# Chapter 4
# Alternative Uses of Crop Stubble

**Abstract** Keeping in view the increasing problems associated with crop stubble burning in the state of Punjab, several initiatives for its proper management have been taken up. Various departments and institutions of the Punjab government are promoting alternative uses of straw instead of burning. This chapter outlines some of these alternative uses such as: use of rice residue as fodder; use of rice residue in bio-thermal power plants; its use for mushroom cultivation, for bedding material for cattle; its use for production of bio-oil; paper production; bio-gas and in situ. Other uses include incorporation of paddy straw in soil, energy technologies and thermal combustion.

**Keywords** Alternate uses of rice residue · End use of paddy straw · Residue use as fodder · Residue use in bio-thermal · In-situ incorporation

## 4.1 Introduction

Paddy straw is a major field-based residue that is produced in large amounts in Asia. In fact the total amount equaling 668 t could produce theoretically 187 gallons of bioethanol if the technology were available (Kim and Dale 2004). However, an increasing proportion of this paddy straw undergoes field burning. This waste of energy seems inapt, given the high fuel prices and the great demand for reducing greenhouse gas emissions as well as air pollution. As climate change is extensively recognized as a threat to development, there is a growing interest in alternative uses of field-based residues for energy applications.

Punjab produces around 23 million tonnes of paddy straw and 17 million tonnes of wheat straw annually. More than 80 % of paddy straw (18.4 million tonnes) and almost 50 % wheat straw (8.5 million tonnes) produced in the state is being burnt in fields. Almost whole of paddy straw, except Basmati rice is burnt in the field to enable early sowing of next crop. Lately, the farmers have extended this practice to wheat crop also. Though part of the wheat straw is used as dry fodder for the milch cattle, the remaining straw is usually burnt for quick disposal.



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There are primarily two types of residues from rice cultivation that have potential in terms of energy—straw and husk. Although the technology of using rice husk is well established in many Asian countries, paddy straw as of now is rarely used as a source of renewable energy. One of the principal reasons for the preferred use of husk is its easy procurement, i.e., it is available at the rice mills. In the case of paddy straw, however, its collection is a tedious task and its availability is limited to harvest time. The logistics of collection could be improved through baling but the necessary equipment is expensive and buying it is uneconomical for most rice farmers. Thus, technologies for energy use of straw must be efficient to compensate for the high costs involved in straw collection.

The chapter is organized as follows: The next section presents disposal pattern of paddy straw giving details of alternate uses of agriculture waste, viz., rice residue as fodder for animals, its use in bio-thermal power plants, its use for bedding material for animals, mushroom cultivation and so on. Section four discusses in details about residue use in power generation citing various biomass power projects commissioned in the state by Punjab Energy Development Agency (PEDA).

## 4.2 Disposal Pattern of Paddy Straw

The disposal pattern of paddy straw by the farmers depends on the market value of the by-product. Table 4.1 presents the methods adopted for end-use of paddy straw as mentioned in various studies. From the table, it is clear that on an average, three fourth of the paddy straw is burnt openly in the fields. The above ratio implies that in the year 2007–2008 around 11,930–15,858 thousand tonnes of paddy straw was burnt in the open field. Burning in Punjab involves partial and full burning. Partial burning entails running of combine harvester followed by burning of small stalks while complete burning entails setting the entire field on fire. The latter practice is mostly followed by the farmers in Punjab. Both the practices cause pollution

**Table 4.1** End use of paddy straw

| S. No | Author | Disposal pattern |
|---|---|---|
| 1 | Badarinath and Chand Kiran (2006) | 75–80 % area is machine harvested |
| | | ¾ or 75 % of straw is burnt |
| 2 | Venkataraman et al. (2006) | 30–40 % straw burnt (IGP) |
| 3 | Sidhu and Beri (2005) | 81 % of paddy burnt and 48 % of wheat burnt, fodder (7 % of rice and 45 % of wheat), rope making (4 % of rice and 0 % of wheat), incorporated in soil (1 % of rice and less than 1 % of wheat), miscellaneous (7 % each of rice and wheat) |
| 4 | Sarkar et al. (1999) | 75 % combine harvested and 100 % burnt |
| Average | | 75 % of paddy is burnt |

*Source* Authors' compilation

but the impact is more severe in the case of complete burning. The farmers in the region are resorting to burning of straw, because they don't have other equal or more remunerative alternatives available to them.

There are many environmental risks associated with stubble burning. If followed continuously burning can reduce soil quality and make land more susceptible to erosion. Moreover, continuous burning is not a sustainable agricultural practice. Smoke from burning straw also contributes to increased carbon dioxide levels in the atmosphere which may affect greenhouse gas build-up.

The Department of Science, Technology and Environment and Non-Conventional Sources of Energy, Government of Punjab, constituted a task force in September, 2006 for formulation of policy to mitigate the problem due to the severity of burning of agricultural waste in the open fields after harvest and its consequent effects on soil, ambient air and health effects on living organism. The task force has suggested promotion of agronomic practices and technological measures for better utilization of agricultural wastes. These include use of happy seeder, developed by PAU in collaboration with Australian Centre for International Agriculture Research (ACIAR) and use of paddy straw for power generation.

## 4.3 Management of Agricultural Waste for Alternate Uses

Agricultural waste includes paddy and wheat straw, cotton sticks, bagasse and animal waste. Keeping in view the increasing problems associated with crop stubble burning several initiatives for its proper management have been taken up. Various departments and institutions are promoting alternative uses of straw instead of burning. These include:

### *4.3.1 Use of Rice Residue as Fodder for Animals*

The rice residue as fodder for animals is not a very popular practice among farmers in Punjab.[1] This is mainly because of the high silica content in the rice residue. It is believed that almost 40 % of the wheat straw produced in the state is used as dry fodder for animals. However to encourage the use of rice residue as fodder for animals, a pilot project was taken up by PSCST at PAU under which trials on natural fermentation of paddy straw for use as protein enriched livestock feed were conducted. The cattle fed with this feed showed improvement in health and milk

[1] There are exceptions to this as in states like Kerala, the powder made out of the rice husk is fed (mixed with water) on to cattle so also the straw. Though it is reported to be unhealthy, probably the lack of other alternative sources of fodder compel people to use the same. It is also seen from Table 4.2, where the consumption of residue per animal is the highest at 0.35 t, (second to Punjab) which is much above many states. Rice being the main crop in Kerala, there is a high proportion of rice husk powder/straw consumption.

production. The technology was demonstrated in district Gurdaspur, Ludhiana, Hoshiarpur and Bathinda. The department of Animal Husbandry, Punjab has propagated the technology in the state. The analysis below presents the position of different states in production; availability and requirement of dry as well as green fodder and indicates which state is surplus/deficit in fodder requirement.

