 3-4 kWe peak for 4 to 12 hours per day; irrigation load: 8-25 peak for 2 to 14 hours per day and enterprise load upto 3.5 kWe to 8.5 kWe peak for 4 to 12 hours per day in the village. The tariff rates against various load categories have been formulated to enhance the plant load factor for the sustainability of the model. These rates are given in Table 2.1.

Entrepreneurs receive electricity from DESI Power and sell to households at a charge of Rs 5/day for a 60-watt bulb and pay Rs 3 to DESI Power. Unlike households, micro-enterprises normally pay for the services at a fixed price of usually Rs 60 for an hour of irrigation (from a 5 HP pump).

| Table 2.1 Tariff rates for DESI Power[4] | | |
|---|---|---|
| | Electricity cost | |
| Slabs | Fixed (Rs) | Unit Rate (Rs) |
| Less than 5 kW | 20 | 4.50 |
| 5–10 kW | 90 | Rs 22.5 for 5 units + Rs 5.5 per unit for additional units above than 5 units |
| More than 10 kW | 160 | Rs 50 for 10 units + Rs 6.5 per unit for additional units above than 10 units |

**Services offered**:

- Providing energy services through 'EmPower Partnership Programs' which will supply 10 clusters of 10 villages each with a 50 kW biomass plant. Total power generation will be 500 kW per cluster and 5MW for 100 villages.
- Energy services will be promoted and micro-enterprises would be built simultaneously with the power plant to the planned installation of 4,000–5,000 MW of generation capacity per year.
- DESI Power and its partners will ensure the training of local micro-entrepreneurs and staff for the use of energy for sustainable productive uses and income generation.
- DESI Power also ensures identification, organization, and training of local promoters/ owners of each village plant.
- A Management Training Centre (DESI MANTRA) has been set up to train local staff, especially women, for all levels of work and management.
- Women gain financial and personal independence and learn business skills they need to work in an administrative job or run their own micro-enterprises.
- DESI Mantra sets aside a portion of their tuition loan, if obtained from a village-based lending group, to pay them as a stipend throughout training.
- It has established the Vermiculture demonstration unit and is promoting vermiculture among farmers in the villages under DESI Power's 100-village project.

**Issues and Challenges:** DESI Power's experience shows that it will be very difficult to implement the dcentralized programme successfully and efficiently by any centralized system, be it the government, the private sector or NGOs. A decentralized implementation, jointly with villagers; local organizations and entrepreneurs; NGOs; plant promoters, suppliers and builders; financiers and corporate entities are the only sustainable route. They will be brought together to implement such projects in their own regions in with support from DESI Power and its partners. Local-capacity building and training will be the starting point for each project.

Self-sustained growth can only take place if the rural electrification programme is linked to village micro-enterprises for local value addition and employment generation. The power generation based on local renewable energy resources can provide reliable and affordable electricity supply to make the micro-enterprises profitable and thus bankable and attractive for private entrepreneurs.

[4] A tool kit for Participatory Village Energy Planning, Prepared by Development Alternatives

### 2.1.3 Saran Renewable Energy (SRE) in Garkha, Bihar

**Figure 2.7**: Saran biomass gasifier power plant

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**About the Company**: Saran Renewable Energy (SRE) was set up by Mr VK Gupta in 2006 as he wanted to address the electricity problem in his home town in Saran District, Bihar. This social enterprise is run by a group of agriculturists and entrepreneurs and operates in two areas that are critical for rural development:

- Energy access using off-grid rural power plants.
- Rural livelihood programmes called "Village Development Program" (wastelands reclamation, improved agriculture, setting up micro industries)

SRE model is community-oriented which delivers social and economic benefits to the rural poor, enabling them to increase their income, have access to energy and improve their quality of life.

The gasifier installed at village Garkha by SRE (2008) is designed to supply 128 kW electricity at 240 V, a high voltage for a gasifier with two 3 kV transmission lines, each 1.25 km long to provide link to the customers. The plant is run for 10 hours every day using 35% of the total capacity. The gasifier used by SRE is down draft open – top gasifier made by Netpro under license from Indian Institute of Science, Bangalore. Gas engines are used to generate electricity.

**Financing**: SRE was largely established with private equity along with 25 per cent of financial support from the Ministry of New and Renewable Energy (MNRE), under its various technology and commerce related schemes. The cost of the entire system was Rs. 83,00,000. The proportionate cost of the gasifier and generation plant was 90% of the total cost and the remaining 10% for the two 3 kV distribution lines.

For setting up the plant, finance was provided by the directors of the company, while ICICI Bank loaned Rs 20 lakh. In the break-up of the expenses incurred, the largest portion was towards paying off the investment, fuel cost and operation and maintenance.

**Business model**: Saran Renewable Energy Limited (SRE) is a build & operate model of decentralized electricity operations in three villages of Bihar. The electricity distribution is outsourced to local people, who had already been providing electricity to the village through diesel generators.

The gasification plant operates daily for about 10 hours from 10:00 am to 09:00 pm (with one hour break in between) with a current peak demand of 90% of the capacity with an average demand of 65%. Twelve staff and five casual workers run the plant. But with such a continuous load on the plant, maintenance and proper running assumes significance. The plant is maintained by technicians who have been trained in Bangalore. If maintained properly, the life of the machine can be up to 15 year.

by technicians who have been trained in Bangalore. If maintained properly, the life of the machine can be up to 15 years.

**Biomass Supply:** SRE used dhaincha as a biomass source for their plants. It typically grows on sizeable empty lands in and around Saran district.

Dhaincha requires low maintenance and has a short cropping cycle of 6-8 months. The gasifier at SRE uses about 70% dhaincha as raw material and the rest is from a variety of other sources like corn cobs, wood and other local plants similar to dhaincha. To maintain an uninterrupted supply of this marshy crop, SRE gave a beneficial offer to the farmers to grow dhaincha by providing free seeds and some incentive. For example, a farmer having marshy land can grow dhaincha. The crop yield of about 5 tonnes a year can earn him an extra Rs. 7,500 to Rs. 10,000 per year.

This is a substantial amount in a region of low incomes. The power plant can sustain on about 75 acres of wasteland sown with Dhaincha. SRE purchase of feedstock ensures income to farmers and economic use of non-fertile lands. However many farmers have not shown enthusiasm to sow the seeds despite clear economic benefits.

**Cost:** SRE buys agricultural waste and dhaincha from nearly 100 farmers. The price varies in the market between Rs. 1.5 – 2 per kg depending on the moisture content. About 1.25 kg of Dhaincha produces electricity at the cost of Rs.8 per unit.

**Tariff:** The sale price of electricity to the consumer is Rs. 10 per unit. The cost is calculated taking into account the pay back of the loan taken by SRE to set up the gasification plant. Although the cost by the state electricity board was around Rs. 6 per unit, customers are willing to pay a little extra for reliable supply, stable voltage and higher frequency. The charges for power from diesel generator were Rs. 12–16 per unit. Farmers are charged Rs. 150 for irrigation water supply compared to Rs. 300 they used to pay earlier for diesel run pumps. A medical clinic can now run a nebulizer, which is used for respiratory problems, especially among children. A blood collection lab now can work unhindered by paying Rs. 200 a day as compared to Rs. 300 a day paid earlier for the diesel supply. In addition to medical clinic now over 1000 businesses (e.g. grain mills, saw mills etc.), households, schools etc. get electricity for 10 hours per day. Irrigation facilities in the area have improved and cost for water supply has reduced by half, thus increasing rural savings.

