Biomass Gasification Based Power Production in India

A Sample of the Market Intelligence Report from EAI

This e-book provides representative sample content to assist in evaluating the India Biomass Gasification Based Power Production Report
Preface

Biomass gasification, with its capability to work in kW scales (as low as 20 kW) and its ability to utilize a wide and diverse range of biomass feedstock (including agriculture and crop waste) is ideally suited for the power needs of many segments. This ideally suits rural areas where access to power is minimal but an easy access to significant amount of cheap (and many times no cost) biomass is prevalent.

EAI predicts that biomass gasification based power production in India could grow from about 80 MW currently to over 500 MW by 2015.

This is a preview of the report “Biomass Gasification Based Power Production in India”. This report has been developed to assist entrepreneurs, businesses and companies keen on exploring this important avenue of renewable power generation.

This is one of the most comprehensive and detailed reports on the subject, and was last updated in September 2012.

The report has been prepared by Energy Alternatives India (EAI), a leader in business intelligence and market research for the Indian renewable energy and cleantech industries.
Key Takeaways from This Report

- With over 60,000 villages not connected to the grid, the use of distributed renewable power sources is the need of the hour for India; among the renewable power sources, biomass could play an important role owing to its easy availability in rural areas, and biomass gasification an even more important role owing to its ability to operate at very low scales.

- Among the biomass power production routes, combustion and gasification are the two primary routes being used today. Biomass gasification works well for small scale power production, up to a maximum capacity of 2 MW. Combustion, on the other hand, works well at 5+ MW scales. As a result, biomass gasification could be one of the most appropriate technologies for biomass-based small scale power.

- The gasifier is the key component in a biomass gasification system. There are two main categories of gasifiers – fixed bed and fluidized bed. Within fixed bed, there are two types – updraft and downdraft gasifiers. The most common gasifier used in India is the downdraft gasifier, which is more suited than others for biomass gasification.

- A wide variety of feedstocks can be used in the biomass gasifiers, and India is endowed with significant quantities of these feedstocks. Some of the prominent biomass used are rice husk, rice straw, coconut shells, cotton husk, bamboo and casuarina.

- The key market segments in India for biomass gasification are the small/medium industries, commercial sector and rural communities. The producer gas from the gasifier is used for power production in some cases and in other cases for thermal purposes, as a replacement of furnace oil or other fossil fuels. Increasingly, biomass based power production is also being explored as a replacement for diesel based backup/standby power.

- One of the critical bottlenecks faced by biomass gasification power plants is the uninterrupted supply of biomass at low prices. This supply chain aspect is by far the most critical determinant of success. As a result, a number of power producers are resorting to long term contracts, choosing the optimal location and sizes for their power plants based on local availability, or are opting for dedicated energy crops for captive consumption.
Key Takeaways from This Report

- The capital cost per MW for a biomass gasification plant is about Rs 5.5 crores, while the operational expenses (excluding the cost of biomass) are about Rs 0.75 per kWh. The levelized cost of power from biomass gasification will be in the range of Rs 2.25-4/kWh, the wide range mainly owing to the wide range in the price of the biomass.

- Under optimal conditions, biomass gasification based power production presents a good business opportunity with attractive IRRs (over 25%) and payback periods (fewer than 3 years).

- In India, the special feed in tariffs for biomass based power varies from state to state – from Rs 3.5 per kWh to about Rs 5 per kWh. Biomass gasification power production can also avail capital subsidies and other government incentives such as based accelerated depreciation.

- The three main governmental bodies in the context of renewable energy funding are IREDA, Power Finance Corporation and Rural Electrification Corporation. A number of commercial banks, venture capital and private equity firms have also started taking an interest in financing renewable energy projects, and some biomass gasification power plants have already been funded by venture capital firms.
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Indian Power Scenario and the Need for Biomass Power

This chapter focuses on the Indian power production scenario, and provides a summary of the potential and benefits of biomass based power in India.

