“Sustainable Biomass Supply Network Model: A Pathway to Efficient Energy Transition”

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ABSTRACT

Biomass represents a promising renewable energy source with significant potential to reduce the carbon footprint of coal-fired thermal power plants and various industrial processes. Unlike other renewable energy sources such as wind power, biomass offers a reliable energy supply with minimal volatility. Despite these advantages, biomass remains underutilized as a renewable energy resource, largely due to constraints in supply chain systems. The primary barriers hindering the development of biomass and biofuel technologies include the high cost of feedstock, lack of consistent and reliable supply chains, and uncertainties in logistics and operational management. This study examines the main components of the biomass pellet supply chain, providing a comprehensive overview and classification of existing contributions in the overview of solid biofuel supply chains. This study of interface platforms highlights the interdependencies among logistics, supply-driven and demand-based collection models and underscores the importance of coordinated logistics to enhance the overall efficiency and sustainability of the biomass supply chain. To address current challenges, this paper focusses on holistic digital models that encompass all facilities within the entire biomass supply chain. Such models should incorporate strategic, tactical, and operational decision-making levels, enabling comprehensive solutions to address issues related to inventory control and real-time decision-making. Additionally, this study identifies state and district-level optimization as a critical area for future research, emphasizing the need for localized solutions to improve biomass utilization and supply chain performance. By addressing these multifaceted challenges, the study provides directions to enhance the viability of biomass as a renewable energy source, contributing to sustainable energy transitions and reducing the carbon footprints of industrial and power generated systems.

Keywords: Biomass Pellet, Supply chain , bioenergy, Pelletization.

1.0 Introduction

Biomass is a key renewable energy source based on which the policymakers reduce green house gas (GHG) emissions (Zahraee et al., 2021) [1]. For attaining the continuity in the biomass feedstock processing sector, there is unavoidable implications on efficiency and agility on continouse biomass supply chain due to various factors (Zahraee et al. 2021). To increase the sustainability of their supply chains, these suppliers strategic methods and new ways of association with these stakeholders to improve their supply chain system. (International Renewable Energy Agency 2020).Biomass consumption share was 10 percent of global energy sources in 2010 which is predicted to double by 2030 (IRENA 2015). Carbon-di-oxide emissions can be significantly decreased by managing and utilizing biomass sources for energy generation. In addition, recycling biomass intakes could retain sizeable carbon masses in manufactured bio products (IRENA 2020).

From the production of biomass feedstock to the end-use of bioenergy across various dimensions, a major research challenge is to systematically design and optimize the entire bioenergy supply chains in order to speed the transition towards sustainable production and use of biofuels and bioenergy products. from unit operations to bio-refinery processes and to the entire value chain, as well as multiple temporal scales, from strategic to operational levels, in a cost effective robust and sustainable manner (Daoutidis, Marvin, Rangarajan & Torres) [5]. The purpose of this study is to identify the important research difficulties and challenges in the optimization of the biomass-to-solid biofuel supply chain and also outline the path to address those challenges. The Government of India has focused on fossil fuel- based centralized energy planning to improve electricity access in rural areas by connecting them to grid. [3-5].

Currently, the utilization of this fuel as an energy source has not been commercially accepted due to a number of technological challenges (Balachandra,2011[6]). The main factor while using biomass for energy production is logistics, collection transportation and seasonal variation. Because of these main factors there may be significant unpredictability in the biomass supply chain rendering the biomass unreliable for energy applications. Overcoming these hurdles is very important for efficiently using biomass for energy purposes. The installation of decentralize systems for small scale energy needs (in remote areas) is one of the options that can be used to produce energy in a reliable, economic and environmentally sustainable manner. This necessitates the establishment of administration as well as energy initiatives with trained stakeholders to set up bioenergy entrepreneurs. This will aid in the cost effective production and distribution of energy carriers to rural households. As a result, the commercialization of decentralized bioenergy systems can be accomplished through collaboration among diverse government and corporate entities that include both people and the environment.

2.0 Biomass network management

Figure 1 illustrates key techniques for converting biomass into bioenergy products, detailing the supply chain from manufacturing to bio-conversion plants [7]. The chain includes biomass production, harvesting, collection, pre-treatment, storage, and conversion, with interdependencies impacting downstream operations. As industrial bioenergy advances, sustainable feedstock networks will link production to bioenergy outputs. Key components include feedstock production, preprocessing, conversion, storage, transportation, and distribution. Developing an efficient system for timely, cost-effective collection, preparation, and transportation of agro-residue biomass remains crucial for consistent, high-quality feedstock supply.

