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Optimal use of Renewable Bio-resources & Technologies towards De-carbonization in Indian Pulp & Paper Industry; A Case Analysis

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Abstract: *The Indian pulp and paper industry is at a critical inflection point, driven by rising energy costs, increasing customer expectations, and tightening regulatory requirements under mechanisms such as the Carbon Credit Trading Scheme (CCTS), Renewable Consumption Obligation (RCO), and the forthcoming European Union Carbon Border Adjustment Mechanism (CBAM). This paper presents an integrated analysis of industrial-scale decarbonization initiatives implemented across ITC Limited's Paperboards & Specialty Papers Division (PSPD), focusing on the strategic deployment of renewable bioresources for both energy and raw materials.*

Through multiple case studies encompassing biomass integration, boiler retrofitting, deployment of high-pressure recovery boiler technology, and adoption of advanced digital technologies, the study demonstrates how renewable bioresources can deliver approximately 30% reduction in Scope 1 and Scope 2 greenhouse gas emissions and improve renewable energy share by more than 10 percentage points from base line year of 2019 at ITC PSPD. The paper further highlights the importance of biomass availability assessments, combustion optimisation through digital tools, and structured supply-chain partnerships in ensuring fuel security and operational reliability. The findings provide a replicable and scalable roadmap for the Indian pulp and paper industry to transition toward a low-carbon, resource-efficient operating model while remaining competitive under emerging carbon-regulatory regimes.

Keywords: *De-carbonization as strategy Technologies for decarbonization, Evaluation of biofuels, Net Zero & Carbon neutralityDigital technologies*

Introduction:

The pulp and paper industry is among the most energy-intensive manufacturing sectors globally, ranking fourth after the chemical, steel, and cement industries. The sector accounts for approximately five percent of global industrial final energy consumption and around two percent of direct industrial carbon dioxide emissions1. In India, the industry emitted an estimated 30.5 million tonnes of CO_2 in 2019, representing about 1.1 percent of national greenhouse-gas emissions2.

Despite its energy-intensive nature, the pulp and paper industry is uniquely positioned to contribute to sustainability through renewable raw materials, circular material flows, and bio-based energy systems. Sustainable farm and social forestry initiatives enable carbon sequestration while supporting rural livelihoods, whereas large-scale recycling of waste paper reduces landfill disposal and energy consumption. These inherent strengths provide a strong foundation for accelerated decarbonization.

Against the backdrop of rising fossil-fuel prices, supply volatility, and evolving climate regulations, renewable bioresources—including agro-residues, plantation wood, process by-products, and recovered fibres—have emerged as critical enablers of sustainable growth. While historically associated primarily with fibre substitution, renewable bioresources are increasingly central to energy decarbonization through biomass-based steam and power generation. This paper examines both dimensions, with emphasis on industrial implementation, technology enablers, and operational learning.

2. Renewable Bioresources in the Pulp & Paper Industry – Scope and Potential

Renewable bioresources in the pulp and paper industry broadly encompass renewable raw materials and renewable energy carriers. On the raw-material front, the industry has progressively diversified its fibre basket to include plantation-grown wood, agro-based fibres such as bagasse and straw, and recovered paper. This diversification reduces pressure on natural forests, improves fibre security, and lowers the embedded carbon footprint of paper and board products.

From an energy perspective, biomass fuels derived from agro-residues, forestry residues, bark, black liquor solids, and biogas provide dispatchable renewable energy with lower lifecycle emissions than fossil fuels. When integrated effectively into mill energy systems, these resources enhance energy security and create rural value chains. However, large-scale adoption requires systematic biomass assessments, appropriate boiler technologies, and robust operational controls.

3. Biomass Availability Assessment and Survey Methodology

A structured biomass availability assessment forms the foundation of sustainable biomass integration. Across the analysed case studies, surveys were conducted within 50-kilometre and 200-kilometre radii around mill locations to map crop patterns, residue generation rates, seasonal availability, and logistics feasibility. Fuel characteristics such as moisture content, ash percentage, calorific value, and slagging behaviour were evaluated alongside landed cost estimates. The results of the study conducted at ITC Bhadrachalam plant are shown in Figs 1 and 2.

