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Exploiting the Unexploited Biomass Energy in India through Finnish CHP Solutions

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Abstract. Biomass based Combined Heat and Power production (CHP) holds a great potential to meet India's growing energy demand but it is not utilized in entirety. This study presents a comparative analysis on the bioenergy value chain between India and Finland from policy, supply chain and biomass conversion technology perspectives. This paper also provides insight into the importance of an organized biomass supply chain and the challenges faced by the existing biomass based industries. The decentralized energy solutions like small scale biomass CHP production would enable to efficiently utilize the surplus biomass available from agriculture, forestry and non-irrigated wastelands. Moreover, the biomass supply security can be achieved through raising energy plantations in waste lands. This study calls for an efficient geographical bioenergy planning involves new systematic-scientific approaches that can contribute greatly to understand the scientific and technical challenges, analyze the issues and constraints, and provide innovative solutions in order to harness the biomass based CHP production potential, enhance the new business opportunities, and ultimately transforming the existing fossil fuel-based economy into low-carbon bioeconomy.

Keywords: CHP, biomass, bioeconomy, supply chain

1. Introduction

Traditionally, biomass in India has been widely used to meet common man's basic energy needs contributing around 32% of total primary energy consumption. Over 70% of the Indian population from rural areas are mainly dependent on the biomass [1]. As on 2011, the 2,665 MWe installed biomass power production capacity across the country was contributed by 999 MW direct biomass power from agro residues, and 1,666 MW bagasse cogeneration in sugar mills [1]. However, the total installed power capacity including state sector, central sector and private sector aggregates around 225,793 MWe in 2013 [2]. The biomass based CHP holds great potential to meet India's growing energy demand but it is not utilised in entirety. There has been a lack of emphasis on biomass CHP production though some policies promote co-generation (in sugar mills) and approval of feed-in tariffs for CHP. Constraints related to biomass resource availability, supply chain logistics and infrastructure, technological modifications (more power to heat ratio), finding the potential customer for heat, and lack of strong legislative and financial measures have resulted in the poor attraction of CHP investments in India. Therefore, there is a need to look at both technical and non-technical barriers to evaluate ways and mechanisms that could make such projects viable and attractive in the future.

As its stands on today, several biomass to bioenergy production routes including thermo chemical conversion (combustion, gasification, pyrolysis), chemical (transesterification, hydrogenation) and biochemical (anaerobic digestion and fermentation) are commercially available to produce various energy products (heat, power, liquid biofuels, biogas). Given present scenario in India, where there is an increasing energy demand, high energy costs, lack of power production and poor energy accessibility, decentralised technology like biomass CHP have great potential to tap the underutilised resources with slight technological modifications. The potential to utilize multiple feedstock from the energy plantations (wastelands), agricultural residues, municipal and industrial wastes is indeed enormous across the states of India. Given the tropical climate, district cooling is one potential option to consider in the technological advancements. Many states in India have been open to foreign direct investments particularly in case of energy generation projects placing emphasis on reciprocal technology and knowledge transfer and at the same time offering energy service to the society [3].

The overarching aim of this paper is to analyse the potential opportunities and challenges of transferring Finnish biomass based CHP technology to India. The paper also presents an overview of Finnish bioenergy technological innovations and their expertise to utilise locally available resources for energy generation. Moreover, the paper also brings out challenges that are facing Indian biomass industry. In addition, a comparative analysis on bioenergy value chain focusing bioenergy policy, supply chain and biomass conversion technology of India and Finland is presented separately.