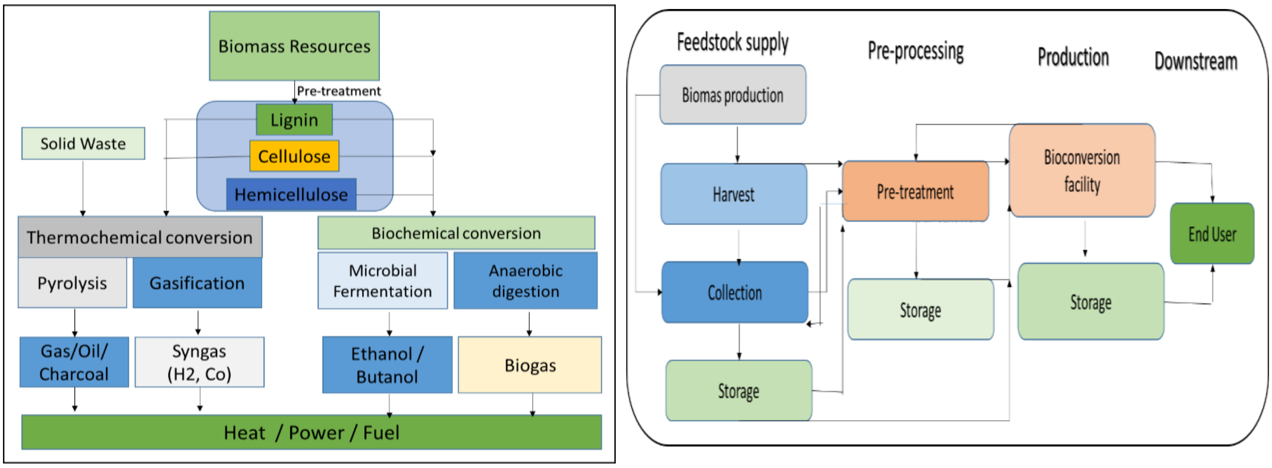


Fig:1 Conversion pathway from Biomass to end-product and its interdependence operations in network

2.1 Process of biomass supply chain

Biomass production involves machinery like combine harvesters, with an expected biomass loss of 10–20%.

- **Storage** aligns biomass generation schedules with conversion facility plans. Storage options include forests, fields, centralized locations, farms, or conversion plants before processing.
- **Preprocessing** involves activities like baling and pelletization for handling and preservation, such as drying. Basic baling is done in the field, followed by compression or transformation using specialized equipment or facilities.
- **Transportation** utilizes industrial logistics and varied methods, often constrained by vehicle fleet size, trip limits, vehicle range, and driving regulations. Road transport, primarily trucks, is common for remote production sites due to their capacity and efficiency. Figure 2 [23] illustrates a typical biomass supply chain network.

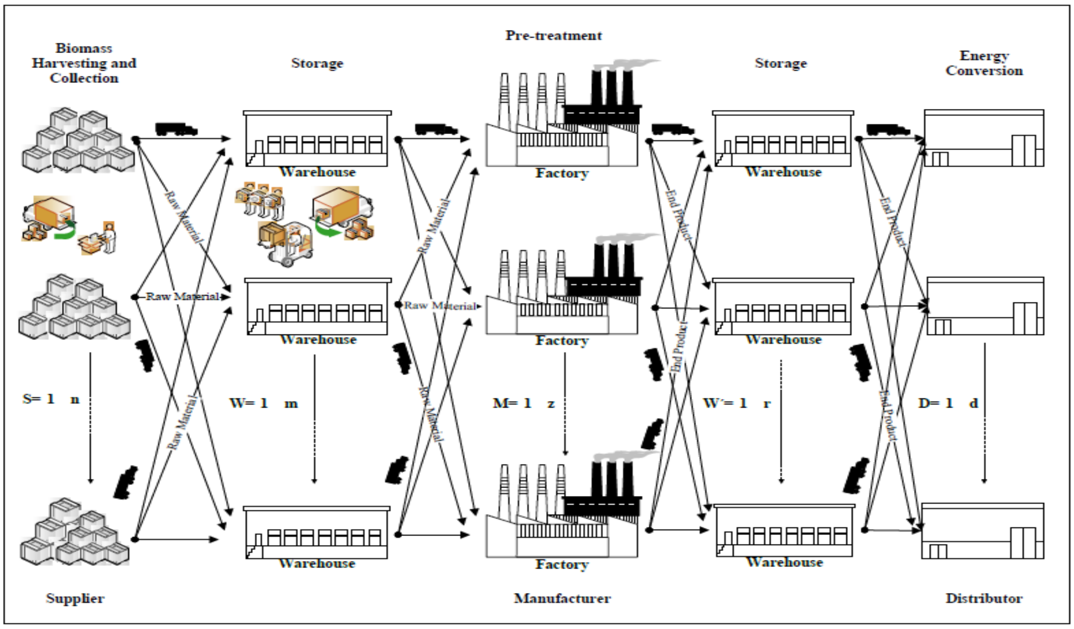


Fig 2: Layout of biomass supply chain network

3.0 Strategies in Biomass supply chain management

Three essential parts may be recognized within biomass network for bio-energy. The upstream process consists from biomass production to conversion through transportation. The midstream process consists of bioenergy conversion process where bioenergy as the output by transformation of agro-residue as the initial input. Finally, downstream segment includes the storage and distribution of the produced bioenergy to customers [18]. In the upstream part, six major procedures are recognized, namely biomass generation, harvesting, collection, pre-treatment, storage and then bioenergy [19,]. In this context, the bioenergy conversion process is considered a 'black box' where biomass is the input and bioenergy along with by-products is the output. These six procedures address the unique characteristics of biomass such as low bulk density, regional fragmentation, high moisture content, seasonal and weather- related unpredictability and low energy content, which distinguish the biomass generation sites or facilities connected by transportation and other mode of infrastructure [18]. The figure illustrates a shows a potential product flows of operational activities of bio-energy. The structure of the biomass supply chain network and the logistics decisions at each stage can be illustrated in Fig.3 .