### 2.1.4 AVANI in Uttarakhand (For Captive Use Only)

**Figure 2.8**: AVANI pine needle based biomass gasifier power plant

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**About the Organization:** AVANI is a voluntary organization working in the Kumaon region of Uttarakhand, located in the middle ranges of the Central Himalayan region. It was in 1997 that AVANI started its journey as the Kumaon Chapter of 'The Social Work and Research Center', also known as the 'Barefoot College' College focuses on capacity building of rural communities, enabling them to make sustainable and capable contributions to society.

In November 1999, AVANI was formally registered, continuing the work initiated in 1997. Rajnish Jain founded AVANI, with a mission to improve the quality of life in far-flung villages. AVANI initiated work on developing and disseminating appropriate technologies for meeting the energy and water requirements of the local villages, promoting craft-based (development of handmade naturally dyed textiles) and farm based livelihood opportunities. To date AVANI projects include the dissemination of solar technology, water resource management, natural textiles and paints, and the social and economic development of rural communities with projects such as healthcare and micro-finance.

AVANI is also a founder member of the World Mountain Peoples' Association, which strives to develop solutions to development problems, influence policies in favour of the mountain communities and bring them together on a common platform.

**Business Model**: The gasifier is for the captive use only. Over 5 years ago, a 9 kWe gasifier based on pine needle was installed at AVANI centre which has continued to generate electricity for the center. For that set up, about 1.5 kW is consumed for running the system and 7.5 kW available for productive use. The gasifier has worked for over 1500 hours and has largely supported the electricity needs of the centre.

AVANI aims to set up a 120 kWe village based power plant. They have signed agreements with Van Panchayats and aims to work with self-help groups to collect pine needles for this power plant (at Re 1 /Kg). The village has donated land for setting up the power plant. They have also signed a Power Purchase Agreement with Uttarakhand Power Corporation Limited (UPCL), the state electricity power company, to sell the generated power. Since it is still a captive project no revenue has been generated.[5]

**Cost:** The cost of the 9 kWe gasifier

[5] Avani bio Energy has signed a power purchase agreement with the Uttarakhand Power Cooperation at a base price of Rs 3.70 a unit. The PPA stands valid for 20 years. (Source: Firing-Up-Dreams, Renewable Energy 01 Dec, 2012,http://www.businessworld.in/news/null/firing-up-dreams/65)

manufactured at Baroda, Gujarat, was approximately Rs. 4.85 lakhs. The capital expenditure for setting up 120 kW gasifier systems is over Rs. 70 lakh with an expected 17% return on investment. The AVANI project with its innovative business model proposes to address the interdependent issues of unemployment, health and improving the overall quality of life of rural communities in the hilly region. The project also addresses one of the most energy intensive and a vital household process – cooking by effectively utilizing bio charcoal, a by-product of the gasification process. This improved cooking energy solution will reduce fuel gathering time by 70% and simultaneously provide smoke free cooking.

**Revenues:** Residue from a 120 kW gasifier system will be sufficient to meet the cooking fuel needs of 100 households as typically the gasification process produces about 10% residue. Families pay for the charcoal, which is cheaper than LPG or kerosene, either by cash or by collecting pine needles in lieu for it. This improved cooking solution not only replaces fuel wood collection (for cooking) an activity typically carried out by women but also promotes smoke free households resulting in reduction in the respiratory related diseases.

To ensure the future sustainability of the project, AVANI plans to form a producer's company with all the players in the production chain as key shareholders. The company will set up more such power plants, generating profits, which in turn will be shared by the producers and pine needle collectors.

There is a good potential to replicate this model in other parts of the central Himalayan region since pine needle is found in plenty. As per estimates typically 1 m² of pine forest will yield 1.19 kg of pine needles. A 100-kW gasifier running for 24 hours will require around 4.5 tonnes of pine needles and 115 ha of cleared forest every year will give 1350 tonnes of pine needles per year (MNRE 2012).

**Figure 2.9**: Pine Needle Collection for gasifier plant

**Services Offered**: AVANI aims at addressing the socio-economic divide at the village level by monetizing the collection of pine needles and use of charcoal in households. The unemployed can earn by collecting and utilizing pine needles in the gasifier and other people can buy the by-product i.e. charcoal for cooking including relatively the well off in the village, who may not participate in collection. Further the sale of electricity to the grid and other users will create surplus to employ more people in collection of pine needles, thus creating a sustainable livelihood model at the village level.

**Challenges and issues**

- Addressing both storage and collection is the key challenge to implement project of this size. This is especially crucial because pine needles are available for only a few months annually.
- Finances and associated project cost are also barriers for the project.
- Lack of availability of technical expertise and training and awareness programmes for plant operators is another barrier.

### 2.1.5 Gasification system in Tumkur district, Karnataka

**Figure 2.10**: Gasification system in Tumkur district, Karnataka (BERI project)

**About the project**: This project was implemented by the United Nations Development Programme (UNDP) with the financing support provided by the Global Environment Facility (GEF) and with the co-financing support of the India- Canada Environment Facility (ICEF) (now closed) , Government of Karnataka (GoK), and Ministry of New and Renewable Energy (MNRE). The project objective was to remove key barriers to the use of biomass for energy generation in rural communities.

**Background:** BERI was conceived as a project with GEF funding to create a decentralized and sustainable energy generation and distribution system to provide comprehensive and high quality rural energy services that are critical for promotion of rural development and improving the quality of life in rural communities. The project's aim was to provide a reliable high quality supply of energy for these services for rural populations. The original design of BERI envisaged sixty 20 kWe biomass gasifier units to supply electricity for 2,500 households in 24 villages belonging to five different talukas (Koratagere, Madhugiri, Sira, Gubbi, and Tumkur) in Tumkur district of Karnataka. To ensure the sustainable supply of biomass fuel to these gasification units, the project also envisaged promoting energy efficient cook stoves and community biogas plants for biomass conservation as well as building of community capacity for irrigation, generation of cooking fuels and growing plantations. The intended impact of BERI was to reduce GHG emissions from the primary use of fossil fuels that were used for various household purposes such as cooking, lighting, fans, irrigation pumps and other power applications.

**Financing:** The original project period was from April 2001 to December 2006. The project has undergone three extensions, first from January 2007 to December 2008, thereafter to December 2010 and finally up to December 2012. BERI was planned as a 5-year project; as such, GEF resources of USD 4,082,220 were managed by UNDP's Project Management Unit (PMU) under the management of the Project Steering Committee (PSC). The project co-financing amounts were estimated to be in the order of USD 1.137 million, roughly 28% of the GEF allocation. Prior to the commencement of the project, co-financing was already committed from ICEF, GoI, GoK and the private sector. During the course of the project, significant in-kind contributions were provided by GoK, GoI, NGOs and private sector stakeholders.