2. Comparative analysis on bioenergy value chain between India and Finland

2.1. Bioenergy policy

Government of India aims to develop the biomass industry in India through several programmes supported by Ministry of New and Renewable Energy (MNRE). Although there is no national level common bioenergy policy, the biomass based power production is being promoted under the Electricity Act (2003), National Electricity Policy (2005), the Integrated Energy Policy (2006), and Rural Electrification Policy (2006) [4]. The National policy on biofuels 2008 sets a binding target of 20% biofuel (bio-ethanol and bio-diesel) by 2017 [4]. Central and State Electricity Regulatory Commission Regulations (2009) sets terms and conditions for tariff determination from renewable energy sources. MNRE's sets a cumulative target of 1525 MWe biomass power to be achieved by 2017 under 12th Five year plan period [1]. To achieve the target, both central and state governments are providing financial assistance (capital subsidy = Rs.25 lakh x (C MWe)^0.646) and fiscal incentives (80% accelerated depreciation, concessional import duty, excise duty, tax holiday for 10 years, custom duty concession, excise duty exemption). The Indian Renewable Energy Agency (IREDA) also provides loan for setting up biomass power and bagasse cogeneration projects [1].

Finland as a member state of European Union aims to achieve low carbon society by promoting clean energy production. The northern most location, cold climate, long distances, and sparse population has been the influencing factors to constantly search for local energy solutions. The bioenergy production in Finland is mainly driven by both strong policies and technological innovations. In accordance with European Union's renewable climate and energy packages, the Finnish national energy and climate strategy sets mandatory 2020 targets; 20% (~10 million tonnes per year) reduction of carbon dioxide emissions (1990 base year), 38% (124TWh) share of renewable energy sources in final energy consumption, 20% energy efficiency improvement and 20% (7TWh) biofuel share in transport (by double counting method) [5]. In 2011, the renewable sources contributed approximately 28% of total energy consumption (387TWh), of which the wood and wood based fuels accounted 80% of renewable [6]. To achieve the above targets, the government has employed different measures such as feed-in tariff for biomass based electricity production, heat bonus for CHP plants, investment support for biomass plant installations, subsidies for biomass procurement (e.g., young thinning wood harvesting), and energy tax. Moreover, for transport fuel, if the retailer fails to meet the obligatory blending quota, then the penalty payment of 0.04€/MJ is charged.

Although different policy measures exist in India to promote the use of biomass for energy generation, the present status of biomass industry is a worrisome. More than 40% of installed capacity (1200 MWe) is temporarily or permanently closed due to various reasons like unviable tariff, restrictions on open access, rise in biomass cost, unsecured biomass supply and unorganized supply chain [7,8]. One of the striking differences of Indian bioenergy policy from Finland is that there are no incentives or subsidies encouraging the farmers to mobilize and supply biomass to power plant which has been ignored in the present policies.

2.2. Biomass resources

India produces the estimated surplus biomass availability of about 120 – 150 million metric tons per year, corresponding to a potential of about 18,000 MWe of electricity capacity. Besides, an additional 5,000 MWe of power capacity could be realised through bagasse in co-generation plants located in the country's 550 sugar mills [1]. Moreover, NRSA [9] calculated that about 66million hectares (16.27 Mha forest degraded land, 38.11Mha wasteland, 11.07 Mha other category) of land area can be made available for biomass production which in turn would also secure the biomass supply. The major agro-biomass used at the existing biomass power plants are mustard stalks, maize stalks, soybean residuals, sugarcane bagasse, rice husk, cotton stalks, prosofis, coconut fronds, maize cobs, paddy straw, groundnut shells, and sawmill residuals. The availability and costs of biomass varies geographically. In 2013, the average price of biomass varied between 1300 Rs/ton – 3300Rs/ton [10].

Finland, the Nordic country is endowed with abundant natural resources (73% forest lands, 10% waters, 6% farmland of 338,424 km2 surface area). Forest biomass (logging residues, stumps, thinning wood) are widely used for energy generation. The techno-economical potential of forest biomass in Finland is about 115 PJ or 15.3 million m^3 (~50 PJ existing consumption) [11].

