BIOMASS
(NAPIER GRASS & PADDY STRAW)
AGGREGATION
FOR
BIOMASS PELLET PROJECTS

1. Introduction:

Biomass refers to organic materials derived from plants and animals that can be used as a source of renewable energy. These materials can include wood, agricultural crops, agricultural waste, organic municipal waste, and animal waste. Biomass can be converted into various forms of energy, including heat, electricity, and biofuels, through processes such as combustion, fermentation, and chemical conversion. It is considered renewable because the organic matter used to produce biomass can be regrown or replenished relatively quickly, unlike fossil fuels which take millions of years to form. Biomass energy is often considered an environmentally friendly alternative to fossil fuels because it can reduce greenhouse gas emissions and dependence on finite resources. Biomass has always been a major source of energy for mankind.

India possesses a rich diversity of biomass resources due to its varied climate, extensive agriculture, and large population.

2. Biomass Availability in India

India ranks first in terms of population, having approx. 17.76% of the world's population. The rate of urbanization is increasing very fast and presently, 35% of the Indian population is in the urban area. The trend of Indian population growth contributes to increasing levels of biowaste per year, including agricultural residues, municipal solid waste, kitchen waste, industrial waste, etc., and hence, the vast potential for its conversion into bioenergy.

2.1 Agricultural-Based Biomass

India is an agricultural powerhouse, having a net sown area of about 139.3 Mha (42.4%) from a total geographical area of 328.7 million hectares (Mha). Further, 54.6% of the total workforce of India is reported to be engaged in agricultural and allied sectors

Table 1. The cropping details of major crops grown in India [8].

Crops	Area (Mha)	Production (Million Tons)
Rice	4.51	122.27
Wheat	31.62	109.52
Nutri/Coarse cereals	23.83	51.15
Pulses	28.83	25.72
Foodgrains	129.34	308.65
Oilseeds	28.79	36.10
Sugarcane	4.86	399.25
Cotton	13.01	35.38
Jute and mesta	0.67	9.56

All these crops contributed to the generation of India's crop waste output and are estimated to grow at a rate of 2.53% annually.

Presently, **India produces about 990 MMT** of agricultural biomass annually, which is the second highest after China. Some portion of the generated biomass is utilized in conventional applications such as combustion as fuel, packaging, pulp, paper, and fiber. A major proportion of this biomass is reported to be decomposed or burnt in an uncontrolled manner. **However, the surplus biomass availability is about 230 MMT.**

2.2 Significant sources of biomass in India apart from Agriculture include:

a) **Agro-industrial Residues:** Industries such as sugar mills, rice mills, Fruit & Vegetable processing units and paper mills produce significant amounts of residues like bagasse, rice bran, veg waste and pulp rejects, which can be utilized for bioenergy generation

b) **Forestry Residues**: Forests cover a significant portion of India's land area, and forestry residues such as branches, tops, bark, and sawdust are generated from logging and wood processing activities. These forestry residues can serve as valuable biomass feedstocks for energy generation and other applications. **However, this source of biomass could not be considered as prime source of feedstock for Bio energy projects due to various reasons like location specific, collection challenges and logistics.**

c) **Energy Crop**: Due to the limited availability of agriculture waste certain fast-growing energy crops such as Napier Grass, switchgrass, and bamboo can be cultivated specifically for bioenergy purposes. These crops can provide a sustainable source of biomass for **Biomass Pellet Projects.** According to the specific project requirement land can be taken on lease for growing napier and alternatively contract farming can also be considered.

From the above sources we can say that agriculture crop residue, Agri-industrial residue and energy crop are the potential & sustainable sources of biomass for the production of bio energy in long term.

