

Crop biomass production and its utilization in Punjab: Some energy considerations

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Abstract

The present study was carried out to estimate the production and utilization of biomass along with the energy potential from surplus biomass in Punjab. It was found that paddy crop was harvested mechanically; cotton was harvested manually while basmati and wheat are harvested by using both mechanical and manual harvesting methods. Average yield of biomass was estimated to be 2.51, 7.59, 6.78, 1.96 and 6.20 tonnes per hectare in the case of wheat, basmati, paddy, paddy husk and cotton sticks respectively. It was estimated that 100, 93.86 and 43.18% of the area was put on fire to burn the stubble in the case of paddy, wheat and basmati respectively. The total production of the biomass was estimated to be 48.26 million tonnes in 2009-10 in Punjab. After meeting the farming consumption needs, the surplus biomass was estimated to be 35.96 million tonnes. Assuming the combustion efficiency being 30%, the energy equivalent of surplus biomass has a potential to run as many as 904 power plants of 5 MW capacities for 365 days 20 hours a day. The findings of the study showed that there exists a vast scope for using biomass in the electricity production and other useful purposes.

Keywords: Biomass, production, stubble burning, harvesting, energy potential

Biomass based electric power generation technologies succeeded in niche applications such as supplying electricity in decentralized locations and industries generating biomass waste. The large scale penetration of biomass power technologies depends on their delivered cost and reliability in direct competition with conventional electricity sources in centralized electricity supply. In India, the principal competing source for electricity supply is the coal based power. Biomass energy cost is highly variable, depending upon the source, location, etc.¹ Biomass energy can be used to avoid greenhouse gas emissions from fossil fuels by providing equivalent energy services: electricity, transportation fuels and heat^{2, 3}. In 2001, global biomass energy use for cooking and heating was 39 exajoules, or 9.3% of the global primary energy use, and biomass energy use for electricity and fuel generation was 6 exajoules, or 1.4% of global primary energy use².

Indian sugar mills are rapidly turning to bagasse, the leftover of cane after it is crushed and juice extracted, to generate electricity. This is mainly being done to clean up the environment, to cut down power costs and to earn additional revenue. According to current estimates, about 3500 MW of power can be generated from bagasse in the existing 430 sugar mills of the country. Around 270 MW of power has already been commissioned and more biomass plants are under construction⁶. It has been noticed that major proportion of biomass produced from crops namely paddy and wheat, is either burned or used as fodder in Punjab. The other crops like cotton, sugarcane, maize, pulses, etc. are also the major contributors towards biomass production in the state. High yield of the irrigated paddy-wheat system result in production of huge quantity of crop residue in Punjab. While wheat straw is collected by the farmers after combine harvesting and fed to

animals; but the paddy residue is considered poor feed for animal due to high silica content. Burning is the normal method of paddy stubbles management in Punjab because residues interfere with tillage and seeding operations for the next crop. The burning of residue has been doing great damage to the environment and substantial loss of plant nutrients and organic carbon⁴.

If the residues from the crops is managed scientifically and used as a conventional sources of energy will go a long way to save the fossil fuel, coal, wood, precious foreign exchange expended on import of petroleum products, create additional employment, protect the environment as the incorporation of agricultural residues into the soil being eco-friendly and will also help to improve soil health if burning is avoided. Besides, this will also add to the income of farmers from the by-product generated in the form of biomass⁵.

At present, more than 26 and 37 lakh hectares of land being allocated to paddy and wheat crops respectively in Punjab. It has been reported in the earlier studies that the major portion of residue produced from these crops is either burned or put to less productive uses. The proper management of biomass will help to employ it for more productive purpose. In the back drop of this, present study was undertaken to examine production and utilization of crop biomass and to estimate the energy potential from the surplus biomass.

Methodology

The study was based on the multistage sampling method for the selection of districts, blocks and then villages. The respondents were randomly selected for each sample village. The methodology adopted is discussed as under:

Locale of the study

The study was conducted in Punjab during 2009-10.

Procedure for sample selection

The procedure for the selection of samples is discussed as under following sub-heads:

Selection of districts

The list of all the districts along with area allocated to wheat, paddy and cotton crops in TE 2008-09

was prepared. At first stage two districts having highest area allocated to wheat, paddy and cotton were selected purposively. The selected districts were Ferozepur, Bathinda, Patiala and Sangrur. As such Sangrur and Patiala represent the wheat crop, Ferozepur and Sangrur district the paddy crop, Bathinda and Ferozepur district the cotton crop.

