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POTENTIAL OF BIOMASS BASED ELECTRICITY GENERATION IN INDIA: A CASE STUDY

1. Introduction

India, although is one of advanced developing countries in the world, still faces a huge shortage of energy provision to its huge amount of population. In order to provide energy access to great number of energy deprived people the growth rate for energy production should be very high. Having this problem in one side, India also has the pressure from developed and other advance developing to grow into a low carbon economy. It is already committed to reduce its emission intensity of its GDP by 20-25% by 2020 (UNFCC 2010). Therefore, to accelerate its growth into a low carbon environment it is needed to focus on renewable sources for power generation.

Being a country of high agriculture production, India has a huge potential for biomass residue based electricity generation (Shukla 1997). The present study, thus tries to describe the present and future potential for electricity generation from

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biomass residue. Besides it also provides a future estimation of growth of electricity generation from this source discussing the requirements for the smooth growth of residue based electricity production. Finally, it shows some suitable locations for pilot projects to produce rice and wheat based power plants.

2. Electricity Production and Usage in India- Present Situation

Although electricity is fundamental for progress, there are about 1.6 billion people in the world living without access to it (German Development Institute 2008). India contributes to this number with more than 35%. According to a research done in 2000, there were 579.10 million people in India with no access to electricity (Bhattacharyya 2006). The economy of a developing country like India with a population of 1 billion people (Stanford University 2003) largely depends on the growth of the industry, agriculture, technology, infrastructure, education, health, and they all depend on power in a form of electricity. Poverty is directly linked to not having access to it, if not the cause for it (State Planning Commission 2009). Consumption of electricity per capita in India is about 363 kWh and growing (Stanford University 2003). The overall situation with electricity in India, especially in rural areas is unsteady with a norm of outages for 12 to 16 hours per day (Rajvanshi 2006). The most densely populated states are Delhi, Chandigrah, Daman and Diu, Lakshwadeep, and Pondicherry (Stanford University 2003). Rural India makes about 70% of the whole population which is about 700 million people (Suresh 200) and here are approximately 1500 people living in each village being 2.5 km distant form each other (Stanford University 2003). The following table-1 summarizes some of the key aspects of present electricity generation and usage in India.

Table-1: Electricity Situation in India

Current Capacity	151,000 MW
Per Capita Consumption	600 kWh (US: 14,000 kWh; China: 1600 kWh; World: 2600 kWh)
People without access to Electricity	579.10 million people (More than 35%)
Norm of outages	12 to 16 hours per day
Target (to meet the world average by 2030)	27000 MW per year
Present Growth	10000 MW per year

The overall situation regarding the access to electricity is quite poor in the rural areas compare to the urban centers. A comparative study done by Bhattacharyya (2006) showed the number of household without access to electricity both in rural and urban areas. The results of studies showed that in all the sates in India rural areas are more deprived than urban areas. This situation is even worse in states like Uttar Pradesh, Bihar and West Bengal where 10 to 15 million people in rural areas do not have access to electricity.

Consumption of electricity is also related with income level of people. Consumption of electricity increases with high level of income and the consumption trend in urban area is much higher than the rural areas with same level of income group. The study of Bhattacharyya (2006) plotted the electricity consumption of different expenditure groups in both rural and urban India. The results showed that in urban area the consumption of electricity increases very slowly as the expenditure of people increases. But the consumption increases quite drastically when the expenditure reaches to the highest range. On the other hand, in rural areas consumption of electricity increases at a steady rate as the expenditure increases.

In this scenario, where the problem of electricity is quite significant mainly in rural India, several steps are being taken by the government to increase the supply of electricity across the country. Some of the policies strongly focus on rural electrification and a shift towards renewable sources of electricity in rural areas.

Until 1997, the definition of an electrified village in India was very vague, so even if 1 household used electricity, it would still be considered to be an electrified village. As of 2005 the criteria have changed and for a village to be considered electrified it should have at least 10% of the population, as well as public places as schools, offices and health institutions using electricity. With such a definition, the number of unelectrified villages increased (State Planning Commission 2009).