**Plant details**: The plant details for BERI project are provided in Table 2.2 below.[6]

**Table 2.2** Plant details for BERI Project

| S. No. | Parameters | Information |
|---|---|---|
| 1. | Technology | CGPL and IISc Banglore |
| 2. | Installed capacity | 1.05MW cumulative capacity (11 gasifier systems) was installed in Kabbigere, Borigunte and Seebanayanpalya clusters in Tumkur district, Karnataka. 900 kW is 100% producer gas (two 100 kW systems, one 200 kW system, two 250 kW systems) and 100 kW one dual fuel (diesel & gasifier) system; and 10 kW five dual fuel (diesel & gasifier) systems were implemented. |
| 3. | Electricity generation for 500kW Kabbigere plant | The cumulative electricity generation was 1,140 MWh (as on 30 June 2012) |
| 4. | Biomass supply for Kabbigere plant | The Kabbigere plant received the biomass supplies from private contractors located more than 40 km from the plant. The price of biomass received was twice as of locally supplied biomass. |
| 5. | Weighted average PLF of the Kabbigere plant | 15% |

**Operation of the plant**: For Kabbigere 500 KW plant, which consists of one engine of 200 KW(represented as GG1), three engines of 100 KW each (as GG2, GG3 and DG4 respectively), and the operational performance was moderately satisfactory. Figure 2.10 shows the operational performance for the period of April 11 to March 12. The GG2 engine performed best out of the four and ran for around 2593 hours during the operational duration.

[6] Terminal Evaluation Report, UNDP/ GEF Project: Biomass Energy for Rural India, March 2013

**Cost**: As per the operational data of Kabbigere unit (May 2011 to April 2012) [7], the average cost of power exported per unit for the 12 months is Rs. 10.64, which is high against the industry benchmark. The operational cost includes the

- cost of biomass (Rs. 2.77/ kWh)
- biomass sizing cost (Rs. 0.58/ kWh)
- O & M cost (Rs. 2.58/ kWh) and
- cost of auxiliary consumption & losses (4.71/ kWh).

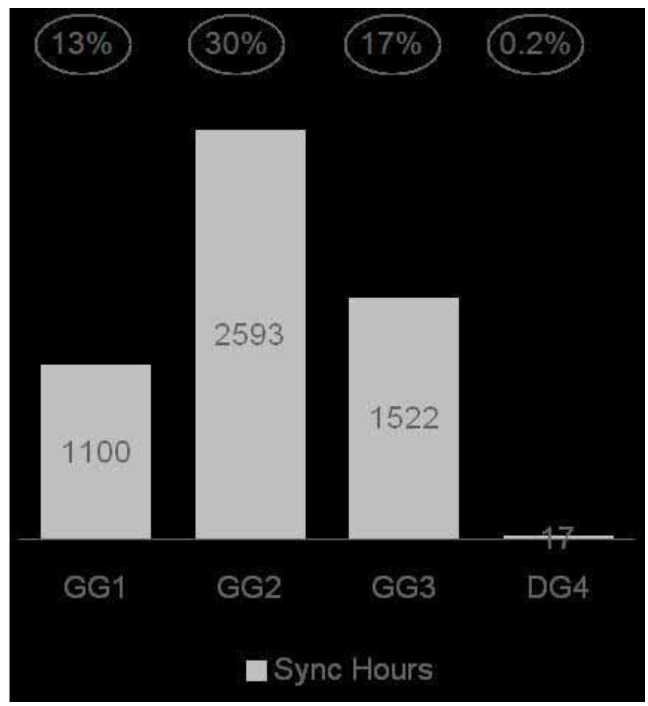


**Figure 2.11**: Operation of Kabbigere 500 kW plant in Karnataka

Primary causes of the high cost of production are traced as (source: Terminal Evaluation Report, UNDP, 2013)

- the operational inefficiencies of the plant including a high number of plant personnel;
- the high cost of biomass due its sourcing 40 km from Tumkur at twice the cost;
- low PLF; and
- a high plant parasitic load

[7] Cost Benefit Analysis of Biomas Gasifier Based Electrification For BERI By V Ranganathan Syed Haque, October, 2012

**Revenue**: The electricity was sold to BESCOM at a rate of Rs.2.85 per unit. Hence in terms of financial viability, the selling to Bescom at the rates mentioned was not profitable. Since the cost per unit exported even in better performing biomass gasification power plants are in the range of Rs. 6.50 to Rs. 7.00, it is clear that the BESCOM rate needs to be increased substantially. BESCOM rates are stipulated by State Renewable Energy Cooperation (SERC). Therefore there is need to pay attention towards low tariff of biomass related power projects.

**Key learning**: The revenue received from the project is very low and thus the project is not viable. Therefore, the BERI project has an approach in the following direction for future growth.

- Continue the existing model. Negotiate better rate with discoms (Bescom currently).
- Explore alternative markets (corporate/ industrial users, viz. Wipro, Infosys) that will pay higher rates.
- Earn Renewable Energy Certificates (RECs)[8] for the biomass project (Details provided in Annexure).
- Go for off-grid model; sell power directly to end users in rural areas.

  ✓ Look for markets to sell electricity directly to users, instead of to KPTCL. Forming a rural electric cooperative under BERI may help achieve this objective. The cooperative can distribute power directly to the adjoining areas and collect revenue direct. It may even be eligible to get subsidy for its operations from the Rural Development and Panchayat Raj department.

- Go for off-grid model, sell power to wholesalers.

  ✓ Outsource entire operation to third party, giving him the right to sell electricity to whoever he wants, and asking the bidder maximum amount he will give to BERI for use of assets; it is given on a lease basis.

[8] Internationally, purchase of REC is deemed as purchase of power generated from Renewable Energy (RE) sources. It is acknowledged that renewable energy generation entails production of certain environmental attributes apart from electricity generation per se. Thus, RE generator can sell two different products on account of renewable energy generation. These products are the electricity and the environmental attributes associated in the form of RE Certificate.

### *2.1.6 Gasification System at Sunderbans*

**Figure 2.12**: Gasification system at Sunderbans

**About the project**: The West Bengal Renewable Energy Development Agency (WBREDA) in collaboration with MNES (presently MNRE), Sunderban Development Department, Forest Department, and South 24 Parganas Zilla Parisad had installed a 500 kW (5x 100 kW) dual fuel mode biomass based power plant and Chotamulakalli was identified as a probable location for setting up the woody biomass based power plant. Gosaba Rural Energy Co-Operative was formed in the year 1996 for the operation of the system. Gosaba Island installation has been a successful case study for the reason that the energy generated from gasifier has turned the socio economic status of the island along with community development. Even when the cost of energy generation is high, the energy generated from gasifier has played a pivotal role in improving the life style of the rural masses of Sunderbans, where grid penetration is impossible in the near future.

**Financing**: The project was carried out by WBREDA. For the project, loan was taken from MNRE under the Remote Village Electrification Programme and the remaining amount were provided from the state funds.

- 75% - MNRE loan
- 25% - State funds

**Business Model**: The plant was setup by the Gosaba Rural Energy Development Cooperative Society Ltd in the year 1996. There were 13 board members: six elected members and seven nominated members. The society comprised of consumers representatives, WBREDA, West Bengal State Electricity Board (WBSEB), Sunderbans Development Board, Forest co-operative department and officials from Government of West Bengal. The entire operation and maintenance of the plant was the responsibility of the Co-operative Society. This cooperative was responsible for ensuring biomass supply, daily plant operation and maintenance, and financial record keeping. For undertaking renovation, repair and maintenance of plants, around 75% of the financing was taken from the co-operative and the rest from MNRE. Ankur Scientific Energy Technologies Private Limited undertook turnkey operation for the project and performed major maintenance and retrofitting functions. The company trained the local unemployed people for gasifier operation. The state nodal agency, WBREDA had functions as the Technical Backup Unit for the project. Also, periodically tests were conducted for the plant operators to monitor their performance.

