Jurnal Teknik Mesin Mechanical Xplore (JTMMX) Vol. 6, No. 1 (2025) 53-68

Jurnal Teknik Mesin Mechanical Xplore (JTMMX)
Journal homepage: https://journal.ubpkarawang.ac.id/index.php/JTMMX

Review

An Integrative Review on the Role of Refuse-Derived Fuel (RDF) in Sustainable Supply Chains for Green Manufacturing

LD Muhammad Raldi[1], Setia Damayanti[2], Ridwan[3]

[1]Program of Master in Infrastructure and Environmental Engineering, Faculty of Engineering, Universitas Pancasila, Jakarta 12630, West Java, Indonesia.

[2]Program of Master in Infrastructure and Environmental Engineering, Faculty of Engineering, Universitas Pancasila, Jakarta 12630, West Java, Indonesia.

[3]Department of Mechanical Engineering, Faculty of Industrial Technology, Universitas Gunadarma, Jakarta 10430, West Java, Indonesia.

ARTICLE INFO

Article history:
Received 14 May 2025
Received in revised form 30 June 2025
Accepted 30 June 2025
Available online 30 June 2025

Keywords:
Refuse-Derived Fuel (RDF)
Green Supply Chain Management (GSCM)
Green Production
Integrative Review

ABSTRACT

Sustainable waste management and environmentally friendly production systems have become central to modern supply chain practices. Refuse-derived fuel, an alternative fuel derived from solid waste, presents significant potential in supporting green supply chain management principles. However, its integration into the green supply chain management framework remains fragmented. This study aims to explore the integration of refuse-derived fuel into sustainable supply chain management using an integrative literature review method. Findings indicate that refuse-derived fuel contributes not only to reducing landfill volume and emissions but also enhances energy efficiency, particularly in cement manufacturing. Key challenges include feedstock quality, technological complexity, and limited policy support. This study proposes a conceptual model positioning refuse-derived fuel as a strategic driver for green production. Through a multidisciplinary understanding of refuse-derived fuel, waste management, and supply chain innovation, refuse-derived fuel emerges as a promising component for systematic integration into sustainable production and circular economy strategies. Future research is recommended to empirically validate this conceptual model and to explore practical implementation pathways in various industrial sectors.

*Corresponding author.
E-mail address: lmraldi10@gmail.com (RD.M. Raldi)
Peer review under the responsibility of Editorial Board of Jurnal Teknik Mesin Mechanical Xplore (JTMMX)

1. Introduction

In recent years, there has been growing global attention toward effective waste management and the pursuit of environmentally friendly production systems, such as biorefineries. This increasing concern has prompted the adoption of Green Supply Chain Management (GSCM) principles to reduce environmental degradation and enhance resource efficiency. While Refuse-Derived Fuel (RDF) has shown considerable promise in converting solid waste into alternative energy [1,2], its optimal integration into GSCM frameworks remains underexplored and fragmented in both theoretical and practical discourse.

Integrating Refuse-Derived Fuel into Sustainable Supply Chains for Low-Carbon Production is important because it transforms municipal solid waste into a valuable energy resource, thereby reducing reliance on landfilling and lowering greenhouse gas emissions. This integration aligns with circular economy

https://doi.org/ 10.36805/jtmmx.v6i1.10448

principles by promoting waste valorization, strengthening energy security through fossil fuel substitution, and contributing to the decarbonization of industrial operations. As a result, it supports the development of environmentally sustainable and economically resilient production systems. Figure 1 illustrates a schematic representation of this approach.

