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Thailand's Biomass Supply Chain: Redesigning for Efficiency and Environmental Impact

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Abstract

This study contributes to the design of a biomass manufacturing network in Central Thailand, focusing on establishing an efficient biomass supply chain. The objective is to propose an optimal supply chain framework using Integration Definition for Function Modeling (IDEF0) and the Supply Chain Operations Reference (SCOR) model. Current challenges include disjointed supply chain activities, high transportation costs, inadequate centralized agricultural residue collection, lower thermal energy yield of biomass compared to fossil fuels, and significant storage space requirements. The proposed model introduces community-based biomass collection centers to minimize transport distances from agricultural sites to production facilities, while ensuring compliance with government regulations. These centers facilitate efficient residue collection and storage, with subsequent processing into biofuel and carbon credits to meet market demands driven by carbon targets and trading opportunities. Additionally, the framework designs five core activities—plan, source, make, deliver, and returns—critical to biomass factory operations. Solutions include a First-In-First-Out (FIFO) storage system, strategic biomass supply planning, location optimization via mathematical modeling, and biomass densification technologies to reduce transport costs. The torrefaction process is highlighted for efficiency gains, supporting sustainable fuel production through a streamlined, integrated supply chain tailored for Thailand.

Keywords
Business Process Analysis, Biomass Fuel, IDEF0, SCOR Model, Supply Chain Management.

1. Introduction
Globally, the energy sector is undergoing a significant transition as countries strive to reduce dependence on fossil fuels, which are the primary sources of carbon dioxide emissions that drive climate change and contribute to global warming. Fossil fuels, including coal, oil, and natural gas, are responsible for over 75% of greenhouse gas emissions worldwide, significantly impacting the Earth's atmosphere and accelerating climate risks such as extreme weather and rising sea levels (International Energy Agency 2023). In response, many countries are implementing policies to increase the adoption of renewable energy sources like solar, wind, and biomass, which have far lower carbon emissions and are more sustainable in the long term.

Thailand, with its strong agricultural base, generates considerable agricultural residues that can be repurposed as renewable fuels, reducing reliance on fossil fuels. In line with the Renewable Energy and Alternative Energy Development Plan 2018–2037 (AEDP 2018), Thailand aims to raise renewable energy's share to 30% of total consumption by 2037 (Ministry of Energy 2020), with biomass playing a crucial role. However, biomass adoption faces hurdles: high moisture content leads to lower energy yields, necessitating larger quantities than fossil fuels, while low energy density results in high transportation costs and storage challenges, as biomass decomposes over time. The EU's Carbon Border Adjustment Mechanism (CBAM), which imposes tariffs on imports based on carbon intensity, further motivates Thai industries to adopt sustainable practices to maintain competitiveness in EU markets. To align with CBAM standards, Thailand's biomass sector can assess carbon emissions across the supply chain, invest in cleaner technologies, engage in carbon markets, and enhance reporting transparency. These steps could enable Thailand's biomass industry to contribute significantly to national sustainability goals, and global emissions targets, and remain competitive internationally.

This study focuses on agricultural wastes from key economic crops in Central Thailand—namely, rice straw, sugarcane leaves, corn stalks and cassava rhizomes—and aims to analyze the biomass fuel supply chain to adapt to evolving fuel trends and support the establishment of biomass torrefaction factory—Torrefaction enhances biomass properties by improving energy density, combustion efficiency, and grindability, while also reducing moisture absorption for better storage and transport (Djurdjevic and Papuga 2023). With the rising demand for sustainable energy, optimizing the biomass supply chain is critical for efficient production. By applying the Integration Definition for Function Modeling (IDEF0) and Supply Chain Operations Reference Model (SCOR model), this study examines the entire biomass supply chain, including raw material collection, transport, processing, storage, and delivery. IDEF0 provides a structured framework to map functions and relationships, revealing inefficiencies (Ongkunaruk 2014), IDEF0 diagram illustrates a process—An activity that transforms Inputs into Outputs, guided by Controls—rules or constraints and supported by Mechanisms—tools or resources. Controls direct the process without changing, as shown in Figure. 1 (Chari et al. 2023), while Mechanisms enable the activity. This framework helps analyze and improve the process systematically, while SCOR breaks down the supply chain into plan, source, make, deliver, and returns (Benjarattanapakee and Ongkunaruk 2023) to improve costs and environmental impact. Key challenges addressed include high transportation costs, storage issues due to biomass degradation, and regulatory compliance with mechanisms like the CBAM. This analysis equips Thailand's biomass sector to meet energy demands and international sustainability standards.