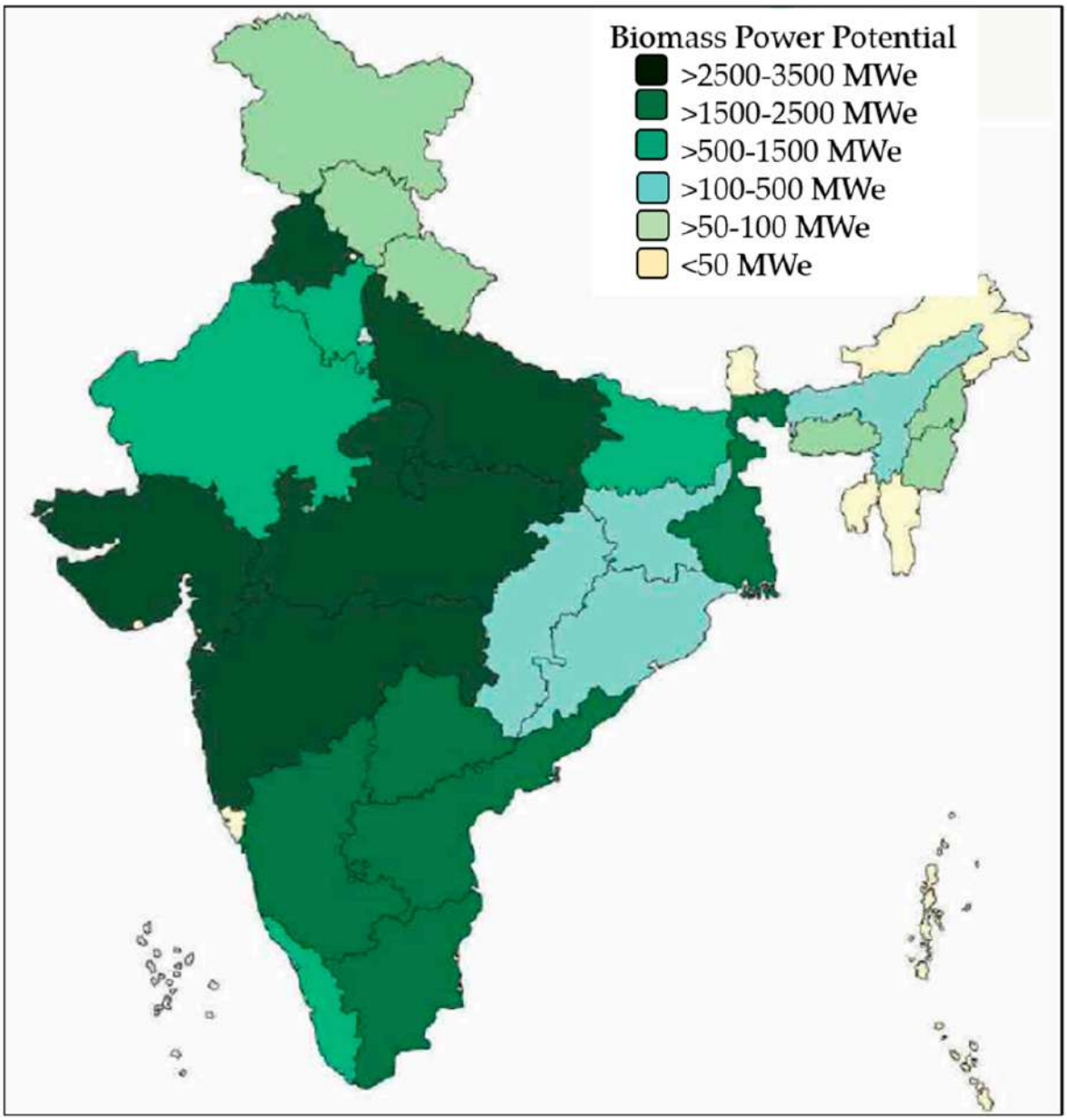


Fig 1: Map of India depicting biomass power potential for 2019–2020 (in MWe)

Above figure shows the biomass potential in terms of electricity generation potential. However, the figure is shown to establish the fact that the biomass is available in all the states of India which can be further utilized for different types of bioenergy production like Biomass Pellets / Briquettes etc.

3. Agriculture Waste Production

Table 2. Biomass Production in Punjab in 2019-2020

Sr. No	Crop Name	Area (Ha)	Crop Production (Tonnes)	Biomass Production (Tonnes)
1	Rice	3075420.7	12916474.0	19374711.0
2	Wheat	3547901.6	17605366.0	31689658.8
3	Bajra	619.6	665.4	1749.9
4	Maize	108497.4	479847.6	1103649.5
5	Gram	129.4	938.1	1031.9
6	Tur (Arhar)	1100.3	1319.3	3694.1
7	Masoor	800.0	500.0	900.0
8	Groundnut	605.2	2327.7	5353.8
9	Rapeseed & Mustard	31662.3	46681.6	84026.9
10	Cotton	349027.2	230050.1	1832413.5
11	Sugarcane	56502.6	4933523.2	246676.2
12	Guarseed	35288.6	28680.2	57360.4
13	Green Gram (Moong)	2323.6	3832.0	4790.0
14	Sesamum	2700.0	900.0	2250.0
15	Black Gram (Urad)	2375.7	1245.6	1619.3
16	Barley	3736.9	17792.8	23130.7
17	Peas & Beans	3177.6	4101.8	2050.9
	Total	**7221868.7**	**36274245.5**	**54435066.8**