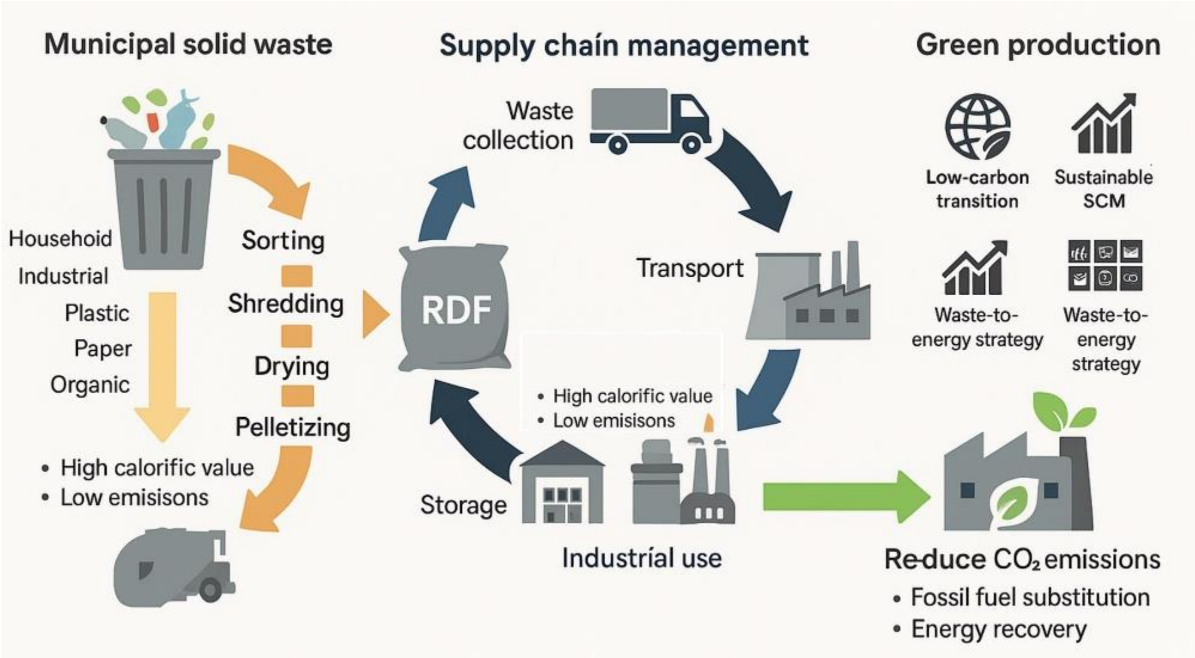

Figure 1. Integrating RDF into sustainable supply chains for low-carbon production is essential.

RDF, produced from the treatment of non-recyclable municipal, agricultural, and industrial waste, offers dual benefits: it reduces landfill volume and serves as a renewable energy source, particularly in industrial sectors such as cement manufacturing [3, 4]. Biomass has significant potential as a renewable energy source and can reduce dependence on fossil fuels through co-firing and torrefaction technologies [5]. Studies have demonstrated RDF's potential as a sustainable waste-to-energy (WtE) solution, highlighting its contribution to renewable energy systems [1, 6, [7]. Simultaneously, sustainable supply chain management literature emphasizes the importance of integrating environmental considerations and alternative energy sources to achieve operational efficiency and long-term sustainability [8].

Despite these insights, few studies have comprehensively addressed the synergetic integration of RDF within Green Supply Chain Management (GSCM), particularly in comparison to traditional supply chain strategies [9]. Continuous improvement in GSCM and the adoption of renewable energy strategies, such as solar and wind energy, are crucial for achieving environmental and operational sustainability [10, 11]. Forced convection and optimized briquette design can accelerate combustion processes and improve heat transfer performance [12], [13]. The application of RDF as a component in green supply chains is still marginal, often limited to isolated case studies without a unifying conceptual framework [14]. Technological advancements in biomass combustion, multi-criteria decision-making for alternative fuels, and innovations in green-emitting materials are crucial for promoting sustainable production and the energy transition [15-17]. Cleaner production models and wastewater reuse are essential strategies for reducing environmental and human health impacts in traditional industries[18].

Improving green productivity through seed innovation, post-harvest handling, and waste utilization is crucial for agricultural sustainability [19]. Optimizing composting parameters is essential for transforming industrial solid waste into valuable resources that meet national standards[20]. High-efficiency densification machines enable large-scale biomass briquette production and promote the use of renewable energy [21]. Furthermore, variations in the composition of biomass briquettes significantly influence their calorific value and combustion rate, supporting the development of optimized fuel alternatives [22]. Using rice husks and sawdust as biomass sources offers potential for alternative fuels, although quality improvements are still needed to meet standards [23]. Additionally, the potential of RDF in managing industrial waste streams, such as cardboard and paper from distribution sectors, remains an underutilized opportunity for achieving closed-loop supply chains [6, 24, 25].

This gap presents a significant opportunity for further research. While RDF technologies have matured, their strategic alignment with GSCM processes—such as procurement, production, and distribution—requires deeper examination, especially for developing countries struggling with waste management infrastructure [26] A review that synthesizes RDF applications within the context of green supply chains can offer critical insights into how waste-to-energy innovations contribute to cleaner production systems.

The novelty of this study lies in its integrative approach to mapping the intersection between RDF and sustainable supply chain management. Unlike prior research that isolates RDF as either an energy solution or a waste management practice, this review proposes a unified conceptual model to position RDF as a strategic enabler of green production in GSCM. By consolidating diverse literature on waste valorization, energy sustainability, and supply chain innovation, this study offers a fresh lens through which RDF can be assessed and applied systematically. Based on the aforementioned background, the researcher is interested in conducting a study entitled *"An Integrative Review on the Integration of Refuse-Derived Fuel (RDF) into Sustainable Supply Chain Management for Green Production."* This study aims to comprehensively explore how RDF can be optimally integrated within the framework of Green Supply Chain Management (GSCM), evaluate its potential to enhance waste-to-energy conversion, and compare it with conventional supply chain management strategies to promote green production.

2. Methodology

2.1. *Research method*

This study adopts an integrative literature review method to explore the integration of Refuse-Derived Fuel (RDF) into Sustainable Supply Chain Management (SSCM) for green production. The integrative review approach was selected because it allows for the inclusion of both theoretical and empirical literature, thereby facilitating a comprehensive understanding of RDF's role in enhancing sustainability within supply chains. The sources reviewed in this study included peer-reviewed journal articles, conference proceedings, and relevant reports published between 2019 and 2025. These were obtained from academic databases such as ScienceDirect, SpringerLink, Scopus and Google Scholar. A total of 1 article was selected based on its relevance to RDF technology, supply chain management, waste-to-energy systems, and sustainable production practices.