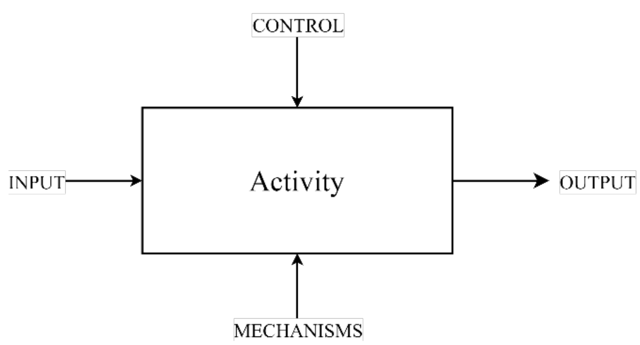

Figure 1. Concept of IDEF0

2. Literature Review

Integration Definition for Function Modeling (IDEF0) is a method for analyzing and representing business processes and activities, focusing on their inputs, outputs, controls, and mechanisms to improve workflows and decision-making.

The case study of manufacturing a Carton-Filling Machine using Design for Manufacturing (DFM) theory and the IDEF0 method enhances collaboration efficiency, reduces costs, and minimizes prototyping waste, offering a valuable model for academia-industry partnerships (Wang et al. 2023). In Ukrainian enterprises, the use of IDEF methodologies to improve supply chains and develop strategies highlights the importance of timely financial analysis, anti-crisis measures, and effective management decision-making. An anti-crisis strategy is recommended to help businesses adapt to changing external conditions and optimize resource use (Liganenko 2024). The case study of closing surface mines using IDEF0 highlights its effectiveness in identifying problems and planning sustainable mine reclamation and repurposing projects (Spanidis et al. 2021).

The Supply Chain Operations Reference (SCOR) model is a comprehensive framework developed by the Association for Supply Chain Management (APICS) to improve and standardize supply chain management practices. It provides a structured methodology for analyzing, benchmarking, and optimizing supply chain performance across industries. The key process of SCOR is Plan, Source, Make, Deliver, Return and Enable (Association for Supply Chain Management 2017). The SCOR model can identify issues and improve company performance more effectively and efficiently. It supports key metrics such as Perfect Order Fulfillment, Order Fulfillment Cycle Time, Cost of Goods Sold, and Cash-to-Cash Cycle Time, helping organizations optimize their supply chain operations (Lubis et al. 2024). In addition, The SCOR model is used to identify a validated set of performance indicators and applies the Analytical Hierarchy Process (AHP) to prioritize them. This approach ultimately enables the development of practical solutions to enhance XYZ Company's overall supply chain efficiency and effectiveness. (Utomo et al. 2024).

3. Methods

3.1 Interviewing Biomass Stakeholders

This study involved interviews with key stakeholders in the biomass supply chain across Lopburi and Saraburi provinces in Central Thailand. Participants included farmers, community enterprise leaders, a logistics manager, a production manager, a biomass fuel investor, and a customer. These discussions offered an in-depth understanding of the supply chain, encompassing biomass availability, transportation logistics, production challenges, investment viewpoints, and customer expectations for sustainable energy. The insights gathered were instrumental in developing an integrated model for a torrefied biomass production facility, aimed at enhancing logistical and operational efficiency throughout the supply chain.