Table 4.2 indicates that total production of residue of paddy is almost 30 million tonnes for the total livestock of 464,472 thousands. Thus the consumption of paddy residue per livestock stands at 0.06 t/animal. Highest imbalance of livestock and consumption is noted in Rajasthan with zero consumption per animal. Other such low ranked state with least consumption rate is Madhya Pradesh,

**Table 4.2** State-wise consumption of paddy (residue) per animal

| States/UTs | Residue (000 tonnes) | Total Livestock (000) | Consumption of residue/animal |
|---|---|---|---|
| | TE 2006–2007 | 2003 | (t/animal) |
| Andhra Pradesh | 5,530 | 48,195 | 0.11 |
| Arunchal Pradesh | 71 | 1,261 | 0.06 |
| Assam | 1,657 | 13,431 | 0.12 |
| Bihar | 1,826 | 9,688 | 0.19 |
| Chhattisgarh | 2,406 | 13,487 | 0.18 |
| Gujarat | 654 | 21,168 | 0.03 |
| Haryana | 1601 | 8884 | 0.18 |
| Himachal Pradesh | 60 | 5,183 | 0.01 |
| J & K | 267 | 10,345 | 0.03 |
| Jharkhand | 1,034 | 15,478 | 0.07 |
| Karnataka | 2,123 | 25,621 | 0.08 |
| Kerala | 1,266 | 3,629 | 0.35 |
| Madhya Pradesh | 699 | 35,365 | 0.02 |
| Maharashtra | 1,236 | 35,770 | 0.03 |
| Manipur | 201 | 971 | 0.21 |
| Meghalaya | 91 | 1,552 | 0.06 |
| Mizoram | 39 | 280 | 0.14 |
| Nagaland | 131 | 1,349 | 0.10 |
| Orissa | 3,358 | 23,410 | 0.14 |
| Punjab | 5,128 | 8,608 | 0.60 |
| Rajasthan | 79 | 49,146 | 0.00 |
| Sikkim | 11 | 426 | 0.03 |
| Tamil Nadu | 2,482 | 24,126 | 0.10 |
| Tripura | 286 | 1,458 | 0.20 |
| Uttar Pradesh | 5,302 | 57,869 | 0.09 |
| Uttaranchal | 286 | 4,943 | 0.06 |
| West Bengal | 7,357 | 41,619 | 0.18 |
| India | 29,809 | 464,472 | 0.06 |

*Source* Lok Sabha Unstarred Question No. 726, dated on 24.11.2009

Himachal Pradesh, Maharashtra and Sikkim. In north, Punjab has got highest ratio of consumption, followed by Kerala and North Eastern state Tripura and Manipur. Uttar Pradesh has highest concentration of livestock which is followed by Rajasthan, Madhya Pradesh and Maharashtra. The residue is found highest in West Bengal and Arunachal Pradesh.

The availability of crop residue in India is 253.26 million tonnes whereas the requirement is 415.83 million tonnes (Table 4.3). Thus there is shortfall of almost 40 %. On the other hand, the availability of green fodder during the same time period is 142.82 million tonnes and requirement is 221.63 million tonnes with a short fall of almost 36 % (Table 4.4). It can be noted that only in Punjab and Mizoram there is surplus in case of crop residues.

**Table 4.3** Status of different states about availability and requirement of fodder

| States/UTs | Availability | Requirement | Livestock numbers (000) | Per animal availability (t/animal) | Per animal requirement (t/animal) |
|---|---|---|---|---|---|
| | Crop residues (million tonnes) | | | | |
| Andhra Pradesh | 15.69 | 31.71 | 48,195 | 0.03 | 0.66 |
| Arunachal Pradesh | 0.47 | 1.00 | 1,261 | 0.04 | 0.79 |
| Assam | 5.82 | 12.39 | 13,431 | 0.04 | 0.92 |
| Bihar | 16.23 | 23.49 | 9,688 | 0.17 | 2.42 |
| Chhattisgarh | 9.93 | 14.93 | 13,487 | 0.07 | 1.11 |
| Gujarat | 10.61 | 22.32 | 21,168 | 0.05 | 1.05 |
| Haryana | 8.75 | 9.95 | 8,884 | 0.10 | 1.12 |
| Himachal Pradesh | 2.3 | 4.60 | 5,183 | 0.04 | 0.89 |
| Jammu & Kashmir | 2.53 | 6.79 | 10,345 | 0.02 | 0.66 |
| Jharkhand | 4.1 | 13.59 | 15,478 | 0.03 | 0.88 |
| Karnataka | 14.59 | 20.66 | 25,621 | 0.06 | 0.81 |
| Kerala | 0.71 | 2.91 | 3,629 | 0.02 | 0.80 |
| Madhya Pradesh | 24.3 | 37.41 | 35,365 | 0.07 | 1.06 |
| Maharashtra | 22.21 | 33.68 | 35,770 | 0.06 | 0.94 |
| Manipur | 0.36 | 0.72 | 971 | 0.04 | 0.74 |
| Meghalaya | 0.31 | 1.17 | 1,552 | 0.02 | 0.75 |
| Mizoram | 0.15 | 0.06 | 280 | 0.05 | 0.21 |
| Nagaland | 0.56 | 0.74 | 1,349 | 0.04 | 0.55 |
| Orissa | 12.25 | 22.27 | 23,410 | 0.05 | 0.95 |
| *Punjab* | 13.71 | 10.58 | 8,608 | 0.16 | 1.23 |
| Rajasthan | 21.67 | 33.53 | 49,146 | 0.04 | 0.68 |
| Sikkim | 0.23 | 0.25 | 426 | 0.05 | 0.59 |
| Tamil Nadu | 7.01 | 16.46 | 24,126 | 0.03 | 0.68 |
| Tripura | 0.53 | 1.09 | 1,458 | 0.04 | 0.75 |
| Uttar Pradesh | 42.07 | 57.19 | 57,869 | 0.07 | 0.99 |
| Uttarakhand | 2.05 | 4.90 | 4,943 | 0.04 | 0.99 |
| West Bengal | 13.77 | 30.30 | 41,619 | 0.03 | 0.73 |
| *India* | *253.26* | *415.83* | 464,472 | 0.05 | 0.90 |

