One size does not fit all: Different types of biomass power plants in India

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Abstract

India faces several challenges on the energy front. Growing economy and increasing energy demand continue to drive fossil fuel imports in India. Increasing energy demand and rising fossil fuel consumption have contributed to India being one of the largest emitters of greenhouse gases (GHG) in the world. Rising emissions of GHG have several climate change and sustainable development implications for India. Besides these, access to electricity and clean cooking fuel continues to remain a market and policy challenge in India. These energy security, climate change, sustainable development, and energy access concerns have been the drivers behind Indian government past and continued push to different renewable sources of energy for various centralized and decentralized applications. Biomass is one of those renewable sources of energy that continue to be promoted by governments at various levels in India.

Biomass plants of different capacities, having different operating and business models, and using different types of fuels are operational for both grid-connected and off-grid applications across several states in India. Past literature on biomass power plants in India has identified multiple technological, supply chain, policies, and market related issues. However, most of the existing literature has considered biomass to be a single entity and considered all biomass power plants as similar, paying little attention to the differences that exist because of differences in location of biomass plants, scale of plant, different operating and business models, and using different types of fuels. These differences, in many cases, can account for the varying success rates of biomass power plants in India. In this paper, we focus on the differences in biomass power plants arising because of scale of plant, number and type of biomass fuel used, differences in operating and business models, and differences in connectivity to local or national grid. This is one of the first of its kind study of different types of, and not just different, biomass power plants in India.

Using a case study approach, I consider case studies of four different types of biomass plants in India and carry out an in-depth analysis of the similarities and differences that exist in the four plants. Data from four biomass power plants, that differ on more than one parameters, were collected from visits to the site and interviews with employees and managers of the plants. Two plants are located in the state of Andhra Pradesh and one each in the state of Rajasthan and Bihar. Three plants were connected to the grid and had capacities over between 5-8 MW, while one plant was off-grid plant and had capacity under 1 MW. Of the three grid connected plants, two were selling to the state electricity utility while one was using open access to sell power directly to end consumer. Two plants used majorly one biomass fuel while the other two plants used multiple biomass fuels. The different geographical locations of the four plants help in the assessment of role of state level policies on the biomass power sector. The analysis throws up several interesting insights, some of which have not been reported in literature so far. For example, demand of biomass for alternative uses in local markets and level of trust between the biomass power plant and local farming community emerges as a key factor that could help explain continuity in supply chain of biomass fuel for biomass power plants. The insights from the study will be useful for policy makers, regulators, biomass power developers, investors, and researchers.

Keywords: biomass power plants, decentralized, centralized, case-study approach

1.0 Introduction

India has been one of the fastest growing large economies in the world for last two decades. The economic growth has been paralleled by the growth in energy demand. India's energy mix is dominated by fossil fuels, mainly oil and coal, and the growing economy and increasing energy demand continue to drive fossil fuel imports in India. Increasing energy demand and rising fossil fuel consumption have contributed to India being one of the largest emitters of greenhouse gases (GHG) in the world.

Rising emissions of GHG have several climate change and sustainable development implications for India. Besides these, access to electricity and clean cooking fuel continues to remain a market and policy challenge in India. These energy security, climate change, sustainable development, and energy access concerns have been the drivers behind Indian government's past and continued push to different renewable sources of energy for various centralized and decentralized applications. India introduced the National Action Plan for Climate Change (NAPCC) in 2008 and various national missions and programs have been launched as part of it including programs for energy efficiency, afforestation, and renewable energy. One of the renewable energy sources that have bene promoted by governments at various levels in India, both before and after NAPCC is biomass.

Biomass plants of different capacities, having different operating and business models, and using different types of fuels are operational for both grid-connected and off-grid applications across several states in India. Past literature on biomass power plants in India has identified multiple technological, supply chain, policies, and market related issues [1]. However, most of the existing literature has adopted a macro approach, considered biomass to be a single entity and all biomass power plants as similar, paying little attention to the differences that exist because of differences in location of biomass plants, scale of plant, different operating and business models, and using different types of fuels. These differences, in many cases, can account for the varying success rates of biomass power plants in India. In this paper, we focus on the differences in biomass power plants arising because of scale of plant, number and type of biomass fuel used, differences in operating and business models, and differences in connectivity to local or national grid. This is one of the first of its kind study of different types of, and not just different, biomass power plants in India.

Using a case study method approach, we study four different types of biomass plants in India and carry out an in-depth analysis of the similarities and differences that exist in the four plants. Specifically we aim to understand *how* and *why* biomass power plants differ from or are similar to each other. As a methodological approach, qualitative case study methodology has been used extensively by researchers from various disciplines to answer questions related to *how* and *why* of a phenomenon particularly when the focus is on contemporary phenomenon with real-life context [2–4]. Data were four biomass power plants, that differ on more than one parameters, were collected from visits to the site and interviews with employees and managers of the plants. Two plants are located in the state of Rajasthan and one each in the state of Telangana and Bihar. Three plants were connected to the grid and had capacities over between 5-8 MW, while one plant was off-grid plant and had capacity under 1 MW. Of the three grid connected plants, two were selling to the state electricity utility while one was using open access to sell power directly to end consumer. Two plants used majorly one biomass fuel while the other two plants used multiple biomass fuels. The different geographical locations of the four plants help in the assessment of role of state level policies on the biomass power sector. The names and exact locations of the biomass plants have not been disclosed owing to requests by those interviewed. However the details can be shared with the reader on an individual basis. For the sake of simplicity the plants have been referred to as A, B, C, and D with their locations as L1, L2, L3, and L4. The four case studies are described in detail one after other followed by a section on discussion and conclusion.

2.0 Case studies of biomass plants

The details of the four biomass plants are described in this section. Details include those on background of the promoters of the plant, operations of the plant, fuel sourcing and requirements, and the business model of the plants.

2.1 Case Study 1: Plant A in location L1

Plant A is a part of a large business group A1 with interests primarily in the real estate and cement sectors in the state of Andhra Pradesh in south India. Hyderabad has witnessed a massive economic growth since 1990s and the business group of Plant A has been in the forefront of real estate projects during this while. At the time of visit, the business group's all previous projects put together occupy more than 30 lakh sqft. of built up area.