There was a programme in 2001 initiated by the Ministry of Nonconventional Energy Sources (MNES) that proposed providing electricity to rural areas where extension of the grid was not possible for various reasons. The idea was to provide electricity from renewable energy sources based on hydro, wind, biomass or hybrid power. A new policy in 2005 announced as National Electricity Plan (NEP) dealt with the issue of electrifying all rural areas. In order to achieve this goal the government proposed providing electricity through a local decentralized network in cases when connection to the central grid would be very expensive. Almost 24,500 villages fall in the category of "remote villages" where electricity grid extension is not possible (Nouni *et al. 2008).* But, even in electrified villages not all of the households are electrified, one of the reasons being the cost (Stanford University 2003).

The National Electricity Policy observes that the crucial progress aim of the power sector is to supply electricity to all areas including rural. Both the central government and the state governments would need to join in order to achieve this objective. Accordingly, the Central Government in April 2005 launched an ambitious scheme 'Rajiv Gandhi Grameen Vidhyutikaran Yojana (RGGVY)' with the goal to electrify all unelectrified villages and provide access to electricity to all households in the next five years. These National Policies were prepared involving not only the State Governments and the State Electricity Regulatory Commissions, but also other stakeholders such as NGOs (Non Governmental Organization), technology providers, existing utilities, etc. The Policy aims at providing electricity at reasonable rates and minimum lifeline consumption of 1 unit per household per day by 2012.

3. Sources of Electricity Production

Electricity is being produced from different sources in India. However, the most dominant source for electricity production in India is Coal based power plants. The Fig-1 below shows the sources of electricity generation in India.

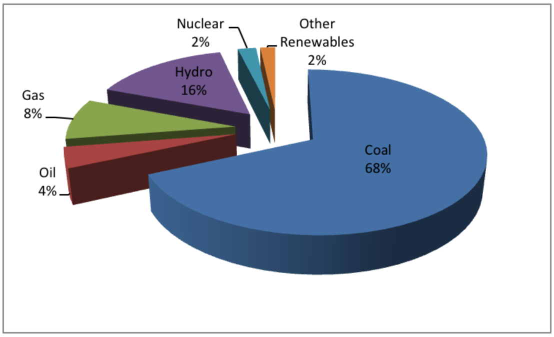

Figure-1: Sources of Electricity Generation in India (IEA 2007a).

Electricity production in India mainly depends on fossil fuel reserve of coal and gas. . The share of renewable sources is very low. Around 20% of electricity is generated by renewable sources, which is mainly dominated by hydropower. Among the renewable resources biomass only accounts for 8%, which is 0.24% of the total (IEA 2007a).

However, the potential for biomass residue based electricity generation in India is huge. At present biomass is used to produce around 4000 MW of electricity. Indian government is putting up strategies to enlarge the electricity production from biomass (Shukla 1997). The following sections will look at the technical and financial potential of biomass residue based electricity generation.

4. Surplus biomass availability in India

The current biomass residue based electricity generation potential is provided in the web-based interactive database called Biomass Resource Atlas of India. This database is a project of the Ministry of New and Renewable Energy (MNRE) of India and has been executed by Indian Institute of Science (IISc)[1]. The data set is presented under various categories such as crop wise, state wise, district wise etc. The total available surplus biomass residues for electricity generation have been estimated as 189 million tons/year. Of these, 76% is agro-based and rest is forest- and wasteland-based, (Fig-2). Further, state wise surplus biomass availability is presented in Fig-3 The availability of surplus biomass is more in states that have higher agricultural productivity owing to favorable climate and soil conditions.

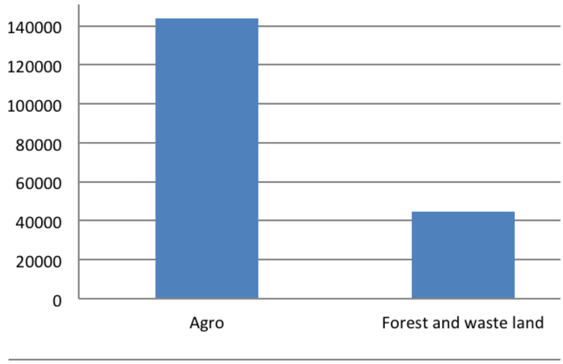

Figure-2: Type wise surplus biomass availability in India.