**Biomass Supply**: Gosaba Biomass Gasifier plant operates on woody biomass. As such, supply of woody biomass is to be ensured for sustainability of the power plant. At Gosaba, energy plantation work was taken up right from the planning stage of the power plant. Generally, it takes three to five years for harvesting of captive energy plantations. The initial three years is the load growth period. Biomass consumption during that period is comparatively low and has to be arranged locally. In subsequent years, biomass is available from the captive energy plantation.

**Cost:** As per data available for the system, for three consecutive years (2002-2004) the electricity generation cost was increased from Rs. 4.20 to Rs. 7.20/kWh. The increase in cost of electricity generation is a result of increase in diesel prices. The total expenditure in running a plant was around Rs. 10 lakh/ annum and total revenue generated was only Rs. 7.20 lakhs/annum approximately. The cost break- up for the project is provided in Figure 2.12.

**Revenue:** The average daily generation was 950 units over the period of 16 operating hours.

- Domestic consumers - Rs. 5/kWh
- Commercial shops and establishments - Rs. 5.50/kWh
- Industrial consumers - Rs. 6/kWh.

The average household consumption was in the range of 1 to 3 units per day. The households with electricity supply connection had to pay a fixed charge of Rs. 75 per month in addition to the variable charges for the units consumed.

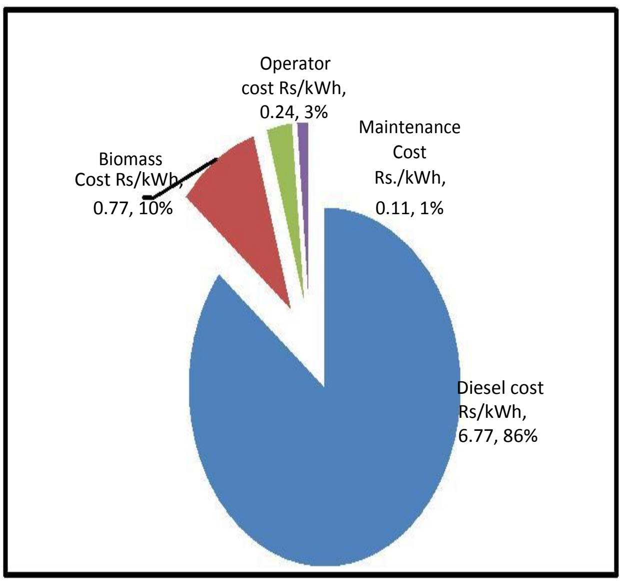


**Figure 2.13:** Break-up of Gosaba gasifier project cost

**Services Offered**:

- Power generation is the only core service offered by the plant apart from the employment offered through the energy plantations and power plant operation and maintenance.

- Small-scale industries – lathe machine units, boat-repairing works, grill welding, domestic iron implements, sharpening machines and machines to grind spices like chilli and turmeric, using automated electricity operated machinery have been established in the region.
- An operation theatre has been made functional in the government health centre in the island. With the availability of refrigerators, it has become possible to store life-saving vaccines or medicines. Electricity operated pump motors for the purpose of irrigation and cultivation of crops.

**Success of the Project**:

- Locals involved in decision making: One of the reasons for the project's success was that locals were involved in decision-making from the very start. A series of public meetings was held to raise awareness of the technology, its limitations, advantages, and the need for an energy plantation.
- Community Campaign for setting up Biomass Plants: Concerned by the threat to their incomes, the local diesel operators initially opposed the setting up of the power plant. But other members of the community undertook a vigourous campaign to sell the benefits of the new approach (which included the health benefit of cutting the toxic fumes from the diesel generators). This dissipated the opposition to a large extent and some of the diesel operators were later employed in the plant.
- No instances of electricity theft: There has been no reported evidence of electricity "theft" or of defaulting on bills since the people are very co-operative with the cooperative society that sets the tariff, advises WBREDA on where the power line should go, and is responsible for collecting electricity bills from each household.
- Good Level of Community Ownership: The boards of directors who are the members of the village panchayats are on the board, which is one of the ways of ensuring a good level of community ownership.

**Challenges and issues**:

- There was resistance from local diesel suppliers. Apprehending the discontinuation of their meager income, the local diesel operators initially opposed the setting up of the power plant. Later, the experienced among them were employed as operators in the gasifier power plant.
- The issue of continued supply of biomass for the plant was resolved by energy plantation of 71 hectares of low-line river bank silt beds char land) under the tutelage of the local Panchayat Samiti, Block Development Officer, and the Chairman of the cooperative so that no scarcity occurred in securing the stock of the main fuel ingredient (wood). Generally, it takes five years for harvesting of captive energy plantation. The initial three years are the load growth period as the number of consumers is less. Biomass consumption during that period is comparatively low. However, this has to be arranged locally.

## 2.2 Sub-Mega Watt Gasifier Projects (GRID-BASED)

### *2.2.1 Grid Connected gasifier project in Kothara, Gujarat*

**About the project:** The project objective is to feed a minimum of 500 kW electric power into the grid at Kothara Sub-station. The Gujarat Energy Development Authority (GEDA) took up Energy Plantation Programmes in the wastelands of Kutch in a major way since the early 1980s. The programme is multi-dimensional in nature with linkages to energy supply, food and fodder, soil regeneration, ecological development and local employment generation. GEDA's energy plantations in district Kutch covers 1450 hectare and has been at different agro-climatic locations developed in villages Moti Sindhodi, Lathedi, Vingabe and Kosha in taluka Abdasa.

**Financing**: The total project cost is Rs 200 lakhs, Ministry of Non-conventional Energy Sources (MNES now MNRE), sanctioned (as of March 1994) Rs 93.15 lakh to GEDA for setting up of 500 kW grid connected biomass gasifier-based power project at Kothara village in Kutch district The financial break-up is given in Table 2.3. The project was mainly aimed to demonstrate technical feasibility and economic viability of medium scale power generation based on gasification using biomass of naturally growing energy tree species like prosopis juliflora and/or fuel wood from energy plantations raised specifically for the purpose. The project was commissioned in June 2002.

**Table 2.3** Finance Break up

| Organization | Amount Sanction out of Rs 200 lakhs (in Rs) | Percentage share |
|---|---|---|
| Government of India through Ministry of New & Renewable Energy | 121 lakhs | 58.5% |
| Gujarat Energy Development Authority | 84 lakhs | % |

**Biomass Supply**: The gando bawal is a highly aggressive tree. It coppices well - annual average growth has been recorded to be up to 3-5 metres. It thrives in difficult physical conditions, and has the ability to strike root and flourish in highly degraded soils. The consumption of biomass per kWh was 1.2 kg. The consumption of diesel was 97 ml/kWh.

**Cost**: The total cost of project was around Rs 200 lakhs that includes cost of plant and machinery (Rs 149 lakh), civil works (Rs 27.15 lakh), and plantation expenditure (Rs 22.87 lakh), etc. The fuel cost for project was Rs 1.5/kWh.

**Tariff**: The charges for the electricity to Gujarat Electricity Board were Rs 2.25/unit.

**Issues and Challenges:** The major problems observed during the gasifier operation time were:

- The project attained an annual generation of electricity of 1, 66,928 kWh against the projected capacity of 13,20,000 kWh (13%). Incurring an operational expenditure of Rs. 89 lakh, GEDA in all generated 3.89 lakh units power (2002-04) and earned an income of Rs. 7.63 lakh by its sales to Gujarat Electricity Board.
- Supplies received from Singhodi site were erratic and inadequate as the wood logs received required resizing at high expenses; relatively green/high moisture wood were supplied.
- There were no biomass supplies for the project from Lakhara-Velara plantation when the plant was commissioned. The biomass gasifier-based power project was implemented dependent on the non-existent plantation and unavailable input material.
- The economic viability has also suffered due to manifold increase in diesel price by the time it is implemented.
- Cost of transportation of fuel wood from Singhodi site was prohibitive due to not meeting the government regulations.
- The project was finally closed down in March 2004.