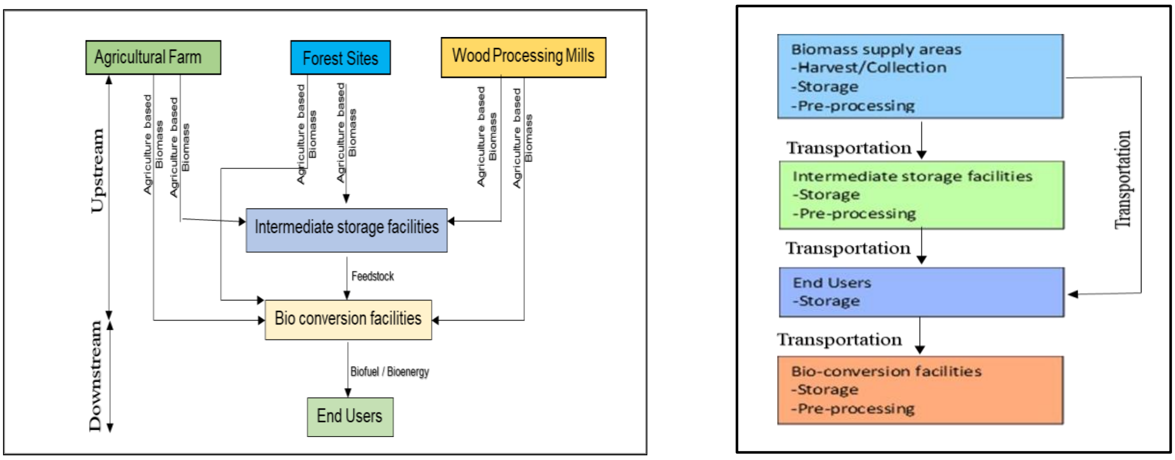


Fig 3: Biomass logistic Activities

3.1 Strategic decision

These decisions are generally taken for long term strategy. When bioenergy is to be developed, these decisions encompass the selection of biomass type, the size and position of preprocessing plants and conversion equipment, the means for transporting, and making a long-term contract for supply. Since there may not be enough historical data available or accessible, the strategic decisions are usually made according to the aggregated information. In majority of the studies, researchers take into consideration a single-time period though, it may be sometimes helpful to take into account multi-period horizons to model the demand fluctuations in long-term, e.g., five periods of three years.

3.2 Tactical decisions

The tactical level of decisions that account for medium-term ones encompass a multi-period planning over a range of few months (for example, finding the quantity of the products generated in each period of time). The tactical decisions are made about the number of means of transportation that are needed to be bought (fleet size), the harvesting rate in each period of time on each piece of land, and the safety stock level.

3.3 Operational decisions

Operational level of decisions is made generally for a short-term period. These decisions involve the detailed operations obtained through decomposing the tactical decisions mentioned earlier. Two important decision components in the biomass supply chain are the details about the route of vehicles and the right time for doing the harvesting activity. To determine whether a decision is tactical or operational, one needs to check if the starting time and/or the exact arrangement of activities have been specified in Table-1.

4.0 Issues and challenges in Biomass supply chain

The uncertainties in biomass logistics are due to the following factors such as biomass supply, weather conditions, biomass properties, biomass cost unless benchmarked or standardized, technology, expansion plans, demand fluctuations, volatile prices, change of regulations, natural disasters etc.

- Seasonal **Supply**: Biomass availability fluctuates with seasons and weather.
- Storage: Requires large space and protection against degradation.
- Transportation: High costs due to low energy density; access to remote sites is limited.
- Pre**-processing**: High equipment costs and lack of standardization for drying, baling, etc.
- Economic **Viability**: Price volatility, high infrastructure costs, and limited incentives.
- Environmental **Impact**: Risk of deforestation and sustainability challenges.
- Logistics: Complex coordination and inefficiencies in planning.
- Technology **Gaps**: Lack of advanced, scalable solutions for processing and monitoring.
- Regulatory **Issues**: Insufficient renewable energy support.
- Quality **Control**: Variability in biomass quality and absence of universal standards

5.0 Developmental of SAMARTH platform and integration of feedstock at other platforms

Initially it is important to develop problems of network and understand and identify suitable stakeholders and the purpose of development of the platform. This was based on refining a concept, after comprehensive understanding of the advanced platform with goal of reducing biomass variability. It is anticipated that the quality of the platform is consistent, standardized and uninterrupted due to handling of authorized body. For this, meetings were held with experts to summarize the concept as in Fig 4.