3.2 IDEF0 and SCOR-Based Analysis

The IDEF0 was developed to improve communication among stakeholders by offering a standardized method for analysing and documenting functional processes (Reslan et al. 2022). As a core technique, IDEF0 models an organizations or system's decisions, actions, and activities, based on functional modelling principles. It maps system functions, their relationships, and the data flow between them through diagrams and symbols that represent functions and sub-functions, as illustrated in Figure 1. Each IDEF0 diagram centres around activity blocks, or boxes, representing specific functions or processes, linked by arrows that denote inputs, outputs, controls, and mechanisms. Inputs provide the necessary data or resources, outputs are the function's results, controls direct the function's operation, and mechanisms indicate the means of execution (Guk et al. 2024).

This study uses IDEF0 Level 0 to map the biomass fuel supply chain, showing stakeholder relationships from source to customer, including third-party interactions. IDEF0 Level 1 then applies the SCOR model to analyze specific activities within the biomass torrefaction factory, represented by activity boxes A1, A2, A3, A4, and A5. The SCOR model offers a standardized framework for evaluating and measuring the effectiveness of a company's supply chain, focusing on five primary processes: plan, source, make, deliver, and returns. These processes provide a foundation for developing streamlined operational strategies. The primary goal of implementing the SCOR model is to comprehensively understand supply chain performance, identify areas for improvement, and enhance the efficiency of current operations. By leveraging SCOR, organizations can evaluate the effectiveness of material and information flows, streamline processes to lower costs, and boost customer satisfaction. Ultimately, this approach helps businesses achieve a sustainable competitive advantage (Abusalma et al. 2024). A solid line indicates current activities in the biomass fuel supply chain, while a dashed line represents planned or future activities to enhance the system's efficiency and sustainability. There are five main activities as follows:

- Plan: The plan process is centred on aligning demand with the available resources.
- Source: The source process focuses on acquiring goods and services as per the plan, including supplier selection, purchasing, and ensuring timely delivery of quality materials to meet demand.
- Make: The make process involves the transformation of raw materials into finished goods through a structured series of manufacturing, assembly, and quality assurance steps, ensuring the final product meets customer requirements both effectively and efficiently.
- Deliver: The delivery process manages the distribution of products to customers, including order fulfillment, transportation, and logistics to ensure timely delivery.
- Return: The return process handles product returns from customers to the company (Anisatussariroh and Rr. Erlina 2024).

This study identified the key activities as A1: Plan, A2: Source, A3: Make, A4: Deliver, and A5: Return.

4. Results and Discussion

4.1 Key Issues of Biomass Supply Chain in Thailand

Through interviews with key stakeholders in the biomass supply chain, the study gathered insights into various aspects of the supply chain and identified several critical areas for focus, details are provided below.

- Farmers Attitude toward agricultural waste: Farmers in the central region typically grow rice, sugarcane, and corn, with planting and harvest times differing for each crop. They frequently burn agricultural waste after harvest, which negatively impacts the environment and surrounding communities. This widespread practice is largely attributed to farmers' lack of knowledge about the potential economic value of these residues. Many are unaware that agricultural waste can be converted into renewable energy or sold as raw materials for biomass industries. Moreover, the absence of clear buyers or established markets leaves farmers uncertain about how to sell their waste or whom to sell it to. Creating Community Enterprises could bridge these gaps by organizing farmers, raising awareness, and establishing efficient collection and sale systems. This initiative would encourage sustainable practices and significantly reduce the harmful practice of open burning.

- Inconsistency in Biomass Supply: Producing pellet biomass fuel is expensive and inconsistent, primarily due to high transportation costs for raw materials and the difficulty of sourcing agricultural residues consistently year-round, given the limited availability of biomass collectors. Furthermore, when wood chips are used, the long growth cycle of trees poses a challenge for biomass to remain competitive with solid fuels like coal.