**Table 4.4** State-wise percentage of short fall of crop residue and greens

| States/UTs | Avail-ability | Require-ment | Shortfall (%) | Availa-bility | Require-ment | Shortfall (%) |
|---|---|---|---|---|---|---|
| | Crop residues (million tonnes) | | | Green fodder (million tonnes) | | |
| Andhra Pradesh | 15.69 | 31.71 | 50.52 | 4.88 | 16.91 | 71.14 |
| Arunachal Pradesh | 0.47 | 1.00 | 53.00 | 1.57 | 0.53 | −196.23 |
| Assam | 5.82 | 12.39 | 53.03 | 0.95 | 6.61 | 85.63 |
| Bihar | 16.23 | 23.49 | 30.91 | 0.81 | 12.53 | 93.54 |
| Chhattisgarh | 9.93 | 14.93 | 33.49 | 2.83 | 7.96 | 64.45 |
| Goa | 0.13 | 0.15 | 13.33 | 0.05 | 0.08 | 37.50 |
| Gujarat | 10.61 | 22.32 | 52.46 | 14.48 | 11.9 | −21.68 |
| Haryana | 8.75 | 9.95 | 12.06 | 6.57 | 5.31 | −23.73 |
| Himachal Pradesh | 2.3 | 4.60 | 50.00 | 1.98 | 2.45 | 19.18 |
| J & K | 2.53 | 6.79 | 62.74 | 0.64 | 3.62 | 82.32 |
| Jharkhand | 4.10 | 13.59 | 69.83 | 0.88 | 7.25 | 87.86 |
| Karnataka | 14.59 | 20.66 | 29.38 | 3.55 | 11.02 | 67.79 |
| Kerala | 0.71 | 2.91 | 75.60 | 0.39 | 1.55 | 74.84 |
| Madhya Pradesh | 24.3 | 37.41 | 35.04 | 11.65 | 19.95 | 41.60 |
| Maharashtra | 22.21 | 33.68 | 34.06 | 25.12 | 17.96 | −39.87 |
| Manipur | 0.36 | 0.72 | 50.00 | 0.00 | 0.38 | 100.00 |
| Meghalaya | 0.31 | 1.17 | 73.50 | 0.4 | 0.62 | 35.48 |
| Mizoram | 0.15 | 0.06 | −150.00 | 0.5 | 0.03 | −1,566.67 |
| Nagaland | 0.56 | 0.74 | 24.32 | 0.3 | 0.4 | 25.00 |
| Orissa | 12.25 | 22.27 | 44.99 | 2.46 | 11.88 | 79.29 |
| *Punjab* | *13.71* | *10.58* | *−29.58* | *7.38* | *5.64* | *−30.85* |
| Rajasthan | 21.67 | 33.53 | 35.37 | 33.53 | 17.88 | −87.53 |
| Sikkim | 0.23 | 0.25 | 8.00 | 0.01 | 0.13 | 92.31 |
| Tamil Nadu | 7.01 | 16.46 | 57.41 | 3.7 | 8.78 | 57.86 |
| Tripura | 0.53 | 1.09 | 51.38 | 0.19 | 0.58 | 67.24 |
| Uttar Pradesh | 42.07 | 57.19 | 26.44 | 15.73 | 30.5 | 48.43 |
| Uttarakhand | 2.05 | 4.90 | 58.16 | 1.73 | 2.61 | 33.72 |
| West Bengal | 13.77 | 30.30 | 54.55 | 0.51 | 16.16 | 96.84 |
| A & N Islands | 0.02 | 0.11 | 81.82 | 0.00 | 0.06 | 100.00 |
| Chandigarh | 0.00 | 0.04 | 100.00 | 0.00 | 0.02 | 100.00 |
| Dadra & Nagar H | 0.04 | 0.80 | 95.00 | 0.20 | 0.40 | 50.00 |
| Daman Diu | 0.01 | 0.10 | 90.00 | 0.00 | 0.00 | – |
| Delhi | 0.09 | 0.43 | 79.07 | 0.10 | 0.23 | 56.52 |
| Lakshadweep | 0.00 | 0.10 | 100.00 | 0.00 | 0.00 | – |
| Pondicherry | 0.06 | 0.11 | 45.45 | 0.01 | 0.06 | 83.33 |
| *India* | *253.26* | *415.83* | *39.10* | *142.82* | *221.63* | *35.56* |

*Source* Lok Sabha Unstarred Question No. 726, dated on 24.11.2009

The availability of crop residue is highest in Uttar Pradesh followed by Maharashtra, Bihar, Rajasthan and Andhra Pradesh. Excepting Assam almost all the north Eastern States and Kerala have least availability of crop residue. As in the case of availability, the highest requirement of crop residue is in Uttar Pradesh and thus the requirement per animal (0.99 t/animal) and per animal availability of the state is also high (0.07 t/animal). States like Punjab, Haryana and Bihar has higher per animal availability as compared to other states of India.