The biomass plant is located on a 8 acre plot in an industrial area outside Hyderabad The plant was originally started by a fertilizer company as a 20 MW power plant and used Naptha and other industrial wastes as its fuel. But due to problems in prices and availability of Naptha, the fertilizer company first decided to shift the plant during late 1990s and then to shut it down when it encountered difficulties in transferring the equipment. At this moment, A1 business group entered into discussions with the fertilizer company and then later purchased the plant from them. A1 business group then made some modifications to the existing plant and boiler and converted the plant into a 9 MW biomass power plant. The plant, in its new version, started its operations from 2002.
The plant began its operation by using wood and saw dust initially as its major fuels along with rice husk. But due to issues in supply and availability of wood, and the ban imposed by the state government on the usage of wood and wooden products in biomass plants, the company stopped using wood after some time. Since then, the company started using rice husk, corn cobs, bagasse, seed rejects, groundnut shells, and poultry feed as its major fuels. In the last financial year 2010-2011, the company used a total of 22 different types of fuel for its plant.
As per the calculations of the company, groundnut shells have the maximum calorific value (3500 kcal/kg), followed closely by corn cobs (3400 kcal/kg), rice husk (3300 kcal/kg), and bagasse (3300 kcal/kg). The company dries the biomass in sun before using it, as it believes drying improves the calorific value by reducing the moisture content. It is for this reason that a vast portion of storage area within the plant premises is kept open.

Though the installed capacity of the plant is 9MW, the company is operating it at 8 MW. This is because the state government's licence allows it to use up to 8 MW. Due to this fact, as soon as the total power exported to the grid crosses the mentioned rating, the Company shuts down the plant. This generally happens after 25th-26th day in a month. The Company uses the spare days it gets for the regular maintenance of the plant and its equipment. The Company also carries out an annual maintenance during late October-early November period.
The boiler used in the plant has a rating of 40 tonnes per hour (TPH), and the pressure inside the boiler is maintained in the range of 35-45 kg/cm^2, with a upper cut-off limit of 47.5 kg/cm^2. Temperature inside the boiler is maintained in the range of 450^o-470^o C. Fuel is mixed with the help of dozers in order to maintain average GCV of input fuel. For its water requirements, the company has obtained permission from the state water board, and has laid pipelines to a nearby river. The company uses an average of 20 Kilo-liters (KL) of water per day, and the average cost of water is Rs 35/KL (1 USD = Rs 56 at the time of plant visit) .
The average daily ash generation from the plant is around 80-100 tonnes. The company sells this ash to local brick manufacturers. The auxiliary consumption of the plant is close to 800 kW, or close to 10% of the rated capacity. There are around 70 employees in the plant, of which only 15 are regular employees, others being employed on contract or daily basis.

The business model of the firm has been depicted graphically in Fig 1.

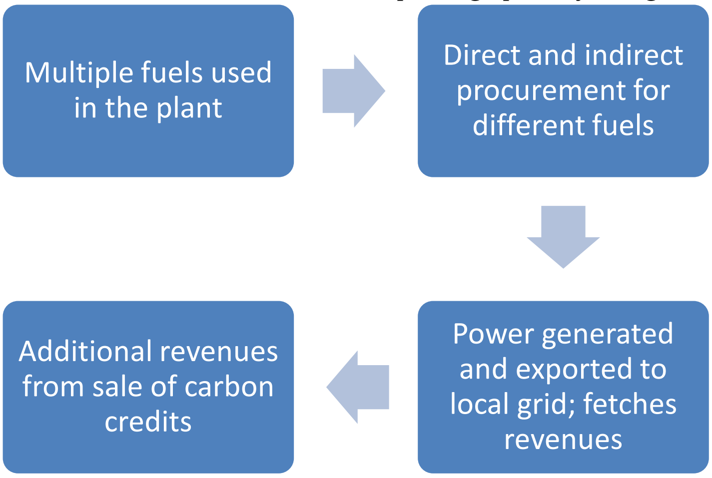

Fig 1 The business model of the biomass plant A

The Company uses multiple fuels for its plant and uses combination of direct and indirect procurements for sourcing. Power generated from the plant is exported to local grid and revenues obtained from this selling. CDM and carbon credits provide alternate mode of revenues for the firm.

Since the company uses may types of fuels, it uses multiple sourcing mechanisms for the procurement of fuel. Rice husk is obtained from traders and rice mills. Bagasse is obtained from the sugar mills. Andhra Pradesh is also a leading player in sugarcane and this helps in easy availability of bagasse from the sugar mills in the state. Groundnut shells and corn cobs are sourced from mills and oil mills. Poultry feed is obtained directly from local hatcheries. During the harvesting season, the company is able to procure its fuel within a 50 KM radius from the plant, but during lean season, the company has to increase the radius to 80 KM.

The average daily consumption of fuel is around 300-325 tonnes. The company has a storage capacity of around 3000 tonnes of biomass within the plant premises. There is a weigh-bridge within the plant which weighs the incoming trucks and lorries and then unloads the fuel. The landed cost of rice husk comes to be around Rs 2,400 per tonne. This is significantly higher than Rs 600-800 which the company had to pay around 2003. The company blames the presence of small number of traders who act as middlemen between the rice mills and the biomass industry. The company also cites the dispersed presence of small road-side eateries (*dhabas*) and brick kilns, which have started using rice husk, as factors behind the sharp rise in rice husk prices.

The Company is not yet listed on the stock exchange and uses internal generated funds along with debt for its operations. The initial acquisition and modification of the plant in early 2000s cost the company close to Rs 300 million. Since then the Company had invested additional Rs 300 million in the plant. For its export of power, the Company has entered into a power-purchase agreement (PPA) with the state electrical transmission company. The Company exports it power at a price of Rs 3.7 per kWh (kilo watt hours, unit of measuring generated electricity). The prices have been revised by the state government several times in the last ten years. When the Company first started exporting its power, it did so at a price of Rs 3.30 per kWh. The state government then revised the prices downwards to Rs 2.7 per kWh, which led to strong protests from the biomass industry in the state. Subsequent to that, the state government increased the prices and follows presently a different slab structure for biomass plants. The slab structure classifies biomass plants according to the installation year and has separate prices for different slabs. The plant is also registered as under CDM, and gets close to 40,000 CERs per annum. The audit for the present year had just been completed by external auditor couple of days before the visit to the plant. Though the Company declined to give an estimate of the operating cost, but it was mentioned that if one considers the CERs, the plant is able to make a profit of close to Rs 5 million per annum.