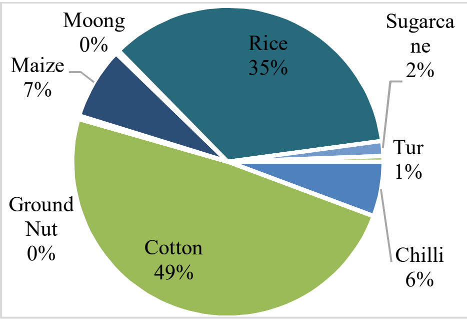


Fig. 1: Biomass availability crop wise

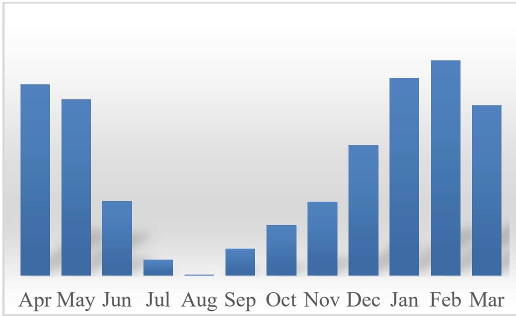


Fig. 2: Seasonal variation in biomass availability

The assessments at ITC Bhadrachalam plant identified significant availability of agro-residues including rice straw, rice husk, cotton stalk, maize stalk, chilli stalk, wood chips, bark, and plantation residues, with aggregate availability exceeding 5,500 tonnes per day in certain regions. These findings confirmed the technical feasibility of replacing up to 40–50 percent of coal consumption in large industrial boilers, subject to appropriate technology and operational controls.

At the Kovai plant, ITC has partnered with Mettupalayam Agroforestry Business Incubation Forum (MABIF) of Tamil Nadu Agricultural University (TNAU), to identify and develop a reliable vendor base for the supply of Biofuels. This collaboration has also enabled the creation of sustainable livelihoods and business opportunities to the local vendors.

In addition, ITC engaged M/S Howast global to undertake a comprehensive assessment of biofuel availability within a 50-200 km radius of the plant. Through this study, M/S ITC identified more than 68 potential vendors supplying 14 different types of biofuels. Of these, 3 biofuel types were found to have year-round availability. The study identified biomass sources such as turmeric spent, Matchstick waste, veneer waste, palm nut shells and apricot shells as viable biofuel options (Fig. 3).