### *4.3.2 Use of Crop Residue in Bio Thermal Power Plants*

Another use of rice residue that is being encouraged by various institutions and departments is the use of rice residue for generation of electricity. A 10 MW biomass based power plant at village Jalkheri, Fatehgarh Sahib with paddy straw as fuel was set up in the year 1992 (Box 4.1). The plant is operational since 2001, after the PSEB entered into a lease-cum-power purchase agreement with Jalkheri Power Private Limited (JPPL). The original system installed by BHEL i.e. firing the boiler with paddy straw in baled form, used to create innumerable problems like ash melting, snagging, super heater choking, clinkerisation, drop in boiler temperature due to moisture in the bales, etc. Hence, the fuel was changed from paddy straw to rice husk, wood chips, cotton waste, etc., in mixed form or rice husk alone to achieve the desired parameters. The total requirement of biomass is estimated to be 82,500 MT/annum at 100 % capacity utilization for optimum plant activity. Crop residues are bought from the farmers at Rs. 35 per quintal (which would otherwise have remained unutilized or burnt in the field). The farmers are being made aware of this offer through newspapers and other awareness activities. Apart from the generation of electricity for supply to state grid to meet the ever-increasing demand for energy in the state, the plant also reduces the Green House Gases (GHGs) emissions. As per Cleaner Development Mechanism (CDM) estimates, the plant would supply energy equivalent of approximately 417.9 million kWh to the grid in a period of 10 years (2002–2012), thereby resulting in total $CO_2$ emission reduction of 0.3 million tonnes.

**Box 4.1 Case Study of Generation of Electricity from Agri-Waste**

The thermal plant at Jalkheri, District Fatehgarh Sahib is the first plant in India which is based on use of Biomass i.e. renewable energy source. This plant can utilize rice husk, waste wood chips, straw of various plants e.g. paddy, wheat, etc. This plant was commissioned in June, 1992 on turn-key basis by M/s BHEL for PSEB to utilize rice straw at a cost of Rs. 47.2 crores.

Some teething problems were experienced initially being an experimental project, but with modifications, full 10 MW capacity has been achieved. As harvesting pattern in Punjab has changed and farmers found it convenient to harvest crop with mechanical means and non-availability of adequate quantity of hand cut rice, the plant was further modified to accept any bio-mass e.g. any straw, rice husk, wood chips etc. The plant has been given on lease and is being operated at 10 MW i.e. full capacity on sustainable basis.

One 10–15 MW agri-waste based power project has been set up jointly by Punjab Biomass Power, Bermaco Energy, Archean Granites and Gammon Infrastructure projects Limited in Punjab. The project uses locally available agricultural waste such as rice straw and sugar cane trash for fuel. The total annual fuel requirement is around 120,000 t of biomass, all of which will be sourced locally. Punjab produces around 20–25 million tonnes of rice straw annually. As rice straw is a poor fodder and fuel, farmers burn it in the fields and make way for the Rabi wheat crop. With the development of technology now there is an option to use this waste for generating electricity. The project is expected to provide additional income to 15,000 farmers from the sale of agricultural waste. The project will be a major milestone in environment protection—converting agricultural waste to energy. Secondly, it will reduce the release of smoke and other pollutants caused by burning of wastes which could now be used for earning carbon credits.

Another biomass based power project of 7.5 MW was initiated by Malwa Power Pvt. Ltd. at village Gulabewalla in district Mukatsar in 2002. The project was commissioned in May 2005 and is operating satisfactorily. The plant is selling electricity to PSEB through power purchase agreement. The plant is using crop residues available in the area like cotton stalks, mustard stalks, lops and tops of Eucalyptus, Poplar and Prosopis juliflora and some quantity of agro waste such as rice husk and saw dust. The total requirement of biomass is estimated to be 65,043 MT per annum at 90 % capacity utilization and 72,270 MT per annum at 100 % capacity utilization.

As per estimates for Clean Development Mechanism (CDM), this plant would supply energy equivalent of approximately 465.10 million kWh to the grid in a period of 10 years (2005–2015) and would result in reduction of 0.43 million tonnes total of $CO_2$ emission. Both these power plants are obtaining Carbon Credits under CDM. Further, in August, 2006, PSEB has signed two agreements with M/S Punjab Biomass Power Limited for setting up 12 MW paddy straw based power plants at village Baghaura near Rajpura and Village Sawai Singh near Patiala. The company intends to collect paddy straw from command area of 25 $km^2$ around each village and would use 1 lakh MT per annum paddy straw for generation of 12 MW of electricity. The company has entered into an agreement with farmers on barter system and farmers will be provided electricity in lieu of supplying paddy straw. The plants were expected to start operations in 2009. Land at Baghaura village has already been purchased.

### 4.3.3 Use of Rice Residue as Bedding Material for Cattle

The farmers of the state have been advised to use paddy straw as bedding material for cross bred cows during winters as per results of a study conducted by the Department of Livestock Production and Management, College of Veterinary Sciences, Punjab Agricultural University. It has been found that the use of paddy straw bedding during winter helped in improving the quality and quantity of milk as it contributed to animals' comfort, udder health and leg health. Paddy straw bedding helped the animals keep themselves warm and maintain reasonable rates of heat loss from the body. It also provides clean, hygienic, dry, comfortable and non-slippery environment, which prevents the chances of injury and lameness. Healthy legs and hooves ensure enhancement of milk production and reproductive efficiency of animals. The paddy straw used for bedding could be subsequently used in biogas plants. The use of paddy straw was also found to result in increased net profit of Rs. 188–971 per animal per month from the sale of additional amount of milk produced by cows provided with bedding. The PAU has been demonstrating this technology to farmers through training courses, radio/TV talks and by distributing leaflets.

### 4.3.4 Use of Crop Residue for Mushroom Cultivation

Paddy straw can be used for the cultivation of Agaricus bisporus, *Volvariella Volvacea* and Pleurotus spp. One kg of paddy straw yields 300, 120–150 and 600 g of these mushrooms, respectively. At present, about 20,000 metric tonnes of straw is being used for cultivation of mushrooms in the state.