One of the major challenges in harnessing the biomass for power generation in India is the reliability of resource estimates. One cannot take investment decisions based on the theoretical surplus biomass potential. Moreover, the information provided by MNRE or Biomass Atlas 2004 is at least 10 years old and therefore, there is a need to update the resources assessment database. Not all agro-biomass can be collected for energy generation without considering the exiting use (cattle fodder, cooking, thatching, land manure) or traditional practices.

2.3. Biomass supply chain

A cost efficient supply chain is essential to transport the biomass from supply sites to the plant location for better economic performance of the plant [13]. In India, the biomass supply chain is location specific and highly unorganized. Most parts of the Indian biomass supply chain (harvesting, collection, loading and unloading, processing) are carried out manually. The carrying capacity of vehicles varies between 1.5 tons to 12 tons.

The Finnish biomass supply chain includes harvesting, forwarding, roadside storage, chipping, and long distance transportation (by roadways, railways and waterways). In Finland, almost 100% of the roundwood harvesting/commercial thinning is carried out mechanically by harvesters and then carried to the road side by the forwarder. Usually, the logging residues (tops and branches) are left at the roadside for drying (to reach optimal moisture content for combustion) up to 6-10 months. The dried logging residues are then chopped by chipper trucker and transported to the plant either by road or rail depending on the distance need to be travelled and infrastructure availability.

Cost effectiveness of biomass transport is often ignored in Indian biomass supply chain. The figure 1 presents the costs of biomass transportation for an existing biomass power plant in India and Finland.

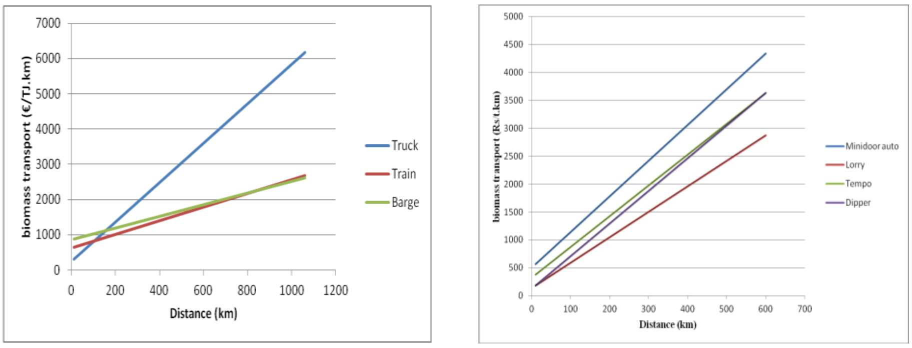

Fig. 1: Biomass transportation costs in Finland (left) and India (right).

2.4. Biomass conversion technology

As it stands on today, almost all of the installed biomass power plants in India employ conventional grate firing technology to produce biomass power. The average installed capacity of the plant is 10-15 MWe. The biomass to power conversion efficiency can reach only up to 21%. '2.2 Kg' of biomass at 40% MC is needed to produce '4.3 kg' of steam to produce '1 kWh' or 1 unit power. The grate firing boilers requires cleaning and operation maintenance once per month. On-line soot blowing of the super heaters is conducted twice per every shift. (The maximum allowable moisture content of biomass feedstock in the boiler should be less than

40%. Ash clogging is a common plant operation constraint. Super heaters are needed to be changed every 3-4 years due to corrosion (Figure 2).

Fig. 2: Manual ash clogging removal (left) and super heater corrosion (right) [14].

Finnish forest industries and energy companies posses cutting-edge expertise in bioenergy technologies such as biomass based CHP production (heat and power), pyrolysis (bio-oil), BTL (Fischer Tropsch biodiesel), and biorefineries (liquid biofuels, chemicals). Finland is a pioneer in biomass based CHP technology. There are over 400 biomass based District Heat (DH)/CHP plants from farm level (5-200kW) to industrial scale (50-500 MW) [15]. Approximately, 50% of the population live in district heated apartments (around 75% of district heat and 35% of electricity produced is cogenerated). The main advantage of CHP over only conventional electricity generation is that total efficiency of the system reaches up to 90% and also generates both electricity and thermal energy in an integrated system. The generated/recovered heat could be then also sold to industries or buildings.

