Sustainable Fuel Energy Potential from Agricultural Biomass

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ABSTRACT

In India, over 370 million tonnes of biomass is generated every year and it contributes to over one third of primary energy (Chauhan, 2010). This biomass can be easily densified in the form of pellets and briquettes. The present study was undertaken to estimate the availability of biomass for major agricultural crops and to work out its energy potential. Based on the area under cultivation and production for the years 2000-01 and 2011-12, ten major agricultural crops of Haryana were selected i.e. rice, jowar, bajra, maize, cotton, sugarcane, wheat, barley, gram, and rapeseed and mustard. Total amount of generated biomass in 2011-12 for kharif season was 10113.69 000 Tonnes and for rabi season was 22774.13 000 Tonnes. In 2011-12, total energy potential from kharif crop was 10.12×10⁸ and from rabi crop was 30.50×10⁷.

Keywords: Energy, Biomass, Potential, Clean

Introduction

Availability and consumption levels of energy are the best indicators of economic and social development of nations and societies. Energy demand is expected to increase considerably in the coming years as a result of increasing population. The largest increase in energy demand will take place in developing countries where population of global energy consumption is expected to increase from 46 to 58 percent between 2004 and 2030.

In many developing countries, crop residues have been the main source of energy, mostly in its traditional forms to meet the demands of domestic users. India produces about 500 million tons (mt) of crop residues annually (MNRE, 2009) which is used as animal feed, composting, thatching for rural homes and fuel for domestic and industrial use. Apart from meeting the needs of energy to such an extent, unfortunately, a large portion of the biomass residue is burnt in field primarily to clear the fields, from straw and stubble after the harvest of preceding crop.

Burning of crop residues in field is unacceptable as it is responsible for emission of greenhouse gases such as carbon dioxide, methane and nitrogen oxide causing global warming, loss of plant nutrients such as nitrogen, phosphorus, potassium and sulphur, adverse impact on soil properties and wastage of valuable carbon and energy rich residues. Likewise, burning of loose biomass at household level in inefficient mud wood stoves, directly affects the health of the
women who spend a lot of time in cooking and heating activities for their families. Report of ICMR (2001) revealed that Indoor air pollution caused by burning traditional fuels has been the major cause of acute respiratory tract infections in children, chronic obstructive lung diseases, pneumoconiosis, lung cancer, cataract and adverse pregnancy effects in women.

Due to diversity of biomass residues and different products that can be obtained, there are several techniques that allow transforming biomass in high energy fuels that are easy to transport, handle and storage. Biomass pelletizing is one such appropriate technology for harnessing clean and renewable fuel-energy from the surplus biomass. Not only are the biomass pellets more energy dense, these are also easier to handle and use in the improved pellet stove at household level. Biomass pellets and pellet stoves were perceived as most beneficial by rural homemakers for meeting their cooking needs (Kumari and Singal, 2012).

Therefore, harnessing of clean energy from biomass will help not only in solving the problems of women’s health and deteriorating environment, but will also help to create employment opportunities for rural youth and women in rural areas. Pelletizing units can be easily established at village level and managed by and women. This, in turn, will slow down the migration rate from rural areas to cities.

Based on the above rationale, need was felt to make detailed estimation of biomass availability from agricultural crop residues and to work out its energy potential.

The main objectives of this study include estimation of biomass quantum available from major agricultural crops in Haryana and Assessment of energy potential from available agricultural biomass.

Materials and Methods

Methodology followed for estimation of biomass quantum and energy potential is discussed as follows:

Identification of crops for estimation of biomass

Major agricultural crops of Haryana were identified on the basis of area under cultivation and production for the year 2000-01 and 2011-12.

Estimation of biomass

Quantum of biomass generated from each crop was estimated by using Crop Residue Ratio (CRR) for various crops, as given by Rajasthan Renewable Energy Corporation, 2011, as follows:

\[
\text{Biomass (kg)} = \text{Yield (kg/Ha)} \times \text{Crop Residue Ratio}
\]

The data on quantum of biomass generated from major agricultural crops in Haryana was calculated for the years 2000-01 and 2011-12 to highlight the percent change in availability of biomass over the last ten years.