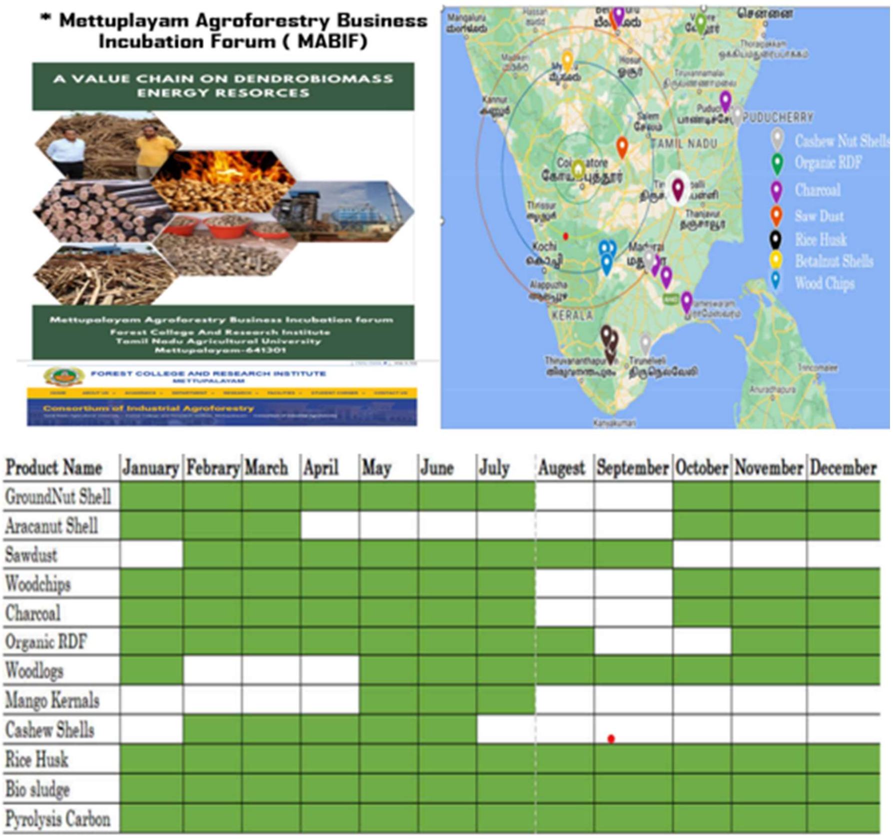


Fig. 3: Biomass availability assessment at ITC Kovai

Evaluation criteria of Biofuel

To ensure the efficient and reliable use of biofuels in boilers and to mitigate the risk of chemical corrosion, comprehensive fuel characterization is undertaken in addition to routine proximate analysis. Complete ash elemental analysis is conducted for every new biofuel through NABL -accredited laboratories. Key parameters such as alkalinity and chlorine content are evaluated to assess the slagging and fouling potential of the fuels.

Seasonal impact of biofuel on quality & Supply chain

The biofuels exhibit seasonal variability in quality due to changes at the point of origin and generation. Fig. 4 illustrates the variation in GCV of same biofuel over a 12 months period.

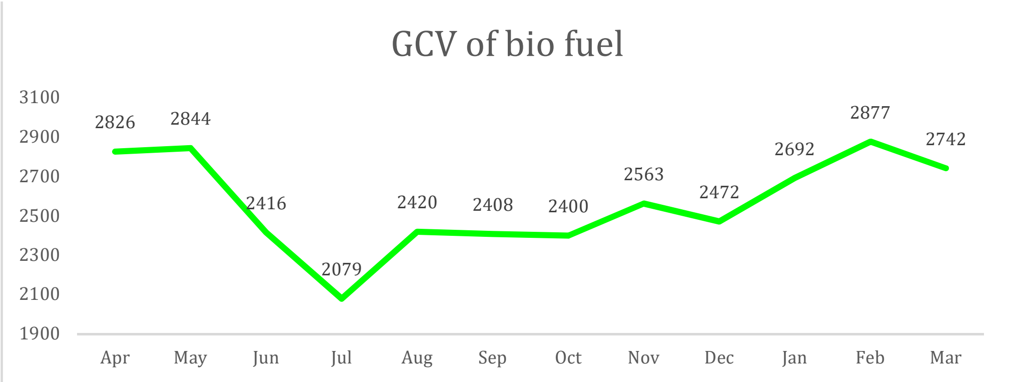
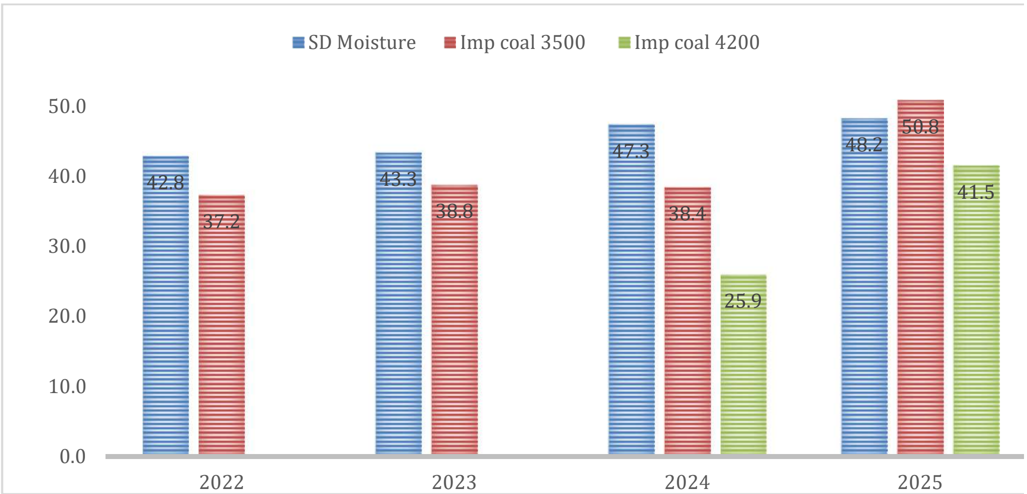