In Finland, both combustion and gasification technologies are applied in CHP plants. Among combustion, grate firing combustion at smaller scale plants and fluidized bed combustion at large scale plants are traditionally followed. Further, fluidized beds are classified into Bubbling Fluidised Beds (BFB) and Circulating Fluidised Bed (CFB). In BFB, the temperature of bed material varies between 750 – 1,000 °C depending on the fuel quality and load whereas in CFB, the temperature varies between 750-900 °C and almost more than 70 different fuel types can be handled. In both BFB and CFB, the wet fuels like peat and tree barks can be used. On the other hand, in late 1990s intensive research had been carried on integrated biomass gasification combustion cycle (BIGCC) but the commercial scale plant could not be realized due to high investment costs and technical risk. The overall efficiency and the electrical efficiency can be achieved higher in BIGCC (43%) than the fluidized bed combustion technology (37%) [16].The companies like Foster Wheeler, Kvaerner, Gasum, Wärtsilä Biopower and Thermia Oy are the leaders in boiler suppliers as Finland exports over 5 billion Euros of energy technology worldwide.

3. Knowledge and technology transfer

Given Finnish's many decades of knowledge and expertise in biomass procurement, supply chain logistics, energy conversion technologies, and energy distribution, there is a great opportunity for India to learn and apply the know-how and benefit from them. The successful models from Finland can be selected and transported to India. Particularly, small scale CHP solutions from Finland could be of interests to harness the biomass based energy production potential in India. For example, model small scale plants located at Kokemaki, Ilomantsi can be tested in Indian conditions. These CHP plants are based on the Novel fixed-bed gasification technology which can efficiently use biomass residues with high moisture content (up to 55%) and varied particle size (sawdust – large wood chips). The plants are equipped with gas reformer, filter and an acid/base scrubber to remove residual nitrogen compounds.

Recenlty, a new CHP plant built at Toholampi (3,500 population size) uses an innovative Organic Rankine Cycle (ORC) technology and it is a first of its kind for such decentralised technology in Finland. ORC for small scale biomass applications uses an organic fluid instead of water as organic fluids increases the higher turbine efficiency even at maximum low temperatures (Figure 3). The plant uses 80% wood chips and 20% peat as fuel. The total BFB boiler capacity is 8.2 MW (5.4 MW heat and 1.3 MW power). The investment cost of the plant is 9.2 million Euros [17].

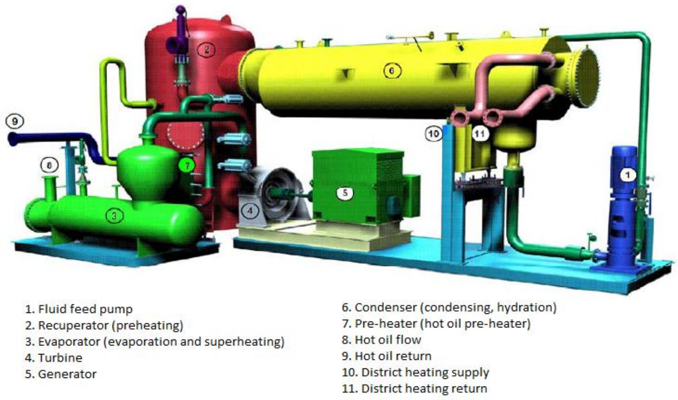

Fig. 3: Toholampi ORC power plant equipment (adapted from [16]).