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1.4 Status of Indian Renewable Power Generation
   1.4.1 Total Installed Capacity of Renewable Power Sources
   1.4.2 Unique drivers for renewable power in India
1.5 Biomass based Power
   1.5.1 Benefits of Biomass Based Power
   1.5.2 Potential for Biomass Power in India

Highlights from the Chapter

- India’s fast growing economy requires that the country relies not just on fossil fuel resources, but also on renewable sources of power.
- With over 60,000 villages not connected to the grid, use of distributed renewable power sources is the need of the hour for India.
- India has already achieved some success in renewable power, having made considerable progress in wind and having started off well in small hydro and biomass.
- Biomass-based power presents a number of benefits that will solve some critical pain points being faced by the country today.
## Biomass Power in India – Now and Future

### Sample Content

### Biomass Power in India – Now and Future

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributed electricity generation</td>
<td>Biomass has a minor contribution</td>
<td>Biomass will be a major contributor</td>
</tr>
<tr>
<td>Use in co-firing in power plants</td>
<td>Fewer than 1% of large power plants use biomass</td>
<td>A much larger % of utility power will be from biomass</td>
</tr>
<tr>
<td>Use of feedstock</td>
<td>Primarily waste biomass and assorted</td>
<td>Dedicated energy crops</td>
</tr>
<tr>
<td>Related revenue streams</td>
<td>Some additional revenue streams already present</td>
<td>A more established end user market for co-products such as charcoal/biochar/activated carbon</td>
</tr>
<tr>
<td>Standalone renewable electricity source?</td>
<td>Primarily standalone mode</td>
<td>Will be used in conjunction with other renewable electricity sources</td>
</tr>
</tbody>
</table>

### Top Five States in India with High Biomass Energy Potential

<table>
<thead>
<tr>
<th>State</th>
<th>Total Potential</th>
<th>Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uttar Pradesh</td>
<td>1,746 MW</td>
<td>581 MW</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>1,984 MW</td>
<td>289 MW</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>863 MW</td>
<td>363 MW</td>
</tr>
<tr>
<td>Karnataka</td>
<td>1,196 MW</td>
<td>336 MW</td>
</tr>
<tr>
<td>Tamilnadu</td>
<td>1,160 MW</td>
<td>419 MW</td>
</tr>
</tbody>
</table>
Chapter - 2  Biomass-based Power Production Technologies

This chapter provides detailed inputs on the various routes for power production from biomass, viz., gasification, anaerobic digestion and pyrolysis.

2.1 Introduction

2.2 Primary Routes for Power from Biomass
   2.2.1 Combustion
   2.2.2 Gasification
   2.2.3 Anaerobic Digestion
   2.2.4 Pyrolysis

2.3 Comparative analysis of biomass power generating technologies

Highlights from the Chapter

- There are four routes for biomass based power – combustion, gasification, anaerobic digestion and pyrolysis - with the first three already being applied for power production in the country.

- Biomass gasification works well for small scale power production, upto a maximum capacity of 2 MW. Combustion, on the other hand, works well at MW scales. Anaerobic digestion can work well for both small and medium scales while pyrolysis can work well in the range of 2-30 MW.

- All the four routes mentioned have their own unique characteristics and will provide more benefits than others, under specific circumstances.
Sample Content

Primary Routes for Power from Biomass

The three primary routes for biomass to power are: Combustion, Gasification and Anaerobic Digestion.

- **Combustion** is easy to understand – instead of using coal or other fossil fuels biomass is used to produce steam that runs a turbine. Combustion of biomass for power could either be in the form of co-firing (when it is burned along with coal) or pure play biomass based combustion.
- In the case of **gasification**, the biomass is first gasified and this gas in turn produces power in a gas engine.
- **Anaerobic digestion** is usually applied to biomass that typically has a high amount of water in them (anaerobic digestion is most used for treating organic waste such as kitchen waste and sewage waste into energy). Under this route, microorganisms act upon the organic matter present in the biomass under anaerobic (absence of air) and convert it into biogas.
- An emerging route for biomass based power is **pyrolysis**. In this, the biomass is rapidly heated to 450 - 600°C in absence of air, and results in a bio-oil called the pyrolysis oil, which can in turn be used for firing the boilers. Typically, 50 - 75 % (by weight) of the feedstock is converted into pyrolysis oil.