Table 3. Biomass Production in Haryana in 2019-2020

Sr. No	Crop Name	Area (Ha)	Crop Production (Tonnes)	Biomass Production (Tonnes)
1	Rice	1404088.00	4585099.00	6877648.00
2	Wheat	2678237.00	13590967.00	24463741.00
3	Jowar	32734.98	34271.81	82252.35
4	Bajra	735869.20	1600021.00	4208056.00
5	Maize	5515.45	14774.73	33981.87
6	Gram	55882.45	69489.01	76437.91
7	Tur (Arhar)	17985.65	24132.40	67570.71
8	Lentil (Masur)	195.75	421.47	758.65
9	Groundnut	3120.53	3527.64	8113.59
10	Rapeseed & Mustard	384158.20	753363.20	1356054.00
11	Sunflower	7152.06	13492.31	26984.62
12	Cotton	509208.70	554318.80	3154495.00
13	Sugarcane	47046.04	429292.90	21464.64
14	Green Gram (Moong)	19526.15	12599.80	15749.75
15	Sesamum	-1843066	220.70	551.75
16	Black Gram (Urad)	2383.50	1378.96	1792.65
17	Potato	14654.58	295296.20	239189.90
18	Barley	52974.33	207516.50	269771.40
19	Peas & Beans	1984.69	1744.54	872.27
	Total	**4129652**	**22191928**	**40905485**

As per the data mention in the table 2 & 3 it is evident that the biomass generation in almost each and every crop is more than the main crop production.

Specially rice straw or paddy straw from the rice crop is approximately 1.5 times the production of rice which shows that a huge amount of paddy straw is available for disposal every year, and which can be used for the production of biomass Pellets / Briquettes.

Moreover, among many feedstocks' paddy straw has one of the highest TS contents which is approximately 80-85% and this characteristic makes the paddy straw a viable and sustainable feedstock for the Biomass Pellet Projects

Alternatively, fast-growing energy crops such as Napier Grass, can be cultivated specifically for the sustainable round the year supply of biomass for the biomass Pellet Projects.

4. Suitable Biomass for Bioenergy Project

4.1 Paddy Straw: Paddy straw, also known as rice straw, is a valuable agricultural residue generated after rice harvesting. Unlike the other crop residue, it is not consumed as cattle feed and due to its generation in large quantities, paddy straw is a valuable resource for bioenergy production, offering several environmental, economic, and social benefits.

However, the availability of paddy straw, is limited to approximately 120 days in a year, coinciding with the rice cultivation cycle. To address this gap and ensure continuous biomass availability, proper storage facility with sufficient quantity should be created for yearlong uninterrupted supply for bioenergy projects.

key characteristics of paddy straw:

1. **Average Yield per Hectare**: Paddy straw yield can vary depending on factors such as rice variety, soil fertility, climate, and management practices. On average, paddy straw yields can range from about 3 to 6 tons per hectare (1.2 to 2.4 tons per acre).
2. **Length and Texture:** Paddy straw varies in length and texture, with the stalks typically ranging from 60 to 120 centimeters (2 to 4 feet) in length.
3. **Fibrous Structure:** Paddy straw consists mainly of cellulose, hemicellulose, and lignin, giving it a fibrous and woody structure.
4. **Carbon-to-Nitrogen Ratio:** Paddy straw has a high carbon-to-nitrogen (C: N) ratio, typically ranging from 60:1 to 100:1. This high C:N ratio makes paddy straw a valuable organic material for soil amendment and composting, as it helps improve soil structure and fertility while promoting microbial activity.
5. **Bulk Density:** Paddy straw has a relatively low bulk density, which means it occupies a large volume relative to its weight. This characteristic can influence storage and transportation considerations, as compacting or densifying paddy straw may be necessary to optimize storage space and handling efficiency.
6. **Combustibility:** Paddy straw is highly combustible and can be utilized as a biomass fuel for energy production.