The first step was defining the layout, followed by determining the content of interface, next step is the logic for grouping information, the resources were reviewed for identifying the developmental process. In all this process the fourth player was actively involved. Also for already identified platforms the transactions of agro-residue were enabled by the fourth player as well as built-in features were incorporated in new platform

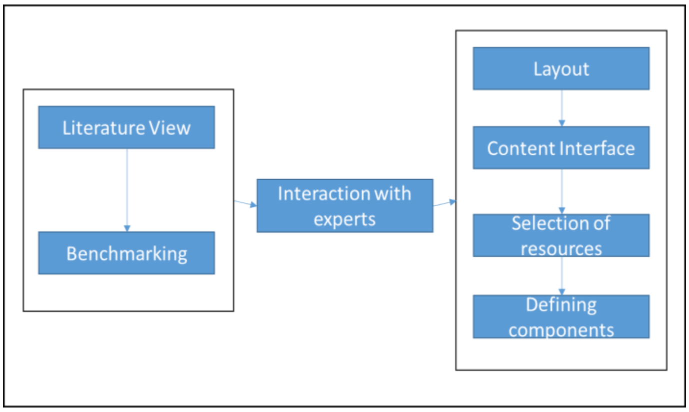


Fig 4: Outline procedure for this study

Table-1 A summary of few investigation in biomass supply chain

Methodology	Objective of the study	Limitations of study	Decision levels			Ref
			Strategic	Tactical	Operational	
Geographic information system	to define a procedure for determining an optimal use of agricultural and forest residue biomass	Environment and social constraints – generating influence areas	√	x	x	[25]
Raster-based model	to determine the satellite storage location	Bioenergy plant limits	√	x	x	[24]
Uniform-Format Solid System	to estimate the cost of herbaceous lignocellulosic BSC for biofuel production	Existing harvesting and collection equipment and incorporation of biomass depots	√	√	x	[27]
Dynamic modeling/Biomass Logistics and Environmental impact Model (BLEM)	to investigate the supply of sugarcane to mills and the supply of green harvesting residues to second-generation ethanol plants under three different strategies	Weather conditions	√	x	x	[28]
Any Logic simulation modeling	to compare demand fulfilment, cost, and emission of a forest BSC for two inventory systems	Duration and cost of transporting harvesters and grinders between cut blocks were ignored	√	√	x	[29]
Spreadsheet	to estimate cost of logistic, delivery and collection	Feedstock options • Conversion processes and outputs	√	x	√	[30]

6.0 The implemented platform model

The primary objective of the proposed platform is to facilitate seamless data exchange among stakeholders in the agro-residue biomass logistics network and to consistently support decision-making processes. The platform is structured across two levels: (1) from raw biomass collection to the processing plant and (2) from the processing plant to electricity generators. This study focuses on the first level, which encompasses the supply chain from agro-residue to pellet formation.

6.1 First Level: Agro-Residue to Pellet Formation

This stage involves three primary participants: the producer (farmers), the transporter, and the receiver (pellet manufacturers). Farmers, often unaware of efficient marketing avenues for their agro-residues, resort to burning the stubble due to the limited time available for sowing subsequent crops and the challenges of complete stubble removal. The inclusion of a fourth participant, an authorized entity, is proposed to bridge gaps among stakeholders, streamline operations, and enhance ease of business.

6.2 Producer Role

Producers interact with platforms such as e-NAM by registering their commodities (Fig. 8). Through this platform, they can access information about raw biomass availability, utilize historical data to guide decisions, and specify the location of agro-residues. Location details can be provided manually, through coordinates, or using location services on the device. Farmers are advised to carefully review e-NAM portal disclaimers regarding logistics and supply chain considerations.

6.3 Transporter Role

The transporter accesses a dedicated interface (Fig. 9) that provides an authorized list of transporters and records of collection and delivery points. This interface ensures efficient material movement from source to destination while allowing transporters to track their logistics operations.

6.4 Manufacturer Role

Manufacturers, as the final users in the first level, manage the collection of biomass either directly or through transporters. Financial transactions are overseen by the manufacturer in both cases, ensuring smooth supply chain operations.

6.5 Implementing/Governing Authority

The governing authority plays a vital role in managing the platform. Their responsibilities include user management (validating new clients and assisting current users) and accessing system-generated and external data to optimize the platform for better decision-making.

Fig 8: Availability of biomass at e-Nam portal

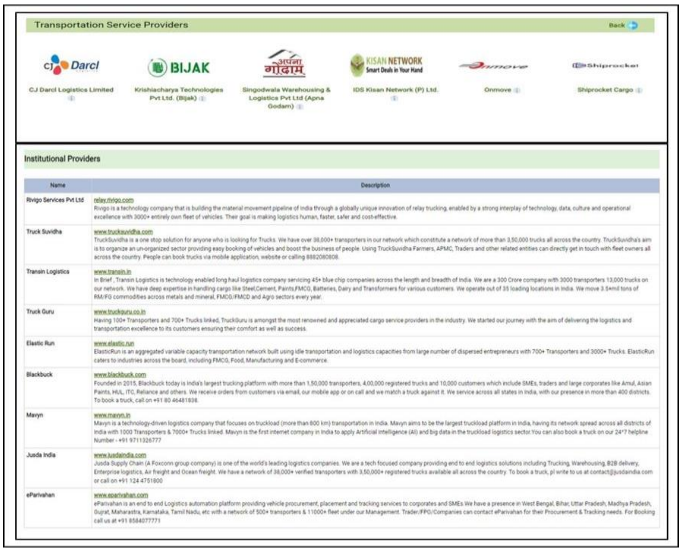


Fig no: 9 Agro-residue and Transporter dashboard

6.6 Second Level: Pellets to Generating Stations

The second level of the supply chain focuses on transporting finished pellets from manufacturers to generating stations for co-firing with coal in boilers. The three key participants in this stage are the producer (pellet manufacturer), the transporter, and the receiver (power generation stations).