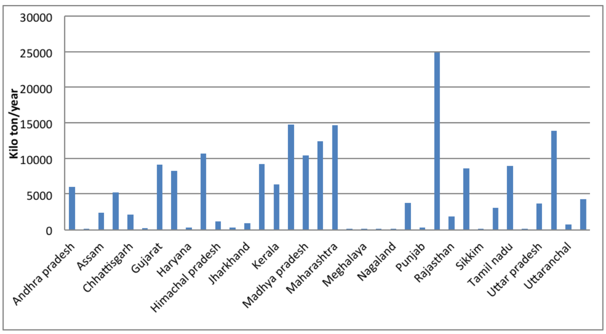

Figure-3 State wise surplus biomass availability in India.

1 http://lab.cgpl.iisc.ernet.in/Atlas/Default.aspx

5. Comparison of different technologies of biomass residue based electricity generation

IEA (2007b) have identified three main technologies for biomass residue based electricity generation. These are:

- Co-firing
- Dedicated steam cycles
- Integrated Gasification Combined Cycle (IGCC)

Brief discussions of each of these technologies are presented below.

Co-firing:

Co-firing is the cheapest available option, with minimum investment requirement among the three technologies (IEA 2007b). Co-firing can be adopted in existing as well in future coal fired power plants with moderate investment (IEA 2007b). Considering 52.3% of the electricity generation in India is coal based (Central Electricity Authority of India 2010), this option faces least hurdles. With coal expected to remain the dominant source of energy for India till 2030 and beyond (Planning Commission, Government of India 2005), adoption of co-firing of biomass in coal fired power plants is a viable option for India. However, price of carbon credit will form an important component for this technology to be competitive with coal based electricity generation in India.

Dedicated steam cycle:

Dedicates steam cycle based electricity generation using biomass as fuel is an established, indigenously available technology in India (MNES 2005). However the generation cost of the same is higher than that of co-firing (IEA 2007b). To encourage investor, Government of India is providing capital subsidies for this technology (MNRE 2006). However capital subsidy alone is not sufficient to make this technology competitive with coal based electricity generation; price of carbon credits also plays a crucial role for this technology to compete with coal based electricity generation in India.

IGCC:

Biomass based IGCC is the most advanced, efficient and capital intensive of the three technologies described (IEA 2007b). According to a report of IEA (2007b) there is only one pilot plant currently operational in Sweden. The government of India provides higher level of subsidy for projects which uses advanced technologies for Biomass residue based electricity generation. IGCC is one of them (MNRE 2006). However, additional revenue stream through sale of carbon credits plays a crucial role for these technologies to make them competitive with coal based electricity generation in India.

Analysis is performed for the above mentioned technologies to calculate the Levelized cost of generation. Levelized cost is the cost per megawatt-hour must be charged over time to pay the total cost. The input variables for the analysis are presented below in Table 2.

Table-2: Input parameters for the comparative analysis

Technical Parameters (All Costs are in US$)				
Description	Co-firing	Dedicated steam cycle	IGCC	Source
Capacity	20 MW			Assumed
Number of days of operation	365			Assumed
Number of hours of operation in a day	24			Assumed
Plant load factor	80%			Assumed
Efficiency	37.5%	32.5%	40%	IEA (2007)
Calorific value of biomass	3461			Average calorific value of biomass in India (CERC 2009)
Financial Parameters				
Capital cost/MW	1,200,000 $	4,000,000	8,000,000	IEA (2007)
Operation and Maintenance (O&M) Cost/year	900000 $			CERC (2009)
Annual escalation of O&M cost	5.72%			CERC (2009)
Biomass fuel price	39 $/ton			Average biomass price in India (CERC 2009)
Annual escalation rate of fuel cost	5%			Assumed
Debt	70%			CERC (2009)
Equity	70%			CERC (2009)
Interest on Term loan	11.5%			Latest median prime lending rate as per Reserve Bank of India (RBI) (http://www.rbi.org.in/home.aspx#)
Moratorium period	2 quarter			Assumed
Repayment period	24 quarter			Assumed
Depreciation on plant and Machinery	5.28%			The Companies Act, 1956
Subsidy	44,444 $ x (C MW)[2]^0.646		222,222 $ x (C MW)^0.646	MNRE/GOI Circular Number 14/8/2004-SHP dated 26.12.06
Exchange rate for $ to Rs	45			RBI reference rate (http://www.rbi.org.in/home.aspx#)
Time horizon for levelised cost of generation computation	10 years			Assumed

Based on the above input parameters the weighed cost of electricity generation for the above three technologies are computed. The Levelized cost has been compared with the cost of electricity generation for coal fired power plants in India, which is 3.1 US Cents/KWh (Sathaye and Phadke 2004). The results presented below in Table 3 do not include any capital subsidy or additional revenue through sale of carbon credits.