Selection of blocks

At the next stage two blocks from each selected district were chosen randomly pertaining to sample crop. Ghalkhurad and Zira blocks from Ferozepur district while Dhuri and Sangrur blocks from Sangrur district were selected for paddy crop. For wheat the two blocks, Patiala and Nabha from Patiala district and, Dhuri and Sangrur blocks from Sangrur district were selected. Finally, for cotton crop the two blocks, Bathinda and Nathan from Bathinda district and Abohar and Ghalkhurad from Ferozepur district were selected.

Selection of villages

In order to reach out ultimate sampling units, two villages from each block for said crops were selected randomly. The total sample consists of 16 villages.

Selection of the farmers

The complete enumeration of farmers along with area allocated to wheat, paddy and cotton was prepared for 2009-10. Consequently, 25 farmers each from sample villages were selected for each crop randomly. The total sample comprised of 200 farmers for each crop.

Collection of data

In order to accomplish the objectives of the study both secondary as well as primary data were collected. The secondary data pertaining to cropping pattern, area allocated to the major crops in Punjab, gross cropped area, etc. were collected in order to estimate the production, consumption and surplus of biomass of crops at the state level. A schedule was prepared to collect the primary data from selected farmers.

The Personal Interview method was used to collect the data pertaining to area allocated to crop, method of harvesting, biomass Utilization pattern, etc

Analysis of the data

The data so collected was analyzed by using simple tools such as percentages, averages, etc.

Estimation of biomass production

For the estimation of biomass yield is taken in quintal per hectare and area in hectares. The following formula was used to compute the yield of biomass per hectare and then extrapolated at the state level using secondary data on area under particular crop.

$$\text{Biomass Yield (qha}^{-1}\text{)} = \frac{\text{MEH} \times \text{Ae} + \text{MH} \times \text{Ah}}{\text{Total Area (ha)}}$$

MEH = Yield of mechanically harvested crop (qha⁻¹)

MH = Yield of manually harvested crop (qha⁻¹)

Ae = Area harvested mechanically (ha)

Ah = Area harvested manually (ha)

Surplus biomass per farm was estimated by using the following formula:

$$\text{Total surplus} = \text{Total production} - \text{Consumption}$$

The definitions of total consumption and surplus of biomass are given as under:

1. Total consumption = Fodder + Used as littering material + Fuel
2. Surplus biomass = Removed as waste material + Collected by others + Quantity sold + burned.

All the values were taken in tonnes per farm. Based on these values, the total% quantities were computed at the farm level. These% values so computed were used to estimate the consumption and surplus biomass generated at the state level by using secondary data based on area allocated to the crops in 2009-10.

Table 1. The calorific value of different types of biomass

Particulars	Energy (MJ kg ⁻¹)	Energy (MJ t ⁻¹)
Wheat straw	17.15	17150
Paddy straw	15.03	15030
Cotton sticks	17.40	17400
Diesel	44.80	44800
Hard Coal	17.30	17300

Source: www.lehrafuel.com

Estimation of energy from surplus biomass

The energy to be generated from surplus biomass was estimated by using energy equivalent in MJ.

The energy was computed by using the following formula:

$$\text{Total energy (MJ)} = \text{Total quantity burnt (tonnes)} \times \text{Calorific value of biomass (MJ tonnes)}$$

Production of electricity by using the energy wasted by burning of the stubbles

Combustion efficiency was assumed to be 30% of the biomass, and it is assumed that plant will operate for 365 days 20 hours per day. The following formula was used to estimate the number of plants with 5 MW capacity which can be set up in the state.

$$\text{Electricity (MWh)} = \frac{\text{Energy (MJ)} \times .3}{365 \times 20}$$

$$\text{No. of 5MW Power Plants} = \frac{\text{Electricity (MW)}}{5}$$

Results and Discussion

The results obtained from the analysis of data are discussed as under:

Method of harvesting used by the sample farmers

The results obtained from the analysis data generated through the sample farmers both mechanical and manual harvesting of crops is discussed below:

Pattern of harvesting of wheat crop

The perusal of Table 2 revealed that at overall level 93.70% of wheat was harvested mechanically in 2009-10. It was noticed that 100, 91.46, 94.63 and 85% of wheat was harvested mechanically in the Ferozepur, Bathinda, Patiala and Sangrur district, respectively. Similarly, 8.54, 5.37 and 14.67% of wheat was harvested manually in Bathinda, Patiala and Sangrur districts respectively. This shows that major area allocated to wheat was harvested mechanically.