6.7 Producer Role

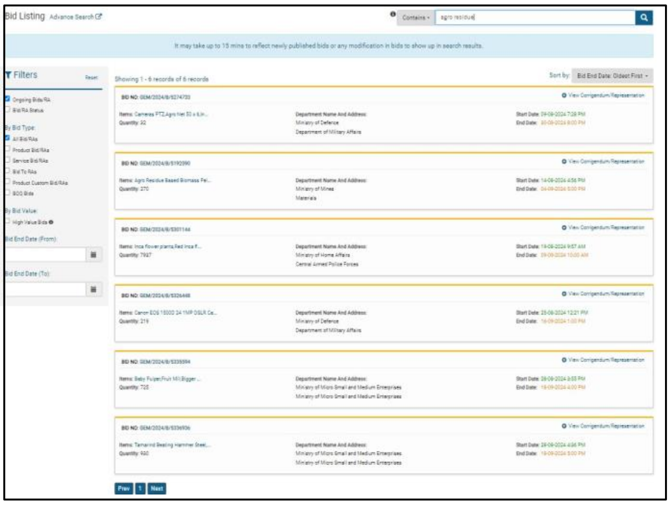
Pellets are manufactured at processing plants from raw biomass and prepared for transportation. Manufacturers oversee the production process and coordinate logistics.

6.8 Transporter Role

Transporters, arranged by the manufacturer, determine optimal routes considering distance, time, and fuel costs. Financial responsibilities for transportation are determined through mutual agreements between the manufacturer and receiver.

6.9 Receiver Role

Power generation stations receive the pellets and conduct quality assessments, such as Gross Calorific Value (GCV), moisture content, and volatile matter, in testing laboratories to ensure compliance with contractual specifications. Upon verification, financial transactions proceed as per procurement agreements. Stations typically issue open bids through authorized portals such as GeM (Fig. 10) to attract vendor participation, selecting the lowest financial bid for contract finalization.



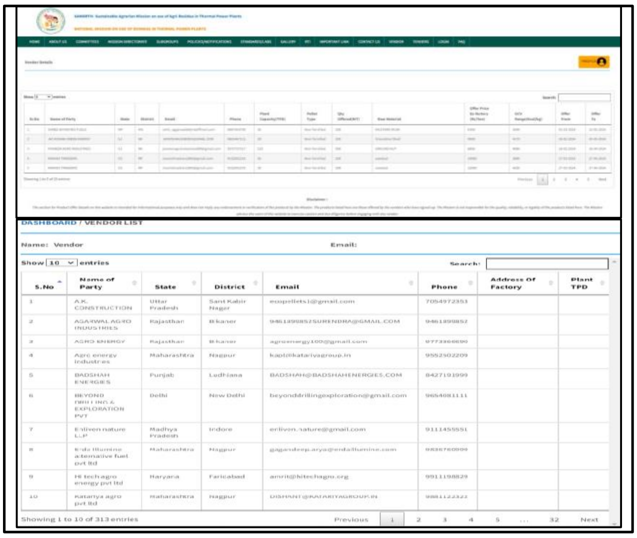


Fig no 10: Procurement bid at GeM platform

Fig no 11: Pellet offers & vendor details at SAMARTH platform

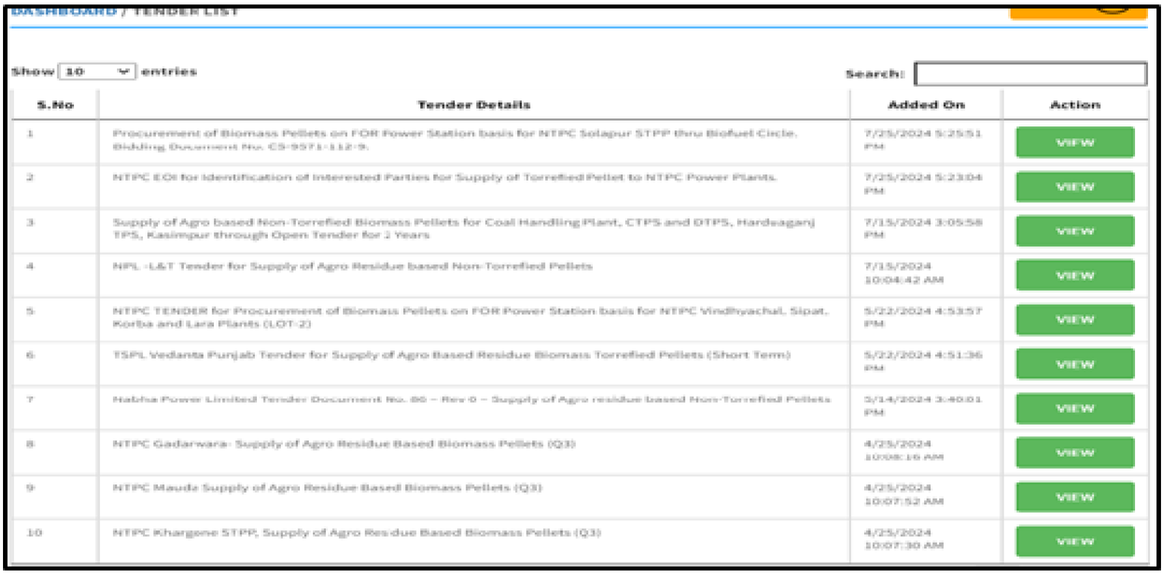
6.10 Vendor Facilitation through SAMARTH Portal