2.2 Case Study 2: Plant B in location L2

Plant B is a owned by company B1, a private limited firm based in Jaipur in the state of Rajasthan and promoted by a business group with interests primarily in the telecom, software development, and agriculture sectors. B1 set up a separate company as a special purpose vehicle for development of renewable energy projects. The Company has set up a 12 MW biomass plant in a district 600 KMs from the state capital Jaipur. The Company has also signed various MoUs with the Government of Rajasthan to set multiple other biomass plants in Rajasthan. The Company has also recently engaged in talks with the state governments of Madhya Pradesh, Himachal Pradesh, and Gujarat for expansion. The Company is also considering foraying into Solar Power sector.

The Biomass power plant was commissioned in September 2010. The plant is situated on a large plot of 40 *beeghas*, (roughly equivalent to 1,00,000 square meters). The land has been leased to the Company by Rajasthan Government. The plant uses a hard shrub Juliflora (called *Vilayati Babool* in local language) as its main fuel for the plant. The plant also uses mustard husk, jeera husk and small quantities of *chana* husk (chick pea husk), moong husk, and rice husk for its plant. Rajasthan is a dry state, with vast parts covered by deserts. Therefore crops which require large amount of water to grow, like rice and wheat, are not grown in most parts of the state, except in districts bordering Punjab in the north. Juliflora is a thorny crop and requires very less water to grow. As such it is found in abundance in Rajasthan. Because of its bitter taste and thorns, Juliflora is neither eaten by animals, nor used by humans, except for burning purposes in some parts of the state. Juliflora also makes the land infertile. Owing to these properties, Juliflora is a menace for both humans and animals alike.

There are large forests of Juliflora in L2 district. In the early 2000s, the government of Rajasthan decided to uproot these forests and invited applications from interested players. B1 then submitted its proposal to the Government about the power plant, after which the Government gave B1 permission to set the biomass plant and use Juliflora from the forests in L2 district.

The daily average consumption of biomass is between 320 to 350 tonnes. Biomass is kept in two storage spaces, one inside the plant premises, one outside the plant premises. Juliflora uprooted from forests is cut and chipped into pieces of 3-4 mm size before feeding it into the boiler. All the machinery, equipment and boilers used in the plant are indigenously sourced. The GCV of fuels used in this plant are on the higher side compared to some of the other biomass plants in the country. Mustard Husk has a GCV of 3,700 Kcal/Kg, while Jeers Husk has a GCV in the range of 3,700-3,750 Kcal/Kg. The GCV of Juliflora is slightly lower at 3,400 Kcal/Kg.

The Company has had to invest heavily in water treatment plans. Though water is available at a depth of only 5 meters from the ground level, but the water is saline. Salt content is very high in the water, perhaps because of the proximity to the arid Rann of Kutch. The Company has therefore installed a Reverse Osmosis plant (RO) for desalination of water. According to the Company, this RO plant is different from the other RO plants because of the number and size of membranes used for desalination.

There are 80 employees on roll of the special purpose vehicle working in the plant. Besides the permanent employees, the Company also employs around 20 workers on daily wages. They are mainly involved in the cutting and chipping of Juliflora. These daily wages workers are genrally migrants who come from Bihar, Odisha, and Uttar Pradesh. Of late the Company has been facing difficulty in hiring their services. The Company attributes this to the decline in number of migrants who come from Bihar, Odisha, and Uttar Pradesh in the last couple of years. Though they could not say with certainty the reasons behind this decline in general, they were of the opinion that NREGS (National Rural Employment Guarantee Scheme), a flagship program of the Indian government that assures assured income to people from rural areas, might have resulted in workers remaining in their states and not moving out of there. To substantiate their point they provided examples of having increased wages in the recent times and the practice of reimbursing transportation expenses from their home states, something which some other industries using migrant workers in Rajasthan generally do not indulge in. But even that had not proved completely effective.

Maintenance requirement for the plant have been relatively high so far. The Company attributes this to the fact that it tries to use different fuel mix for the boiler because of which it needs to shutdown boiler for maintenance on a more frequent basis. The Company hopes that maintenance will come down this fiscal year. The auxiliary consumption in the plant is in the range of 8%, and the Company has set a target of bringing it down to 6% in the near future.

The business model of the Company is shown graphically below in Fig 2:

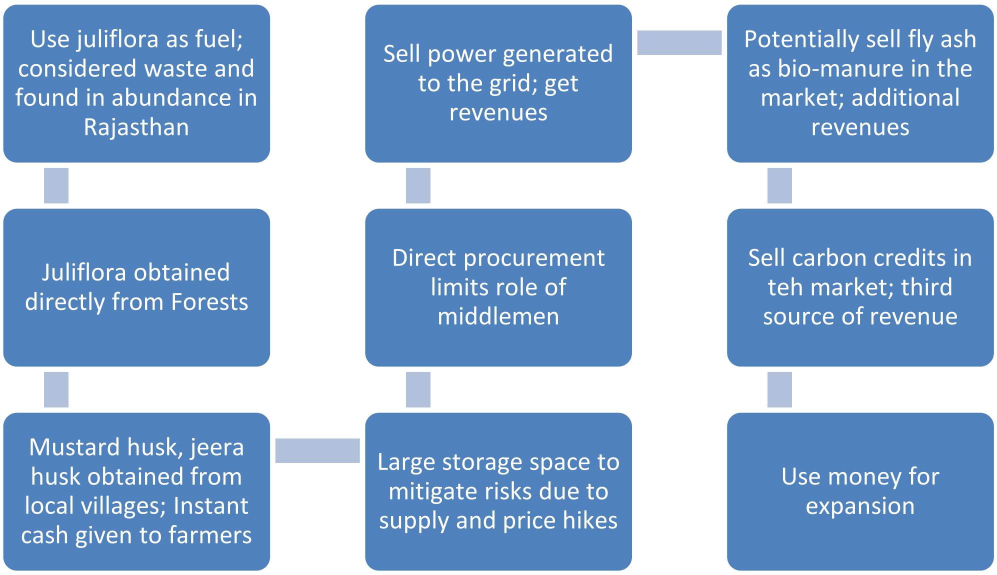

Fig 2 Business model of Plant B

The Company uses Juliflora as a fuel, which is not only considered waste but also found in abundance in Rajasthan. The Company procures it directly from forests, which allows no scope for middlemen in the supply chain. This helps Company to mitigate risks due to supply and price hikes. Similar method followed for procurement of jeera and mustard husks. Provision for instant cash gives an incentive to the farmer to sell husk directly to the Company. The Company has also built large storages to act as cushion when supply of biomass is hampered due to some reasons. The Company gets its revenues from multiple sources. It sells power to the grid and generates revenue. It will also start selling carbon credits this year onwards which will fetch additional revenues. The Company is also collaborating with a University to start selling fly ash generated as bio-manure in the market. This could be a third source of revenue for the firm.

