

Can India Make its Biomass Supply Chain more Effective? Infrastructure Needs and Financial Estimates for Effective Storage of Paddy Straw in Punjab

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Annexure 1 to 5 | September 2025

Annexure 1: Factors compiled from literature review

Table A1 : Categorized findings found from literature review

	Factors	Units/Measurement method	Remarks
1	Feedstock Quality		
1.1	Moisture content	Percentage	The biomass collectors have a permissible moisture percentage beyond which they cut the price to be paid. The literature suggests less than 20 per cent moisture as the feasible moisture for storage.
1.2	Gross calorific value	Kcal/kg	The factor relates to the industries using biomass for power generation. GCV helps us to understand the quality of biomass.
1.3	Colour	Colour discolouration	The good quality of biomass is golden in colour and darker colour represents degradation of biomass due to self heating and decomposition.
1.4	Physical appearance of bale	Intact or broken	The bales are tied with a twine for transportation and handling. At times the twine is broken while transportation or toppling. These bales can impact the stack stability and need to be stored separately from the intact bales.
2	Feedstock Collection and Handling		
2.1	Shape of bale	Round and rectangular	The bale shape is decided based on the method of biomass collection. The biomass can be collected through biomass aggregators or baling machines procured by the industry. The processing required for feedstock also determines the shape of bales to be collected. For e.g. the small width conveyor requires 25-30 kg bales.
2.2	Size of bale	Dimension and weight of bales (rectangular/round)	The baling machine model for feedstock collection determines the size of the bales and density. The size serves as the building block for the stack and the storage depot area.
2.3	Bale collection method	Self collection or outsourced (aggrgeators/VLEs)	The method of bale collection depends on the industry's supply chain model. The biomass can be collected by the industry or sourced through biomass aggregators and VLEs.
2.4	Feedstock transportation cost	INR/tonne/km	The cost of transportation depends on the industry's supply chain model. The transportation cost can be fixed or variable depending on the distance for transportation. The transportation cost can also be included in the fixed feedstock
2.5	Feedstock cost	INR/tonne	The cost of feedstock at the time of collection is lesser than the feedstock cost after storage at the depot. The cost is influenced by reduction in biofuel production due to less energy conversion and the investment for feedstock

			storage
3	Feedstock Storage		
3.1	Land ownership	Own or leased land	To identify the permanent infrastructure which can be laid over the land. Lease land provides limited flexibility to invest in the infrastructure like boundary wall, raised platform, shed, etc.
3.2	Land levelling	Land leveling, raised platforms,	The levelling determines the water logging potential of the site. The accumulation of water at the storage results in faster rate of decomposition of the biomass at the base of the stack if directly stored on the land
3.3	Stack shape and size	Pyramid, hut shaped, rectangular	The stack shape and size determines the land requirement for storage, the machinery required for achieving stack height, surface area of the stack, pressure on stacks at the bottom among other factors.
3.4	Feedstock quantity to be stored	tonne	The feedstock quantity to be stored helps determine the feasible collection method as in case of large biomass to be collected the catchment for collection will increase and require an efficient supply chain. In addition the land requirement, infrastructure and workforce requirement is a direct result from the scale of functioning of the storage depot.
3.5	Distance between stacks	Feet	The stack distance is important to prevent spread of fire in case of an incident. Although it increases the cost of storage and land requirement.
3.6	Distance for vehicular movement	Feet	The stack distance is important for turning of vehicles and also easy access through fire brigade in case of hazard. Although it increases the cost of storage and land requirement.
3.7	Infrastructure		
3.7.1	Shed	Present/ Absence	Sheds, although expensive, are an easy way to protect biomass in the rainy season to ensure continuous feedstock supply.
3.7.2	Tarp	Present/ Absence	Tarps are cheaper fixtures to protect biomass stored in the open in the rainy season.
3.7.3	Drainage	Present/ Absence	The trenches can either be provided around the stack platform or stack boundary to collect and discharge rain water to prevent water logging and biomass degradation of base layers.
3.7.4	Boundary wall	Present/ Absence	The infrastructure provides barrier to prevent intervening with the biomass storage depot to limit sources of spark at the storage depot
3.7.5	Fire safety equipment	Present/ Absence	To start the fire fighting operations to prevent spreading of the fire to other stacks
3.7.6	Moisture metre	Present/ Absence	The set checks for moisture percent at the time of collection
3.7.7	CCTV	Present/ Absence	To monitor storage site and get information on any fire hazard as soon as possible
3.7.8	Lightning arrestor	Present/ Absence	
4	Operations and Maintenance		
4.1	Workforce		
4.1.1	Security guard	Present/ Absence	To identify the investment required for collection, handling and operations of biomass storage depot.