**Comparative evaluation of Gasification and Combustion**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Combustion</th>
<th>Gasification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Process</td>
<td>Full Oxidation</td>
<td>Partial Oxidation</td>
</tr>
<tr>
<td>Chemical Environment</td>
<td>Excess oxygen (air) oxidizing</td>
<td>Oxygen-starved - reducing</td>
</tr>
<tr>
<td>Primary Product</td>
<td>Heat(e.g.Steam)</td>
<td>Producer gas(CO &amp; H₂)</td>
</tr>
<tr>
<td>Downstream Products</td>
<td>Electric power</td>
<td>Electric power, pure H₂, liquid fuels, chemicals</td>
</tr>
<tr>
<td>Current application</td>
<td>Dominates coal-fired power generation worldwide</td>
<td>Mostly for power generation and thermal applications</td>
</tr>
<tr>
<td>Efficiency</td>
<td>35-37%(HHV)</td>
<td>39-42%(HHV)</td>
</tr>
<tr>
<td>Emissions</td>
<td>~NSPS</td>
<td>~1/10 NSPS</td>
</tr>
<tr>
<td>Capital cost</td>
<td>Rs 5 Crores/MW</td>
<td>Rs 5.5 Crores/MW</td>
</tr>
<tr>
<td>Maturity/Risk</td>
<td>High experience, low risk</td>
<td>Reliability needs improved</td>
</tr>
</tbody>
</table>
This chapter discusses biomass gasification technology and processes in detail and provides insights on the environmental and economic benefits from biomass gasification. It also provides a comparative study of currently available gasification technologies.

3.1 Introduction

3.2 Environmental and Economic Benefits from Biomass Gasification

3.3 Components of a Biomass Gasification System for Power Production

3.3.1 Stages in implementation of biomass gasification technology

3.3.2 Operation and maintenance

3.3.3 Safety aspects in biomass gasification

3.4 Types of Gasification and Gasifiers

3.4.1 Fixed bed gasifiers

3.4.1.1 Updraft Gasifiers

3.4.1.2 Downdraft Gasifiers

3.4.2 Fluidized Bed Gasifiers

3.4.3 Selection Criteria for Gasifiers

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3.4.6 Summary on types of gasifiers and their functional performance

3.5 Limitations of Gasifiers

3.6 Biomass Gasification FAQ

Highlights from the Chapter

- Biomass gasification based power production provides significant environmental and economic benefits.

- The main components of a biomass gasification system are the gasifier and the gas engine.

- There are two main categories of gasifiers – fixed bed and fluidized bed. Within fixed bed, there are two types – updraft and downdraft gasifiers.
### Sample Content

#### Efficiency of Different Technologies of Gasification

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Fixed bed</th>
<th>Fluidized bed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Updraft</td>
<td>Downdraft</td>
</tr>
<tr>
<td>Carbon conversion</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>Thermal efficiency</td>
<td>*****</td>
<td>*****</td>
</tr>
<tr>
<td>CGE</td>
<td>*****</td>
<td>***</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>Start-up facility</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Management facility</td>
<td>****</td>
<td>****</td>
</tr>
<tr>
<td>Control facility</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Scale-up potential</td>
<td>***</td>
<td>*</td>
</tr>
<tr>
<td>Sized feed elasticity</td>
<td>****</td>
<td>*</td>
</tr>
<tr>
<td>Moisture feed elasticity</td>
<td>****</td>
<td>**</td>
</tr>
<tr>
<td>Ash feed elasticity</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Fluffy feed elasticity</td>
<td>****</td>
<td>**</td>
</tr>
<tr>
<td>Sintering safety</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Mixing</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Cost safety</td>
<td>*****</td>
<td>****</td>
</tr>
<tr>
<td>Tar content</td>
<td>*</td>
<td>*****</td>
</tr>
<tr>
<td>Particulate content</td>
<td>*****</td>
<td>***</td>
</tr>
<tr>
<td>LHV</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*Poor, **Fair, ***Good, ****Very good, *****Excellent.
Source: Modified data by Juniper, 2000; Bridgwater, 1994 a
Gasifier Systems and Gasifier Fuels

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Gasifier type</th>
<th>Capacity</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood blocks</td>
<td>Fixed-bed/down-draft</td>
<td>&lt;500 kWel</td>
<td>Electricity / shaft power</td>
</tr>
<tr>
<td>Charcoal</td>
<td>Fixed-bed/down-draft</td>
<td>&lt; 50 kWel</td>
<td>Electricity / shaft power</td>
</tr>
<tr>
<td>Rice husks</td>
<td>Fixed-bed/down-draft (also called Fixed-bed / open-core)</td>
<td>&lt; 200 kWel</td>
<td>Electricity / shaft power</td>
</tr>
<tr>
<td>Coconut shells</td>
<td>Fixed-bed/down-draft</td>
<td>&lt; 500 kWel</td>
<td>Electricity / shaft power</td>
</tr>
<tr>
<td>Wood / charcoal / coconut shells</td>
<td>Fixed-bed/cross-draft</td>
<td>&lt; 5 MWth</td>
<td>Electricity / shaft power</td>
</tr>
</tbody>
</table>

Note: kWel = kilowatt electric; MWel = megawatt electric; MWth = megawatt thermal

Stages in Implementation of Gasification Technology for Power Generation

The total duration from the time of signing the contract with the gasifier/project turnkey provider until the time when the power is generated will take in all 40 weeks (about 9 months). EAI estimates that it will take a minimum of 6 months from the start to completion of the entire power plant, in the best case scenario.