2 C refers to capacity of the plant in MW

Table- 3: Levelized cost of electricity generation

	Co-firing	Dedicated Steam cycle	IGCC	Coal fired plant
Levelised cost of electricity generation (US Cents/KWh)	5.1	7.2	8.6	3.1

Thus, it can be clearly seen from the above table that none of the biomass residue based technologies is currently competitive with coal based electricity generation in India without any additional incentive such as capital subsidy or carbon credit sale.

Further analysis is performed to check at what level of capital subsidy and carbon credit price the above mentioned technologies become competitive with coal based electricity generation in India. The results of the same are presented below in Table 4 and Table 5.

Table-4: Levelized cost of electricity generation with carbon credit

	Co-firing	Dedicated Steam cycle	IGCC	Coal fired plant
Required price of carbon credit	25 $/ton	50 $/ton	65 $/ton	Not Applicable
Levelised cost of electricity generation (US Cents/KWh)	3.0	2.9	3.0	3.1

Table-5: Levelized cost of electricity generation with subsidy

	Co-firing	Dedicated Steam cycle	IGCC	Coal fired plant
Capital subsidy as percentage of total capital cost	97.47%	96.58%	97.15%	Not Applicable
Levelized cost of electricity generation (US Cents/KWh)	4.6	5.4	5.0	3.1

Thus it can be seen from the above tables that even higher than 95% of the capital subsidy is not sufficient to make the biomass residue based technologies competitive. As compared to capital subsidy carbon credits can be more crucial in increasing competitiveness of these technologies. In fact for the co-firing technology, the level of required carbon credit price was reached back in 2008.[3] However, for IGCC and dedicated steam cycles the required rate of carbon credit price is much higher than the present rate of

3 http://communities.thomsonreuters.com/carbonprices

carbon credit price of around 16 US$/ton. The future price of carbon credit is extremely difficult to predict since this will depend on the outcome of international negotiation for the post Kyoto Green House Gas (GHG) reduction regime and the fate of climate change bill at the US House of Senate. However, Weyant *et al* (2006) in a synthesis report published under the aegis of Stanford Universities' Energy Model Forum (EMF) have sought to answer this question through a modeling approach. The report predicted the future carbon price based on the analysis of 18 leading models in the world. The prices are predicted for two scenarios, one for CO_2 only GHG regime and another for the present multi gas format GHG regime. The result of the same is presented below in Table 6.

Table-6: Carbon permit price (Weyant et al 2006)

	2000	2025	2050	2075	2100
CO_2 only (US$/ton)	2.7	101.3	314.2	406.2	877
Multi gas (US$/ton)	2	57.8	158.7	241.8	480.3

Thus based on the above prediction, all the three technology becomes competitive by 2025 for the CO_2 only scenario. In case we consider the multi gas scenario, which is probably more realistic, barring IGCC, rest of the technologies will be competitive by 2025.

Thus, considering the analysis of the study together with the future carbon price projection as presented above, it can be said that carbon price provides more potential in terms of making biomass residue based energy generation competitive in future.

6. Modeling the potential of Biomass residue based electricity production

The above section discussed about the technical and financial parameters to promote biomass residue based electricity generation in India. This section will discuss the future production possibility of electricity of biomass residue based electricity generation under different scenarios. The projection is being done using Stella modeling software (Stella 2002). The software helps to calculate the amount of electricity can be produced from biomass residue in different favorable and constraint conditions.

In this particular study, the projection is being done for electricity production for rice and wheat. The residue from rice (or paddy) and wheat are having the highest calorific value and power potential among the all the agricultural and forest residues (MNRE 2006 and Buragohain *et al 2010).* In order to calculate potential electricity production from rice and wheat the following parameters are being considered:

- **Annual production of rice and wheat:**

In this process, we have used arrays to replicate the same functions required to calculate the annual production of rice and wheat in India. From the area of the last two years, we calculated the growth rate in the agricultural land for the two crops. Then we calculate the annual increase in the agricultural area, which depends on the increase last year and not on the stock of land. The land has different fertility depending on the number of years under production. Older lands have lower fertility. We calculated the yield figures of both rice and wheat by taking the yield 5 years back and so on. After that, the average percentage change in yield is calculated to reach the final calculation of rice and wheat production.