4.1.2	Supervisors	Present/ Absence	
4.1.3	Drivers	Present/ Absence	
4.1.4	Labourers	Present/ Absence	
4.2	Cost of workforce	INR/day/person	The cost for operations for biomass collection and safety
4.3	Insurance	Yes/No	To identify the risk to assured biomass availability and biofuel production
4.4	Trainings	Yes/No	To identify the capacity of the personnel to handle to handle the hazard and minimise the feedstock

Source: Author's compilation from literature

Annexure 2: Losses reported

Table A2: Reported losses by companies visited and types of discard method

Companies visited	Feedstock procured reported (tonne)	Loss reported (per cent)	Estimated feedstock lost (tonne)	Discard method reported
Dee Development Engineering Ltd	80000	20	16000	Mulched back or thrown
Malwa Power Pvt Ltd	90000	15	13500	Mulched back or thrown
Ecostan Biofuels Pvt Ltd	60000	5	3000	Did not report
Shri Ganesh Edibles Ltd	250000	17	42500	Mulched back in farms
Punjab Renewable Energy System Pvt Ltd	10000	20	2000	Lying at storage site, JCB used to mix it
SPS Eco Friendly Fuels Ltd	64000	25	16000	Lying at storage site
Verbio India Pvt Ltd	90000	2	1800	Given to gatta factories

Source: Author's compilation from ground visits

Annexure 3: Cost calculation for setting up and operating of biomass storage facility for 10,000 tonnes of paddy straw

Table A3: Infrastructure cost calculation for rectangular bales

Calculations	Assumption	Formula	Cost (INR Lakh)
Weighbridge			
Cost of weighbridge (INR Lakh)	25 tonne weight capacity, market based cost		10
Tarpaulin			

Stack area to be covered with tarpaulin	Only small and medium stacks to be covered as large stacks are utilised first	L = Length of biomass stack W = Width of biomass stack H = Height of biomass stack O = Overhang needed on each side Required Tarpaulin Length = $L+(2\times O)$ Required Tarpaulin Width = $W+(2\times O)$ Total Area Required (sq ft) = $(L+2O)\times(W+2O)$	
Small stack area cover (sq ft)	(50ft x 80 ft) O - 1ft	4536	
No. of small stacks to be covered (sq ft.)	9	40824	
Medium stack area cover (sq ft)	(80ft x 80 ft) O - 1ft	7056	
No. of medium stacks to be covered (sq ft.)	9	63504	
Total tarpaulin area required (sq. ft)		104328	
Cost of tarpaulin (INR Lakh)	HDPE Tarapulin (250 gsm) - INR 5/sq ft	Total tarpaulin area x cost of tarpaulin	5.2
Drainage			
Total area (sq. m)	7acres required 1 acre = 4046.86 sq meters)	28328.02	
Length of one side (m)	Square root of area	168.31	
Perimeter of storage side (sq. m)	4 x length	673.24	
Cost of drainage (INR/mtr)	Punjab labour rates - 100/mtr		67323.72
Cost of drainage (INR Lakh)			0.7
Fencing			
Total area (sq. m)	7acres required. 1 acre = 4046.86 sq meters)	28328.02	
Length of one side (m)	Square root of area	168.31	
Perimeter of storage side (sq. m)	4 x length	673.24	
Cost of fencing (INR/mtr)	Material and labour cost - INR 470/mtr		316421.48
Cost of fencing (INR Lakh)			3.16
Security Infrastructure			
CCTV			
Number of CCTV required	Based on survey results	4	