7. **Availability:** Paddy straw availability is seasonal, typically coinciding with the rice harvesting season which is typically 120 days per year.

4.2 Napier Grass: Napier grass, scientifically known as Pennisetum purpureum, is a robust perennial grass species also referred to as elephant grass. Napier grass with its rapid growth, high biomass yield, and adaptability to various climatic conditions, presents a promising resource for bioenergy production.

key characteristics of Napier grass:

1. **Height and Growth Habit:** Napier grass is known for its tall and vigorous growth, capable of reaching heights of 3 to 5 meters (10 to 15 feet) under favorable conditions. Its upright growth habit and dense foliage make it an ideal candidate for biomass production.

2. **Fresh Weight Yield:** On average, Napier grass can yield approximately 40 to 70 tons of fresh biomass per Acre per harvest under optimal conditions. This yield can vary based on factors such as irrigation, fertilization, and harvesting frequency.

3. **Dry Matter Yield:** The dry matter content of Napier grass typically ranges from 20% to 30% of the fresh weight.

4. **Harvest Frequency:** Napier grass can be harvested multiple times throughout the growing season, with each harvest interval typically ranging from 60 to 90 days. With proper management, including fertilization and irrigation, 4-6 harvests can be obtained in a single growing season, maximizing biomass production.

5. **Adaptability:** One of the notable characteristics of Napier grass is its adaptability to various soil types and climatic conditions.

6. **Nutritive Value:** While Napier grass is primarily cultivated for biomass production, it also has value as a livestock feed. The foliage of Napier grass is relatively nutritious, with high protein content and digestibility.

7. **Regeneration Capacity:** Napier grass has excellent regenerative capacity, capable of regrowing vigorously after harvesting or grazing. With proper management practices, including timely cutting and fertilization, it can sustain multiple harvests without significant loss in productivity.

4.3 Napier Grass Varieties:

In India, several varieties of Napier grass, also known as Elephant grass or Uganda grass, are cultivated for various agricultural purposes. Some of the common varieties grown in India include:

1. **CO (Cumbu Napier Hybrid) 1**: Developed by the Tamil Nadu Agricultural University (TNAU), CO 1 is a high-yielding hybrid variety of Napier grass. It exhibits excellent adaptability to diverse agroclimatic conditions and is valued for its high biomass yield and nutritive value.
2. **BN (Bajra Napier Hybrid) 4**: Another hybrid variety developed by TNAU, BN 4 is known for its superior biomass yield and fodder quality. It is a cross between Napier grass and pearl millet (bajra), combining the desirable traits of both parent species.
3. **NB (Napier Bajra Hybrid) 21**: Developed by the National Dairy Research Institute (NDRI), NB 21 is a hybrid variety of Napier grass and pearl millet. It is well-suited for cultivation in arid and semi-arid regions and is valued for its high biomass production and drought tolerance.
4. **CO (Cumbu Napier Hybrid) 3**: Similar to CO 1, CO 3 is another hybrid variety developed by TNAU. It is characterized by its high biomass yield, rapid growth rate, and adaptability to diverse soil and climatic conditions.
5. **NB (Napier Bajra Hybrid) 14**: Developed by NDRI, NB 14 is a hybrid variety of Napier grass and pearl millet. It is well-adapted to marginal lands with poor soil fertility and limited water availability, making it suitable for cultivation in resource-constrained environments.

These are some of the popular Napier grass varieties cultivated in India. Farmers and livestock keepers select varieties based on factors such as agroclimatic conditions, soil type, intended use (fodder or biomass), and availability of planting material. Proper selection of suitable varieties is essential for maximizing productivity and achieving desired outcomes in Napier grass cultivation.

5. Biomass Production Method & Yield

5.1 Paddy Straw Production:

Since paddy straw is a byproduct or crop remnant of rice, rice and paddy are closely related. Since rice is the staple meal of India, it is grown in practically every state, meaning that paddy is accessible everywhere in the country. Though the amount varies by location, for example, rice farming is restricted in the Himalayan region because of the nature of the terrain; otherwise, rice is the main crop in practically all of India's states.