Operation and Maintenance

Regular maintenance is vital to maintain the efficiency and plant load factors at the desired levels. The frequency, at which maintenance has to be carried out, depends on the type of gasifier, quality of feedstock used, PLF at which the plant is usually operated, and size of the gasifier.
This chapter discusses the current status of biomass gasification based power in India. It provides comprehensive inputs on the different types of feedstock for biomass gasification, and the key market segments in India for biomass gasification. It also provides case studies and a list of suppliers and consultants.

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   4.2.3 Feedstock Processing and Transportation
4.3 Status of Biomass Gasification
   4.3.1 Current status of Biomass gasification in India
   4.3.2 Market segments and applications
   4.3.3 Biomass Gasification Power Production – Bottlenecks and Barriers
4.4 Biomass Gasification Plants in India
   4.4.1 Statewise Installation of Biomass Power Plants
   4.4.2 List of Installed Biomass Gasification Plants in India
4.5 Case Studies
4.6 Suppliers and Consultants
   4.6.1 Indian Gasifier Manufacturers
   4.6.2 Gas Engine Manufacturers
   4.6.3 Indian Biomass Gasification Consultants

Highlights from the Chapter

- India has a wide variety of crop and agricultural biomass that will suit as feedstock for biomass gasification
- The key market segments in India for biomass gasification are the small and medium industries, commercial sector and rural communities
- India already has a considerable number of biomass gasification plants in operation, at different scales and using diverse biomass.
Sample Content

Current Status of Biomass Gasification in India

*Size (Capacity) Distribution for Gasification and Combustion Technologies*

<table>
<thead>
<tr>
<th>Size</th>
<th>Combustion</th>
<th>Gasification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (10 kW – 25kW)</td>
<td>Not prevalent</td>
<td>Prevalent</td>
</tr>
<tr>
<td>Small-medium (25kW – 250kW)</td>
<td>Not prevalent</td>
<td>Prevalent</td>
</tr>
<tr>
<td>Medium (250 kW – 2 MW)</td>
<td>Not prevalent</td>
<td>Prevalent</td>
</tr>
<tr>
<td>Large (2 MW and above)</td>
<td>Prevalent</td>
<td>Not prevalent</td>
</tr>
</tbody>
</table>

List of Installed Biomass Gasification Plants in India

<table>
<thead>
<tr>
<th>State</th>
<th>Location of the plant</th>
<th>Built/Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Delhi</td>
<td>UNIDO</td>
<td>CGPL</td>
</tr>
<tr>
<td>Gujarat</td>
<td>Speri, Vallabha Vidyanagar</td>
<td>CGPL</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>IIT Bombay</td>
<td>CGPL</td>
</tr>
<tr>
<td>WB</td>
<td>Tezpur University</td>
<td>CGPL</td>
</tr>
<tr>
<td>WB</td>
<td>Banahut</td>
<td>CGPL</td>
</tr>
<tr>
<td>Bihar</td>
<td>Chief Executive Officer, Shri Domen Mehto, C.G.C.Vaishali, Vaishal (Dist)</td>
<td>OVN</td>
</tr>
<tr>
<td>UP</td>
<td>Arun Shah CAPART, Janak Puri, New Delhi-58</td>
<td>OVN</td>
</tr>
<tr>
<td>WB</td>
<td>Dimapur</td>
<td>SYNERGY</td>
</tr>
<tr>
<td>WB</td>
<td>Kolkata</td>
<td>SYNERGY</td>
</tr>
</tbody>
</table>

Case Studies

We have provided a few case studies of biomass gasification power plants in India and have tried to provide as much useful data about them as possible.
While biomass gasification based power production provides a number of benefits, especially for remote electricity needs, it is imperative that it is economically sustainable to operate. The primary cost components of a biomass gasification system comprises feedstock cost, capital costs (gasifier + gas engine + supporting equipments + land + installation) and operating expenses (including maintenance and repairs).