The Company gets Juliflora directly from forests managed by the Government. The following steps describe the supply chain of Juliflora:

1) Company vehicles (tractors, trolleys) go daily into the forests.
2) Forest Officials verify the documents and allow them to enter into the forests.
3) The shrub is uprooted and kept in the vehicles. One important thing to note here is that uprooting is necessary and mere cutting of shrub would not do. Forest officials check this aspect while uprooting is going on.
4) The uprooted shrub is weighed and then the vehicle is allowed to move out of the forests.
5) The incoming vehicle is again weighed while entering the plant premises. This is done to ensure that the two weights tally.
6) The incoming fuel is then either sent to the storage inside plant premises, or is sent to the outside storage.

The Company has to pay penalty to the Forest Department if it does not completely uproot the plant. Penalty is also imposed on the Company if the uprooted plants are not transported out of forests within 3 days.
One important thing to note here is that the uprooting of plant inside the forest is not allowed during the 4 months period between June and September (Monsoons). The ban for four months is done for the breeding of julifora. Juliflora grows very rapidly, and these four months allow new saplings to grow. It is also perhaps because of this restriction on sourcing juliflora for four month that the Company has built two moderate-to-large storage spaces for its biomass. The storage space located inside the plant has a capacity of storing upto 12,000 tonnes of juliflora, roughly equivalent to requirements for 34 days. The storage space located outside the plant has a capacity to store up to 25,000 tonnes of juliflora, roughly equivalent to requirements for 72 days. In total, the storage space can store biomass for around 105 days of use, roughly the same time for which it is not allowed to go inside the forests.

While building the plant, the Company had thought of having two storage spaces mainly for storing large amount of biomass to ensure adequate biomass availability. But during construction in April 2009, there was a massive fire in one of the storage space inside the plant. Transmission lines of one of the 11 kV towers came in touch with one of the incoming trucks filled with with juliflora, after the truck rammed into one of the electric poles. This resulted in a massive fire which destroyed entire juliflora stored inside the plant. This incident then forced Company to build a large space outside the plant. Most of the storage space is now covered, so as to protect it from rains.

For mustard husk, the Company has got in touch with farmers in the nearby districts and informed them about their requirements. The Company uses cash payment to bring more farmers in its folds. Farmers bring mustard husk to the plant premises, where after deducting for moisture content, instant payment is made to the farmers. Sourcing for rice husk and jeers husk also follow the pattern of mustard husk, with only difference being the place of sourcing. Rice husk generally comes from neighbouring states like Uttar Pradesh and Haryana. Rice traders are often involved in the sourcing and they transport rice husk in trucks and lorries. Jeers husk is available in Rajasthan itself, but often it comes from districts located far off from L2.

The landed price of Julflora comes to around Rs 2,000 per tonne. The prices for other husks vary in the range of Rs 1,600 to Rs 2,000 per tonne. Prices of mustard and jeera husk have increased sharply in the last 24 months by two times. The Company attributes this to the presence of other plants using mustard and jeers husk for their biomass plants. The Company invested close to Rs 600 million as initial investment for the plant. The invested amount was funded partly through debts from public sectors banks, and partly through owner’s fund.
The Company tried to raise loan through couple of private banks for its biomass plant but was disappointed in raising loans. Accordingly the Company raised loans through public sector banks. The Company official however could not comment on the loan raised and expressed his ignorance on the subject. The Company also plans to go public in the near future for expansion.

The Company exports its power to Rajasthan Electricity Board via Grid Sub Station. The Company has signed a 15 year pre purchase agreement (PPA) with the Rajasthan Electricity Board for this. At present, the Company exports its power at the rate of Rs 4.53 per unit. There are escalation clauses in the agreement and rates will be hiked accordingly in future. The approximate cost of generation is around Rs 4.10 per unit, amounting to a profit of around 40 paise per unit. The plant is a CDM approved plant but it is yet to receive any money through this channel. The Company expects to get carbon credits and then trade it subsequently later this year.

The Company is also working with a local non-governmental organization (NGO) involved in providing education to children in nearby places. B is also working with the NGO to educate farmers about the potential benefits jeera husk and mustard husk can bring to them. The Company has also formed panchayat level committees in villages for interaction with farmers. The NGO provides B an opportunity to reach out to a large number of places and spread awareness about its work.

The Company has cited Biomass investor friendly policies of Rajasthan Government as one of the reasons for its successful operations so far and plans for further expansion in Rajasthan. According to the Company, Rajasthan Government follows a policy of exclusivity, where it does not allow another biomass plant within a range of 80 KMs from an already existing plant with capacity less than or equal to 5 MW. In case the capacity of plant is more than 5 MW, the exclusivity range increases to 100 KMs. The Company believes that this will ensure that it does not have to competition from other players in sourcing of biomass and that enough biomass is available for its consumption and potential future expansion.

The fire accident very early in the construction of the plant has made Company take extra precautions for its plant. The Company checks every incoming vehicle and person for inflammable substances, cigarettes, matches, explosives, and sharp objects. The Company has also installed multiple fire hoses, fire hydrants, and fire extinguishers inside the plant. The Company is also contemplating shifting its entire storage area outside the plant to minimize damages to plant and machinery in case of any accidents. The Company plans to store only 500 tonnes of fuel inside the plant and store the rest in the other storage space.