Therefore, no separate arrangement is needed for the production of paddy, only timely collection of paddy is to be ensured to aggregate the paddy in the limited window of 120 days which is the harvesting period after that field will be used for another crop.

Paddy Straw Yield: The yield of paddy straw (rice straw) can vary depending on several factors including rice variety, climate, soil fertility, agricultural practices, and harvesting techniques. However, in most of the regions on average, paddy straw yield can range from about 3 to 6 tons per hectare (**1.2 to 2.4 tons per acre**) for a single crop cycle.

5.2 Napier Grass Production:

Production of napier grass for bioenergy plant can be done through mainly two methods:

a) Self-Grow:
b) Contract Farming

a) Self-Grow: Growing Napier grass on your own for various purposes is very simple and quite possible even you don’t have previous farming experience.

Here's a step-by-step guide to growing Napier grass

Land: First step is to take the large land parcel on long term lease which is a simple task in India compared to buying.

Land Preparation: Plough the land with help of tractors or manually.

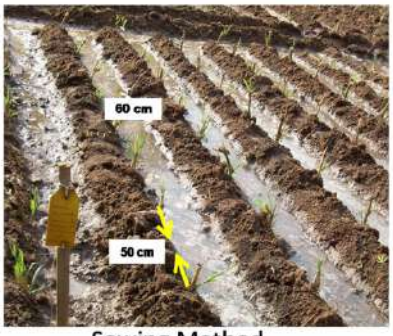
Create '^' shapes row sections at the distance of 2 feet each. These '^' shapes will help plants to get all the ingredients particularly without disturbing another one.

Sowing of Cuttings / Seeds: Napier grass grows by cuttings of at least 2 nodes. In the sowing process, every cutting pinch deep inside the soil and just the upper part of the cutting opens towards the sky.

Every cutting must fix at a 45 to 55-degree angle. They sow as a plant-to-plant distance should be 2 feet and row to row distance should be 2 feet.

Seeds

Germination of seed



Sowing Method

Irrigation Process: After the sowing process gets completed, the first irrigation does just by showering water on the soil.

After getting sprout and 15 to 20 days older, when plants get 15 cm height, we knew first irrigation apply on the plants. Sewage or waste-water can also be used for irrigation.

Fertilizer Process: Apply and spread 25 T /FYM/ha of or compost every year on the un-ploughed land and incorporate the manure in the soil during ploughing. Apply NPK fertilizers as per soil test recommendations as far as

possible. If soil testing is not done, follow the blanket recommendations of 50: 50: 40 of kg NPK/ha.

Harvesting: The first harvesting of Napier grass is after 70 to 90 days. Plants get their maximum height till the time of 15 feet tall. During the harvesting process, plants cut direct from their bottom portion of the stem but just above (2 to 3 inches) from the ground.

Napier grass is well-suited to diverse Agro-climatic conditions in India, including tropical and subtropical regions. It thrives in areas with adequate rainfall or irrigation facilities and can tolerate a wide range of soil types, from sandy to clayey soils, as long as they are well-drained.

b) Contract Farming:

Contract farming for Napier grass involves an agreement between a farmer and a buyer (often a bioenergy producer).

1. **Agreement Negotiation:** The process begins with negotiation between the farmer and the buyer to establish the terms of the contract. This includes discussions on land area, cultivation practices, input supply, expected yield, quality requirements, pricing mechanism, payment terms, and duration of the contract.
2. **Contract Signing:** Once the terms are agreed upon, a formal contract is signed between the farmer and the buyer. The contract outlines the rights and obligations of both parties, including production targets, delivery schedules, quality specifications, pricing formulas, and dispute resolution mechanisms.
3. **Land Preparation:** The farmer prepares the land for Napier grass cultivation according to the specifications provided in the contract.
4. **Input Supply:** The buyer may supply inputs such as Napier grass seeds, fertilizers, pesticides, and irrigation equipment to the farmer as per the contract terms.
5. **Cultivation Practices**: The farmer follows recommended cultivation practices for Napier grass, including planting methods, spacing, irrigation scheduling, fertilization, weed control, pest management, and crop monitoring.

6. **Crop Management:** Throughout the growing season, the farmer manages the Napier grass crop according to the contract requirements.
7. Harvesting and Delivery: Upon reaching maturity, the harvested Napier grass is delivered to the buyer as per the agreed-upon schedule and quantity.