Fig 4: GCV variation over a 12 months period for a particular biofuel

Further, Climate change and increasing instances of unseasonal and intense rainfall across the region have had a sustained impact on fuel quality over recent years. The subsequent chart (Fig. 5) presents the trends in moisture content variations observed over the last 3 years.



SD-saw dust

Fig. 5: Moisture variation overall last 3 years

Key challenges associated with higher biomass utilization

- Elevated boiler exit flue gas temperature
- Localized high temperature combustion in the superheater zone, leading to premature failure of secondary superheater coils (predominantly affecting the first tube row)
- Non-uniform heat absorption across the cross-section of primary and secondary superheater coils due to slagging and ash deposition
- Increased frequency of soot blowing required to maintain flue gas path cleanliness
- Slag deposition over the heat transfer areas of furnace surfaces, resulting in reduced heat transfer efficiency and overall boiler performance.

4. Boiler Technology and Biomass Co-Firing

To enable high levels of biomass utilization, existing conventional lignite fired AFBC boilers were retrofitted through targeted engineering interventions. These included conversion from single-row to double-row bed coils to enhance heat-transfer surface area, augmentation of secondary superheater sections to manage lower furnace temperatures, and installation of over-fire air systems to enhance the secondary combustion stabilize combustion. Over-bed fuel-feeding systems were introduced to handle medium-sized biomass fuels. Also, additional soot blowers were installed to remove the soot deposits over the heat transfer areas.