- **Electricity Production from residue from rice and wheat:**

From the annual production of the crops, we calculate the amount of husks and straws produced - these are the main residues of the crops that we use for power generation. Husks and straws have different calorific values and depending upon the technology used, we can calculate the total annual power potential.

- **Different available technologies and their relative cost and efficiency:**

In this process we considered different technical parameters for electricity generation from biomass residue, which is being described in section 5. In this calculation the cost effectiveness of different technologies is estimated.

- **Financial parameters that affect the cost of power generation:**

Different financial parameters such as interest rate, subsidy, the price of biomass residue based fuel, the capital cost of different technology etc., are considered in this section. The model

- **Policy options:**

The impact of different policies like government subsidy, climate change and price of carbon is considered to see which one has highest influence towards the creation and subsistence of the project.

- **The comparison between cost and emission:**

The comparison of cost of electricity generation from biomass residue is compared with other fossil and renewable sources and the affect for different financial and technical scenarios is calculated. Besides, the emission from different sources of electricity is also calculated to compare them with biomass.

The model shows the following key outcomes to describe the feasibility of biomass residue based electricity generation in India:

Technology Implication	From analyzing the various scenarios in the model we can conclude, that Integrated Gasification Combined Cycle (IGCC) is the best available technology for biomass residue based power plants as its least cost option and the most efficient in terms of power generation.
Cost comparison	IGCC -is the most effective of all technologies and will cost us less per unit of power generation (Fig-8)
Domestic Policy on Subsidy	There is not much significant change even if the government provides subsidy. Hence, domestic policy of financing such projects with subsidy is not very effective.
International Policy on CER	Certified Emission Reductions (CER) plays a very important role in financing such projects. In the absence, of such international policy on climate change, such projects are not financially attractive.
Price of Carbon	We see that the price of electricity generation from biomass residue is inversely proportional to the price of carbon and affects the cost of generation significantly.
Cost compare to other sources	Biomass residue based power generation is very much competitive with other sources (both renewable and fossil) if the some assumed condition is being made in favor of biomass.
Emission compare to other sources	The emission from biomass residue based power plant is significantly low compare to other fossil fuel sources and very much competitive with the renewable.

In the assumed condition to promote biomass residue based power plant in India, the total electricity production potential from these source in 2030 will be ***62.093 MW***. The following Fig-4 depicts the trend of the increase by 2030.

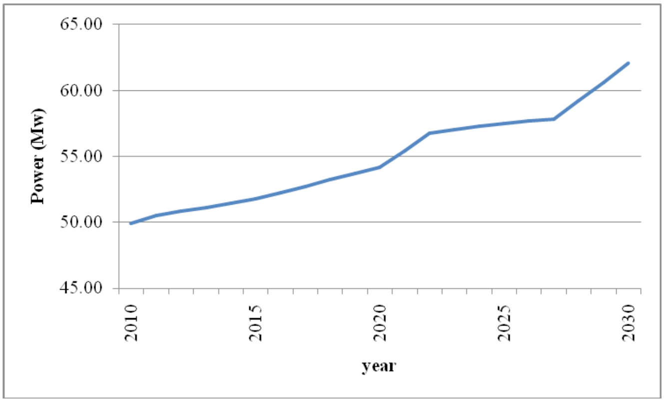

Figure-4: Growth trend of biomass residue bass electricity generation in India. (Recreated from the results of the model)

7. Finding out suitable locations for biomass residue based power plants in India:

In order to ensure a desirable start to biomass residue based electricity generation in India it is always important to have a perfect and profitable start (BRAI, 2010). In this part of the article, we would like to suggest some suitable locations for biomass residue based power plant in Indian context. In this analysis the following datasets are being used:

Dataset	Source
World administrative boundaries.	UNEP Geo Data portal (1998) URL: http://geodata.grid.unep.ch
World Rice yield 2008.	Land Use and Global Environmental Change, Department of Geography, McGill University URL: http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html
World Wheat yield 2008	Land Use and Global Environmental Change, Department of Geography, McGill University URL: http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html
Nighttime Lights of the World - Human Settlements 1994-95	UNEP Geo Data portal 1994-95 URL: http://geodata.grid.unep.
Gridded Population of the World: Future Estimates of 2015 -Population Density	UNEP Geo Data portal 2005 URL: http://geodata.grid.unep.ch
Rail network in India 1993	MindSites Group, LLC 1993 URL: http://data.geocomm.com
Utilities network in India 1993	MindSites Group, LLC 1993 URL: http://data.geocomm.com
Road network in India 1993	MindSites Group, LLC 1993 URL: http://data.geocomm.com

It can be noted that the analysis is again done for two of the main source of biomass in India: rice and wheat residue. The analysis is being done using the principals of GIS analysis and the ArcGIS 9.1 software. The main principal who is followed is to find the suitable locations under each set criteria and dataset. The following Fig-5 will describe the criteria taken into account for the analysis of rice (or paddy) residue based electricity generation plans. These criteria were used to filter suitable locations. The datasets are visualized as maps in the software. The filtered datasets were then overlaid with each other to find the places where all the criteria match.

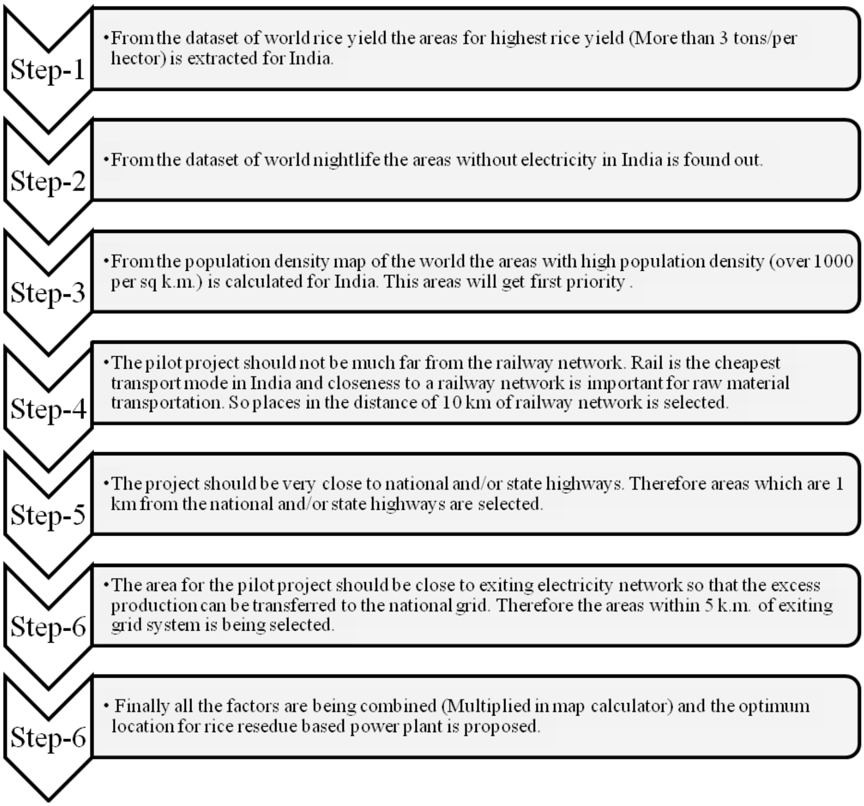

Figure-5: Steps to find out suitable location for Rice residue based power plant in India.

The GIS analysis of the rice residue based power plant in India shows the following outcome, which is presented in Fig-6. The same steps are being followed to find out locations for power generation from wheat residue and the results are being shown in Fig-7.