Assessment of energy potential

Calorific values for various crop residues were obtained from the literature (Hiloidhari et al., 2011; Friedl et al., 2005; Singh et al., 2008 and Jekayinfa and Scholz, 2009).

Quantum of biomass generated for each major agricultural crop was multiplied by its calorific value to assess the energy potential of various crop residues, as follows:

\[
\text{Energy potential (MJ)} = \sum \text{Biomass } \times \text{Calorific value}
\]
The percentage change in energy potential from residues of major agricultural crops in Haryana in 2011-12 over 2000-01 was also calculated.

**Results and Discussion**

Results were discussed under the following heads:

Identification of crops for estimation of biomass
Estimation of biomass
Assessment of energy potential

**Identification of crops for estimation of biomass**

Major agricultural crops of Haryana were identified on the basis of area under cultivation and production for the years 2000-01 and 2011-12.

**Area under cultivation of various agricultural crops in Haryana**

Figure 1 depicts that in 2011-12, rice, cotton and bajra comprised the largest area under cultivation (92.00%) in kharif season. Out of the remaining 8.00 per cent area under cultivation, 7.00 per cent area was cultivated under sugarcane and jowar.

Similar cropping pattern was also observed for the year 2000-01, reflecting that there has been no change in the area under cultivation over the last ten years. Further perusal of Figure 1 reveals that in 2011-12, wheat crop comprised the largest area under cultivation (79.00%) while rapeseed and mustard, gram, and barley comprised 20.00 per cent of the total area under cultivation. Like kharif season, no change in cropping pattern of rabi crops was observed for the year 2000-01.

The area under cultivation by other crops, both in kharif season and rabi season, was negligible i.e. 1.00 per cent only. Therefore, on the basis of area under cultivation, ten crops viz., rice, jowar, bajra, maize, cotton, sugarcane, wheat, barley, gram, and rapeseed and mustard emerged as major crops of Haryana.

**Production of various agricultural crops in Haryana**

Production of various agricultural crops was also tabulated for the years 2000-01 and 2011-12 to cross check the major crops of Haryana.

Perusal of data presented in Figure 2 reveals that in 2011-12, rice and cotton contributed highest to the total production (77.00%) under kharif crops while bajra and sugarcane contributed to another 22.00 per cent of the total production. Similar pattern was also observed for the year 2000-01, where rice and cotton contributed to 73.00 per cent of the total production. Sugarcane and bajra contributed to another 26.00 per cent of the total production.

Further scrutiny of Figure 2 postulates that under rabi crops of 2011-12, production of wheat was highest (91.00%) while rapeseed and mustard, barley, and gram contributed to another 7.00 per cent of the total production. Similarly, in 2000-01, wheat was highest in production and rapeseed and mustard, barley, and gram contributed the remaining percentage of the total production.

The contribution of other crops to the total production was negligible both, in kharif and rabi seasons. Based on the production of the crops, ten crops viz., rice, jowar, bajra, maize, cotton, sugarcane, wheat, barley, gram, and rapeseed and mustard, emerged as major crops of Haryana.

Conclusively, based on the area under cultivation and the percentage contribution of
the crops to the total production, both for the years 2000-01 and 2011-12, the major kharif crops were identified as rice, jowar, bajra, maize, cotton, and sugarcane, whereas, wheat, barley, gram, and rapeseed and mustard were identified as major crops of rabi season.

**Estimation of biomass**

Estimation of biomass generated from major agricultural crops in Haryana was calculated by multiplying the yield with Crop Residue Ratio (RREC, 2011). As the Crop Residue Ratio (CRR) for different types of biomass generated by various crops i.e. husk, straw, stalk etc. varies, therefore, the quantum of biomass for each crop was calculated by multiplying its yield with the CRR value of its biomass types (Table 2).

The scrutiny of Table 2 unveils that under kharif crops, in 2011-12, the highest amount of biomass was generated by rice i.e. 4507.92 000 Tonnes, followed by bajra (3091.41 000 Tonnes), cotton (2090.22 000 Tonnes), sugarcane (277.53 000 Tonnes), jowar (77.63 000 Tonnes) and maize (68.98 000 Tonnes).