Paddy Straw Mushrooms (*Volvariella Volvacea*) also known as grass mushrooms are so named for their cultivation on paddy straw used in South Asia. Paddy Straw is high temperature mushroom grown largely in tropical and subtropical regions of Asia, e.g. China, Taiwan, Thailand, Indonesia, India, and Madagascar. In Indonesia and Malaysia, mushroom growers just leave thoroughly moistened paddy straw under trees and wait for harvest. This mushroom can be grown on a variety of agricultural wastes (the cultivation method of this mushroom is similar to that of Agaricus bisporus) for preparation of the substrate such as water hyacinth, oil palm bunch waste, dried banana leaves, cotton or wood waste, though with lower yield than with paddy straw, which is most successful. Paddy straw mushroom accounts for 16 % of total production of cultivated mushroom in the world.

### 4.3.5 Use of Rice Residue in Paper Production

The paddy straw is also being used in conjunction with wheat straw in 40:60 ratios for paper production. The sludge can be subjected to bio-methanization for energy production. The technology is already operational in some paper mills, which are meeting 60 % of their energy requirement through this method. Paddy straw is also used as an ideal raw material for paper and pulp board manufacturing. As per information provided by PAU, more than 50 % pulp board mills are using paddy straw as their raw material.

### *4.3.6 Use of Rice Residue for Making Bio Gas*

The PSFC has been coordinating a project for processing of farm residue into biogas based on the technology developed by Sardar Patel Renewable Energy Research Institute (SPRERI). A power plant of 1 MW is proposed to be set up at Ladhowal on pilot basis on land provided by PAU. The new technology will generate 300 $m^3$ of biogas from 1 t of paddy straw.

### *4.3.7 In Situ*

The technical measures are 'straw incorporation' and 'straw mulching'. In both these measures, the residue is incorporated in the field itself and is thus used to increase the nutrient value or fertility of the soil. In the first measure, the residue is allowed to decompose in the field itself through a chemically developed process (available at PAU), and in the second measure, incorporation is done with the help of a properly designed machine along with seeding (know-how developed at PAU). The second measure is more useful as there is no weeding in this process and it is less expensive.

Another study (Singh 1992) reveals that, incorporation of paddy straw in soil immobilized native as well as added fertilizer N and about half of the immobilized N was mineralized after 90 days of straw incorporation. Straw and N application alone or in combination increased biomass carbon, phosphates and respiratory activities of the soil. Microbial biomass carbon and phosphate activities were observed maximum at 30 days of straw decomposition. In field trials, incorporation of paddy straw 3 weeks before sowing of wheat significantly increased the wheat yield at Sonepat district in a clay loam soil while no such beneficial effect was observed in a sandy loam soil at Hissar (Singh 1992).

### *4.3.8 Incorporation of Paddy Straw in Soil*

The incorporation of the straw in the soil has a favorable effect on the soil's physical, chemical and biological properties such as pH, Organic carbon, water holding capacity and bulk density of the soil. On a long-term basis it has been seen to increase the availability of zinc, copper, iron and manganese content in the soil and it also prevents the leaching of nitrates. By increasing organic carbon it increases bacteria and fungi in the soil. In a rice-wheat rotation, Beri et al. (1992) and Sidhu et al. (1995) observed that soil treated with crop residues held 5–10 times more aerobic bacteria and 1.5–11 times more fungi than soil from which residues were either burnt or removed. Due to increase in microbial population, the activity of soil enzymes responsible for conversion of unavailable to available form of nutrients also increases. Mulching with paddy straw has been shown to have a favorable effect on the yield of maize, soybean and sugarcane crops. It also results in substantial savings in irrigation and fertilizers. It is reported to add 36 kg per hectare of nitrogen and 4.8 kg per hectare of phosphorous (6 g of Nitrogen and 0.8 g of phosphorous per kg of paddy straw) leading to savings of 15–20 % of total fertilizer use.

### *4.3.9 Production of Bio-oil from Straw and Other Agricultural Wastes*

Bio-oil is a high density liquid obtained from biomass through rapid pyrolysis technology. It has a heating value of approximately 55 % as compared to diesel. It can be stored, pumped and transported like petroleum based product and can be combusted directly in boilers, gas turbines and slow and medium speed diesels for heat and power applications, including transportation. Further, bio-oil is free from $SO_2$ emissions and produces low $NO_2$. Certain Canadian companies (like Dyna Motive Canada Inc.) have patented technologies to produce bio-oil from biomass including agricultural waste. Though their major experience is with bagasse, wheat straw and rice hulls, feasibility of this technology with paddy straw needs to be assessed. The state government, through PSCST and PEDA, could promote further studies in this direction.

## 4.4 Agricultural Residues for Power Generation

The State of Punjab has been a victim of acute power famines, load shedding and power cuts, year after year. Agricultural requirement for power is highest during June to September for the purpose of paddy cultivation. Biomass, such as agricultural residue, bagasse, cotton stalks, rice husk, etc., is emerging as a viable source of power for rural electrification in India. Direct burning of such waste is inefficient and leads to pollution. When combusted in a gasifier at low oxygen and high temperature, biomass can be converted into a gaseous fuel known as producer gas. This gas has a lower calorific value compared to natural gas or liquefied petroleum gas, but can be burnt with high efficiency and without emitting smoke.

The advantages of utilizing crop residue over and above the conventional resources are that such residue is renewable, readily available and can be used successfully by burning in boilers with the efficiency of 99 %. Further, they are available at low cost as compared to that of coal while ash contents is much less (as compared to 36 % ash content of coal) and at the same time the calorific value of both, coal and paddy straw are comparable, i.e., 4,200 and 3,590 kcal/kg, respectively. Additional income to the farmers from the sale of straw is an added advantage. At the same time, the agencies involved/state could also take advantage of carbon credit policy set up under the UNFCCC (United Nation Framework Convention on Climate Change) from developed countries. The policy involves emission credit for programmes which help in curbing global warming. The government should encourage private parties/agencies to take advantage of this carbon credit policy of UNFCCC.

According to Dr. A.K. Rajvanshi, who runs the non-profit Nimbkar Agriculture Research Institute, Phaltan, Maharashtra, it is feasible to set up a bio-mass-based power plant of 10–20 MW capacity in every Taluka (a block of about 100 villages). This can meet energy needs of villages and employ thousands of people. Similarly, in Punjab the developers of biomass energy can sell their power to PSEB, which will be purchased as per, 'New & Renewable Sources of Energy Policy' notified by the government from time to time and distributed as per usual norms.