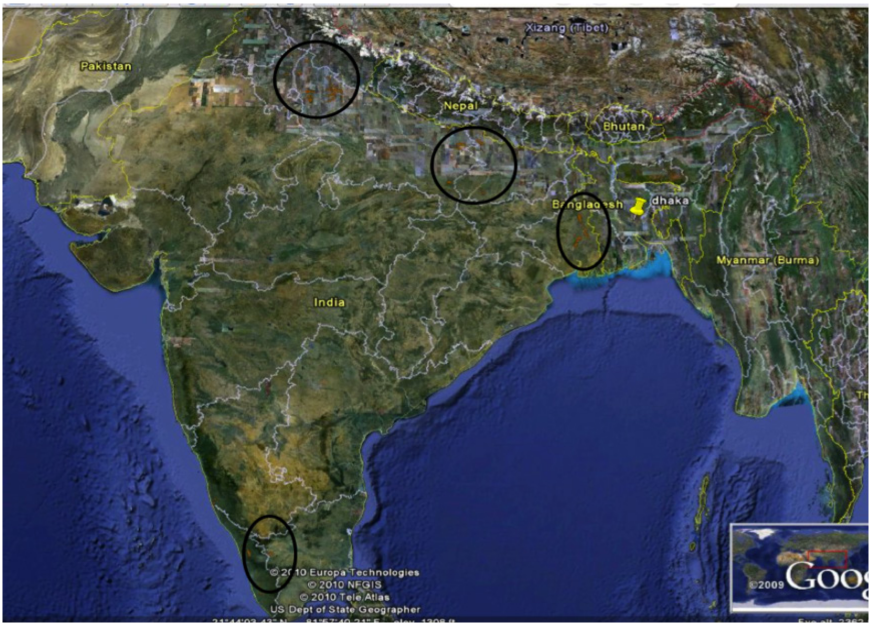

Figure-6: Potential location for Rice residue based power generation in India (Base image source Google Earth (2010))

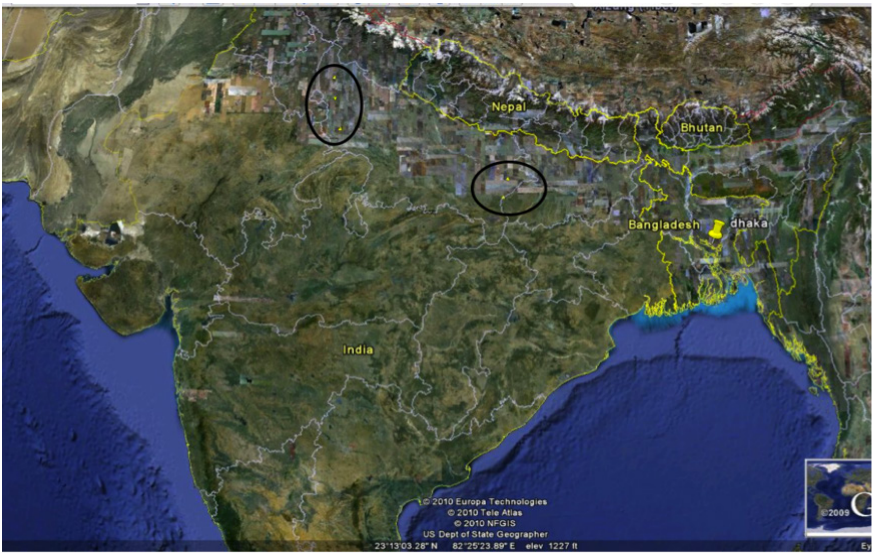

Figure-7: Potential location for Wheat residue based power generation in India (Base image source Google Earth (2010))

8. Some concerns about using crop residue for power generation

There are several ways of procuring biomass for energy generation. It can be through plantation of energy crops, forests or even using the crop residue that is left after processing the crops (Lal, 2004).

In this paper, one of our main concerns is producing power from crop residue. Ernest and Buffington (1981) define crop residue as the non-edible plant parts that are left behind after harvest. This may also include materials that are thrown away after crop packing and crop processing. They have a heating value that is 50% of that of the coal and 33% of that of the diesel fuel. It is around $3x10^6$ kcal/Mg (Larson 1979).

According to the project of Indian government (which is mentioned in section 4), the current power potential from biomass residue in India is 24841 Mega Watt (MW). Of this, 75% is agriculture-based residue while the rest is residue from forests and wasteland (BRAI 2010). This paper aspires to review whether removing this residue from the soil for other purpose environmentally sustainable.