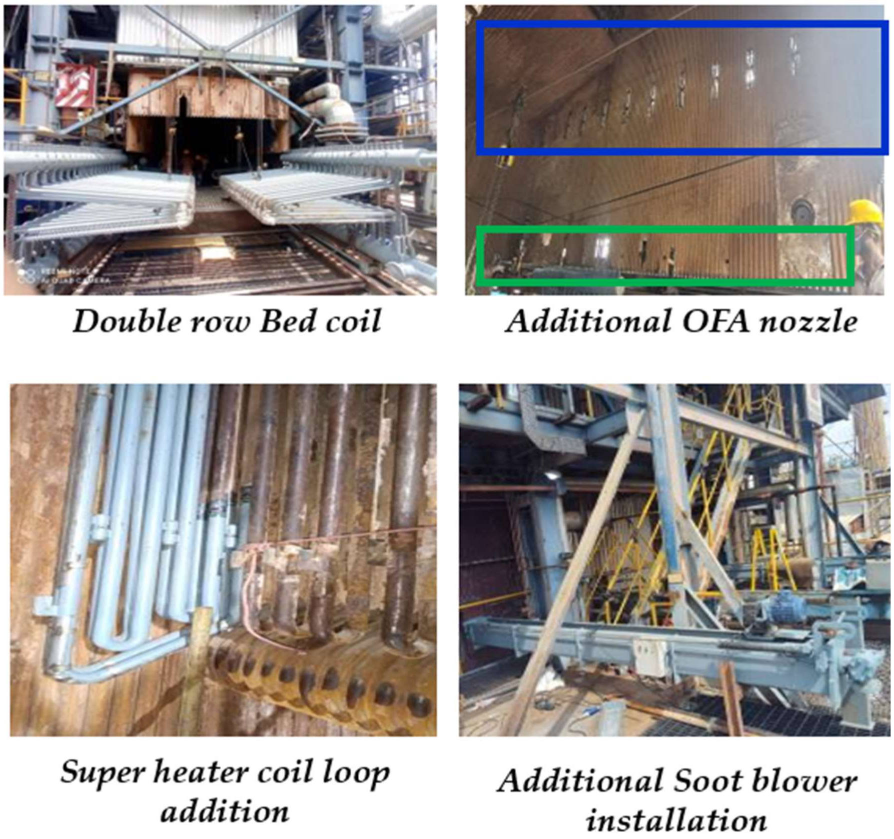


Fig. 6: Boiler upgrade to increase biomass cofiring

Collectively, these upgrades enabled stable co-firing of biomass at levels of up to 40–50 percent without compromising steam parameters, availability, or reliability. In parallel, dedicated biomass boiler technologies such as bubbling fluidised bed systems and build-own-operate models were evaluated for sites with high and stable biomass availability.

5. Digital Initiatives for Enhanced Biomass Utilisation

Process instability arising from biomass fuel variability represents a key barrier to higher biomass penetration. To address this challenge, advanced digital tools were deployed, including SCADA-based monitoring, advanced process control using multi-input multi-output models, and data-analytics-driven optimization (Fig. 7).

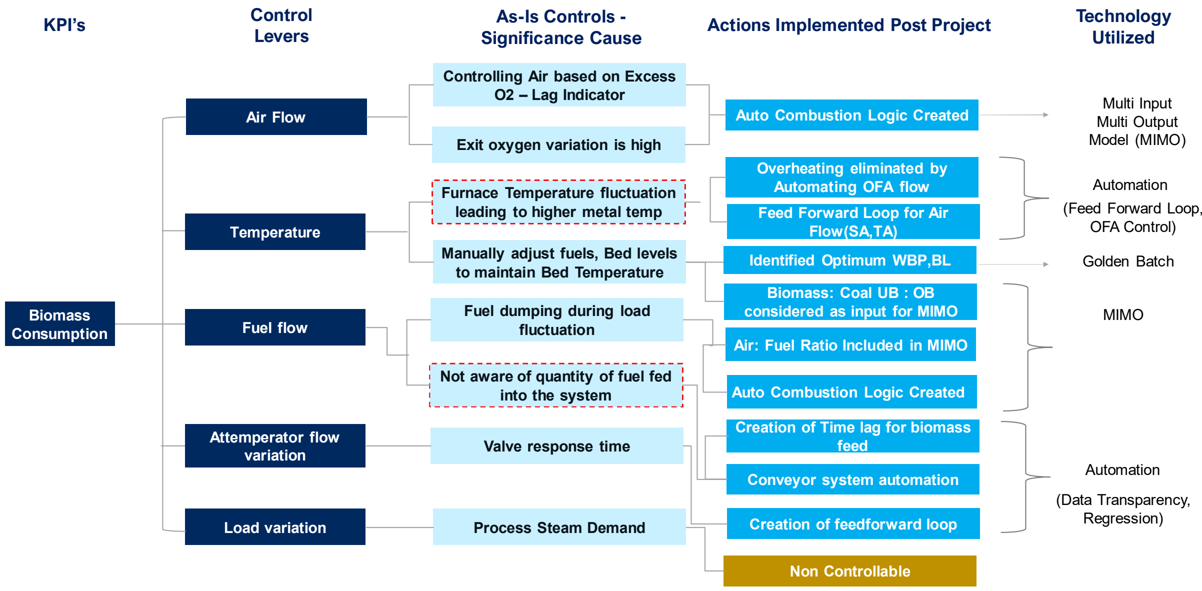


Fig. 7: Multi-input & multi-model for optimization of boiler performance to enhance biomass cofiring

Feed-forward control loops for air-fuel ratio, over-fire air, and attemperation enabled proactive adjustment to fuel variability, while identification of optimal operating envelopes through data analytics reduced furnace disturbances. These measures resulted in substantial increases in biomass firing, improved combustion stability, and measurable reductions in fuel costs and emissions.