The SAMARTH portal provides an integrated platform for vendors to register their plants and capacities (Fig. 11). Tender listings are updated regularly, allowing vendors to submit competitive bids based on proximity and transportation costs. Power plants select the most economical offers, enhancing cost efficiency.

6.11 Role of Governing Authority in Second Level

The implementing authority, including SAMARTH, plays a crucial role in managing procurement operations. This involves addressing issues such as tender linkage, bid discrepancies, vendor updates, and stakeholder-specific modifications (Fig. 12). The authority also facilitates communication between generating stations and pellet manufacturers to resolve technical queries and improve operational clarity.

By ensuring effective integration across both levels of the supply chain, the platform enhances transparency, efficiency, and sustainability in biomass logistics, paving the way for broader adoption and practical implementation of renewable energy solutions.



DASHBOARD / TENDER LIST

Show 10 entries Search:

S.No	Tender Details	Added On	Action
1	Procurement of Biomass Pellets on FOR Power Station basis for NTPC Solapur STPP thru Biofuel Circle. Bidding Document No. CS-9571-112-9.	7/25/2024 5:25:51 PM	VIEW
2	NTPC EOI for Identification of Interested Parties for Supply of Torrefied Pellet to NTPC Power Plants.	7/25/2024 5:23:04 PM	VIEW
3	Supply of Agro based Non-Torrefied Biomass Pellets for Coal Handling Plant, CTPS and DTPS, Hardeaganj TPS, Kasimpur through Open Tender for 2 Years	7/15/2024 3:05:58 PM	VIEW
4	NPL -L&T Tender for Supply of Agro Residue based Non-Torrefied Pellets	7/15/2024 10:04:42 AM	VIEW
5	NTPC TENDER for Procurement of Biomass Pellets on FOR Power Station basis for NTPC Vindhyachal, Sipat, Korba and Lara Plants (LOT-2)	5/22/2024 4:53:57 PM	VIEW
6	TSPL Vedanta Punjab Tender for Supply of Agro Based Residue Biomass Torrefied Pellets (Short Term)	5/22/2024 4:51:36 PM	VIEW
7	Nabha Power Limited Tender Document No. 80 – Rev 0 – Supply of Agro residue based Non-Torrefied Pellets	5/14/2024 3:40:01 PM	VIEW
8	NTPC Gadarwara- Supply of Agro Residue Based Biomass Pellets (Q3)	4/25/2024 10:08:16 AM	VIEW
9	NTPC Mauda Supply of Agro Residue Based Biomass Pellets (Q3)	4/25/2024 10:07:52 AM	VIEW
10	NTPC Khargone STPP, Supply of Agro Residue Based Biomass Pellets (Q3)	4/25/2024 10:07:30 AM	VIEW

Fig no 12 : Vendor tender links at SAMARTH platform

7.0 Discussion

Literature analysis highlights challenges in managing residual biomass chains, often hindering their utilization. A key factor is the organizational cost of biomass. Logistics optimization can be achieved through technologies, improved transportation methods, optimal location of generating stations, efficient material collection, and process adjustments [9,16]. However, existing studies often overlook critical aspects. The proposed concept addresses these gaps by involving three key players across the supply chain, optimizing transporter routes, and encouraging governing authorities' participation [14,15]. Financial costs and environmental considerations are key factors in supply chain optimization models.

The outlined platform is strategically designed to digitally optimize its logistics network, facilitating efficient material distribution. This digital transformation enables cost-effective procurement for receivers, provides transporters with data-driven advantages, and allows stakeholders with undervalued agro-residue waste to derive economic benefits. From an environmental perspective, the platform offers two primary advantages: (1) mitigating carbon dioxide emissions associated with stubble burning and (2) improving the allocation efficiency of biomass pellets to end-users .Additionally, the integration of a fourth stakeholder fosters collaboration across all interface levels, ensuring the economic and environmentally sustainable utilization of biomass pellets. This effort aligns with the overarching goals of advancing green transition strategies and reducing atmospheric carbon footprints.

Under the Government of India's **SAMARTH Mission** initiative, the adoption of this digital platform has driven a significant increase in biomass pellet utilization between the fiscal years 2021–2022 and 2024–2025. This is reflected in the rapid growth of biomass consumption during this period, as illustrated in Fig.