Kirangatevalu village in Karnataka has set an example in this regard. Electrification of the village earlier meant supply of power to a few homes and farms for 4–5 h a day. The transformation of the village is the result of an initiative taken by a private firm that has set up a power plant using agricultural waste such as sugarcane refuse and coconut fronds that are plentiful in the area. Villagers sell their agro waste to the plant and get access to quality power at commercial rate. A supply chain to procure agricultural waste from villages in a radius of 10 km has been established to ensure the supply of agricultural waste throughout the year. The waste that was burnt in open fields has now become a source of income and jobs. The 4.5 MW power plants set up by Malaballi Power Plant Private Limited supplies electricity to 48 villages inhabited by 120,000 people in Mandya district in Karnataka.

In Punjab in the 1980s PSEB had set up a 10 MW power plant based on paddy straw at Village Jalkheri, District Fatehgarh Sahib in which 250–3,000 TPD of fuel is burnt in a boiler furnace of steam generation capacity of 50 TPH. The plant earlier used paddy straw but due to clinkerisation of boiler, paddy straw was replaced with rice husk, cow dung and other agro waste. This plant has since been leased out by PSEB to M/S Jalkheri Power Private Limited. Now these plants will be using improved technology and M/S Punjab Biomass Power Limited has signed two agreements with PSEB for setting up 12 MW paddy straw based power plants at Baghaura in Rajpura Tehsil and Sawai Singh village in Patiala Tehsil. A total amount of 0.1 million ton paddy straw would be collected from a command area of 25 km$^2$ around each unit and a barter system of providing electricity will be worked out with the farmers. The units will be run on BOO basis. DPRs have been prepared and land is being purchased.

The bottlenecks apprehended by PSEB in generation of power from paddy straw are the availability of paddy straw for power generation in case the Happy

Seeder technology succeeds in the State. Hence, it is recommended that areas around these power plants could be reserved to ensure enough availability of straw. Further, techniques to collect and store paddy straw may also be developed and incentives provided.

### *4.4.1 Energy Technologies*

The transportation of biomass is one of the key cost factors for its use as a source of renewable energy. Decentralized energy systems provide an opportunity to use biomass to meet local energy requirements that are, heat and electricity. In contrast to straw, the use of rice husk for energy has been realized faster. One important factor is that rice mills can use husk to serve their internal energy requirement. As an alternative, rice millers could sell the husk to a power-plant operator. The propagation of rice husk use for energy was accelerated by energy providers, who deal with a relatively small number of rice millers for supplying husk, which is an easier task than dealing with thousands of farmers supplying paddy straw.

As a new trend, electricity is now often produced by the millers themselves and then sold to a power grid. This setup has to be seen as the most promising option in terms of logistics and transportation for energy generation. Transportation costs of straw are a major constraint to its use as an energy source. As a rule of thumb, transportation distances beyond a 25–50 km radius (depending on local infrastructure) are uneconomical. For long distances, straw could be compressed as bales or briquettes in the field, rendering transport to the site of use a viable option. Nevertheless, the logistics of a supply chain is more complicated in the case of straw.

Although five different energy conversion technologies seem to be applicable for paddy straw in principle only combustion technology is currently commercialized and the other technologies are at different stages of development. As a general rule for energy use, each step in the chain consumes a certain amount of energy and thus reduces the net energy at the end product. The following sections describe the principal features of the possible energy conversion technologies, experiences and technical difficulties in the use of paddy straw.

### *4.4.2 Thermal Combustion*

Paddy straw can either be used alone or mixed with other biomass materials (the latter is called co-firing or co-combustion) in direct combustion. In this technology, combustion boilers are used in combination with steam turbines to produce electricity and heat. In thermal combustion, air is injected into the combustion chamber to ensure that the biomass is completely burned in the combustion chamber. Fluidized bed technology is one of the direct combustion techniques in which solid fuel is burned in suspension by forced air supply into the combustion chamber to achieve complete combustion. A proper air-to-fuel ratio is maintained and, in the absence of a sufficient air supply, boiler operation encounters various problems.

In straw combustion at high temperatures, potassium is transformed and combines with other alkali earth materials such as calcium. This in turn reacts with silicates, leading to the formation of tightly sintered structures on the grates and at the furnace wall. Alkali earths are also important in the formation of slags and deposits. This means that fuels with lower alkali content are less problematic when fired in a boiler (Jenkins et al. 1998). The byproducts are fly ash and bottom ash, which have an economic value and could be used in cement and/or brick manufacturing, construction of roads and embankments, etc.

National Biomass Assessment Project of Ministry of New and Renewable Energy, Government of India conducted a biomass study in which 29 Tehsil were surveyed which was started in the late eighties and continued till 1995–1996. Total 36 Talukas were included from different districts. The total estimated power generating potential was estimated AT 342 MW. Biomass Power project has the following inherent advantages over thermal power generation:

- It is environmentally friendly because of relatively lower $CO_2$ and particulate emissions
- It displaces fossil fuels such as coal
- It is a decentralised, load based means of generation, because it is produced and consumed locally, losses associated with transmission and distribution are reduced
- It offers employment opportunities to locals
- It has a low gestation period and low capital investment
- It helps in local revenue generation and upliftment of the rural population
- It is an established and commercially viable technology option.
- Punjab has substantial availability of Biomass/Agro-waste in the state sufficient to produce about 1,000 MW of electricity.

PEDA has planned to develop some of the available potential talukas/tehsils with the aim to promote and install biomass/agro waste based projects. PEDA has so far allocated 30 sites/tehsils for setting up of total 332.5 MW capacity Biomass/Agro waste based power projects under three phases. In different phases the biomass power project were allocated.

- In Phase I agreement is already done with two companies- M/s Turbo Atom TPS and M/S. Green Field Energen Pvt. Ltd., in New Delhi and Chandigarh, respectively for two Tehsils, Ferozepur and Patti with a total capacity of 56 MW.
- In Phase II three companies were there for Abohar, Sunam and Ajnala, respectively. The two companies of Sunam and Ajnala are cancelled having 41 MW. With the capacity of 8 MW the company M/s Dee Development in Abohar Tehsil is commissioned.