6. High-Pressure Recovery Boiler Technology

In integrated pulp mills, high-pressure recovery boilers play a pivotal role in renewable energy generation by recovering energy from black liquor solids and producing high-pressure steam for power generation. Upgrading recovery boilers to higher pressure and temperature levels improves overall energy efficiency, increases renewable power generation, and further reduces dependence on auxiliary fossil fuels. The deployment of high-pressure recovery boiler technology therefore complements biomass-based energy systems and strengthens the overall renewable energy portfolio of integrated mills.

India's first high-pressure recovery boiler (HPRB) project is designed to significantly boost renewable energy generation, improve resource efficiency, reduce waste generation, increase power generation per ton of high-pressure (HP) steam and reduce greenhouse gas (GHG) emissions. The proposal involves replacing all three conventional soda recovery boilers (SRBs) with HPRB designed to generate HP steam at 110 kg/cm2 & 505 °C (Fig. 8). Further, this strategic project will allow additional in-house blown pulp production by 270 TPD resulting scope-3 emission reductions on account of import substitution.

Comparison HPRB Vs Conventional SRBs

		UOM	Conventional SRBs	HPRB
1	Boiler Capacity – black liquor solids firing capacity	tds/day	1975	2700
2	Steam Generation	tph	270	404
3	Steam per Ton of Black liquor solids	t/t	3.1	3.6
4	Flues gas out let Temp	°C	160	135
5	Steam temperature	°C	460	505
5	Steam Pressure	Kg/Cm2	62	110

Fig. 8: India's 1st high pressure recovery boiler installed at ITC Bhadrachalam

The investment involves installation of state-of-the-art recovery boiler with the capacity to fire 2700 tons of black liquor solids per day, 65 MW steam turbine and a 390 TPH evaporator. In HPRB, heat recovery from flue gas is further increased through vent gas scrubber, economizers & flue gas coolers. The additional heat recovered is used to raise the temperature of combustion air and feed water which are not available with conventional SRBs

Key benefits

- Steam generation in HPRB would be 3.6 ton per ton (T/T) of Black Liquor Solids fired compared to 3.1 T/T in conventional SRBs.
- Heat value of HPRB steam is 813 kcal/kg compared to 797 kcal/kg in steam from conventional SRBs results in higher power generation in steam turbine
- Renewable energy share improvement by 7.6%
- Reduction in coal consumption by 1.6 lac TPA
- Reduction in scope-3 emissions due to import substitution of bleached hardwood pulp by ~ 83,000 TPA

7. Emerging pathways: Advancing Renewable Bioresources through Emerging Fuel Pathways

The pulp and paper industry is uniquely positioned to extend the utilization of renewable bioresources beyond conventional on-site energy generation and fibre production, thereby playing a broader role in the global energy transition. As decarbonization pathways for hard-to-abate sectors gain momentum, emerging biofuel and e-fuel technologies offer strategic opportunities for biomass-rich industrial ecosystems.

Pulp and paper mills generate large, continuous streams of renewable biomass residues and biogenic carbon dioxide. These resources should be recognized not merely as internal energy inputs, but as platform feedstocks capable of supporting the production of advanced low-carbon fuels. Strategic planning frameworks should therefore evaluate biomass availability and quality with a view toward external fuel value chains, in addition to internal energy optimization.

Sectors such as aviation and maritime transport face structural limitations in electrification and are increasingly dependent on sustainable fuels, including Sustainable Aviation Fuel (SAF) and bio- or green methanol. Theoretical integration of pulp and paper mills within SAF and methanol production ecosystems can improve regional fuel security while enabling efficient utilization of agro-residues, forestry residues, and process by-products. Co-location or industrial clustering should be prioritized to minimize logistics costs and enhance overall system efficiency.