The ash obtained from the boiler is used primarily for land filling as of now. The Company has sent fly ash to laboratories and the University at Deesa for analyses to determine its suitability for use as bio-manure. The Company is also considering using small quantities of coal for its plant. The Company can use up to 15% of its annual fuel requirements as coal, and the Company is exploring options of purchasing Coal from different sources.

2.3 Case Study 3: Plant C in location L3

Plant C is promoted by an infrastructure development company that specializes in construction and operations of power plants. The Company focuses on the development of small and medium gas, hydro, biomass, and coal power projects across different states in India. The Company has had two rounds of private equity infusion in 2007 and 2009. While in the first round the company raised Rs 290 Crores from Citigroup Venture and UTI Venture, it raised additional Rs 425 Crores in 2009 from Citigroup Venture Capital, Sequoia Capital, and Bessemer Venture Partners in the second phase. The Company operates four biomass power plants in the states of Tamilnadu, Maharashtra, and Andhra Pradesh (Miryalguda). The installed capacities of the plant vary from 6 MW to 20 MW. Plant C, spread over 7.47 acres of land, has a capacity of 6 MW. Plant C is the oldest plant of the Group and commenced its operations from October 2000.

Plant C uses a mix of fuel for its plant, rice husk, juli-flora, cotton cobs, coconut pieces, chilly stalks, and waste wood. The average daily consumption of fuel is around 220 tonnes. The plant has adequate storage capacity within the plant premises, and can store upto 3000 tonnes of biomass. There is one steam turbine generator and one boiler installed in the plant. While the turbine is sourced from a European manufacturer, the generator and the boiler have been sourced locally. The rating of the boiler is 35 TPH, and the corresponding Pressure and Temperature ratings are 45 Kg/cm^2, and 480º C respectively. The height of the chimney is around 75 feet from ground level.

Another distinguishing feature of this plant, different from the other three plants described in this paper, is that the plant is allowed to undertake third party sales. One reason for this could be the fact that the Company entered into a power wheeling and purchase agreement with the state electricity board in 1999, when it was among the first companies to enter into such a contract. The Company has to pay a wheeling charge of 2% to the state board for transmission and distribution of power to the consumers. The tariffs for such sales are based on High Tension (HT) tariffs which are determined by the local regulatory bodies. The income and cost details for the previous years have been provided later in this report. Regular maintenance is carried out two days in a month. Annual maintenance, carried out during October-November period, generally lasts 15 days.
The business model for the plan has been depicted in Fig 3.

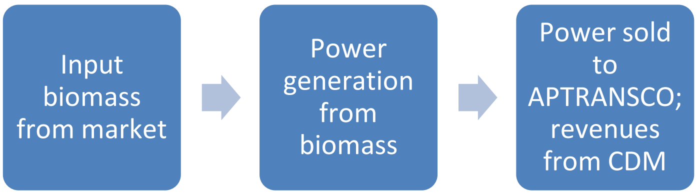

Fig 3: The business model of Plant C

Biomass is purchased from the rice mills, rice traders, or directly from villages (market). This biomass is then fed to the boiler, where steam is generated after combustion. This steam drives the turbine and power is generated. The power generated is then sold to the state transmission company APTRANSCO (Andhra Pradesh Transmission Company) to fetch revenues for the plant. The Company gets additional revenues by selling carbon credits earned in the process.

The plant gets its rice husk from local rice mills and other traders. There are around 200 rice mills in L3 district which helps the Company in sourcing and bargaining from the suppliers. This is also represented in the price of rice husk, which despite having increased in the recent years, is still lower than the other biomass plants covered during the study. The price of rice husk varies within a range of Rs 1, 600- Rs 2,000 per tonne, and at the time of visit to the plant, it was Rs 1,750 per tonne. The price is decided by the Company and is updated every fortnightly. Waste wood is obtained directly by the Company. Purchasing persons go to villages to purchases waste wood. The coal for the plant, when needed, is procured from the spot market. The plant can use up to 20% of annual requirements of fuel as coal and still qualify for benefits meant for biomass power plants according to the existing provisions of the state government.

The plant requires around 450 tonnes of water per day, which it gets from a nearby river. The Company has a licence to draw up to 1200 tonnes of water per day and it has laid pipelines from the river to its plant. It has also built a small reservoir in the plant premises which is also used for fishing (internal consumption only). The total costs incurred in water in the previous years have been less than Rs 100,000 per annum.

Plant C was financed through debt and funded through equity contributions from the Company and its shareholders. Land for the plant was acquired at a cost of Rs 2.14 million. One noticeable feature of the plant is that it does not have any outstanding term loan at the time of visiting the plant. All the debt taken for the plant has been fully repaid. The fact that the plant has been able to repay its debt completely could be construed as an indicator of the sound financial performance of the plant. All the four plants of the Company are registered as CDM projects. The CERs obtained by the four plants are aggregated and the Company sells them in the market regularly.

Tractors (Capacity: 5-6 tonnes), and lorries (Capacity: 10-12 tonnes) are the preferred mode of transportation by the suppliers for biomass. On being asked about the comparisons between the coal and biomass plants of the Company, one Company official cited the variation in calorific value of biomass as a major problem. GCV of coal is fairly constant and accordingly designing of boiler is easy. It is also easy to set the temperature and pressure ratings and frequent manual monitoring is not required. This is one of the reasons why the Company has installed automation system in the coal plant. In case of biomass, there is large variation in the GCV of different fuels uses. There is also variation across months, with GCV dipping down during monsoons. Accordingly automation of biomass plants is difficult. There are also problems in fuel handling. Problems of adulteration in biomass (sand, soil) also surfaces occasionally. Maintenance expenses are however same for both types of plants, though per MW maintenance cost of biomass plant is slightly higher than that of coal plants.
There are around 65 employees in the plant including regular employees. The wages for daily-wages labour is in the range of Rs 130-150 per day.

2.4 Case Study 4: Plant D in location L4

Plant D, with a capacity of 32 kW, is one of the several small biomass plants set up in Bihar by its promoter company. Unlike the other three biomass power plants discussed above, this plant is not connected to the grid (off-grid) and distributes generated electricity directly to the consumers in the village through a micro-grid set up by the plant. The promoter company has been funded by leading venture capital firms besides global, private and national financial institutions. The firm was started in 2007 by a team of three students from University of Virginia. The first plant was started as an experiment on August 15, 2007 in a village in West Champaran district of the state. The village was the native place of one of the owners of the firm and prior to the setting up of the plant, the village did not have any electricity distribution line coming to the village.