As mentioned before, there are numerous avenues from where biomass can be collected for energy generation. However, the other side of the story is that whenever we use biomass for energy, we are using it at the cost of other benefits. A simple example would be the land used for energy plantation could have been used for agriculture, forestry or other purposes like parks for recreation. However, some studies objects to the general perception that the crop residue is a "waste", and hence, is a "free" fuel. Lal (2004) mentions that all residues should not be removed from the fields as this will decrease soil quality and eventually lead to other severe environmental problems. Some studies (Kim and Dale 2004) claim that preventing soil erosion is the only objective of returning the crop residues to the soil and 20%-40% of the residue can be removed for other purposes. However, these studies were done based on the US Corn Belt and may differ from region to region. According to Lindstrom and Holt (1983), the residue requirements to control soil erosion alone may depend on various factors like the terrain, force of rainfall, land use and also soil management practices like farming system and tillage methods, among others.

Fortunately, the BRAI (2010) estimate of the power potential from residue takes into account the fact that 100% of the residue cannot and should not be used for power generation. After calculating from the available data, we concluded that on an average it is assuming that 60%-70% of the biomass generation from the residue will be used for power generation. However, this is a much higher percentage than the one recommended by the US study, which we admit was specifically for the US Corn Belt. Hence, further research needs to be done in the Indian context on whether this amount is high and might lead to decline in the soil quality in the long run.

Unfortunately, such a study alone might not be able to justify the case for crop residue based energy generation, as is being promoted by the Government of India. Apart from soil erosion there are several more factors that are influenced by returning the residue to the cropland:

- Decline in the Soil Organic Matter content (Wilhelm et al 2004).
- Decline in the source of macronutrients (N, P, K) and micronutrients (S, Cu, B, Zn, Mo) needed for crop growth and humification of residue (Mubarak et al 2002).
- Decline in soil aggregration and eventually the stability of its structure (Carter 2002).
- Decline in energy for all microbial processes in soil (Franzluebbers 2002)
- Decline in water retention and transmission properties (Lal 2004).

Therefore, in order to go for a mass generation of biomass residue based electricity in India these aspects should be considered upon.

9. Conclusion

The potential of biomass residue based power plant in India is quite significant. It can be very much helpful to provide electricity in remote rural areas. Among the other renewable resources (particularly solar) biomass residue based power generation is cheap. Besides it produces very small amount of GHG emission, which can help India to move in a low carbon economy. However, there are conflicting issues that can hinder the growth of biomass residue power growth. One of them is the conflict with food security and other is the appropriate subsidy and carbon pricing. These parameters have to be considered in the future policies and regulation for biomass residue power generation. The government can start with some pilot project to find out the solutions for these conflicting issues. In a nutshell, proper policy, regulation and financial incentives can create the situation of significant portion of power generation from biomass particularly in the rural India.

Abstract

The use of biomass residue for power generation can on one hand be used as a very cheap source of energy where on the other hand help reduce the impact of energy production on environment to a great extent. The study thus tries to analyze the potential of Biomass residue based power generation in India. Firstly, it compares the economic feasibility of different technologies of biomass residue based power generation. The results show that carbon pricing is an important factor in making these technologies more suitable. Secondly, it uses a simple model to predict the future potential of power generation based on this raw material and potential reach up to 62.093 MegaWatt by 2030 and finally, it conducts a GIS analysis that was done to find some suitable locations where rice and wheat residue-based electricity can be launched as pilot project.

Резиме

Употребата на остатоци од биомаса за производство на електрична енергија, од една страна може да се користи како многу евтин извор за енергија, а од друга страна да помогне во намалување на влијанието на производството на електрична енергија врз животната средина во голема мера. Оваа студија се обидува да го анализира потенцијалот на производство на електрична енергија од остатоци од биомаса во Индија. Прво, таа ја споредува економската остварливост на различни технологии на производство на електрична енергија од остатоци од биомаса. Резултатите покажуваат дека јаглеродниот отпечаток (carbon pricing) е важен фактор што допринесува овие технологии да бидат посоодветни. Второ, таа користи едноставен модел да го предвиди идниот потенцијал на производство на електрична енергија од овој вид суровини и потенцијално достигнување до 62,093 мегавати до 2030 година и, на крај, покажува резултати од спроведена ГИС (Географски информационен систем) анализа чија цел е да се лоцираат некои соодветни локации каде може да се лансираат пилот проекти за призводство на електрична енергија од остатоци од ориз и од пченица.

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