Table 2. Harvesting pattern of wheat crop by the respondents in the Punjab

(ha)

Name of the district	Mechanical harvesting	Manual harvesting
Ferozepur	6.48 (100)	-
Bathinda	5.89 (91.46)	0.55 (8.54)
Patiala	5.81 (94.63)	0.33 (5.37)
Sangrur	3.20 (85.33)	0.55 (14.67)
Overall	5.34 (93.70)	0.36 (6.30)

Figures in parentheses are the percentage to the total

Area of basmati paddy harvested by using different methods

The perusal of Table 3 revealed that 56.82% of basmati paddy was harvested manually at the overall level. The district-wise analysis shows that 38.82, 54.39 and 68.75% of basmati paddy was harvested manually in Ferozepur, Patiala and Sangrur districts respectively.

Table 3. Pattern of harvesting of basmati paddy of the respondent in Punjab

(ha)

Districts	Harvested manually	Harvested mechanically	Total
Ferozepur	0.33 (38.82)	0.52 (78.79)	0.85 (100)
Patiala	0.31 (54.39)	0.26 (45.61)	0.57 (100)
Sangrur	0.22 (68.75)	0.10 (31.25)	0.32 (100)
Over all	0.25 (56.82)	0.19 (43.18)	0.44 (100)

Figures in parentheses are the percentage to the total

The figures at the overall level for the mechanically harvested basmati paddy were estimated to be 43.18%. The further district-wise analysis shows that 78.79, 45.61 and 31.25% of basmati paddy was harvested mechanically in Ferozepur, Patiala and Sangrur districts respectively.

Yield of biomass from mechanically and manually harvested wheat crop

The perusal of Table 4 revealed that the overall yield of mechanically harvested wheat straw was estimated to be 24.38 in 2009-10. The districts wise analysis show that the yield of mechanically generated wheat straw was 21.05, 24.31, 25.40 and 25.77 quintals per hectare in Ferozepur, Bathinda, Patiala and Sangrur districts respectively. It was found that the overall yield of biomass from manually harvested wheat crop was estimated to be 47.96 quintals per hectare 2009-10. The district-wise analysis shows that the yield of manually generated wheat straw was 46.62, 49.42 and 47.84 quintals per hectare in Bathinda, Patiala and Sangrur districts respectively.

Table 4. Yield of biomass from mechanically harvested wheat crop in Punjab

District	Area harvested (ha)		Yield (Qha ⁻¹)	
	Mechanically	Manually	Mechanically	Manually
Ferozepur	6.48	-	21.05	-
Bathinda	6.68	0.55	24.31	46.62
Patiala	5.81	0.33	25.40	49.42
Sangrur	3.20	0.55	25.77	47.84
Overall	5.34	0.36	24.38	47.96

Biomass yield of manually harvested cotton and basmati

The perusal of Table 5 revealed that the biomass in the form of sticks in the case of cotton was estimated to be 61.98 quintals per hectare in 2009-10 at overall level. The district wise analysis shows that biomass yield was 55.94 and 68.02 quintal per hectare in Ferozepur and Bathinda districts respectively. The results revealed that the overall yield of basmati straw was estimated to be 75.88 quintal per hectare. The district-wise analysis shows that yield of paddy straw was estimated to be 75.29, 76.87 and 75.58 quintals per hectare in Ferozepur, Patiala and Sangrur districts respectively.

Production of biomass in Punjab

The perusal of the Table 6 revealed that the total production of biomass in Punjab was estimated to be 482.57 lakh tonnes. The categories wise analysis

showed that the total production of wheat straw in Punjab was estimated to be 169.07 lakh tonnes during 2009-10. The production of paddy straw was estimated to be 77.54 lakh tonnes in the above said year. The total production of paddy husk in Punjab was estimated to be 54.92 lakh tonnes in 2009-10. The paddy husk was the by-product generated at the milling in the paddy processing units and sold to in the market through traders or wholesaler.