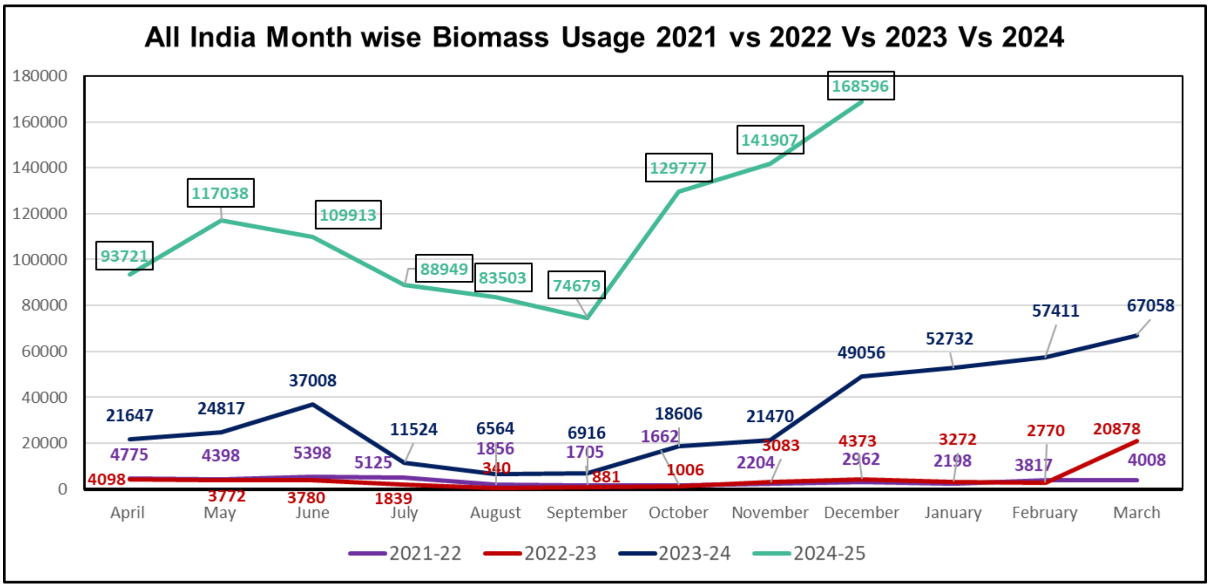


Fig : Utilization of Biomass Pellets

8.0 Conclusion

This study addresses a critical gap identified in previous research by proposing and analyzing an interactive interface platform for the efficient management of biomass transactions and logistics. The platform establishes a dedicated communication channel to disseminate essential information that facilitates informed decision-making in the procurement, transportation, and handling of raw biomass and biomass pellets. Theoretically, the research advances a conceptual framework for the interface platform, delineating stakeholder roles and interactions tailored to their specific demands. Practically, the platform seeks to enhance coordination and communication across the diverse participants in the agro-residue biomass logistics network.

The inclusion of a fourth stakeholder at each interaction level offers a novel perspective, exploring models that, despite being conceptually sound, remain underrepresented in the literature. The study critically examines key logistics operations, including biomass collection, harvesting, transportation, storage, and pre-processing. To address operational inefficiencies, the implementation of advanced inventory management systems is proposed, enabling real-time tracking of biomass quantity, quality, and location. Furthermore, the use of mobile storage units is recommended to provide flexibility, reduce material waste, and optimize inventory management processes.The. Effective collaboration among stakeholders is emphasized as a prerequisite for aligning objectives and enhancing overall efficiency.

Future work could expand the proposed framework by fostering awareness and engagement at the state and district levels through localized interface platforms. Additionally, integration of supply chain management would enable, offering real-time visibility and control across the entire biomass supply chain, from source to end-user delivery. Conducting validation tests with industry stakeholders would provide empirical feedback for refining the platform. The development of dedicated storage facilities or warehouses for seasoned biomass materials is identified as another key area for enhancing supply chain robustness and sustainability. By addressing these aspects, the research contributes to the development of a more resilient, efficient, and environmentally sustainable biomass logistics system to attain pathway to efficient energy transition.

REFERENCES

(1) Zahraee, S.M., Golroudbary, S.R., Shiwakoti, N., Stasinopoulos, P., Kraslawski, A., 2021.Economic and environmental assessment of biomass supply chain for design of transportation modes: strategic and tactical decisions point of view. Procedia CIRP 100, 780–785.

(2) Zahraee, S.M., Shiwakoti, N., Stasinopoulos, P., 2021. Simulation scenario analysis of operational day to day storage system of biomass supply chain for a power plant case study based on logistic cost and transportation emissions. In: 2021

(3) R.B. Hiremath, B. Kumar, P. Ramachandra N.H. Rabindranath, Bottom-up approach for decentralized energy planning: case study of Tumkur district in India, Energy Policy 38 (2010) 862–874,

(4) S.D. Das, R. Srikanth, Viability of power distribution in India –challenges and way forward, Energy Policy 147 (2020) 111882, Saubhagya Dashboard, (n.d.). https://saubhagya.gov.in/(accessed January 31, 2021).

(5) Daoutidis, P., Marvin, W. A., Rangarajan, S., & Torres, A. I. (2013). Engineering biomass conversion processes: A systems perspective. AIChE Journal, 59, 3–18.

(6) Balachndra, P., 2011. Modern energy access to all in rural India: an integrated implementation strategy. Energy Policy 39 (12), 7803e7814.