- In Phase III there are six companies which are based differently. The M/s Green Planet of Chandigarh is based on paddy stubble which is planned in 14 Tehsils with total 146.5 MW of capacity. Out of which Garhshankar with 10 MW capacity is likely to begin. The M/s Univeral Biomass of Mukatsar which is mostly based on cotton stock with 14.5 MW in Malout Tehsil is commissioned. The Malwa Power Ltd., in the village Gulabevala in the district of Muketsar was started before PEDA took over with 6 MW. Other three companies had total capacity of 65 MW.

Thus, PEDA has so far allocated 30 sites/tehsils for setting up of total 332.5 MW capacity Biomass/Agro-waste based power projects during three phases (details in Appendix).

## 4.5 Summary of the Chapter

To avoid burning of rice (and wheat) stubble, management of agricultural waste for alternate uses is being practiced and promoted. Agricultural waste includes paddy and wheat straw, cotton sticks, bagasse and animal waste. Keeping in view the increasing problems associated with crop stubble burning several initiatives for its proper management have been taken up. Various departments and institutions are promoting alternative uses of straw instead of burning. These include use of rice residue as fodder, crop residue in Bio thermal power plants and mushroom cultivation, rice residue used as bedding material for cattle, production of bio-oil, paper production, bio-gas and in situ. Other uses include incorporation of paddy straw in soil, energy technologies and thermal combustion. Although five different energy conversion technologies seem to be applicable for rice straw in principle only combustion technology is currently commercialized and the other technologies are at different stages of development. PEDA has so far allocated 30 sites/tehsils for setting up of total 332.5 MW capacity Biomass/Agro-waste based power projects during three phases.

**Box 4.2 Punjab Farmers Take Lessons on Straw Management, Swarleen Kaur, Posted: Thursday, Feb 04, 2010 at 2,253 h IST, Financial Express**

Chandigarh: Punjab government, an entrepreneur and an NGO have joined hands to bring about a change in the way farming is done in the state. To fight with the problem of burning paddy straw in fields, farmers are being given lessons and field training on rice straw management. Farmers are taught eco friendly way of zero tillage and how to use straw as an organic fertilizer. The ban imposed by state government on burning paddy residue meant little for growers and they continued to set fire to the dry straw in the state.

On an average, paddy is grown in around seven million acres in the state. An acre yields around 25–30 quintals of crop residue, thereby the aggregate crop residue is estimated at 175 million quintal of which more than 90 % paddy straw is burnt. It is estimated that farmers burn 19.6 million tonnes straw every year that is worth crores of Rupees, besides losing 38.5 lakh tonne of organic carbon, 59,000 t nitrogen, 2,000 t phosphorous and 34,000 t potassium every year. “We have decided to educate farmers of Ferozepur district about the adverse effects of residue burning. By focusing on better straw management, farmers can cut down their input costs, save water, fuel, use organic matter, make additional money while nursing the environment at the same time. Initially our team will provide training to Sarpanches who act as opinion leaders in villages. We will promote the use a new post-harvest-technology machine happy seeder that helps farmers in the incorporation of rice crop residue”, Vikram Ahuja who runs Zamindara Farm Solutions, a farm equipment bank in Fazilika told FE.

Contrary to the local belief that rice straw is not a very good cattle fodder, farmers will be educated by taking them to cowsheds. Properly cut, chopped, collected and baled straw can also be sold at profitable price, he highlighted. Cereal Systems Initiative, a non-governmental initiative for South Asia (CSISA) headed by HS Sidhu in Punjab, has volunteered to offer technology to one part of this campaign. Elaborating on the concept, Sidhu said, “Under the CSISA project we have carried out eight sessions with farmers and have given 150 demonstrations. It has been found that farmers are able to save Rs. 1,500–1,800 if they use scientific methods. We intend to cover Amritsar, Kapurthala, Ludhiana, Fatehgarh-sahib, Patiala, Sangrur and Bathinda. This programme will be expanded gradually”. According to agri-experts, only 15 % of the total paddy straw being produced in Punjab can be used in a productive way. PS Rangi, consultant with Punjab State Farmers’ Commission (PSFC) told FE, “In Punjab, October onwards there is a haze over the countryside since paddy residue, being moisture and silica rich, keeps burning for days. This residue cannot be ploughed back either and since it is rich in silica, decomposition takes a long time. In the absence of viable alternatives, farmers are left with no other option but to burn paddy stubble. In such a situation the Farmers Commission as well as the agricultural department are promoting rotavators, which buries the paddy straw in the fields and happy seeders that uses the zero tilling method to sow wheat in the fields with paddy straw given that only 10 % of total paddy straw can be used to produce electricity at bio-mass power projects”.

# Appendix

A. Biomass Power Projects Commissioned in the State by PEDA: (52.5 MW) (*Source*http://peda.gov.in/eng/Bio-mass%20Power.html*; accessed on 25 May 2014)*

| S. No. | Name of the company | SITE | CAPCITY (MW) | Month of commissioning | Remarks |
|---|---|---|---|---|---|
| 01 | M/s Malwa Power Ltd. | Vill. Gulabewala, Distt. Mukatsar | 6 | May 2005 | First project allocated by PEDA |
| 02 | M/s Dee Development Engineers Pvt. Ltd. | Vill.GaddaDhob, Tehsil. Abohar Distt Ferozepur | 8 | Feb 2009 | Project was allocated under Phase-II |
| 03 | M/s Universal Biomass Energy Pvt. Ltd. | Vill. ChannuTeh. Malout, Distt. Sri Mukatsar Sahib | 14.5 | Oct 2009 | Project was allocated under Phase-III |
| 04 | M/s. Punjab Biomass Power Pvt. Ltd. | Distt. Patiala | 12 | June 2010 | Project allocated by PSPCL |
| 05 | M/s. Green Planet Energy Pvt. Ltd. | Binjon, Distt. Hoshiarpur | 6 | March 2012 | Project was allocated under Phase-III |
| 06 | M/s. Green Planet Energy Pvt. Ltd. | Bir Pind, Distt. Jallandhar | 6 | Feb 2013 | Project was allocated under Phase-III |
| *Total* | | | *52.5* | | |