This chapter discusses the costs of biomass gasification based power production, along with breakups of the same and also provides analyses the total levelized costs of power production under various scenarios.

5.1 Introduction
5.2 Cost of Power Production from Renewable Energy Sources
5.3 Costs of Biomass Gasification Based Power Production
   5.3.1 Capital Costs
   5.3.2 Operating Costs
   5.3.3 Costs of Feedstock
   5.3.4 RoI and Payback Periods
   5.3.5 Incentives
   5.3.6 Levelized Cost of Electricity (LCOE)
5.4 Cash flow projections
   5.4.1 Operational Parameters Considered
   5.4.2 Revenues from the Plant
Highlights from the Chapter

- The key cost component in biomass gasification based power production is the cost of the biomass, which can have significant impact on the economic attractiveness of the operations.

- Per MW, the total capital cost for a biomass gasification plant will be about Rs 5.5 crores.

- The operational expenses (excluding cost of biomass) for a biomass gasification power plant will be about Rs 0.75 per kWh.

- The levelized cost of power from biomass gasification will be in the range of Rs 2.25-4/kWh, depending mainly on the cost of the biomass.

- Under optimal conditions, biomass gasification based power production presents a good business opportunity with attractive IRRs and payback periods.

Sample Content

Levelized Cost of Electricity (LCoE) from Primary Renewable Power Sources

Let’s consider the approximate costs of electricity generation from various sources today (in Rs/kWh)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Levelized cost of electricity production* (Rs/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal / natural gas</td>
<td>2.5</td>
</tr>
<tr>
<td>Wind</td>
<td>2.25-3.0</td>
</tr>
<tr>
<td>Biomass gasification</td>
<td>2.25-3.25</td>
</tr>
<tr>
<td>Diesel generator sets</td>
<td>12-13</td>
</tr>
<tr>
<td>Solar PV</td>
<td>11-12</td>
</tr>
<tr>
<td>Solar CSP</td>
<td>10-11</td>
</tr>
</tbody>
</table>

*: Levelized cost denotes the total cost, after taking into account all direct and indirect variable expenses such as insurance, and depreciation of capital costs. All investments assume a 70:30 debt:equity split.
Chapter - 6  Tariffs and Government Incentives

This chapter highlights the feed in tariffs, capital subsidies and the government incentives for biomass gasification and biomass power projects in general.

6.1 Introduction
6.2 Feed in Tariffs
6.3 Capital Subsidies and Incentives
6.4 Government incentives for biomass power projects in general (national level and state level)
6.5 Depreciation Benefits

Highlights from the Chapter

- Many states in India have prescribed special feed in tariffs for biomass based power, though the tariff varies from state to state – from Rs 3.5 per kWh to about Rs 5 per kWh.

- Biomass gasification power production can also avail capital subsidies and other government incentives such as accelerated depreciation.
Sample Content

Most Indian states have specified feed in tariffs for biomass power. In addition, biomass gasification power plants can also avail other financial incentives from the government. These details are dealt with in a comprehensive manner in this chapter.