- The Empowerment of Community Enterprise: A group of nearby farmers often forms a collective to engage in value-added activities and boost their bargaining power when selling agricultural products. These enterprises thrive with strong leadership, clear goals, and access to shared resources like facilities, financial support, and market information, ensuring sustainable growth and improved livelihoods.

- High transportation cost: Transporting biomass fuel presents challenges, as its light and fluffy nature results in low weight per transport load, leading to high transportation costs. For optimal efficiency, factories or storage areas should be in areas that minimize transportation expenses.

- Community Biomass Center Establishment: The centre can collect biomass from farmers and set up agreements to buy it at fair prices, providing a reliable market for agricultural by-products. One challenge, however, is biomass storage; without proper management, the material decomposes over time, making it unsuitable for fuel production. Effective storage solutions are essential to maintain biomass quality.

- Location of biomass fuel production: One challenge in selecting a location for a biomass fuel production plant using the torrefaction process is securing a consistent supply of agricultural residues. Individual farming practices often result in farmers burning biomass, as they see it as waste.

- Increasing Demand of Biomass: The demand for biomass fuel is rising due to CBAM requirements for exports to Europe. Additionally, manufacturers are committed to the AEDP 2018 plan, which mandates that biomass fuel must have a calorific value comparable to coal, driving interest in high-quality biomass solutions.

In the biomass supply chain, farmers often burn agricultural waste, such as rice straw, sugarcane leaves, and corn stalks after harvest, harming the environment and society. Establishing biomass collection from farms can mitigate these issues and generate additional revenue for farmers. Locating collection centers near farms can help lower transportation costs. To address biomass inconsistency and degradation during storage, implementing optimal crop planning and scheduling is crucial to ensure a steady year-round biomass supply. However, investors face challenges in determining a fair price for sourcing biomass. This effort aligns with the needs of customers aiming to reduce carbon emissions and meet European CBAM and AEDP 2018 standards by adopting biomass as an alternative to fossil fuels.

4.2 Business Process Analysis at Organization Level

The business process model for a biomass fuel production plant includes a level 0 diagram illustrating the supply chain, with four main components as shown in Figure. 2.

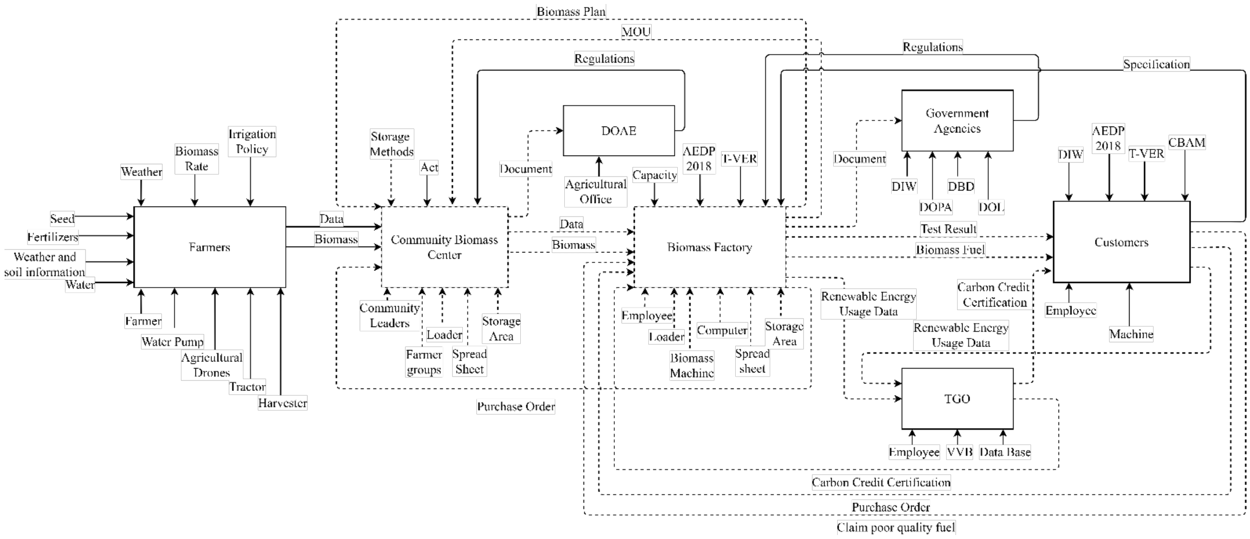

Figure 2. The Business Process of Biomass Fuel Supply Chain (IDEF0 Level 0)