The Table further reveals that the highest percentage increase in the amount of biomass was found in cotton (88.85%) over 2000-01, followed by bajra (79.08%). About 40.00 per cent increase was found in the amount of biomass generated from jowar (42.16%) and rice (39.34%) over 2000-01. It was further revealed that in case of sugarcane and maize, the quantum of biomass generated in 2011-12 decreased by 15.06 per cent and 14.08 per cent, respectively over the base year (2000-01).

Scrutiny of Table 2 highlights that under rabi crops, in 2011-12, the highest amount of biomass was generated by wheat i.e. 20991.56 000 Tonnes. This was followed by rapeseed and mustard (1494.08 000 Tonnes), barley (193.72 000 Tonnes), and gram (94.77 000 Tonnes). The highest percentage increase in the amount of biomass was found in wheat (35.69%) over 2000-01, followed by rapeseed and mustard (33.48%), and barley (25.99%). On the other hand, 8.50 per cent decrease was found in the amount of biomass generated from gram in 2011-12 over 2000-01.

**Assessment of energy potential**

Data presented in Table 2 clearly reveals that the highest amount of biomass was generated from rice in kharif season and wheat in rabi season. However, it is well established that the biomass generated from these two crops is put to multiple uses. Biomass from rice crop is used for making fireboard, resin binders, paper etc. since last several years (Punia et al., 2008). Wheat straw is used as animal feed till date. Keeping in view the productive end uses of the biomass from these two crops, this amount of biomass was not included for the calculation of fuel energy potential.

Energy potential for the remaining major crops of Haryana was calculated by multiplying the quantum of different types of biomass generated from each crop with its calorific value (Table 3).

Table 3 postulates that in 2011-12, under kharif crops, the highest energy potential was calculated for the biomass generated from bajra i.e. 56.64×10⁷ MJ/Kg, followed by biomass generated from cotton (36.47×10⁷ MJ/Kg), sugarcane (55.50×10⁶ MJ/Kg), jowar (13.93×10⁶ MJ/Kg) and maize (11.57×10⁶ MJ/Kg). The highest percentage increase in the energy potential in 2011-12 over the year 2000-01 was observed for the biomass generated from cotton (88.85%), followed by bajra (79.08%), and jowar (42.16%).
Table 1: Estimation of biomass generated from major agricultural crops in Haryana