Napier Grass Yield: Many Farmers are doing Napier grass farming for the bioenergy plants and for the green fodder in India. On average, Napier grass production yield is approximately **200 tons of fresh biomass per acre per year** in 3-5 harvest under optimal conditions. This yield can vary based on factors such as irrigation, fertilization, and harvesting frequency.

Napier Grass Seeds Per Acre	Yield Per Acre	Avg weight of seed Per harvest	Harvest season Per Year	Total Production of Napier Per Acre per Year
10000	81%	7	4	226800

Table 4: Yield Potential of CO 5 Variety of Napier Grass developed by TAU

Napier Grass Required Per Day	Total Production of Napier Per Acre per Year	Napier Grass required Per Year in Tons	Land Required in Acre
114	227	37714	166

Table 5: Napier Grass Required for 40 TPD Biomass Pellet Plant

5.3 CAPEX of Napier Grass Cultivation:

The capital expenditure (CAPEX) involved in Napier grass farming can vary depending on several factors, including the scale of the operation, land acquisition costs, infrastructure requirements, equipment investment, and ongoing operational expenses.

CAPEX - INITIAL COST	Value in INR	Unit
Infrastructure Development	150000	Per Acre
Planting Materials	20000	Per acre
Equipment and Machinery	3000000	Per Set
Infrastructure for Biomass Storage	150000	Per Acre
Utilities and Energy	150000	Lump Sump

5.4 OPEX of Napier Grass Cultivation:

Operating expenses (OPEX) in Napier grass farming encompass the various costs associated with cultivating, managing, and maintaining a Napier grass plantation. These expenses can vary depending on factors such as farm size, location, labor availability, management practices, input costs, and market conditions.

Napier grass OPEX cost calculation			
Sl.No.	Description	Unit	Value in Rs
1	Land Size	Acre	100
2	Number of seed required per acre	Nos. / Acre	10000
3	Total weight of grass per harvest	Kg / Per acre	103950
4	Cost of Seeds	Rs / Acre	11000
5	Lease charges of the Land	Rs / Acre/Year	100000
6	Cost of seed (3 Years life)	Rs / year	366667
7	Lease charges for land	Rs/Year	10000000
8	Total yearly cost	Rs / Year	10366667
9	Total Yearly Grass Generation	Tons / Year	23389
10	Organic fertilizer required	Ton/Acre	10
11	Cost of organic fertilizer	Rs/ton	2500
12	NPK Required	Ton/Acre	0.10
13	Cost of NPK	Rs/Ton	2000
14	Cost of organic fertilizer and NPK	Rs/Year	7649393
15	Cost of Fertilizer per ton of grass	Rs/Ton	327
16	Labour cost	Rs/Ton	31
17	Tractor cost for transportation	Rs/ton	156
18	Seed and land cost	Rs/ton	443
19	Total Cost of Grass	Rs/Ton	957

6. Collection Process of Paddy Straw

In today's world collection of biomass involved high tech machinery unlike the old times where collection use to happen manually. The collection of paddy straw involves several steps to efficiently gather and manage the straw residues left behind after rice harvesting. Here's a detailed overview of the paddy straw collection process:

6.1 Paddy Straw Cutter

A paddy straw cutter is a type of agricultural machinery specifically designed for the purpose of cutting and shredding paddy straw residues left behind in fields after rice harvesting. These machines play a crucial role in the management of agricultural residues and facilitate the efficient collection, processing, and utilization of paddy straw. It is the very first step of crop residue collection process.

6.2 Paddy Straw Hay Rack

A paddy straw rake, also known as a straw rake or a hay rake, is an agricultural implement used specifically for collecting and raking paddy straw or rice straw after the rice harvesting process. The primary function of a paddy straw rake is to gather the loose straw residues left behind in the field after the rice grains have been harvested. It meets the forage delicately without much of twisting/entangling thereby making subsequent harvesting (by a baler) easy. It works seamlessly on flat and hilly terrains. Its light yet sturdy construction ensures optimized harvesting by raking greater quantity of hay at once.

Paddy straw rakes are commonly mounted on tractors or other agricultural machinery, such as combine harvesters or tractor-drawn implements. The rake is typically towed behind the tractor or attached to the rear of the harvester, allowing it to be easily maneuvered through the field during the straw collection process.