- Farmers: Farmers in the region cultivate crops such as rice, sugarcane, corn, and cassava, generating significant biomass by-products like rice straw, sugarcane leaves, corn stalks, and cassava rhizomes, leaves, and stems. Despite their industrial fuel potential, these residues are often burned or used as organic fertilizer due to a lack of awareness, causing environmental harm and missed economic opportunities. Rice and sugarcane are typically grown consecutively on the same land, while corn and cassava are alternated. Corn, the main crop in the rotation for its higher economic return, is planted during the rainy season due to its high-water requirements, followed by cassava after the corn harvest. Rice, planted from January to April, matures in 3–4 months, with leftover straw often burned. Sugarcane, planted between May and June, matures in 10–14 months, with leaves frequently burned during harvest to cut costs. Corn, grown from May to July, has a growth period of 3–4 months, with stalks commonly burned. Cassava, planted from May to July, matures in 8–12 months, with most residues burned, though some stems are saved for replanting. Establishing a community biomass center could address these issues by creating a market for agricultural residues, reducing waste, improving farmer incomes, and encouraging sustainable practices and land use.

- Community Biomass Centre: This centre, operating as a community enterprise, would collect biomass from agricultural areas and supply it to the biomass factory. The centre would need proper storage facilities, handling equipment, and data management systems to monitor biomass quality and inventory, ensuring efficient distribution to the factory. A robust community enterprise of Community Biomass Centre typically requires at least seven members; a larger membership base often contributes to increased strength, resource pooling, and decision-making capacity. Additionally, suitable infrastructure is vital for operational success. A community enterprise benefits from having a designated building for operations and an area of approximately five rai (equivalent to about two acres). This area should include a roofed section to store biomass, ensuring protection from weather and preserving its quality for further processing. Together, these structural and organizational elements provide a solid foundation for sustainable and productive community enterprises in biomass value chains.

- Biomass Factory: The Biomass Fuel Production Plant will be established following local regulations, focusing on site selection, construction, and transportation costs while complying with government agencies such as the Department of Industrial Works (DIW) and the Department of Provincial Administration (DOPA). The plant will engage in Memoranda of Understanding (MOU) with community biomass centers to ensure a steady biomass supply. The biomass, primarily rice straw, sugarcane leaves, and corn stalks, will undergo torrefaction at temperatures between 200°C and 300°C, improving its density, calorific value, and reducing moisture content (Djurdjevic and Papuga, 2023). With a production capacity of 216,000 tons per year, the plant will supply biomass for its operations and sell the processed fuel. Additionally, the plant will generate Carbon Credit Certificates by registering under the T-VER system with the Thailand Greenhouse Gas Management Organization (TGO), contributing to sustainable energy and environmental goals.

- Customers using fossil fuels like coal or oil in industrial processes, especially those with export products, may seek biomass fuel to comply with CBAM or obtain carbon credit certifications. These credits, gained by registering under T-VER with TGO, allow trading on carbon markets or meeting government policies like AEDP 2018. Customers place purchase orders for biomass with specified quality and quantity or request carbon credit. If biomass fails to meet standards, it can be returned for analysis and correction, ensuring high quality and added value through carbon credits.

4.3 Business Process Analysis at Activities Level

The business process model for a biomass fuel production plant includes five main activities: Planning, Sourcing, Production, Delivery, and Returns shown in Figure. 3.