| Crop            | Biomass types | CRR | 2000-01       |          | 2011-12       |          | % change over 2000-01 |
|-----------------|---------------|-----|---------------|----------|---------------|----------|----------------------|
|                 |               |     | Yield (Kg/Ha) | Biomass (000 Tonnes) | Yield (Kg/Ha) | Biomass (000 Tonnes) |          |
| Kharif          |               |     |               |          |               |          |                      |
| Rice            | Husk          | 0.2 | 2557          | 539.6    | 3044          | 751.32   | 39.35                |
|                 | Straw         | 1.0 | 2695.84       |          | 3756.60       |          | 39.34                |
|                 |               |     | 3235.00       |          | 4507.92       |          | 39.34                |
| Bajra           | Cob           | 0.33| 1079          | 216.59   | 2040          | 387.89   | 79.08                |
|                 | Husk          | 0.3 | 196.90        |          | 352.63        |          | 79.09                |
|                 | Stalk         | 2   | 1312.71       |          | 2350.89       |          | 79.08                |
|                 |               |     | 1726.20       |          | 3091.41       |          | 79.08                |
| Cotton          | Stalk         | 2.5 | 424           | 588.72   | 739           | 1111.82  | 88.85                |
|                 | Boll shell    | 1.1 |              | 259.03   |              | 489.20   | 88.85                |
|                 | Husk          | 1.1 |              | 259.03   |              | 489.20   | 88.85                |
|                 |               |     | 1106.78       |          | 2090.22       |          | 88.85                |
| Sugarcane       | Bagasse       | 0.3 | 5713          | 245.08   | 7319          | 208.15   | -15.06               |
|                 | Top and leaves| 0.1 |              | 81.69    |              | 69.38    | -15.06               |
|                 |               |     | 326.77        |          | 277.53        |          | -15.06               |
| Jowar           | Cob           | 0.5 | 208           | 11.37    | 500           | 16.17    | 42.21                |
|                 | Husk          | 0.2 |              | 4.55     |              | 6.47     | 42.19                |
|                 | Stalk         | 1.7 |              | 38.68    |              | 54.99    | 42.16                |
|                 |               |     | 54.60         |          | 77.63         |          | 42.16                |
| Maize           | Cob           | 0.3 | 2267          | 10.47    | 2727          | 8.99     | -14.13               |
|                 | Stalk         | 2   |              | 69.82    |              | 59.99    | -14.07               |
|                 |               |     | 80.29         |          | 68.98         |          | -14.08               |
| Total           |               |     | 6529.6        |          | 10113.69      |          | 54.88                |
| Rabi            | Wheat         |     |               |          |               |          |                      |
|                 | Straw         | 1.3 | 4106          | 12569.45 | 5183          | 17055.65 | 35.69                |
|                 | Pod           | 0.3 |              | 2900.64  |              | 3935.91  | 35.69                |
|                 |               |     | 15470.09      |          | 20991.56      |          | 35.69                |
|                 | Rapeseed and mustard | Stalk | 2 | 1369 | 1119.29 | 1394 | 1494.08 | 33.48 |
|                 | Barley        |     |               |          |               |          |                      |
|                 | Stalk         | 1.3 | 2682          | 153.75   | 3617          | 193.72   | 25.99                |
|                 | Gram          |     |               |          |               |          |                      |
|                 | Stalk         | 1.1 | 640           | 103.58   | 924           | 94.77    | -8.50                |
| Total           |               |     | 16846.71      |          | 22774.13      |          | 35.18                |
Table 2: Change in energy potential for the year 2011-12 over 2000-01

| Crop          | Biomass type | Calorific value | 2000-01          | 2011-12          | % change over 2000-01 |
|---------------|--------------|-----------------|------------------|------------------|-----------------------|
|               |              |                 | Biomass (Kgs) 2000-01 | Energy potential (MJ/Kg) | Biomass (Kgs) 2011-12 | Energy potential (MJ/Kg) |                      |
| Kharif        |              |                 |                   |                   |                       |                         |                      |
| Bajra         | Cob          | 17.39           | 216597381         | 37.67×10^6       | 387897840             | 67.46×10^6               | 79.08                |
|               | Husk         | 17.48           | 196906710         | 34.42×10^6       | 352634400             | 61.64×10^6               | 79.08                |
|               | Stalk        | 18.60           | 1312711400        | 24.42×10^7       | 2350896000             | 43.73×10^7               | 79.08                |
|               |              |                 |                   | 31.62×10^7       |                       |                         |                       |
| Cotton        | Stalk        | 17.40           | 588724000         | 10.24×10^7       | 1111825500             | 19.35×10^7               | 88.85                |
|               | Boll shell   | 18.30           | 259038560         | 47.40×10^6       | 489203220             | 89.52×10^6               | 88.85                |
|               | Husk         | 16.70           | 259038560         | 43.26×10^6       | 489203220             | 81.70×10^6               | 88.85                |
|               |              |                 |                   | 19.31×10^7       |                       |                         |                       |
| Sugarcane     | Bagasse      | 20.00           | 245087700         | 49.02×10^6       | 208152360             | 41.63×10^6               | 88.85                |
|               | Top and leaves| 20.00           | 81695900          | 16.34×10^6       | 69384120              | 13.88×10^6               | 88.85                |
|               |              |                 |                   | 65.36×10^6       |                       |                         |                       |
| Jowar         | Cob          | 17.39           | 11377600          | 19.79×10^5       | 16175000              | 28.13×10^5               | 42.16                |
|               | Husk         | 17.48           | 4551040           | 79.55×10^4       | 6470000               | 11.31×10^5               | 42.16                |
|               | Stalk        | 18.16           | 38683840          | 70.25×10^5       | 54995000              | 99.87×10^5               | 42.16                |
|               |              |                 |                   | 97.99×10^5       |                       |                         |                       |
| Maize         | Cob          | 17.39           | 10473540          | 18.21×10^5       | 8999100               | 15.65×10^5               | 42.16                |
|               | Stalk        | 16.67           | 69823600          | 11.64×10^6       | 59994000              | 10.00×10^6               | 42.16                |
|               |              |                 |                   | 13.46×10^6       |                       |                         |                       |
| Total         |              |                 |                   | 59.73×10^7       |                       |                         | 40.97                |
| Rabi          |              |                 |                   |                   |                       |                         |                      |
| Rapeseed and mustard | Stalk | 17.00           | 1119294400        | 19.03×10^7       | 1494089200             | 25.40×10^7               | 33.48                |
| Barley        | Stalk        | 18.16           | 153759060         | 27.92×10^6       | 193726520             | 35.18×10^6               | 25.99                |
| Gram          | Stalk        | 16.02           | 103584000         | 16.59×10^6       | 94774680              | 15.18×10^6               | -8.50                |
| Total         |              |                 |                   | 23.50×10^7       |                       |                         | 29.78                |
**Fig. 1** Area under cultivation of various agricultural crops in Haryana