Integrated pulp mills equipped with high-pressure recovery boilers represent concentrated and reliable sources of biogenic CO_2. From a systems perspective, capturing and utilizing this CO_2 for green methanol synthesis—when combined with renewable electricity and green hydrogen—offers a pathway to convert unavoidable process emissions into value-added products. Such utilization aligns with circular-carbon principles and significantly improves lifecycle emission performance.

Emerging regulatory mechanisms, including India's Carbon Credit Trading Scheme (CCTS) and the European Union's Carbon Border Adjustment Mechanism (CBAM), are progressively internalising the cost of carbon. Theoretical adoption of advanced biofuel pathways allows pulp and paper producers to proactively reduce embedded emissions, generate tradable carbon credits, and enhance competitiveness in export markets. Technology selection should therefore be guided not only by technical feasibility but also by long-term regulatory resilience.

Given current cost and maturity levels, SAF and green methanol technologies should be approached through phased deployment—beginning with feasibility studies, pilot-scale integration, and strategic partnerships. Modular design philosophies allow mills to scale capacity in line with biomass availability, renewable power expansion, and market demand, while managing technical and financial risks.

Collectively, these emerging pathways suggest a fundamental shift in the role of the pulp and paper industry—from a traditional energy-intensive manufacturing sector to an active participant in renewable fuel and carbon value chains. Theoretical integration of biomass, digital optimisation, recovery boiler systems, and advanced fuel synthesis technologies can transform pulp and paper mills into renewable energy and carbon hubs, contributing meaningfully to national and global decarbonization objectives.

8. Results and Impact

Across the analysed case studies, biomass consumption increased significantly, nearly doubling over a five-year period in certain mills. Renewable energy share increased from approximately 18 percent to over 30 percent, while specific carbon emissions declined by around 30 percent on a per-tonne-of-product basis. In addition to environmental benefits, the initiatives delivered improved fuel-cost stability, reduced exposure to coal price volatility, and enhanced compliance readiness for emerging carbon regulations.

Social co-benefits included creation of rural employment opportunities through biomass sourcing and strengthened engagement with farmer and aggregator communities.

9. Regulatory Drivers: CCTS and CBAM

India's Carbon Credit Trading Scheme3 mandates progressive reductions in emission intensity across energy-intensive sectors, including pulp and paper. Renewable bioresources directly support compliance by reducing fossil-fuel combustion emissions and improving emission-intensity metrics. Early adoption positions mills favourably under future tightening of regulatory thresholds.

The European Union's Carbon Border Adjustment Mechanism introduces carbon costs on imported products based on embedded emissions, creating direct implications for export-oriented paper and packaging producers. Biomass-based energy and renewable fibre sourcing significantly reduce product-level carbon intensity and mitigate CBAM exposure, thereby enhancing competitiveness in low-carbon markets.

10. Conclusions and Way Forward

The case studies presented in this paper demonstrate that renewable bioresources can be effectively integrated for both energy generation and emission reduction in the pulp and paper industry at industrial scale. It is recommended to explore the following series of initiatives to maximize the biofuels impact in decarbonization journey

1. Comprehensive biofuel availability assessments
2. Targeted boiler upgrades and retrofits in collaboration with boiler suppliers
3. Deployment of digital process optimization tools to enable biofuel firing
4. High-pressure recovery boiler technology
5. Evaluating and implementing emerging technologies based on feasibility

As regulatory mechanisms such as CCTS and CBAM gain momentum, renewable bioresources will increasingly shift from optional sustainability initiatives to core business enablers. The approaches outlined in this paper provide a replicable and scalable roadmap for pulp and paper mills seeking long-term competitiveness in a low-carbon economy.

11. References

1. https://www.globalefficiencyintel.com/pulp-and-paper-industry
2. https://ippta.co/wp-content/uploads/2023/03/62-65.pdf
3. https://beeindia.gov.in/carbon-market.php
4. ITC Internal data base