(7) De Meyer, A., Cattrysse, D., Snoeck, M., Van Orshoven, J., 2015. Generic data model to represent the biomass-to-bioenergy supply chain logistics. Int. Conf. Agric. Eng., C0156, 2012.

(8) Rentizelas, A. A., Tolis, A. J., & Tatsiopoulos, I. P. (2009). Logistics issues of biomass: The storage problem and the multi- biomass supply chain. Renewable & Sustain- able Energy Reviews, 13, 887–894.

(9) J.C. Pulido-Ocegueda, J.E. Santiba˜nez- Aguilar, J.M. Ponce-Ortega, Strategic Planning of Biorefineries for the Use of Residual Biomass for the Benefit of Regions with Low Human Development Index, Waste Biomass Valorization (2023) 1–17.

(10) Cundiff, J. S., Dias, N., & Sherali, H. D. (1997). A linear programming approach fordesigning a herbaceous biomass delivery system. Bioresource Technology, 59,47–55.

(11) DOE/EERE. (2013a). Advanced uniform- format feedstock supply system. U.S. Depart- ment of Energy, Office of Energy Efficiency & Renewable Energy.

(12) L. Rivera-Cadavid, P.C. Manyoma- Velasquez, D.F. Manotas-Duque, Supply chain optimization for energy cogeneration using sugarcane crop residues (SCR), Sustain. Times 11 (23) (2019).

(13) M.D. Berry, J. Sessions, The economics of biomass logistics and conversion facility mobility: an Oregon case study, Appl. Eng. Agric. 34 (1) (2018).

(14) Y. Li, P. Tittmann, N. Parker, B. Jenkins, Economic impact of combined torrefaction and pelletization processes on forestry biomass supply, GCB Bioenergy 9 (4) (2017).

(15) L. Moretti, M. Milani, G.G. Lozza, G. Manzolini, A detailed MILP formulation for the optimal design of advanced biofuel supply chains, Renew. Energy 171 (2021)159–175.

(16) H. Paulo, X. Azcue, A.P. Barbosa- P´ovoa, S. Relvas, Supply chain optimization of residual forestry biomass for bioenergy production: The case study of Portugal, Biomass Bioenergy 83 (2015)245–256

(17) Ferrarini A, Serra P, Almagro M, Trevisan M , Amaducci S. Multiple ecosystem services provision and biomass logistics management in bioenergy buffers: A state-of-the-art review, Renew Sustain Energy Rev 2017:73:277-90.

(18) De Meyer A, Gattrysse D, Rasinmaki J, Van Orshoven J., Methods to optimize the design and management of biomass-for- bioenergy supply chain: A review Renew Sustain Energy Rev 2014;31:657-70.

(19) Rentizelas AA, Tolis AJ, Tatsiopoulos IP. Logistics issues of biomass. The storage problem and the multi-biomass supply chain. Renwe Sustain Energy Rev 2009; 13:887-94.

(20) Malladi KT, Sowlati T, Biomass logistics. A review of important features optimization modeling and the new trends. Renew Sustain Energy Rev 2018; 94:587-99.

(21) VgBetter M, Glover F. Simulation optimization: applications in risk management. The International Journal of Information Technology and Decision Making 2008; 7(4): 571-87.

(22) Chen C-W, Fan Y. Bioethanol supply chain system planning under supply and demand uncertainties. Transportation Research Part E 2011;48(1):150-64

(23) S.M. Zahraee, S.R. Golroudbary, N. Shiwakoti, A. Kraslawski, P. Stasinopoulos, An investigation of the environmental sustainability of palm biomass supply chains via dynamic simulation modeling: a case of Malaysia, J. Clean. Prod. 237 (2019) 117740.

(24) J. Resop, J. Cundiff, C. Heatwole, Spatial analysis to satellite storage locations for herbaceous biomass in the piedmont of the Southeast, Appl. Eng. Agric. 27 (1) (2011) 25–32.

(25) C. Perpina, D. Alfonso, A. P´erez-Navarro, E. Pe˜nalvo, C. Vargas, R. C´ardenas, Methodology based on Geographic Information Systems for biomass logistics and transport optimisation.

(26) J. Hess, K. Kenney, L. Ovard, E. Searcy, C. Wright, Uniform-Format Bioenergy Feedstock Supply System Design Report: Commodity-Scale Production of an Infrastructure-Compatible Bulk Solid from Herbaceous Lignocellulosic Biomass, Idaho National Laboratory, Idaho Falls, ID, 2009. Technical Report No. INL/EXT- 08-14752.

(27) F. Zhang, D.M. Johnson, M.A. Johnson, Development of a simulation model of biomass supply chain for biofuel production, Renew. Energy.
(28) J.A. Lozano-Moreno, F. Mar´echal, Biomass logistics and environmental impact modelling for sugar-ethanol production, J. Clean. Prod. 210 (2019).
(29) S. Akhtari, T. Sowlati, D.G. Siller-Benitez, D. Roeser, Impact of inventory management on demand fulfilment, cost and emission of forest-based biomass supply chains using simulation modelling.
(30) C. Mitchell, Development of decision support systems for bioenergy applications, Biomass Bioenergy.

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