However, in Finnish CHP technology adoption, the main challenge comes down to the utilisation of residual heat. The cold climate in Finland demands more heat and therefore, potential to sell the produced heat energy is very high. On the other hand, tropical climate conditions in India would not be favourable for utilising the residual heat. Nevertheless, the heat produced could be converted to cooling using Vapour Adsorption Chillers (VACs) and/or then the heat could also be pumped as hot water supply /central cooling in the existing or new apartmental buildings in big cities. But then the production plant must be located close to the cities as the heat/hot water cannot be distributed to longer distance. On the other hand, siting biomass plants close to the cities mean biomass procurement costs would go higher as the biomass has to be transported from rural areas and hence the transportation costs would increase. In Finland, the most cost effective distance for biomass procurement for CHP plants are less than 60km radius. In addition, truck transportation is cost effective for distances less than 100km while train transportation is more effective for longer transportation distances (over 100km). Moreover, the agricultural biomasses are bulky in nature and therefore, an efficient supply chain is crucial to increase the cost and energy efficiency. One could select appropriate fuel collection methods like bundling (paddy straw, corn cubs, sugarcane baggase), chipping (e.g eucalyptus, casuarina) with respect to fuel type which eventually allows more biomass to be transported in a single truck. Finland supplies procurement machines like bundlers, chippers, forwarders and the Finnish biomass procurement supply chain are organised efficiently. Several studies present the importance of organized supply chain for the successful plant operation [18]. In addition, the biomass could be further processed using fuel processing technologies like pelleting, briquetting to increase the energy efficiency of the fuel. In addition to its increased energy value, the fuel handling becomes easier and the biomass can be efficiently transported at longer distances.

Integrated biomass CHP solutions would also provide opportunities to meet the energy demand in the existing industries. For example, industries like textile, pharmaceuticals, tobacco, steel, fertilizers industries would be of good choice in India to potentially tap the residual heat produced at the CHP plant. Many case examples from Finland (typical pulp and paper mill integrated CHPs) illustrates that the overall energy and cost efficiency are high when CHP plants are integrated [19]. Additionally, the waste heat could also be used in the biomass pre-treatment process.

Most successful models from Finland illustrate the importance of cost and energy efficiency of bioenergy value chain. Particularly, the secured biomass supply is crucial for the continuous plant operation and therefore, an organized supply chain is vital. Most existing biomass power plants in India face the unsecure biomass supply situation and also the biomass prices have gone up from 1000 Rs/ton to 4000 Rs/ton in couple of years due to various reasons like fossil fuel price hike, transportation costs, and increasing competition. Unlike Finland, there is neither common price regulation for biomass feedstock nor the established biomass market. Sustainable biomass market development is crucial for the success of biomass industry in India to provide multiple benefits to society, economy and environment.

The sustainability of biomass for energy must be evaluated in detail with respect to food security, environmental performance and energy efficiency. Importantly, country like India cannot afford to have pure energy plantations in agricultural lands which would eventually increases the food competition and food prices. On the other hand, agroforestry practices (where agriculture and energy crops are cultivated together) could be adapted to meet agricultural and biomass production. Unlike Finland where forest residues are widely used for energy production, most of the Indian forests are protected under The Forest Conservation Act (1980) and therefore, the scope for biomass production is very limited in Indian forests.

To maximise the biomass power production in India, an efficient geographical bioenergy planning involving new systematic-scientific approaches is needed to understand the scientific technical and social challenges, analyse the issues and constraints, and provide innovative solutions in order to harness the biomass based CHP production potential, enhance the new business opportunities, and ultimately transforming the existing fossil fuel-based economy into low-carbon bioeconomy.

4. Conclusion

With the advancement of science and knowledge, the major technological hurdles affecting biomass based CHP production can be overcome eventually. The biggest challenge for Indian biomass industry is the lack of strong driving factors particularly energy policies and poor regulation. The potential biomass CHP technologies achieving higher power to heat conversion ratio would be most optimal to suit Indian conditions. Geographical bioenergy planning strategy should be developed to efficiently utilize the biomass for energy sustainably. New investments in bioenergy business would bring manifold benefits to the environment (GHG emission savings), society (employment) and economy (new market development).

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