Feed in Tariffs

<table>
<thead>
<tr>
<th>State</th>
<th>Tariff fixed by Commissions</th>
<th>RPO (Renewable Purchase Obligations) Specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>Rs 4.28/kWh (2010-11) (BM)</td>
<td>Min 3.75%</td>
</tr>
<tr>
<td></td>
<td>Rs 3.48/kWh (2010-110 (Co-gen)</td>
<td></td>
</tr>
<tr>
<td>Bihar</td>
<td>Rs 4.17/unit (2010-11)–BM</td>
<td>1.50%</td>
</tr>
<tr>
<td></td>
<td>Rs 4.25/unit (2010-11) – existing (Cogen)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rs 4.46/unit (2010-11) – New Cogen</td>
<td></td>
</tr>
<tr>
<td>Chhattisgarh</td>
<td>Rs 3.93/unit (2010-11) (BM)</td>
<td>5.0%</td>
</tr>
<tr>
<td>Gujarat</td>
<td>Rs 4.40/unit (With accelerated depreciation) (BM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rs 4.55/unit (Cogen) for first 10 yrs (With accelerated depreciation)</td>
<td>10.0%</td>
</tr>
<tr>
<td>Haryana</td>
<td>Rs 4.00/unit – BM</td>
<td>1.0%</td>
</tr>
<tr>
<td></td>
<td>Rs 3.74/unit (Cogen)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3% escalation (base year 2007-08)</td>
<td></td>
</tr>
<tr>
<td>Karnataka</td>
<td>Rs 4.14/unit (10th Year) (Cogen)</td>
<td>Min 10%</td>
</tr>
<tr>
<td></td>
<td>Rs 3.66 per unit (PPA signing date)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rs 4.13 (10th year) (BM)</td>
<td></td>
</tr>
<tr>
<td>Kerala</td>
<td>Rs 2.80/unit (BM) escalated at 5% for five years (2000-01)</td>
<td>3.0%</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>Rs 4.79/unit (Comm yr.) (Cogen) (I.T.)</td>
<td>6.0%</td>
</tr>
<tr>
<td></td>
<td>Rs 4.98 (I.T.) (BM) (for 2010-11)</td>
<td></td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>Rs 3.33 to 5.14 /unit paisa for 20 yrs. With escl of 3-8paise</td>
<td>10.0%</td>
</tr>
<tr>
<td>Punjab</td>
<td>Rs 5.05 /unit, (2010-11) BM</td>
<td>Min 3%</td>
</tr>
<tr>
<td></td>
<td>Rs 4.57/unit (2010-11) Cogen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Escalation at 5%-Cogen &amp; 5%-BM</td>
<td></td>
</tr>
<tr>
<td>Rajasthan</td>
<td>Rs.4.72/unit-water cooled (2010-11) &amp; Rs.5.17-air cooled(2010-11)-(BM)</td>
<td>1.75%</td>
</tr>
<tr>
<td>Tamilnadu</td>
<td>Rs.4.50-4.74/unit (2010-11) – (BM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rs.4.37-4.49/unit (2010-11)-(Cogen) (Escalation 2%)</td>
<td>13.0%</td>
</tr>
<tr>
<td>Uttaranchal</td>
<td>Rs.3.06/unit (2010-11) – BM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rs.3.12/unit (2010-11)-(Cogen) (new projects)</td>
<td>9.0%</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>Rs.4.29 / unit, for existing and 4.38 for new with escalated at 4 paise/year, base year (2006)</td>
<td>4.0%</td>
</tr>
<tr>
<td>Orissa</td>
<td>Rs.4.09/unit</td>
<td></td>
</tr>
<tr>
<td>West Bengal</td>
<td>Rs 4.36/unit fixed for 10 years-BM</td>
<td>4.0%</td>
</tr>
</tbody>
</table>

Source: http://www.mnre.gov.in/
Chapter - 7
Availability of Finance for Renewable Energy Investments

This chapter categorizes the sources of finance for renewable energy in general and biomass gasification based power projects in particular. It also provides VC / PE perspectives and opinions, and prominent investments in Indian renewable energy and clean technology.

7.1 Introduction
7.2 Sources of Finance
   7.2.1 Project Finance
   7.2.2 Asset Finance
   7.2.3 Corporate Finance
   7.2.4 Venture Capital and Private Equity
7.3 Nodal Agencies that Support Renewable Energy Financing in India
   7.3.1 IREDA
   7.3.2 Power Finance Corporation Ltd
   7.3.3 Lease Finance Scheme
   7.3.4 Debt Refinancing Scheme
   7.3.5 Asset Acquisition Scheme
   7.3.6 Rural Electrification Corporation
7.4 Other Financial Institutions that Fund RE Projects in India
7.5 Other Funding & Investment Avenues
7.6 VC / PE Perspectives and Opinions
   7.6.1 VC Perspectives
   7.6.2 PE Perspectives
7.7 Prominent Investments in Indian Renewable Energy and Clean Technology
   7.7.1 Cleantech Funds and Their Investments in India

Highlights from the Chapter

- The main financing routes for new renewable energy projects in India are project finance, asset finance, corporate finance and venture capital/private equity.