Table 5. Yield of biomass from manually harvested cotton and basmati Punjab, 2009-10

(Q ha⁻¹)

Districts	Cotton	Basmati
Ferozepur	55.94	75.29
Bathinda	68.02	-
Patiala	-	76.87
Sangrur	-	75.58
Overall	61.98	75.88

Table 6. Production of biomass in Punjab during 2009-10

Particulars	Yield (t ha ⁻¹)	Area (L ha)	Production (Lakh tonnes)
Wheat straw	2.51	35.22	169.07
Basmati	7.59	5.99	77.54
Paddy	6.78	22.03	149.36
Paddy husk	1.96	28.02	54.92
Cotton sticks	6.20	5.11	31.68
Total biomass production	-	-	482.57

The respective figure (Table 6) for the cotton sticks was estimated to be 31.68 lakh tonnes in 2009-10. It is pertinent to mention here that the estimates of biomass generation consisted of the biomass being burned.

Stubble burned in the area: Paddy

It was noticed that a vast majority of the sample farmers put their fields on fire to burn the stubbles after harvesting of the crops. It can be seen in Table 7 that all the paddy growers put the field on fire to burn the stubbles because of expenses borne to mulch the stubbles into the soil are quite high.

The results presented in Table 7 further show that the entire area under paddy (4.91 hectare) was burned in 2009-10 at the overall level. The district-wise analysis shows that 100.00% of area under paddy was burned in each of the districts. So they prefer to put the stubbles on fire.

Stubble burned in the area: Basmati

The perusal of the Table 7 revealed that at the overall 43.18% of the area allocated to basmati paddy was burned in 2009-10. The districts-wise analysis show that 61.18, 45.61 and 31.25% stubble the basmati area was burned in Ferozepur, Patiala and Sangrur districts respectively. This shows that in the case of basmati entire area was not burned after harvesting because its straw is used as fodder, etc.

Stubble burned in the area: Wheat

The perusal of the Table 7 revealed that the 93.86% of the area under wheat was burned in 2009-10 to clear

Table 7. Area burned of paddy in Punjab during 2008-09 and 2009-10 (ha)

Districts	Paddy		Basmati		Wheat	
	Area allocated	Area burned	Area allocated	Area burned	Area allocated	Area burned
Ferozepur	5.87	5.87 (100)	0.85	0.52 (61.18)	6.48 (100)	6.48 (100)
Bathinda	4.71	4.71 (100)	-	-	6.44 (96.25)	5.89 (91.46)
Patiala	5.6	5.6 (100)	0.57	0.26 (45.61)	6.14 (100)	5.81 (94.63)
Sangrur	3.46	3.46 (100)	0.32	0.10 (31.25)	3.75 (100)	3.25 (85.3)
Overall	4.91	4.91 (100)	0.44	0.19 (43.18)	5.7 (100)	5.35 (93.86)

Figures in parentheses are total% area burned to crop area

the field after harvesting. The district-wise analysis show that 100, 91.46, 94.63 and 85.30% of the wheat area was burned after harvesting in Ferozepur, Bathinda, Patiala and Sangrur districts to clear the field. This shows that nearly 94% of the area allocated to wheat was put to fire to burn the stubbles after harvesting the crop.

Utilization pattern of biomass

It was noticed that the biomass from different crops is utilized in different forms such as fodder, littering material, etc. The detailed results are presented here under and discussed separately for each crop:

Utilization pattern of wheat straw

The results presented in Table 8 revealed that the wheat biomass in Punjab is used in various forms such as fodder, littering material, etc. It was observed that 77.34% of wheat straw was used as fodder at the overall level.

In Table 8 districts-wise analysis shows that the 75.88, 77.93, 83.40 and 69.94% of wheat straw was used as fodder in Ferozepur, Bathinda, Patiala and Sangrur districts respectively. The quantity of biomass used for littering material was estimated to be 2.03% in the overall level. The districts-wise analysis shows that 1.76, 1.82, 1.69 and 3.39% of wheat straw was used as a littering material by the respondents in Ferozepur, Bathinda, Patiala and Sangrur districts respectively.

The quantity of biomass removed as a waste material was estimated to be 1.41% at the overall level. The district-wise analysis shows that 1.47, 1.05, 1.08 and 2.42% of biomass was removed as a waste material in Ferozepur, Bathinda, Patiala and Sangrur districts respectively.