Cost of CCTV (INR Lakh)	Market based data		1
Solar lighting			
Cost of 1 solar light	Market based data		10,000
Cost of solar lighting (INR lakh)			1
Lightning arrestor			
Cost of 1 lightning arrestor	From CRM Operational Guidelines		40,000
Coverage of 1 arrestor (mtr)	A 7-acre site (approx. 168m x 168m) requires multiple arrestors to ensure full coverage.		
Total arrestors required	Placing 4 systems (e.g., one in each quadrant) creates overlapping zones of protection, ensuring no stack is left exposed.	4	
Total cost of lightning arrestors (INR lakh)			1.6
Total security infrastructure cost (INR lakh)			3.6
Platform			
Cost of Land Levelling (per acre)	7 acres to be levelled with sloping		25000
Total Platform Cost (INR lakh)			1.75
Fire Safety			
Number of fire extinguishers required		6	6
Cost of one fire extinguisher	From CRM Operational Guidelines		15,000
Total fire safety cost (INR lakh)			0.9
Total infrastructure cost (INR lakh)			25.3

Source: Author's analysis from ground visits and literature

Table A4: Infrastructure cost calculation for rectangular bales

Calculations	Assumption	Formula	Cost (INR Lakh)
Weighbridge			
Cost of weighbridge (INR Lakh)	25 tonne weight capacity, market based cost		10
Tarpaulin			
Slant height (SH)	Stack Height is 30ft Stack Width 36ft	$\sqrt{(\text{Height}^2 + (\text{Half Width})^2)} = 35\text{ft}$	
Stack area to be covered with tarpaulin	Small stack length (100ft) Medium stack length (200ft) Large stack length (300ft)	Area of slanted rectangles = $2*(L \times SH)$ Area of Triangular ends = W	

		x SH Total Area of one stack = (2 x L x SH) + (W x SH)	
Small stack area cover (sq ft)		8080	
No. of small stacks to be covered (sq ft)	11	88880	
Medium stack area cover (sq ft)		15080	
No. of medium stacks to be covered	13	196040	
Large stack area cover (sq ft)		22080	
No. of large stacks to be covered (sq ft)	4	88320	
Total tarpaulin area required (sq ft)		373240	
Cost of tarpaulin (INR Lakh)	250 gsm HDPE Tarapulins INR 5/Sq ft	Total tarpaulin area x Cost of tarpaulin	18.7
Drainage			
Total area (sq. m)	9.3 acres required. 1 acre = 4046.86 sq meters)	37635.798	
Length of one side (m)	Square root of area	194.00	
Perimeter of storage side (sq. m)	4 x length	776.00	
Cost of drainage (INR/mtr)	Punjab work rates - 100/mtr		77599.79
Cost of drainage (INR Lakh)			0.8
Fencing			
Total area (sq. m)	9.3 acres required. 1 acre = 4046.86 sq meters)	37635.798	
Length of one side (m)	Square root of area	194.00	
Perimeter of storage side (sq. m)	4 x length	776.00	
Cost of fencing (INR/mtr)	Punjab labour wages - INR 470/mtr		364719.02
Cost of fencing (INR Lakh)			3.65
Security Infrastructure			
CCTV			
Number of CCTV required	Based on survey results and market based data	4	
Cost of 4 CCTV (INR Lakh)			1
Solar lighting			