## 2.3 Mega Watt Gasifier Projects

### *2.3.1 Sankheda 1.2 MW Biomass Gasifier project in Gujarat*

**About the project**: Ankur Scientific Energy Technologies Pvt. Ltd. has set up a 1.2 MW grid-connected, biomass power plant based on its own gasification technology in Sankheda taluka of Vadodara district. This project is the first of its kind in Gujarat and also the first project to be set up under the status of 'Model Investment Project[9]' implemented under a project by by MNRE- UNDP funded by GEF. The project was commissioned in a short duration of 6 months with the help of local villagers and farmers, panchayats, the taluka offices, the collectorate and departments of land conversion and town planning, the District Industries Centre (DIC), the pollution control board, the Gujarat Energy Development Agency (GEDA, the Madhya Gujarat Vij Company Ltd, the Gujarat Energy Transmission Corporation Ltd, and MNRE.

**Financing**: The project cost was Rs 640.67 lakh. The cost break up is

- Cost of land: 16.94 lakhs
- Civil and Construction: 100.70 lakhs
- Plant and machinery: 517.61 lakhs
- Other assets: 5.42 lakhs

The project was funded under the MNRE-UNDP implemented project, and received partial financial assistance along with the bank loan.

**Business Model**: It is a grid based model that is owned, operated and maintained. The overall system designed has two woody biomass based gasifiers which are coupled to three units of 400 kWe each running on 100% producer gas engine gensets.

**Biomass Supply**: The biomass for the project is based on crop residues of the common crops available near the project site, mainly cotton, tur, and astor stalks, mango seeds, and corn cobs. The surrounding area of the project site is rich in cotton, tur, and maize cultivation. The agri-residues are willingly sold by farmers and villagers to the project developers for some added income generation. A few young villagers and farmers have been identified and trained to manage the supply chain. The purchase price of biomass is approx. Rs 2/kg.

**Cost**: The project cost comes to Rs 640.67 lakh including cost of land, civil and construction, plant and machinery etc. The O&M cost for gasifier is 3.5% of the gasifier cost and O&M cost of gas engine is Rs 0.25/kWh. The purchase price of biomass is approx. Rs 2/kg.

**Tariff**: The developer signed the project purchase agreement with third party buyer for the duration of 10 years with affixed tariff rate of Rs 4.10 per kWh for 10 year. As per the selling agreement, the seller is responsible for payment of applicable transmission, wheeling and other charges including the electricity duty.

**Uniqueness**: The waste heat from the exhaust of two engines is being used for biomass drying.

- Char produced has high calorific value and is used as a fuel for small scale industry requiring thermal energy.
- Char of sizes below 1 mm would be given to the local farmers as biochar for soil addition as it increases the fertility of the soil and thereby the yield.
- Sizes between 1 mm and 10 mm are used for briquetting. A separate briquetting machine has been installed at the project site and the briquettes thus made would initially be sold to industries for their thermal application.

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9 MNRE has implemented a MNRE - UNDP / GEF assisted Project on "Removal of Barriers to Biomass Power Generation in India to accelerate the adoption of environmentally sustainable biomass power technologies by removing the barriers identified, thereby laying the foundation for the large scale commercialization of biomass power through increased access to financing. As part of this Project, the Ministry is contemplating establishment of a few Model Investment Projects (MIPs) in different parts of the country with a view to focus removal of barriers related to technology, Size and Sustainability and would like to provide financial support to grid interactive, MW capacity projects based on Biomass Gasification Technology. The aim of establishing these model projects is to standardize the technology package in this capacity range and also to generate information / data to develop benchmark norms related to Capex, O&M, PLF etc. which are essential inputs for determination of separate tariff for such projects. The developed financial models would facilitate in mainstreaming of the gasification technology in the biomass power sector and for its faster replication in the country.

# Chapter 3

# Tariffs

The Chapter provides the information about tariff related to biomass power projects in India. The Central Electricity Regulatory Commission (CERC) outlined tariffs for biomass gasifier-based power projects in October 2012.[10] As per that, the state-level tariffs for biomass gasifier power project will be as provided in the Table 3.1.

The fixed cost given in Table 3.1 comprises the following components:

(a) Return on equity;
(b) Interest on loan capital;
(c) Depreciation;
(d) Interest on working capital;
(e) Operation and maintenance expenses

It should be noted that the depreciation in these calculations are based on straight line depreciation, which comes to 5.28% for the assumed project life of 20 years. The project developer may, however, also avail of the option of accelerated depreciation, using the 80% of the written down value method.

The variable component of the tariff given in Table 3.1 is based on the biomass fuel cost for FY 2012– 13. This variable component will change each year based on whether the project

**Table 3.1** State level tariffs for biomass gasifier power projects

| State | Fixed Cost | Variable cost (FY 2012–13) | Applicable tariff Rate (FY 2012-13) | Benefit of Accelerated Depreciation (if availed) | Net levelized Tariff upon adjusting for Accelerated Depreciation Benefit (if availed) |
|---|---|---|---|---|---|
| | Rs/kWh | Rs/kWh | Rs/kWh | Rs/kWh | Rs/kWh |
| Andhra Pradesh | 2.46 | 3.48 | 5.94 | 0.12 | 5.82 |
| Haryana | 2.53 | 3.96 | 6.48 | 0.12 | 6.36 |
| Maharashtra | 2.54 | 4.05 | 6.58 | 0.12 | 6.46 |
| Punjab | 2.55 | 4.14 | 6.69 | 0.12 | 6.57 |
| Rajasthan | 2.46 | 3.45 | 5.91 | 0.12 | 5.79 |
| Tamil Nadu | 2.46 | 3.42 | 5.88 | 0.12 | 5.76 |
| Uttar Pradesh | 2.47 | 3.55 | 6.01 | 0.12 | 5.89 |
| Others | 2.50 | 3.72 | 6.21 | 0.12 | 6.09 |

[10] CERC-Petitions No. 243/SM/2012 (Suo-Motu): Date of Order 25th October 2012

developer opts for fuel price indexation or escalation factor of 5%. The fuel costs for the various states that have been considered by CERC are given in Table 3.2.

**Table 3.2** State-wise fuel cost considered by CERC

| State | Biomass price |
|---|---|
| | (Rs/tonne) |
| Andhra Pradesh | 2,502.01 |
| Haryana | 2,847.86 |
| Maharashtra | 2,912.71 |
| Punjab | 2,978.63 |
| Rajasthan | 2,485.80 |
| Tamil Nadu | 2,460.94 |
| Uttar Pradesh | 2,545.24 |
| Other States | 2,676.01 |

The fixed cost and variable cost components together comprise the applicable tariff rate. If the project developer avails accelerated depreciation as mentioned above, in that case, the net levelized tariff is reduced by an amount equal to the income tax benefit accrued by the developer on this account. The net levelized tariff applicable in that case is given in the sixth column of Table 3.1. A sample detailed calculation, including all the assumptions made, is presented in Chapter 4.

Also, with the view of motivating more entrepreneurs for implementation of biomass based power projects, Ministry of New and Renewable Energy (MNRE) gives Central Financial Assistance (CFA) and fiscal incentives to the project implementer, which are as provided in the Tables 3.3 and 3.4.