The results further show that the 2.19% of the wheat straw was collected by the labour and others to clear the fields. It was found that 2.49, 2.23, 1.69 and 2.42% of wheat straw was collected by others in Ferozepur, Bathinda, Patiala and Sangrur districts respectively. The results further revealed that at the overall level, 17.03% of the wheat straw was disposed of in 2009-10. Similarly, 18.40, 16.96, 12.13 and 24.24% of farmers sold their wheat straw in the above said districts respectively.

Utilization of basmati straw

The perusal of Table 9 revealed that at the overall level 53.44% of basmati straw was used as fodder in 2009-10. The results further show that the 54.62, 52.60 and 52.41% of a basmati straw was used as fodder in Ferozepur, Patiala and Sangrur districts respectively. It was estimated that on the average 35.98% of the basmati straw was paid in kind to the labour for harvesting of basmati. It was found that the 36.14, 35.06 and 36.75% of the basmati straw was paid in kind in Ferozepur, Patiala and Sangrur districts respectively.

Table 8. Utilization pattern of wheat straw of the respondent farmers in Punjab

(t farm⁻¹)

Particulars	Ferozepur	Bathinda	Patiala	Sangrur	Overall
Fodder	10.35 (75.88)	11.16 (77.93)	12.31 (83.40)	5.77 (69.94)	9.90 (77.34)
Littering material	0.24 (1.76)	0.26 (1.82)	0.25 (1.69)	0.28 (3.39)	0.26 (2.03)
Remove as waste material	0.20 (1.47)	0.15 (1.05)	0.16 (1.08)	0.20 (2.42)	0.18 (1.41)
Collected by others	0.34 (2.49)	0.32 (2.23)	0.25 (1.69)	0.20 (2.42)	0.28 (2.19)
Sold	2.51 (18.40)	2.43 (16.96)	1.79 (12.13)	2.00 (24.24)	2.18 (17.03)
Total	13.64 (100)	14.32 (100)	14.76 (100)	8.25 (100)	12.8 (100)

Figures in parentheses are percent of the total

Table 9. Utilization pattern of basmati straw of the respondent farmers in Punjab*(t farm⁻¹)*

Particulars	Ferozepur	Patiala	Sangrur	Overall
Fodder	1.36 (54.62)	0.81 (52.60)	0.87 (52.41)	1.01 (53.44)
Paid in kind	0.9 (36.14)	0.54 (35.06)	0.61 (36.75)	0.68 (35.98)
Remove as waste material	0.06 (2.41)	0.05 (3.25)	0.06 (3.61)	0.06 (3.17)
Sold	0.12 (4.82)	0.08 (5.19)	0.08 (4.82)	0.09 (4.76)
Collected by others	0.05 (2.00)	0.06 (3.90)	0.04 (2.41)	0.05 (2.65)
Total	2.49 (100)	1.54 (100)	1.66 (100)	1.89 (100)

Figures in parentheses are total% of the total

The overall quantity of biomass removed as a waste material was estimated to be 3.17%. On an average 2.41, 3.25 and 3.61% of the basmati straw was removed as a waste material in Ferozepur, Patiala and Sangrur districts. It can be seen in Table 9 that 4.76% of the basmati straw was sold by the selected farmers at the overall level. The district-wise analysis shows that the 4.82, 5.19 and 4.82% of basmati straw was sold by the farmers in Ferozepur, Patiala and Sangrur districts respectively. The results further show that 2.65% of basmati straw was collected by others, particularly by the labourers in order to clear the field. The results further shows that the 2.00, 3.90 and 2.41% of basmati straw was collected by others in Ferozepur, Patiala and Sangrur districts respectively (Table 9). This shows that basmati straw was being put to more useful purpose as compared to paddy straw.

Utilization pattern of cotton

The results presented in Table 10 revealed that the crop biomass of cotton called cotton sticks was being put to various uses such as fuel, paid in kind, sold, etc. The total production of cotton sticks was estimated to be 10.31 tonne per farm in Punjab.

Table 10 results further show that the 55.09% of the cotton sticks were used as fuel. It was found that 20.17% of the cotton sticks were paid in kind. It can be seen from Table 10 that 24.64% of cotton sticks

were being sold by the farmers. This shows that cotton sticks are used optimally in the area as it is easy to collect and store. Moreover, it can be used more commonly as fuel.