| Kharif crops          | 2000-01 | % Area |
|-----------------------|---------|--------|
| Rice                  | 42%     |        |
| Bajra                 | 24%     |        |
| Cotton                | 22%     |        |
| Sugarcane             | 6%      |        |
| Jowar                 | 4%      |        |
| Maize                 | 1%      |        |
| Other crops           | 1%      |        |

| 2011-12 | % Area |
|---------|--------|
| Rice    | 47%    |
| Bajra   | 22%    |
| Sugarcane | 3%  |
| Jowar   | 4%     |
| Maize   | 1%     |
| Other crops | 1% |

| Rabi crops | % Area |
|------------|--------|
| Wheat      | 80%    |
| Rapeseed and mustard | 14% |
| Gram       | 4%     |
| Barley     | 1%     |
| Other crops | 1%    |

**Fig. 2** Production of various agricultural crops in Haryana

| Kharif crops | 2000-01 | % Production |
|--------------|---------|--------------|
| Rice         | 48%     |              |
| Bajra        | 12%     |              |
| Other crops  | 1%      |              |
| Sugarcane    | 14%     |              |
| Cotton       | 25%     |              |

| 2011-12 | % Production |
|---------|--------------|
| Rice    | 45%          |
| Bajra   | 14%          |
| Sugarcan | 8%      |
| Jowar   | 4%           |
| Maize   | 1%           |
| Other crops | 1% |

| Rabi crops | % Production |
|------------|--------------|
| Wheat      | 92%          |
| Barley     | 1%           |
| Gram       | 1%           |
| Rapeseed and mustard | 5% |
| Other crops | 1%  |

| % Production |
|--------------|
| Wheat        | 91%          |
| Barley       | 1%           |
| Gram         | 1%           |
| Rapeseed and mustard | 2% |
| Other crops  | 2%           |
Under rabi crops, the highest energy potential was found in the biomass generated from rapeseed and mustard i.e. $25.40 \times 10^7$ MJ/Kg, followed by biomass generated by barley ($35.18 \times 10^6$ MJ/Kg), and gram ($15.18 \times 10^6$ MJ/Kg). While comparing this energy potential for the year 2011-12 with the energy potential for 2000-01, the highest percentage increase in energy potential was found in the biomass from rapeseed and mustard (33.48%), followed by biomass from barley (25.99%).

It is, therefore, concluded that the biomass generated from major agricultural crops of both kharif and rabi season (excluding rice and wheat, respectively) has a huge energy potential, which can be used for harnessing clean green energy for household uses through pelletization. It has been found that conversion of biomass into pellets and burning it in improved pellet stoves gives a clean, smoke free flame. Hence, use of biomass in the form of pellets can overcome the problem of inefficient combustion as observed in traditional mud stoves. Use of biomass pellets will also help in mitigating the health problems associated with smoke pollution. Ultimately, this will also result in maintaining sustainable health of the environment and the economy.

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