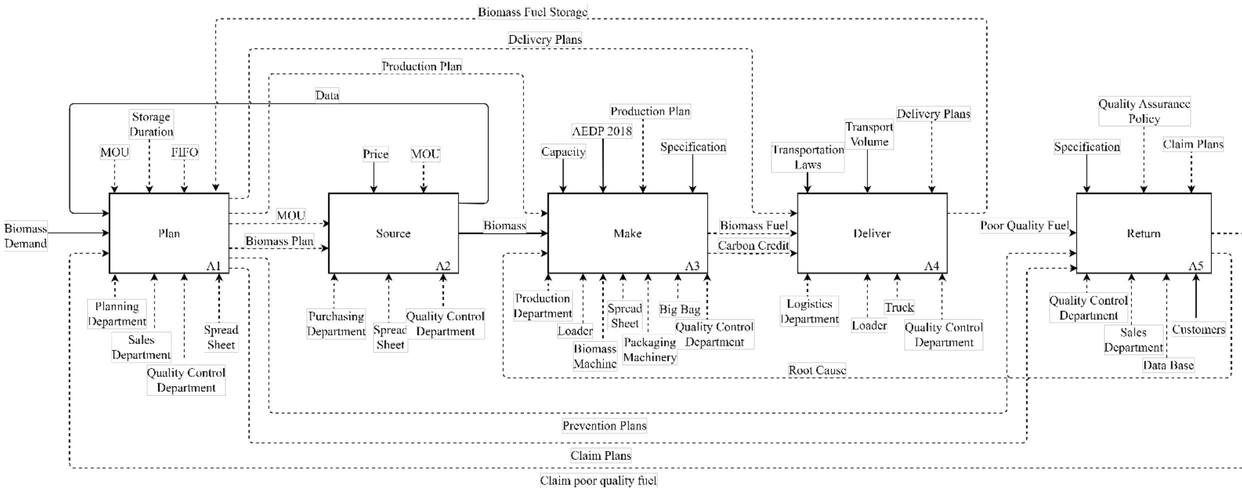

Figure 3. The Business Process of Biomass Fuel Supply Chain (IDEF0 Level 1)

- Plan: The process begins with evaluating customer demand for biomass fuel to develop an efficient production plan, which is then shared with the production department. At the same time, a biomass procurement plan is created to coordinate the collection of biomass from community centres, ensuring that sufficient quantities are available to meet production requirements. A delivery schedule is also prepared and sent to the logistics department. A mathematical model for optimal location of production and collection centers could also aid in finding the ideal plant location to reduce transport costs. Biomass sourcing is complicated by the dispersed nature of agricultural by-products. To enhance supply stability, establishing community-run biomass centres can centralize and streamline sourcing, preventing waste and adding value to these agricultural residues. Additionally, a MOU for biomass purchase agreements and contracts with local farmers will be established to ensure a reliable and continuous biomass supply. To further enhance efficiency, a mathematical model is recommended to determine the optimal location for the biomass production plant, minimizing costs and improving the overall effectiveness of the supply chain.

- Source: Sourcing biomass materials like rice straw and corn stalks presents challenges, including seasonal availability, the widespread practice of burning by-products, and biomass degradation from natural decomposition. Implementing a First In, First Out (FIFO) system in storage can address quality concerns. To ensure a stable supply, signing MOUs with farmers and offering them shareholder opportunities fosters loyalty and sustainable practices. Additionally, regular supplier assessments for biomass quality and volume are essential for maintaining a reliable supply chain.

- Make: Production uses torrefaction to convert biomass into fuel, with a production capacity of 216,000 tons annually. Production relies on biomass fuel as a renewable energy source, aligning with the AEDP 2018 goal to reduce fossil fuel dependence. Additionally, moisture issues arise in the final product, with potential solutions including equipment adjustments or open-air drying before packaging.