**Table 3.3** State-level central financial assistance

| | Special Category States (NE Region, Sikkim, J&K, HP and Uttaranchal) | Other States |
|---|---|---|
| Biomass Power projects | Capital Subsidy | |
| | Rs 25 lakh X(C MW)^0.646 | Rs 20 lakh X (C MW)^0.646 |

**Table 3.4** Fiscal Incentives for Biomass Power Generation

| Item | Description |
|---|---|
| Accelerated Depreciation | 80% depreciation in the first year can be claimed for the following equipment required for co-generation systems<br>Back pressure, pass-out, controlled extraction, extraction-cum-condensing turbine for co-generation with pressure boilers<br>Vapour absorption refrigeration systems<br>Organic Rankine cycle power systems<br>Low inlet pressures small steam turbines |
| Income Tax Holiday | Ten years tax holiday. |
| Customs/Excise Duty | Concessional customs and excise duty exemption for machinery and components for initial setting up of Biomass power projects. |
| General Sales Tax | Exemption is available in certain states |

# Chapter 4

# Financial Feasibility of 1-MW Biomass Gasifier Based Power Plant

This chapter provides an analysis of financial feasibility of 1MW biomass gasifier based power plant. The analysis is based on MNRE and CERC guidelines. The purpose of the analysis is to develop understanding of the stakeholders about the calculations of tariff determination and this chapter has also found out the viability gap for each unit generated.

**Plant Capacity**: Mega Watt Scale (>= 1 MW)

**Financing**: Ministry of New and Renewable Energy (MNRE) is promoting gasification technology by giving cash incentives such as capital subsidy. Demonstration of indigenously developed and produced or imported 100% producer gas engine will be taken up in power generation projects up to 1 MW capacity. Central Financial Assistance (CFA) of Rs. 10.00 lakhs per 100 kW on prorate basis, or in multiple thereof, will be provided on the gas engine and biomass gasifier systems.

**Gasifier systems**: One with three producer gas engines of 380 KVA (300kWe) and one diesel genset of 380 KVA (300kWe).

**Feedstock**: The raw material (wood waste) will be procured from the local market at a price of approximately Rs. 2000 per tonne or Rs 2/ kg.

### Key Parameters

**Project Cost & Financing**: The total cost of the project is estimated to be Rs. 594.21 lakhs, which includes plant & machinery of Rs 412.98 lakhs. Out of this, it is estimated that Rs. 100.00 lakhs will be capital subsidy (CFA is Rs 10 lakhs/ 100kW; therefore subsidy provided will be 16.8% of the total project cost. A total of 30% will be promoter's contribution and the balance as loan from the financial institutions.

**Manpower Requirement**: The number of people required for the project execution will be around 21, including manager, gasifier operators, electricians, maintenance staff etc.

**Table 4.1** Manpower details

| Particulars | Wages (Rs) | Nos |
|---|---|---|
| Manager | 8,000 | 1 |
| Electrical Supervisor | 6,500 | 1 |
| Electricians | 4,000 | 4 |
| Gasifier Operators | 5,000 | 4 |
| Labour | 1,500 | 7 |
| Maintenance Staff | 4,000 | 4 |
| Total Wages | | 21 |

### Major Assumptions

- Power plant will be operating for 330 days in a year. The capacity utilization of this power plant will be 75% in first year, 80% in second year and 85% from third year onwards.
- For a producer gas engine, wood consumption 1.30 kg/ kW.
- Auxiliary power consumption[10] is 6.0% of power generated.
- The line loss is 2% of power transmitted in the line.
- The calorific value of gas produced will be 1000-1200 KCal/Nm$^3$. The acceptance feedstock for the gasifier is wood chips of 150-200 mm size with less than 15% moisture.
- The average consumption of wood waste is

[10] Auxiliary power consumption is power consumed by system accessories such as blower, pump, automated feeding systems, etc.

around 1.30 kg per unit of power generation.

- The wood waste required in the first year is 7,722.00 tonnes, in second year is 8,236.80 tonnes and from third year onwards 8,751.73 tonnes. The price of the wood waste available is Rs. 2000 per tonne. It is assumed that the price of wood waste will increase by 3% every year.
- Selling price of power is taken as Rs 5.46 per unit. Increase in selling price is 3% per annum.
- Operating hours are 7920 per annum
- Depreciation @10% per annum, interest @12% on the amount of loan from financial institution
- Capital subsidy of Rs. 100.00 lakhs.
- Loan repayment period of 10 years including one year moratorium.
- Wheeling charges is 25 paise per unit transmitted in line.
- Consumable is taken as Rs. 1.00 lakh in the first year and increasing by 5% every year.
- Selling expenses are taken as Rs. 0.50 lakh per year.
- Manpower charges are increasing by 5% every year.
- Net Profit will be 15% p.a. after tax.
- Average Debt Service Coverage Ratio will be 3.04 times.
- Payback period is approx. 4 years.
- Benefit of REC scheme during calculation, is not considered.
- The internal rate of return of the project is 21.50%

Based on the above mentioned assumption, financials of 1 MW plant is provided in Table 4.2 below.

**Table 4.2** Financial analysis for a 1-MW biomass gasifier plant

| Particulars | Amount (Rs in lakhs) |
|---|---|
| Installed capacity (MW) | 1000.00 |
| Power export during season | 1000.00 |
| Plant Load Factor | 0.85 |
| Working days in year | 330.00 |
| Working hours in a day | 24.00 |
| Actual units generated (in lakhs) | 67.32 |
| Less: Auxiliary Consumption (in lakhs) @ 6% | 4.04 |
| Units available for sale | 63.28 |
| Less: Line Loss @ 2% | 1.27 |
| Units sold (in lakhs) | 62.02 |
| Sales price per unit (Rs) | 5.30 |
| Revenue | 328.96 |
| Carbon Credit Benefits | 25.00 |
| Charcoal Sale Receipts | 34.82 |
| Sub Total (A) | 388.78 |
| Manufacturing expenditures | |
| Raw material | 185.69 |
| Consumables | 1.10 |
| Wages | 10.19 |
| Repair and maintenance | 21.78 |
| Sub Total (B) | 218.76 |
| Administrative Expenses & | |
| Insurance | 1.05 |
| Selling, wheeling, and other misc. | 16.32 |
| expenses | |
| Sub Total (C) | 17.37 |
| Gross Profit (A-B-C) | 152.65 |
| Depreciation (SLM) | 42.31 |
| PBIT | 110.34 |
| Financial Expenses | |
| Interest on term loan | 28.82 |
| Interest on working capital | 7.77 |
| PBT | 73.75 |
| Provision for taxation including Dividend | 11.39 |
| Tax | |
| Profit After Tax (PAT) | 62.35 |

## Feasibility of the Project

The average cost borne is Rs. 10 per unit. The tariff for biomass gasifier power plant is determined by the tariff decided by respective state government. The producer can sell the power to the distribution company. The power can also be supplied to other companies at the rate of Rs.5.46 in comparison to present average rate of Rs.10 per unit. The REC certificates and carbon credits can also be provided to project developer.