6.3 Paddy Straw Baler

Straw Baler are used for baling of straw into bales of rectangular or circular cross section. The tractor operated machine consists of reel type straw pick up assembly, and straw compaction and tying units. It automatically picks up the residue straw from field with the help of reel which is transferred into bale chamber with the help of feeder and then straw is compressed with the reciprocating ram into a compact variable length size. It also automatically ties the knots using metal wire or nylon rope.

6.4 Tractor

Tractors play a crucial role in biomass collection, offering efficiency, speed, and versatility in gathering agricultural residues such as paddy straw

6.5 Trolley

A trolley, often used in conjunction with biomass collection, serves as a practical and efficient means of transporting harvested biomass materials from the field to storage or processing areas.

6.6 Potential Capacity of One Bailing Set

A typical baling set for paddy straw, also known as a baler, consists of several key pieces of equipment (mentioned above 6.1 to 6.5) designed to efficiently compress and package straw residues into compact bales for storage, transportation, or further processing.

One Baling Set Equipment's	Baling Capacity Per Set	Avg. Harvesting Season in Day	Average Paddy Straw Per Acre	Capacity of one Baling Set
Tractor, Cutter, Hay Raker, Bailer & Trolley	25	100	1.5	3750
	Acre Per Day	Days Per Year	Ton / Acre	Tons / Season

Table 7: Baling Set Baling capacity in tons / Year

6.7 Baling Set Required For 40 TPD Biomass Pellet Plant

Biomass Plant Capacity in Tons / Day	Biomass Required Per day in Tons	Biomass required per year	Capacity of one Baling Set Per season in Tons	No of Bailing set required
40	57	18857	3750	5.0

Table 8: Bailing set required for 40TPD Plant

6.8 CAPEX Cost of 5 Baling Sets

CAPEX - INITIAL COST	Value In INR	Unit
One baling set which include, Tractor, Raker, Cutter and Bailer	16000000	Per Set

6.9 OPEX Cost of 5 Baling Sets

DESCRIPTION	VALUE	UNIT
Cost of Set of Bailer including Tractor in Rs	3200000	in INR
Paddy required	18857	Ton / Year
No Of Bailing Set required	5	Nos.
total cost of Baling Set	16000000	in INR
Yearly Cost of Baling Set	6380000	in INR
Cost of Bailing in Rs per Ton	337	Rs / Ton
transport and stacking charges at site basis. In Rs / Ton	1500	Rs / Ton
Payment to Farmers in Rs/ Ton	500	Rs / Ton
Spares and Maintenance cost of Machinery and over heads	250	Rs / Ton
Total Cost Per Ton	**2587**	**Rs / Ton**

7. Biomass Collection Method

For large scale bioenergy projects like biomass pellet plant wherein biomass requirement is in huge quantities round the year, biomass collection is the main aspect of biomass aggregation. Therefore, Biomass collection center are needed and they shall also provide the services of biomass collection from the source through Custom Hiring Centers (CHCs).
Through Custom Hiring Centers (CHCs) biomass processing equipment like baling sets shall be provided to farmers and other stakeholders involved in biomass aggregation. These centers aim to facilitate the adoption of modern and efficient biomass processing technologies as previously mentioned among farmers, particularly in agricultural regions where biomass resources are abundant.

Operation of custom hiring centers for biomass:

1. **Equipment Rental**: CHCs offer a complete baling set which shall include cutter, raker, baler etc. Farmers can rent these machines as per their requirement or they have to option take the complete aggregation services from the CHCs wherein HCs shall do the whole process with their teams and send the baled paddy straw to collection center.
2. **Affordable Access**: Smallholder farmers often lack the financial resources to invest in expensive biomass processing machinery. CHCs bridge this gap by providing access to modern equipment at affordable rental rates, enabling farmers to process biomass residues efficiently without significant upfront investment.
3. **Technical Support**: CHCs often provide technical assistance and training to farmers on the proper operation and maintenance of biomass processing equipment. This support helps farmers maximize the performance and efficiency of the rented machines while ensuring safe operation.

Overall, custom hiring centers for biomass play a crucial role in promoting the sustainable utilization of biomass resources, enhancing rural livelihoods, and supporting the transition towards cleaner and more sustainable energy systems and creating additional revenue for farmers.

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