- Deliver: Delivery ensures that biomass fuel is transported within legal load limits. Since customers are responsible for transport costs, optimizing plant location and vehicle routes can help minimize expenses and maintain competitiveness.

- Returns: If biomass fuel fails to meet quality standards, the sales department manages customer claims and alerts the production department to investigate the root cause and implement corrective actions. To address high return logistics costs, customers are offered credit instead of returning the product, preserving relationships and reducing expenses.

The summary of problems and solutions of biomass supply chain are shown in Table 1.

Table 1. Summary of Problem and Solution

Activity	Problem	Solution
Plan	• Lack of Demand Planning • Limited biomass availability due to seasonal harvesting • Inefficient transport costs	• Demand Forecast • Establish community biomass centers • Use a mathematical model to determine the optimal location of production and collection centers
Source	• Biomass degradation over time • Lack of supplier evaluation • Raw material shortage	• Implement a First In, First Out (FIFO) system for storage • Evaluate suppliers for quality and quantity to ensure reliability • Sign an MOU with farmers, offering them shareholder opportunities to promote loyalty and sustainable practices.
Make	• Moisture issues in the final product	• Adjust equipment or use open-air drying to manage moisture
Deliver	• High transport costs for customers due to distance from the production plant	• Determine optimal locations • Implement vehicle routing problem
Return	• High return logistics costs	• Offer credit instead of physical product returns

5. Conclusion

This study presents a comprehensive analysis of the biomass supply chain in preparation for establishing a torrefied biomass production facility in Thailand. Using the IDEF0 and SCOR models, it addresses key challenges and opportunities related to agricultural waste utilization. In the central region, farmers often burn residues like rice straw, sugarcane leaves, and corn stalks, which harm the environment. Inconsistent biomass supply complicates production, exacerbated by high transportation costs and the seasonal nature of agricultural by-products. The long growth cycles of wood chips further affect biomass fuel's competitiveness compared to solid fuels like coal.

Empowering community enterprises offers a sustainable solution, as farmer collectives engaging in value-added activities can enhance bargaining power and improve market access, although strong leadership is crucial for their success. Establishing community biomass centers can stabilize the supply chain by collecting biomass at fair prices and implementing storage solutions to prevent decomposition. High transportation costs require strategic location planning to optimize efficiency. Additionally, increasing demand for high-quality biomass fuel, driven by CBAM regulations and AEDP 2018 commitments, emphasizes the need for fuels with calorific values comparable to coal.

The key supply chain factors, including raw material availability, logistics challenges, processing requirements, and market demand for sustainable energy. The proposed solution includes a coordinated production and procurement plan based on customer demand, shared across departments to ensure efficient operations. Establishing community-run biomass centers is essential for centralizing residue collection, reducing waste, and maintaining a steady supply. A mathematical model is recommended to optimize the placement of plants and collection centers, reducing transport costs and enhancing supply chain efficiency. Seasonal and decomposition challenges will be addressed through a First In, First Out (FIFO) storage system, and supplier assessments will ensure consistent quality. The production process will use torrefaction, aligning with renewable energy goals and mitigating transport and moisture issues through drying techniques. Efficient delivery planning will maintain legal transport limits, while strategic plant locations will reduce customer costs. Quality issues will be managed collaboratively by sales and production teams, offering credits to minimize return costs and maintain customer satisfaction. This framework fosters a sustainable, efficient, and resilient biomass supply chain, supporting Thailand's renewable energy goals and contributing to global emissions reductions.

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References
Abusalma, A., Oraini, B. Al, Al-Daoud, K. and Alshurideh, M. T., The impact of supply chain performance on financial performance: Dimensions of the SCOR model, *Uncertain Supply Chain Management*, vol.12, no. 3, pp. 1409–1416, 2024.

Anisatussariroh, N. A. and Rr. Erlina., Supply chain performance analysis using the SCOR method, *Asian Journal of Economics and Business Management*, vol. 3, no. 1, pp. 413–420, 2024.