- The three main governmental bodies in the context of renewable energy funding are IREDA, Power Finance Corporation and Rural Electrification Corporation

- A number of commercial banks, venture capital and private equity firms have also started taking an interest in financing renewable energy projects, with some of them already having funded biomass based power plants, including that using biomass gasification.
Project Finance

Project Debt Financing for Renewable Energy – Highlights

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt: Equity</td>
<td>70:30</td>
</tr>
<tr>
<td>Loan Tenure</td>
<td>6-8 years (including 1 year moratorium)</td>
</tr>
<tr>
<td>Interest</td>
<td>11-11.5%</td>
</tr>
</tbody>
</table>

*Note: All details provided are only indicative in nature;*

List of Private Equity firms in India active in the Renewable Energy Sector

<table>
<thead>
<tr>
<th>Private Equity</th>
<th>Funded Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>3i Group (<a href="http://www.3i.com">http://www.3i.com</a>)</td>
<td>• GVK Power and Infrastructure</td>
</tr>
<tr>
<td>ADB (<a href="http://www.adb.org">http://www.adb.org</a>)</td>
<td>• CLP Wind Farms Private Ltd (CWFPL)</td>
</tr>
<tr>
<td></td>
<td>• Gujarat Paguthan Wind Energy</td>
</tr>
<tr>
<td></td>
<td>• A total of $7540m was invested in the energy sector (that is about 33% of the total funding) by ADB</td>
</tr>
<tr>
<td>Blackstone (<a href="http://www.blackstone.com">http://www.blackstone.com</a>)</td>
<td>• Moser Baer (solar Energy)</td>
</tr>
<tr>
<td>Barings India Private limited (<a href="http://www.bpepindia.com">http://www.bpepindia.com</a>)</td>
<td>• Auro Mira (biomass Energy)</td>
</tr>
<tr>
<td>Chrys Capital (<a href="http://www.chryscapital.com">http://www.chryscapital.com</a>)</td>
<td>• Pratibha Industries Ltd. (Water treatment company)</td>
</tr>
<tr>
<td>Green Environment Fund (<a href="http://www.globalenvironmentfund.com">http://www.globalenvironmentfund.com</a>)</td>
<td>• Greenko Group (Biomass, Hydro, Wind etc)</td>
</tr>
<tr>
<td>Shell Foundation (<a href="http://www.shellfoundation.org">http://www.shellfoundation.org</a>)</td>
<td>• Husk Power systems (Biomass based power generation)</td>
</tr>
<tr>
<td>IFC (<a href="http://www.ifc.org">www.ifc.org</a>)</td>
<td></td>
</tr>
<tr>
<td>DEG</td>
<td></td>
</tr>
</tbody>
</table>
Commercial banks and financial institutions actively involved in RE financing are given below. While there are no specific mandates for banks, organizations such as IREDA provide soft loans for renewable energy projects through certain designated banks.

<table>
<thead>
<tr>
<th>Bank</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADB</td>
<td><a href="http://www.adb.org">http://www.adb.org</a></td>
</tr>
<tr>
<td>DEG</td>
<td><a href="http://www.deginvest.de">http://www.deginvest.de</a></td>
</tr>
<tr>
<td>DBS</td>
<td><a href="http://www.dbs.com">http://www.dbs.com</a></td>
</tr>
<tr>
<td>ICICI Bank</td>
<td><a href="http://www.icicibank.com">http://www.icicibank.com</a></td>
</tr>
<tr>
<td>IDFC</td>
<td><a href="http://www.idfc.com">http://www.idfc.com</a></td>
</tr>
<tr>
<td>IFC</td>
<td><a href="http://www.ifc.org">http://www.ifc.org</a></td>
</tr>
<tr>
<td>IL&amp;FS</td>
<td><a href="http://www.ilfsindia.com">http://www.ilfsindia.com</a></td>
</tr>
<tr>
<td>IREDA</td>
<td><a href="http://www.ireda.in">http://www.ireda.in</a></td>
</tr>
<tr>
<td>PFC</td>
<td><a href="http://www.pfc.gov.in">http://www.pfc.gov.in</a></td>
</tr>
<tr>
<td>Proparco</td>
<td><a href="http://www.proparco.fr">http://www.proparco.fr</a></td>
</tr>
<tr>
<td>Rabobank</td>
<td><a href="http://www.rabobank.com">http://www.rabobank.com</a></td>
</tr>
<tr>
<td>SBI</td>
<td><a href="http://www.statebankofindia.com">http://www.statebankofindia.com</a></td>
</tr>
<tr>
<td>SBI Caps</td>
<td><a href="http://www.sbicaps.com">http://www.sbicaps.com</a></td>
</tr>
<tr>
<td>Yes Bank</td>
<td><a href="http://www.yesbank.in">http://www.yesbank.in</a></td>
</tr>
</tbody>
</table>
Chapter - 8
India’s Regulatory Framework for Renewables

This chapter familiarizes potential investors and developers with the Indian government’s regulatory framework for the renewable energy industry and provides an overview of the government bodies that handle the regulatory framework.