Cost of 1 solar light	Market based data		10,000
Cost of 12 solar lighting (INR lakh)			1.2
Lightning arrestor			
Cost of 1 lightning arrestor	From CRM Operational Guidelines		40,000
Coverage of 1 arrestor (mtr)	A 8.3-acre site (approx. 168m x 168m) requires multiple arrestors to ensure full coverage.		
Total arrestors required	Placing 4 systems (e.g., one in each quadrant) creates overlapping zones of protection, ensuring no stack is left exposed.	4	
Total cost of lightning arrestors (INR lakh)			1.6
Total security infrastructure cost (INR lakh)			3.8
Platform			
Cost of land levelling (per acre)	9.3 acres to be levelled with sloping		25000
Total platform cost (INR lakhs)			2.1
Fire Safety			
Number of fire extinguishers required			9
Cost of one fire extinguisher	From CRM Operational Guidelines		15,000
Total fire safety cost (INR lakh)			1.35
Total infrastructure cost (INR lakh)			40.3

Source: Author's analysis from ground visits and literature

Table A5: Annual operations cost calculation

Cost Category	Assumptions	Monthly Cost (INR)	Cost for storing 10,000 tonnes of biomass (INR Lakh)
Workforce Cost			
Supervisor	Responsible for overall management of the depot	15,000	180,000
Security Guards	6 personnel required (2 guards x 3 shifts)	60,000	720,000
Total workforce cost		75,000	900,000
Maintenance cost			
Tarpaulin	Replacing old/spoilt to cover stacks		200,000
Electricity and water costs	Based on current power rates		100,000

Land cleaning and preparation	Survey-based data	15,000	15,000
Water pump rent	Survey-based data	5,000	5,000
Total maintenance cost			320,000
Total operations cost			1,220,000

Source: Author's analysis from ground visits and literature

Annexure 4: Payback period calculations for both rectangular and round bales

Table A5: Loss factor and net annual savings calculation

Loss scenario for 10,000 tonnes of rectangular bales				
	Loss factor (per cent)			
Procurement Price (INR/tonne)	5	10	15	20
1000	500,000	1,000,000	1,500,000	2,000,000
1500	750,000	1,500,000	2,250,000	3,000,000
2000	1,000,000	2,000,000	3,000,000	4,000,000
2500	1,250,000	2,500,000	3,750,000	5,000,000
Assumptions				
Initial Setup Cost	2500000			
Annual Operating Cost	1220000			
Net Annual Savings	Loss factor (per cent)			
Procurement Price (INR/tonne)	5	10	15	20
1000	-720,000	-220,000	280,000	780,000
1500	-470,000	280,000	1,030,000	1,780,000
2000	-220,000	780,000	1,780,000	2,780,000
2500	30,000	1,280,000	2,530,000	3,780,000

Table A6: Payback period calculation for rectangular bales

Payback Period (in years) = Initial Setup Cost / Annual Net Savings

Rectangular bales	Loss factor (per cent)			
Benchmark Price (INR/tonne)	5	10	15	20
1000	Not viable	Not viable	8.9	3.2
1500	Not viable	8.9	2.4	1.4
2000	Not viable	3.2	1.4	0.9
2500	83.3	2.0	1.0	0.7

Source: Author's analysis

Table A7: Payback period calculation for round bales

Payback Period (in years) = Initial Setup Cost / Annual Net Savings

Round Bales	Loss factor (per cent)			
	5	10	15	20
Benchmark Price (INR/tonne)				
1000	Not viable	Not viable	14.3	5.1
1500	Not viable	14.3	3.9	2.2
2000	Not viable	5.1	2.2	1.4
2500	133.3	3.1	1.6	1.1

Source: Author's analysis

Annexure 5: Punjab state projection calculation

Table A8: Land and infrastructure required to store 6 million tonnes of paddy straw

Land required to store 6 million tonnes (acres)			
Bale Type	Storage per 10,000 tonnes (acres)	Scaling Factor	Required Storage for 6 million tonnes (acres)
Rectangular Bales	7	600	4,200
Round Bales	9.3	600	5,580
Infrastructure investment required to store 6 million tonnes			
Bale Type	Cost per tonne (INR)	Total paddy straw (tonnes)	Total Infrastructure Cost (INR crore)
Rectangular Bales	250	6,000,000	150
Round Bales	400	6,000,000	240

Source: Author's analysis