At the time of visit to the plant, the company had set up 64 small biomass power plants in the state. Close to three fourth of their biomass plants were located in the western part of the state. There are three major reasons for this. First, rice is one of the major crops in the north-western parts of Bihar where the two districts are located. It ensures easy and cheap availability of rice husk. Second, there is no alternate use of rice husk in the region, which ensures that the firm does not face competition for rice husk from other players. The third reason is that these two districts have traditionally been very backward on most indicators, electricity being one of them. There are no electrical lines, even today, in many parts of these districts. The locals have to rely on diesel generators for electricity, that too generally in the evenings. This electricity demand-supply mismatch also contributed to firm expanding in the two districts.

The plant visited was located in a village about 25 KMs from the nearest city. It was started on 5th May 2010 and was being looked after by a person who claimed to be a relative of one of the co-founders of the company. The plant is located on a plot with area approximately 2800 square feet. The location of the plant in the village is chosen such so that it is easy to distribute power to consumers within a range of 2 KMs.

The plant is supplies generated power to 500 households or small shops. For the power distribution, the company has set up a small grid in the village through which it distributes the generated power to consumers. Unlike the other 3 plants discussed in this paper, this biomass plant does not operate continuously in a day and rather operates for only a few hours. In the summer season, the plant operates for 6 hours (6:30 PM to 12:30 PM) and in the winters it operates from 5 PM to 11 PM. The rationale for choosing these hours is that the maximum is that those hours witness the peak load and the demand for electricity is the highest in the day during those hours. In villages of Bihar where the supply of electricity is erratic or which do not access to electricity, it is common to observe power being supplied by diesel generators during evening hours. During evening hours electricity is mainly used for lighting purposes and allows economic activities (e.g. shops, flour mills) to continue operations.

The following steps describe the running operation of the plant in brief:

1) Rice husk is fed in a fed in a cylindrical gasifier at a high temperature.
2) The high temperature maintained causes rice husk to release ‘Producer Gas’, a combustible gas.
3) The gas is then filtered and taken through pipes to a converted Diesel Engine. The Company has got Diesel Engines, used in Diesel Generators, modified to make it suitable for use with gas.
4) The gas is ignited and burnt inside the engine. The rotary motion generated by the engine is used to generate electricity in the Alternator attached to the engine. The electricity thus generated is then distributed in the village.

Fig 4 below shows graphically the steps involved in the operations of plant:

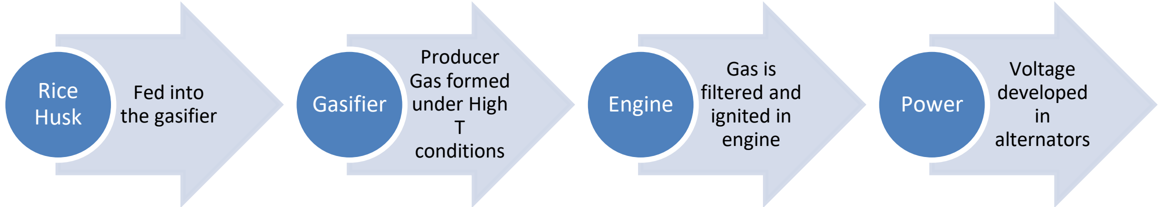

Fig 4 The plant operation

The gasification process is described in detail below:

1) The cylindrical gasifier is made up of cast iron, with inside layering of cement to withstand high temperatures.
2) There is a 'hopper' on top of the gasifier which vibrates periodically to allow the husk to be fed from top at a controlled rate.
3) Rice husk is kept in oxygen less environment at high temperature. This ensures that the husk does not burn completely but instead release Producer Gas, a combustible gas.
4) The gas, thus formed, needs to be continuously pulled out of the gasifier by suction. When the generator is loaded, the 4-stroke action of the piston provides the necessary suction force. But during the start-up of gasifier, a venture system is employed to suck gas. Water is pumped through nozzles, which pulls the gas through an outlet pipe.
5) The gas coming out of the outlet pipe contains some impurities, chief being tar. Accordingly, a series of filters is used to clean the gas. The filters are boxes filled with rice husk char and rice husk itself. The gas is cleaned and dried in these filters before being sent to the engine.
6) There is a separate mechanism at the bottom of the gasifier to remove the rice husk char by pumping water.

The electricity generation and distribution processes are described in detail below:

1) The engine use is a 4-stroke internal combustion engine (ICE). The engine used at the plant was of Kirloskar make.
2) The generators used at plants have a rating of 32 kW.
3) Power is supplied to a 2 KM radius around the plant in a 3-phase voltage supply. Bamboo poles are used as poles to set up the distribution network. Three wires coming out of the engine, carrying the three phases are taken by these poles in different directions.
4) There are fuses installed in the system to limit the use of power by customers beyond their agreed limit.

There are 3 more employees in the firm: one husk loader, one electrician, and one collector. The husk loader loads the husk in the plant and looks after the engine also. The collector is responsible for collecting money/bills from the consumers. The electrician looks after the maintenance of distribution lines and also looks after customer complaints.

The business model of the plant has been graphically described in Fig 5 below.