Table 10. Utilization pattern of cotton sticks in the sample districts in Punjab*(t farm⁻¹)*

Particulars	Bathinda	Ferozepur	Average	Per cent
Fuel	5.90	5.46	5.68	55.09
Paid in kind	2.27	1.90	2.08	20.17
Sold	3.18	1.91	2.54	24.64
Total	11.35	9.27	10.31	100

Utilization of biomass from different crops in Punjab

In order to estimate the surplus of biomass in Punjab the consumption based on the sample farmers has been deducted from the total production. It is worth mentioning here that the consumption constitutes fodder and fuel. The surplus constitutes the quantity paid in kind, removed as waste material, burned, etc. It was noticed that 25.58% biomass was consumed at the overall level during. The category-wise analysis shows 41.49, 58.90 and 43.37% of the crop biomass was consumed in respect of wheat straw, cotton

sticks and basmati straw on the farm itself in various forms. The surplus biomass generated was estimated to be 74.47% in 2009-10. The category-wise analysis shows that, 59.86, 41.10, 52.63 and 100% of the crop biomass was generated in the form of wheat straw, cotton sticks and basmati straw respectively. It was found that in the case of paddy the whole quantity of biomass was burned whereas the entire quantity of rice husk was sold (Table 11).

Table 11. Utilization of biomass from different crops in Punjab

(Lakh tonnes)

Particular	Wheat straw	Cotton sticks	Basmati straw	Paddy straw/ Paddy husk	Total
Fodder	66.07	-	36.73	-	102.80
Fuel	-	18.66	-	-	18.66
Littering material	1.79	-	-	-	1.79
Total consumption (a)	67.86 (41.49)	18.66 (58.90)	36.73 (43.37)	-	123.5 (25.58)
Remove as waste material	1.25	-	1.44	-	2.69
Collected by others	1.94	-	1.20	-	3.14
Paid in kind	-	6.49	16.36	-	22.85
Sold	15.05	6.53	2.17	54.92	78.67
Burned	82.97	-	19.64	149.36	251.97
Total surplus (b)	101.21 (59.86)	13.02 (41.10)	40.81 (52.63)	204.55 (100)	359.59 (74.47)
Total biomass (a + b)	169.07 (100)	31.68 (100)	77.54 (100)	204.55 (100)	482.84

Figures in parentheses are% of the total

The respective figures in the case of basmati paddy were estimated to be 16.96 million tonnes during 2009-10. The same for paddy came out to be 16.9 million tonnes. By taking into account the calorific values the total energy wasted was estimated to be 396307 million mega joules during the period. By burning wheat stubbles energy was estimated to be 142294 million mega joules (MJ) whereas the energy

to the tune of 254013 million MJ was wasted by burning paddy stubbles in Punjab (Table 12).

Table 12. Estimation of energy from burned biomass in Punjab

Crop	Quantity burned (Million tonnes)	Energy (Million MJ)
Wheat	8.29	142294
Paddy	16.9	254013
Total	25.20	396307

The perusal of the Table 13 revealed that the total energy wasted by burning stubbles of wheat, paddy and basmati was estimated to be 396306 million mega joules. By taking combustion efficiency of the fuel at 30%, the expected amount of energy in MJ was estimated to be 16.28 during 2009-10.

Table 13. Expected generation of electricity from burned biomass stubbles in Punjab

Particulars	2009-10
Energy from burned biomass (Million MJ)	396306
Combustion efficiency at the rate of 30% (Million MJ)	16.28
Expected amount of electricity to be generated (MW)	4522.22
Number of plants to be installed having capacity of 5 MW	904

By using the above data it was expected that 4522.22 mega watt of the electricity could be produced. It was estimated that 904 power plants of 5 MW could be established in Punjab which run for 365 days at the rate of 20 hours a day. Therefore, a wide scope for the energy to be generated which is being wasted by burning the biomass. This calls for better management of biomass so that it can be put to productive purposes.

Conclusion

The total energy wasted by burning of wheat stubbles was estimated to be 142294 million mega joules (MJ) during 2009-10. The energy to the tune of 254013 million MJ was wasted by burning paddy stubbles in Punjab. Assuming the combustion efficiency of 30%, the energy equivalent of surplus biomass has a potential to run as many as 904 power plants of

5 MW capacity for 365 days at the rate of 20 hours a day. The results indicated that more than 4852 megawatt of electricity can be produced through the above mentioned plants. If the biomass produced from different crops is used as fuel to run biomass plants for generating electricity a large amount of coal used by the thermal plants in the state can be saved.

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