### *Biomass Gasification based Power Generation cost estimates on the basis of CERC guidelines:*

We have carried out the following analysis by considering the CERC's benchmark cost and other parameters of biomass gasification power generation project. The benchmark cost and parameters considered for various components is as follows:

**Table 4.3** Cost estimates of biomass gasification based power generation based on CERC guidelines

| | | |
|---|---|---|
| Capacity | 1 | MW |
| Project Life | 20 | Years |
| PLF | 65 | % |
| Auxiliary Consumption | 10 | % |
| Capital Cost | 572 | Rs in lakh/MW |
| Capital Subsidy | 150 | Rs lakh/MW |
| Subsidized Capital Cost | 422 | Rs lakh/MW |
| Depreciation for first 12 years | 5.83 | % |
| Depreciation from 13th year onwards | 2.51 | % |
| Debt (70%t) | 295.4 | Rs in lakh |
| Equity (30%) | 126.6 | Rs in lakh |
| Interest on Loan | 13 | % |
| Discount Rate | 10.63% | |
| Fuel Requirement | 1.25 | kg/kWh |
| Feedstock Price | 3000 | Rs/MT |
| Fuel-cost Escalation | 3% | |
| O&M Cost | 42.29 | Lakhs/MW |
| O&M Cost Escalation | 5.72 | % |
| Maintenance Spares | 15 | % of yearly O&M cost |
| Corporate Tax Rate | 32.45% | % |
| MAT | 20% | |
| Tax Holiday Start Year | 6 | Years |
| Tax Holiday Period | 10 | Years |
| MAT Set-off Start Year | 16 | Year |
| MAT Set-off Allowed | 10 | Years |
| MAT Set-off Duration | 5 | Years |
| CapEx | 422 | Rs lakh/MW |
| Plant and Machinery Tax Depreciation | 25% | |

**Table 4.4**: The annualized cost and tariff based on CERC-approved parameters

| Years | Yr-1 | Yr-2 | Yr-3 | Yr-4 | Yr-5 | Yr-6 | Yr-7 | Yr-8 | Yr-9 | Yr-10 | Yr-11 | Yr-12 | Yr-13 | Yr-14 | Yr-15 | Yr-16 | Yr-17 | Yr-18 | Yr-19 | Yr-20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fixed Charges | | | | | | | | | | | | | | | | | | | | |
| O&M(In Rs.lakh) | 42.29 | 44.71 | 47.27 | 49.97 | 52.83 | 55.85 | 59.04 | 62.42 | 65.99 | 69.77 | 73.76 | 77.98 | 82.44 | 87.15 | 92.14 | 97.41 | 102.98 | 102.98 | 108.87 | 115.10 |
| Interest on Working Capital | 14.86 | 15.21 | 15.59 | 15.99 | 16.41 | 16.86 | 17.33 | 17.83 | 18.36 | 18.92 | 19.51 | 20.14 | 20.80 | 21.49 | 22.23 | 23.01 | 23.01 | 23.83 | 24.71 | 25.63 |
| Depreciation ( In Rs. Lakh) | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 24.60 | 10.59 | 10.59 | 10.59 | 10.59 | 10.59 | 10.59 | 10.59 | 10.59 |
| Interest on Loan(In Rs. Lakh) | 38.40 | 35.20 | 32.00 | 28.80 | 25.60 | 22.40 | 19.20 | 16.00 | 12.80 | 9.60 | 6.40 | 3.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ROE(in Rs. Lakh) | 25.32 | 25.32 | 25.32 | 25.32 | 25.32 | 25.32 | 25.32 | 25.32 | 25.32 | 25.32 | 30.38 | 30.38 | 30.38 | 30.38 | 30.38 | 30.38 | 30.38 | 30.38 | 30.38 | 30.38 |
| Total fixed cost (in Rs. Lakh) | 145.47 | 145.05 | 144.78 | 144.69 | 144.77 | 145.04 | 145.50 | 146.18 | 147.08 | 148.21 | 154.66 | 156.30 | 144.21 | 149.62 | 155.34 | 161.39 | 161.79 | 167.79 | 174.55 | 181.70 |
| Fixed cost / Unit(in Rs. Lakh/kWh) | 5.33 | 5.31 | 5.30 | 5.30 | 5.30 | 5.31 | 5.33 | 5.35 | 5.39 | 5.43 | 5.67 | 5.73 | 5.28 | 5.48 | 5.69 | 5.91 | 6.15 | 6.15 | 6.39 | 6.66 |
| Variable Charges | 5.92 | 5.90 | 5.89 | 5.90 | 5.89 | 5.90 | 5.92 | 5.95 | 5.99 | 6.03 | 6.29 | 6.36 | 5.87 | 6.09 | 6.32 | 6.57 | 6.83 | 6.83 | 7.10 | 7.40 |
| Fuel Require-ment(MT) | | | | | | | | | | | | | | | | | | | | |
| Feedstock Price(Rs/MT) | 3000.00 | 3090.00 | 3182.70 | 3278.18 | 3376.53 | 3477.82 | 3582.16 | 3689.62 | 3800.31 | 3914.32 | 4031.75 | 4152.70 | 4277.28 | 4405.60 | 4537.77 | 4673.90 | 4814.12 | 4958.54 | 5107.30 | 5260.52 |
| Fuel Cost(Rs. Lakh) | 102.38 | 105.45 | 108.61 | 111.87 | 115.22 | 118.68 | 122.24 | 125.91 | 129.69 | 133.58 | 137.58 | 141.71 | 145.96 | 150.34 | 154.85 | 159.50 | 164.28 | 169.21 | 174.29 | 179.52 |
| Fuel Cost(Rs. Lakh/kWh) | 3.75 | 3.86 | 3.98 | 4.10 | 4.22 | 4.35 | 4.48 | 4.61 | 4.75 | 4.89 | 5.04 | 5.19 | 5.35 | 5.51 | 5.67 | 5.84 | 6.02 | 6.20 | 6.38 | 6.58 |
| Actual Variable Cost(Rs. Lakh/ kWh) | 4.17 | 4.29 | 4.42 | 4.55 | 4.69 | 4.83 | 4.98 | 5.12 | 5.28 | 5.44 | 5.60 | 5.77 | 5.94 | 6.12 | 6.30 | 6.49 | 6.69 | 6.89 | 7.09 | 7.31 |
| Total Cost(Rs. Lakh) | 247.85 | 250.49 | 253.39 | 256.55 | 259.99 | 263.72 | 267.74 | 272.09 | 276.76 | 281.79 | 292.24 | 298.01 | 290.17 | 299.96 | 310.20 | 320.89 | 332.07 | 337.00 | 348.84 | 361.22 |
| Tariff(Rs./kWh) | 10.09 | 10.20 | 10.31 | 10.44 | 10.58 | 10.73 | 10.90 | 11.07 | 11.26 | 11.47 | 11.89 | 12.13 | 11.81 | 12.21 | 12.62 | 13.06 | 13.52 | 13.72 | 14.20 | 14.70 |