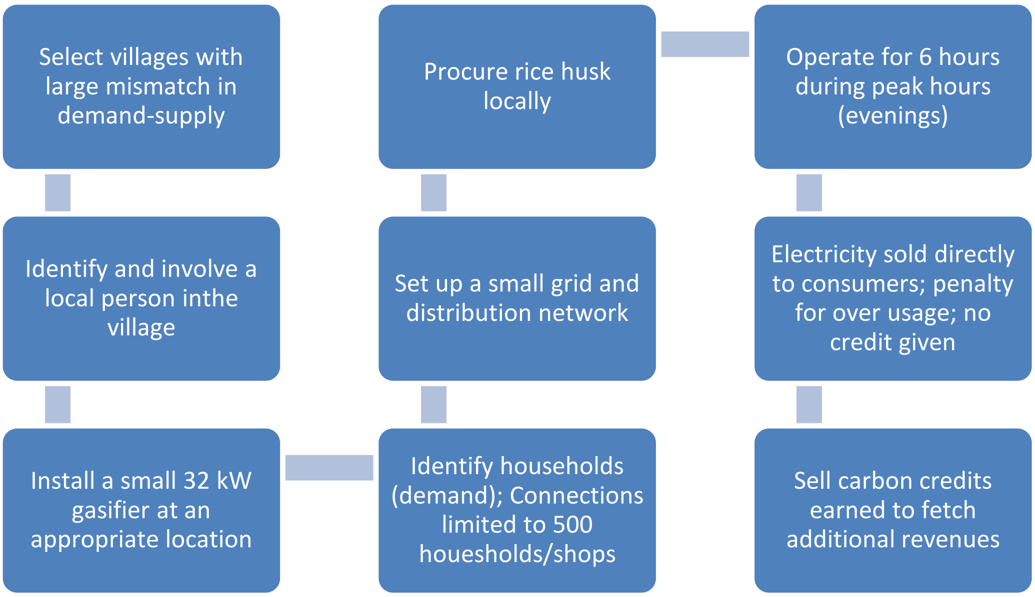

Fig 5 Business Model of Husk Power Systems

The Company first identifies villages with large demand but erratic or no supply. Then the Company identifies a local person from the village and tries to involve him. The small 32 kW gasifier is then installed at an appropriate location, such that it is easy and economical to provide connection to consumers. Number of connections is limited to 500, with minimum load being 30 W. The Company then sets up a small grid and distribution network using bamboo poles. Rice husk is procured locally and the plant operates for 6 hours during evenings; the peak hours. Billing has to be prompt with no credit given to consumers. There is a penalty to

prevent thefts and over usage. The Company also sells carbon credits to fetch additional revenues. The revenues earned is then distributed as salary to the plant employees, and a part goes to the Company.
The Company uses close to 300 Kgs of rice husk daily and generates around 75 Kgs of ash daily. The Company earlier used to get its rice husk from neighbouring villages in the adjoining district, but stopped it once prices of rice husk started proving high for the plant. Thought there aren't any biomass plants in the nearby villages, but according to the plant operator, the husk is being sold at a higher price (at Rs 4/Kg) and transported to industries in Meerut district in north India where it is used to make lubricants and rice bran oil. The plant has adopted a innovative strategy to source its rice husk. Trucks carrying fishes from Andhra Pradesh come regularly to the nearest city and other districts of Bihar. These trucks use rice husk as a packaging material or a covering material for the fishes. Since rice husk is available in abundance in Andhra Pradesh, and is also relatively cheaper there, and that explains for it being used as a packaging material. Besides, rice husk absorbs very less water, and this also makes it as a good packaging material. While unloading the fishes in city market, the husk is discarded away. The plant sends its vehicles to the markets, which collect the husk early in the morning around 2 AM and bring it to the plant. The landed cost of rice husk is around Rs 2/Kg. This price is also an indicator of the prices of rice husk in Andhra Pradesh, estimated to be around Rs 1-1.5 /Kg. There is a covered storage space inside the plant, used for storing husk. The ash generated is also used in an innovative way. The ash is taken away by one incense sticks making firm based in Gaya district of Bihar.

The land for the plant has been taken on a 10 year lease by the company from the land owner who in turn is a relative of the plant operator. The rental rate is fixed at Rs 4000 per month, with a clause for 10% escalation every 3 years. The equipment in the plant are owned by the company which pays a monthly salary to the operator and three other employees employed by the plant in the village. Though the exact details of salaries was not shared, the salaries of operator and technician was said to be in the range of Rs 2000-4000 per month. The plant operator gets around Rs 9000 per month as his salary.

A customer can get a connection for a minimum of 30 W load. There is no upper limit for load prescribed by the Company, but the maximum connected load in the village visited was around 700 kW. A customer can only use 2 CFLs of rating 15 W each in case of 30 W load. Other loads are not permitted for the 30 W connections. In case of consumers with higher ratings, the Company gives them the flexibility to use it for other electrical purposes, but not for running water pumps. The monthly charge for 30 W load is Rs 80. There is an alternate model of plant which the Company has started since last year. In this model, local persons from villages are invited to invest in the plant. The upfront investment required is Rs 2 lakhs. This includes the cost of machinery provided by the company. Besides this, the investor has to pay the company Rs 15,000/month (in case of domestic connections) or Rs 20,000/month (in case of connections to small commercial establishments), as the case may be. This will go on for 6 years, after which the ownership of equipment will be passed on to the investor. One important aspect of this model is that the investor is free to fix charges he deems fit. There have been some plants set up on this model in the last 12 months.

The Company has set itself very ambitious target of having 2014 plants, reaching 5000 villages and 10 million consumers by 2014. The Company is also considering expanding to other Indian states and also parts of Africa, Asia and Latin America. In setting up the biomass plants, the Company claims to have not received any assistance from Bihar Government, though it got financial assistance from the Ministry of New and Renewable Energy (MNRE), Government of India. It has so far relied on the money invested by various investors and revenues generated.

The average downtime for complaints redressal is 5-7%, corresponding to around 1-2 days in a month. Consumers can come to the plant to lodge their complaints, for which they are given a receipt. Ensuring that complaints are resolved at the earliest is one of the main responsibilities of the operator. Consumers can also lodge complain through phones/mobiles, but consumers generally prefer coming to the plant and get a receipt for the complaint lodged. Preventing theft is the major challenge for the Company as far as distribution is concerned. Cases of thefts are quite common, both by consumers as well as non-consumers. In case of consumers, the Company has launched a fine-based system, where the first offence is excused, but subsequent offence carries a penalty of Rs 100. In case of repeated complaints, connection to the consumer is withdrawn. In case of non-consumers, the Company cuts their illegal connection at once. Cases of over usage are also common. To address this problem, the Company is planning to install pre-paid metering devices that will shut-off connection to consumers if the consumption exceeds the purchased amount. Credit is not provided for bill payments. Ensuring this is also a challenge for the Company and the plant. In villages, people tend to know almost everybody which makes commercial dealings with them slightly complicated. It is for this reason that the Company carefully studies the personality and stature of operator before taking land on lease.

3.0 Discussion and Conclusion

After a detailed description of the four biomass plants, we would consider some key aspects of a biomass plant in this section and try to understand the similarities and the differences between the four plants. The aspects considered for analysis are types of biomass fuel, fuel sourcing strategies, and business operating models.