B. Detailed status of project work of biomass power projects being setup by private developers allocated by PEDA

| | |
|---|---|
| Total no. of sites initially allocated | 31–348 MW |
| Total no. of sites—projects commissioned | 5–40.5 MW |
| Total no. of sites cancelled so far | 13–142 MW |
| Total no. of balance sites | 13 + 2–4 MW |
| Total capacity | 165.5 MW |
| Phase I | 20 MW (2 Nos.) |
| Phase II | One project of 8 MW commissioned |
| Phase III | 145.5 MW (11 Nos) |

C. Company wise-status report of biomass power projects
1. M/s. Green Planet Energy Pvt. Ltd.

| S. No. | Name of site | Capacity (MW) | Project status | | Scheduled date of commissioning |
|---|---|---|---|---|---|
| | | | Activities completed | Activities in process | |
| 1 | Vill. Binjon, Tehsil Garhshankar, Distt. Hoshiarpur | 6 + 4 | 6 MW Rankine Cycle:- project commissioned in May 2012 | 90 % Mechanical and Electrical works of 4 MW project is completed. 100 %Civil works completed | 4 MW—June 2013 |
| 2 | Vill. BirPind, Tehsil Nakodar, Distt. Jalandhar | 6 + 4 | 6 MW Rankine Cycle:- project commissioned in Feb. 2013 | 4 MW Otto cycle:- civil works 30 % completed, G. Engine reached at site | 4 MW—June 2014 |
| 3 | Vill. Manuke Gill, Tehsil Nihal Singh Wala,,Distt. Moga | 6 | Land acquired MoU, IA and PPA signed | 100 % Civil works completed. Erection of transmission line under process | 6 MW—May 2013 |
| 4 | Vill. Ramiana, Tehsil Jaito, Distt. Faridkot | 12 + 1 | Land acquired MoU, IA and PPA signed | Civil construction work yet to start. Order placed for Boilerand turbine | 12 MW—Dec 2014 1 MW—Dec 2014 |
| 5 | Vill. Deep Singh Wala, Tehsil & Distt. Faridkot | 6 + 3 | Land acquired MoU, IA and PPA signed | Civil construction work yet to start | 6 MW—Sept 2014 3 MW—March 2015 |
| 6 | Vill. TalwandiRai, Tehsil Raikot, Distt. Ludhiana | 12 + 2 | Land acquired MoU, IA and PPA signed | Civil construction work yet to start | 12 MW—Dec 2014 2 MW—March 2015 |
| 7 | V. Dhanasu Teh & Distt. Ludhiana | 15 | Land acquired MoU signed | Company has taken the Panchayat Land on lease | March 2015 |
| 8 | V. Borana Teh & Distt. Fatehgarh Sahib | 12 | Land acquired MoU signed IA & PPA not signed | Company has taken the Panchayat Land on lease. Civil construction work yet to start | March 2015 |
| 9 | Tehsil Bathinda | 13.5 | MOU signed | Land not taken | Dec 2015 |
| | *Total* | *102.5* | | | |

2. M/s. Turboatom-TPS Projects Pvt. Ltd.

| S. No. | Name of site | Capacity (MW) | Project status | | Scheduled date of commissioning |
|---|---|---|---|---|---|
| | | | Activities completed | Activities in process | |
| 1 | Vill. BurjBaghel Singh, Malerkotla (Sangrur) | 20 | MoU signed | No work started | Dec 2013 |
| | | | Land acquired | | |
| | | | IA signed on dated 13.12.2010 | | |
| | | | PPA signed on 10.6.2011 | | |
| 2 | Vill. JhokTehal Singh, Ferozepur (Ferozepur) | 10 | Land acquired | No work started | Dec 2013 |
| | | | MoU signed | | |
| | | | IA signed | | |
| | | | PPA with PSPCL signed | | |
| | *Total* | *30* | | | |

3. M/s. Orient Green Power Pvt. Ltd.

| S. No. | Name of site | Capacity (MW) | Project status | | Scheduled date of commissioning |
|---|---|---|---|---|---|
| | | | Activities completed | Activities in process | |
| 1 | Vill. WadalaBhittiwind Teh. Amritsar | 10 | Land acquired | Company asked to sign IA with PEDA & PPA with PSPCL | Sept 2014 |
| | | | MoU signed | Civil works yet to start at site | |
| | *Total* | *10* | | | |

4. M/s. Viaton Energy Pvt. Ltd. (formerly M/s. Food Fats & Fertilizers Pvt. Ltd.)

| S. No. | Name of Site | Capacity (MW) | Project status | | Scheduled date of Commissioning |
|---|---|---|---|---|---|
| | | | Activities completed | Activities in process | |
| 1 | Vill. KhokharKhurd, Tehsil Mansa | 20 | Land acquired<br>MoU signed<br>IA & PPA signed | Site mobilized, 70 % civil works completed, boiler erection in progress, other boiler components already reached site. Turbine already imported and reaching site shortly | March 2013 |
| | *Total* | *20* | | | |

5. M/s. P & R Agri Energy Pvt. Ltd.

| S. No. | Name of site | Capacity (MW) | Project status | | Scheduled date of commissioning |
|---|---|---|---|---|---|
| | | | Activities completed | Activities in process | |
| 1 | Vill. Gopalpur Teh. Anandpur Sahib | 5 | Land acquired MoU signed IA signed on 10th Nov.'2010 PPA signed 8.8.2011 | Civil work started<br>Work orders placed for boiler and turbine | Sept 2014 |
| 2 | Vill. PatharmajraTeh. Ropar | 10 | MoU signed Land acquired | Company asked to sign IA with PEDA & PPA with PSPCL<br>Company asked to start the project work immediately | Sept 2014 |
| | *Total* | *15* | | | |

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