Asia Pacific Energy Pottal, Available: https://policy.asiapacificenergy.org/sites/default/files/Alternative%20Energy%20Development%20Plan%202018-2037%20%28AEDP%202018%29%28TH%29.pdf, Accessed on November 10, 2024.

Association for Supply Chain Management., APICS Supply Chain Operations Reference Model SCOR, Version 12.0, Association for Supply Chain Management, Chicago, 2017.

Benjarattanapakee, C. and Ongkunaruk, P., Analyzing the supply chain sustainability of an internet service provider in Thailand, *E3S Web of Conferences*, vol. 408, no. 01011, pp. 1-8, Izmir, Turkey, July 12, 2023, https://doi.org/10.1051/e3sconf/202340801011.

Chari, A., Stahre, J., Bärring, M., Despeisse, M., Li, D., Friis, M., Mörstam, M., and Johansson, B., Analysing the antecedents to digital platform implementation for resilient and sustainable manufacturing supply chains - An IDEF0 modelling approach, *Journal of Cleaner Production*, vol. 429, no. 139598, 2023, https://doi.org/10.1016/j.jclepro.2023.139598.

Djurdjevic, M., and Papuga, S., Torrefaction: Process Parameters and Reactor Design, *Periodica Polytechnica Chemical Engineering*, vol. 67, no. 3, pp. 416–426, 2023.

Guk, O., Mokhonko, G., Darmits, R., Karpii, O., and Mykhailyk, N. Digital transformation: Driving innovation and projects in companies. *Revista Amazonia Investiga*, vol. 13, no. 74, pp. 103–114, 2024.

International Energy Agency (iea), Available: https://www.iea.org/reports/thailands-clean-electricity-transition, Accessed on November 12, 2024.

Liganenko, I., Pidhurska, B. O., Vlasenko V., Glebova, A. and Bodenchuk, L., Formation and Implementation of the Business Development Strategy of Ukrainian Enterprises: Functional Modelling (IDEF), *Economic Affairs*, vol. 69, no. 3, pp. 1543-1555, 2024.

Lubis, Z. K. A. S., Rahmani, A. N. and Harahap, I. M., Performance Analysis of Supply Chain Management PT. Asia Palem Lestari Uses the Supply Chain Method Operation Reference (SCOR), Quantitative Economics and Management Studies (QEMS), vol. 5, no. 5, pp. 1035-1042, 2024.

Ongkunaruk, P., Business Process Analysis and Improvement for a Raw Milk Collection Centre in Thailand, *Agriculture and Agricultural Science Procedia*, vol. 3, pp. 35–39, Yogyakarta, Indonesia, November 24-25, 2014.

Reslan, M., Last, N., Mathur, N., Morris, K. and Ferrero, V., Circular Economy: A Product Life Cycle Perspective on Engineering and Manufacturing Practices, *29th CIRP Life Cycle Engineering Conference*, vol. 105, pp. 851-858, Leuven, Belgium, April 4-6, 2022, https://doi.org/10.1016/j.procir.2022.02.141.

Spanidis, P. M., Pavloudakis, F. and Roumpos, C., Introducing the IDEF0 Methodology in the Strategic Planning of Projects for Reclamation and Repurposing of Surface Mines, *International Conference on Raw Materials and Circular Economy*, vol. 5, no. 26, pp. 1-8, Athens, Greece, September 5-9, 2021, https://doi.org/10.3390/materproc2021005026.

Utomo, P. A., Setiawati, M. and Prasetya, D., Supply Chain Performance Measurement at XYZ Company Distribution Center Using SCOR 12, *Petra IJBS,* vol. 7, no. 1, pp. 66-79, 2024.

Wang, B., Yao, C., Li, X. and Wei, G., A Green Cooperative Development Method Based on the IDEF0 Model of Manufacturing Knowledge: Case Study of a Carton-Filling Machine, *Sustainability*, vol. 15, no. 4047, 2023, https://doi.org/10.3390/su15054047.

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