Of the four biomass plants studied, two used primarily one biomass as the main fuel while the other two used multiple biomass fuel. Of those which used multiple biomass fuel, it was not always the case. The plants had started as primarily single biomass fuel but owing to factors like shortage of biomass fuel, price fluctuations in biomass fuel, the plants had to change their fuel strategy.

In the case of plant using juliflora, assurance of sourcing juliflora from government managed forest and absence of demand for juliflora by others in the region were important reasons for the plant being able to continue using a single biomass fuel strategy. Incidentally demand for biomass fuel by others in the region played a major role in shortages of supply of biomass and price fluctuations of fuel for the two plants using multiple biomass fuel. In the category of others it was not only other biomass plants that competed for the same fuel but road side eateries, rice mills present locally, and even other industries using biomass as a raw material located far off from the plants also competed for the same fuel. One common feature of all biomass plants was the distance the biomass was sourced from. In none of the 4 biomass plants was the fuel sourced from a distance greater than 30 KMs. Landed price of input biomass fuel depends on the transportation distance and therefore when faced with competition for biomass fuel, plants resort to using other biomass fuels for the operations of the plant. A multi biomass fuel strategy allows for the continual operations of the plant but it does so at the cost of increased challenges related to fuel handling, boiler maintenance, and efficiency. While selecting other biomass fuels that can be used for the plant, the two power plants checked the gross calorific value of the fuel and physical and chemical feature of the fuel before using it with the primary biomass fuel.

Closely related to the decision of number of biomass fuel to be used for the plant, was the decision related to fuel sourcing strategies. Fuel sourcing strategies were impacted by factors such as availability of fuel and competition for the fuel from other industries located not necessarily in the vicinity of plants. In the plant located in Bihar, shortage of biomass led the plant to go the nearest city in search of biomass. The plant used to transport the biomass from the district to be used for the plant. In case of the plant in Rajasthan too, the plant had to go to the forest to cut juliflora and transport it back to the plant. The plants in Andhra Pradesh used a dual strategy where in some cases they collected the biomass from agricultural fields in collection centres located close to the fields and then bring it to the plant from the collection centres.

The plants also differed in terms of their business operating models. Three plants were grid connected and sold their generated electricity to the grid at rates dictated by respective power purchase agreements (PPAs) they had signed with the local grid operator. The plant in Bihar was not connected to the grid and operated on a micro grid model where the micro grid was set up by the plant itself and the generated power was directly distributed to the houses of consumers. The risks faced by the two categories of plants were multiple and different. In the case of grid connected plants, the plants have to invest in equipment required to maintain mandated voltage and frequency levels since the plant feeds directly in the grid. While in the case of Bihar based plant, no such investment was done. This investment, or the lack of it adds to the cost of operations of the plant that got reflected in the price they charged for selling their electricity. The plants connected to the grid also faced a penalty in case their supplied electricity fails to meet the technical requirements of generated electricity by the local grid operator.

In the case of grid connected plants, the plants were assured of payment as the state utilities with whom they had entered into agreements were financially sound and were able to pay on time. However in case of the mico grid plant, there were instances of customers wither refusing to pay altogether or negotiating on the price to be paid once billed. The micro grid plant also had to face instances of damages done to their micro grid by consumers who were dissatisfied with their services. Such disruptions are a possibility in micro-grids but not in the larger grid connected plants. However micro-grids allow small biomass plants to revise their price quickly compared to large grid connected biomass power plants in case of upward movement of input biomass cost. The increased fuel costs can be passed on more quickly to consumers in case of such micro-grid plants than large power plants bound by PPAs.

Another insight that emerges from the study is the impact of state government policies on growth of biomass power plants in respective states. The state of Andhra Pradesh (AP) was a leader in promoting biomass based power plant since the late 1990s and this resulted in setting up of large number of power plants using biomass as a fuel, particularly just after the year 2000. AP has been a leading state in the production of rice in India, and many politicians in AP have traditionally been from the agricultural background. Many of them also own rice fields and mills across the state. This had ensured cheap and easy availability of rice husk in the early years of biomass plants, which could be one of the reasons behind the fact that early promoters of biomass generally had political backgrounds. The then government policies also facilitated setting up biomass plants and the promoters also got their projects registered under clean development mechanism (CDM) of Kyoto Protocol. This resulted in huge profits for them for a couple of years, but in the absence of a well thought of and clear policy, many plants shut down after 3-4 years.

One of the reasons behind plants shutting down was the rampant use of wood and wood products for the biomass plants. There were allegations of smuggling of wood and deforestation in the name of using wood for the plants. This caused the state legislation to ban the use of wood and wooden products in the plant. Subsequently, some plant closed the operations as they had already made handsome profits from the venture. Some plants did shift to other fuel, but the management of these plants was often poor. Very few of the plants used people with technical and management background and often used non-technical persons for the running of plant. Sourcing of fuel emerged as a major issue, particularly in districts where many plants had mushroomed up. The plants also faced competition from small *dhabas*, and brick kilns which started using husk for their burning purposes. These factors also led to the closure of many plants.

The impact of state policies was also seen in case of the plant in Rajasthan where the plant was allowed to use juliflora from a forest managed by a state government entity. The mechanism from the state government allowed uninterrupted access to input fuel to the biomass plant and limited competition for the fuel by any other industry in the region. Control over quantity and cost of input material accordingly helped the plant in operations of their plant.

The four plants chosen for this study were located in three different Indian states, had varying installed capacities, used different types of biomass fuel, and had different operating models. One of the main reasons of choosing these biomass plants was to showcase the differences within and between biomass plants so as to enhance our understanding of their operations and context. This enhanced understanding can then lead to further research into the different types of challenges faced by the biomass plants and draw the interest of policymakers, investors, and researchers. The analysis throws up several interesting insights, some of which have not been reported in literature so far. For example, demand of biomass for alternative uses in local markets and level of trust between the biomass power plant and local farming community emerges as a key factor that could help explain continuity in supply chain of biomass fuel for biomass power plants. The analysis also throws light on supplier-biomass power plants and biomass power plants-customer relationships. The insights from the study will be useful for policy makers, regulators, biomass power developers, investors, and researchers.

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