8.1 Introduction
8.2 Regulatory Policy Framework
8.3 Regulatory Bodies

Highlights from the Chapter

- Some of the instruments being used by India’s regulatory authorities to accelerate the adoption of renewable sources for power are: Renewable Purchase Obligations (RPO), Renewable Energy Certificates (REC), Renewable Portfolio Standards (RPS) and CDM (Clean Development Mechanism).

- The key regulatory bodies in the context of renewable power are Ministry of Power (MOP), Central Electricity Authority (CEA), Ministry of New and Renewable Energy (MNRE), State Nodal Agencies (SNA), Central Electricity Regulatory Commission (CERC) and State Load Dispatch Centers (SLDC)
Sample Content

Regulatory Policy Framework

<table>
<thead>
<tr>
<th>State</th>
<th>Date of issue of order</th>
<th>RPO (per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>27-09-2005</td>
<td>5 %</td>
</tr>
<tr>
<td>Gujarat</td>
<td>11-08-2006</td>
<td>2 %</td>
</tr>
<tr>
<td>Haryana</td>
<td>15-05-2007</td>
<td>3 - 10 %</td>
</tr>
<tr>
<td>Karnataka</td>
<td>11-02-2008</td>
<td>Min 10 %</td>
</tr>
<tr>
<td>Kerala</td>
<td>24-06-2006</td>
<td>5 %</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>11-06-2004</td>
<td>10 %</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>16-08-2006</td>
<td>3 % (annual increase of 1 %)</td>
</tr>
<tr>
<td>Orissa</td>
<td>23-04-2005</td>
<td>450MU</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>21-11-2006</td>
<td>7.5 %</td>
</tr>
<tr>
<td>Tamilnadu</td>
<td>15-05-2005</td>
<td>10 %</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>12-01-2006</td>
<td>7.5 %</td>
</tr>
<tr>
<td>West Bengal</td>
<td>04-05-2006</td>
<td>3.8 %</td>
</tr>
</tbody>
</table>

Solar: Under the National Solar Mission, the GoI has announced a policy change, which if enacted, would specify that solar specific RPO is to start with 0.25% in the 1st phase, and increase to 3% by 2022. Other sector-specific RPOs have not yet been announced.

Regulatory Bodies

Government of India (GoI)

Ministry of Power

Ministry of New and Renewable Energy (MNRE)

Central Electricity Authority (CEA)

Central Electricity Regulatory Commission (CERC)

State Governments

State Nodal Agencies (SNA)
Chapter - 9

Indian Biomass Gasification- Market Updates

There has been significant acceleration recently in India in investments and activities for biomass gasification based power production. This chapter provides the latest news and updates in India in the context of biomass based power production in general and biomass gasification in specific.

9.1 Introduction
9.2 India Biomass Gasification – Market Updates

Sample Content

Rice husk used for power in one of India’s poorest states

The government of Punjab, India, plans to produce about 1,000 MW of green energy from livestock residues by 2015, as large quantities of cattle manure became a main pollutant in the region.

In addition to livestock residues, the state generates about 21 million tons of rice stalks and similar biomass plant wastes every year, which can be used for the production of green power. The state government has plans to use renewable resources as the source of power to contribute 10% of its total energy production in the next five years.

Punjab already runs a biomethanation facility with a capacity of 1 MW, located close to Ludhiana, which uses methanogens as microbes for the manufacture of methane gas. The facility uses 235 tons of cattle wastes to generate 18,000 kWh of electricity and also produces 45 tons of organic fertilizer every day.

The Punjab Energy Development Agency has developed 318 MW of green power projects, which includes the Ludhiana plant, until today. These projects comprise 37 MW of small hydro facilities, 28 MW of biomass power facilities, 250 MW of biomass co-generation facilities and 2 MW of solar projects.

The agency is currently developing 132 MW of green power projects, which include 11 MW of hydropower, 100 MW of biomass co-generation and 20 MW of traditional biomass. If all become operational, the state will generate 700 MW of green power by 2012. Sukhbir Singh Badal, the deputy chief minister of the state stated that the planters are getting an income of about RS. 4,000 per acre every year by marketing agro wastes to biomass facilities.
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- Cleantech Funds and Their Investments in India

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- Downdraft Gasifier
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- Regulatory Bodies
To Purchase the Biomass Gasification Based Power Production in India Report.....

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Nungambakkam
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Ph: 044-42027144

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600034, Tamilnadu, India
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