# Sample Calculation for Tariff Determination for Biomass Gasifier Power Project

| Assumption for Biomass Gasifier Power Project Parameters | | | | | |
|---|---|---|---|---|---|
| S. No. | Assumption Head | Sub-head | Sub-head (2) | Unit | Assumptions |
| 1 | Power Generation | Capacity | Installed Power Generation Capacity | MW | 1 |
| | | | Auxiliary consumption during stablisatisation | % | 10 |
| | | | Auxiliary consumption after stabilization | % | 10 |
| | | | PLF (stabilization for 6 months) | % | 85 |
| | | | PLF (during first year after stabilization) | % | 85 |
| | | | PLF (second year onwards) | % | 85 |
| | | | Useful life | Years | 20 |
| 2 | Project Cost | Capital cost/MW | Power Plant Cost (before subsidy) | Rs (in lakhs)/MW | 571.42 |
| | | | Power Plant Cost (after subsidy) | Rs (in lakhs)/MW | 421.42 |
| 3 | Financial Assumptions | Debt equity | Debt | % | 70% |
| | | | Equity | % | 30 |
| | | | Total debt amount | Rs (in lakhs | 294.99 |
| | | | Total equity amount | Rs (in lakhs) | 125.43 |
| | | Debt component | Loan amount | Rs (in lakhs) | 294.99 |
| | | | Moratorium period | Years | 0 |
| | | | Repayment period (including Moratorium) | Years | 12 |
| | | | Interest rate | % | 13.00 |
| | | Equity component | Equity amount | Rs (in lakhs | 126.43 |
| | | | Return on equity for first 10 years | % p.a | 20.00 |
| | | | Return on equity after 10 years | % p.a | 24.00 |
| | | | Weighted average of ROE | % p.a | 22.00 |
| | | | Discount rate (equivalent to WACC) | % p.a | 10.95 |
| 4 | Financial Assumptions | Fiscal assumptions | Income tax | % | 32.44 |
| | | Depreciation | Depreciation rate (power plant) | % | 5.83 |
| | | | Depreciation rate 13th year onwards | % | 2.51 |
| 5 | Working Capital | For Fixed Charges | | | |
| | | O&M charges | | Months | 1 |
| | | Maintenance spare | (% of O&M expenses) | % | 15% |
| | | Receivables for Debtors | | Months | 2 |
| | | For Variable Charges | | | |
| | | Biomass stock | | Months | 4 |
| | | Interest on working capital | | % | 13.50% |
| 6 | Fuel-related Assumptions | Biomass | Specific Fuel consumption | Kg/kWh | 1.25 |
| | | | Base price | Rs/ t | 2545.24 |
| | | | Biomass price escalation factor | % | 5.00% |
| 7 | Operation and Maintenance (O&M) | Power plant | | Rs/ lakhs | 42.29 |
| | | Total O&M expenses escalation | | % | 5.72% |

| Determination of Tariff Component: Biomass Gasifier Power Projects | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Units Generation | Unit | Year---> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Installed Capacity | MW | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Gross Generation | MU | | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 | 7.45 |
| Auxiliary Consumption | MU | | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |
| Net Generation | MU | | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 | 6.70 |
| Fixed Cost | Unit | Year---> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| O&M Expenses | Rs Lakh | | 42.29 | 44.71 | 47.27 | 49.97 | 52.83 | 55.85 | 59.04 | 62.42 | 65.99 | 69.77 | 73.76 | 77.98 | 82.44 | 87.15 | 92.14 | 97.41 | 102.98 | 108.87 | 115.10 | 121.68 |
| Depreciation | Rs Lakh | | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 24.57 | 10.56 | 10.56 | 10.56 | 10.56 | 10.56 | 10.56 | 10.56 | 10.56 |
| Interest on term loan | Rs Lakh | | 36.75 | 33.56 | 30.36 | 27.16 | 23.97 | 20.77 | 17.58 | 14.38 | 11.19 | 7.99 | 4.79 | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interest on working Capital | Rs Lakh | | 26.14 | 27.29 | 28.50 | 29.78 | 31.13 | 32.55 | 34.04 | 35.62 | 37.28 | 39.02 | 40.98 | 42.91 | 44.67 | 46.89 | 49.22 | 51.67 | 54.24 | 56.95 | 59.79 | 62.78 |
| Return on Equity | Rs Lakh | | 25.29 | 25.29 | 25.29 | 25.29 | 25.29 | 25.29 | 25.29 | 25.29 | 25.29 | 25.29 | 30.34 | 30.34 | 30.34 | 30.34 | 30.34 | 30.34 | 30.34 | 30.34 | 30.34 | 30.34 |
| Total Fixed Cost | Rs Lakh | | 155.04 | 155.41 | 155.98 | 156.77 | 157.78 | 159.03 | 160.52 | 162.27 | 164.31 | 166.63 | 174.44 | 177.40 | 168.00 | 174.94 | 182.25 | 189.97 | 198.12 | 206.72 | 215.79 | 225.36 |
| Levelised tariff corresponding to Useful life | | | | | | | | | | | | | | | | | | | | | | |
| Per Unit Cost of Generation | Unit | Levellised | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Variable COG | Rs/kWh | 4.97 | 3.54 | 3.71 | 3.90 | 4.09 | 4.30 | 4.51 | 4.74 | 4.97 | 5.22 | 5.48 | 5.76 | 6.05 | 6.35 | 6.67 | 7.00 | 7.35 | 7.72 | 8.10 | 8.51 | 8.93 |
| O&M expn | Rs/kWh | 0.94 | 0.63 | 0.67 | 0.71 | 0.75 | 0.79 | 0.83 | 0.88 | 0.93 | 0.98 | 1.04 | 1.10 | 1.16 | 1.23 | 1.30 | 1.37 | 1.45 | 1.54 | 1.62 | 1.72 | 1.82 |
| Depreciation | Rs/kWh | 0.33 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 |

| Contd... | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Units Generation | Unit | Year---> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Int. on term loan | Rs/kWh | 0.28 | 0.55 | 0.50 | 0.45 | 0.41 | 0.36 | 0.31 | 0.26 | 0.21 | 0.17 | 0.12 | 0.07 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Int. on working capital | Rs/kWh | 0.53 | 0.39 | 0.41 | 0.43 | 0.44 | 0.46 | 0.49 | 0.51 | 0.53 | 0.56 | 0.58 | 0.61 | 0.64 | 0.67 | 0.70 | 0.73 | 0.77 | 0.81 | 0.85 | 0.89 | 0.94 |
| RoE | Rs/kWh | 0.40 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Total Cost of Generation | Rs/kWh | 7.44 | 5.85 | 6.03 | 6.23 | 6.43 | 6.65 | 6.88 | 7.13 | 7.40 | 7.67 | 7.97 | 8.36 | 8.69 | 8.86 | 9.28 | 9.72 | 10.18 | 10.67 | 11.19 | 11.73 | 12.30 |
| | | | | | | | | | | | | | | | | | | | | | | |
| Levellised Tariff | Unit | Year --> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Discount Factor | | | 1 | 0.90 | 0.81 | 0.73 | 0.66 | 0.59 | 0.54 | 0.48 | 0.44 | 0.39 | 0.35 | 0.32 | 0.29 | 0.26 | 0.23 | 0.21 | 0.19 | 0.17 | 0.15 | 0.14 |
| Variable Cost (FY 2013-14) | | | | 3.54 | | Rs/Kwh | | | | | | | | | | | | | | | | |
| Levellised Tariff (Fixed) | | | | 2.47 | | Rs/Kwh | | | | | | | | | | | | | | | | |
| Applicable Tariff (FY2013-14) | | | | 6.01 | | Rs/Kwh | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |

The cost of generation estimated for the biomass project is Rs 7.44/ unit while assuming the applicable tariff of State of Uttar Pradesh of Rs 6.01/unit. There is a viability gap of Rs 1.43/ unit. As per the calculations, the annual net unit generation is 6.70 MU and therefore, the annual project deficit will be around Rs. 9.6 million. It is suggested that there should be government intervention to make biomass gasifier based power generation business sustainable. To ensure the long term sustainability of such projects, there should be policy intervention in the form of viability gap funding for the promotion of biomass power projects in India. In addition to that there should also be focus on fuel linkages for the projects.

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