2.2. *Selection Criteria and Procedure*

The article selection process was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, which involves four stages: identification, screening, eligibility, and inclusion. The inclusion criteria were as follows: articles must be written in English, published between 2019 and 2025, and focused on topics related to RDF, sustainability in supply chains, or green production. In addition, the articles had to include conceptual frameworks, case studies or empirical findings. Duplicate publications and studies lacking relevance or methodological rigor were excluded.

2.3. *Data analysis*

The selected articles were analyzed using thematic content analysis. Key themes identified in the literature include the technological aspects of RDF production, integration of RDF into supply chain processes, environmental and economic benefits of RDF utilization, challenges and policy implications associated with RDF, and comparative analyses with traditional fuel or waste management systems. The findings of this thematic analysis were synthesized to highlight research gaps, identify best practices, and formulate policy recommendations for integrating RDF into sustainable supply chain management.

3. Results and Discussions

3.1. *Overview of reviewed studies*

To establish a comprehensive understanding of current research trends and methodological approaches in waste-to-energy conversion, a systematic review of 18 peer-reviewed studies was conducted. Table 1 summarizes their methodological orientations, data sources, applied techniques, and geographical focuses. The synthesis reveals dominant research patterns in the academic and practical exploration of Refuse-Derived Fuel (RDF) technologies. Notably, approximately 83% of the studies employed quantitative approaches, reflecting the technical and analytical nature of the field, particularly in areas such as combustion testing, energy yield analysis and techno-economic assessment. Studies such as those by Yahya et al. [27] and Darmawan & Sudarmanta [30] utilized techno-economic and cost-benefit analyses to assess RDF viability. In contrast, a smaller number of studies adopted qualitative methods, focusing on document analysis, literature reviews, and policy evaluations, as seen in the work of Janda and Urbańska [36]. Additionally, experimental research such as that conducted by Robi et al. [30] focused on the performance of RDF biomass pellets via gasification and dual-fuel engine testing, contributing significant insights into both the technical and economic aspects of RDF deployment.

In terms of data sources, most studies relied on primary data, indicating a strong emphasis on original fieldwork, laboratory testing, and direct data collection. For instance, experimental research conducted by Azam et al. [32] and Shun et al. [41] involved combustion testing to evaluate the fuel performance of RDF under controlled conditions. A smaller subset of studies utilized secondary data, mostly in the context of qualitative approaches, where literature-based or document-based evidence played a central role. The research methods employed in these studies were diverse, reflecting the multidisciplinary nature of waste-to-energy research. Common methods include techno-economic analysis, waste characterization, combustion testing, experimental design, simulations, and case study analyses. Some studies combined methods, such as literature reviews and survey analyses, to enrich the scope and depth of their findings. Kristanto and Rachmansyah [33] employed simulation-based approaches to model RDF applications [33], while Wijaya et al. [34] focused on direct experimental testing in laboratory settings.

Geographically, Indonesia emerged as the most represented country, with nine of the 18 reviewed studies conducted in various regions across the nation, reflecting a strong academic and policy commitment to sustainable waste management and alternative energy development. Other countries identified in the analysis include Ghana, Poland, Austria, Portugal, China, Madagascar, Thailand, and South Korea, indicating a broad international engagement in RDF and waste-to-energy research. The distribution of these studies illustrates the adaptability of RDF technologies across a range of socio-economic contexts, from emerging economies to industrialized nations. Insights from each country are shaped by differing waste characteristics, energy needs, infrastructure capacities, and regulatory landscapes. Figure 2 provides a comparative overview of the methodological approaches and data types used in the selected studies.

The reviewed literature consistently emphasizes the integration of RDF into municipal solid waste management systems, industrial co-firing processes—particularly in cement manufacturing—and renewable energy applications. Across the studies, reported benefits include reductions in greenhouse gas emissions, decreased reliance on landfill disposal, and improvements in overall energy efficiency. These advantages position RDF as a critical component in achieving circular economy goals and advancing decarbonization efforts. In rapidly urbanizing regions, RDF adoption offers practical solutions for managing increasing waste volumes while simultaneously contributing to cleaner and more resilient energy systems.

Table 1. Summary of the research methods, data types, and study locations.

No.	Author(s) (Year)	Quantitative	Qualitative	Primary Data	Secondary Data	Main Method	Location
1	Robi et al. (2025) [30]	Y	N	Y	N	Experimental analysis	Indonesia
2	Natvaree Chommontha et al. (2024) [42]	Y	N	Y	N	Co-Gasification Study	Thailand
3	Do-Won Shun et al. (2024) [41]	Y	N	Y	N	Combustion Testing	South Korea
4	Ting Li et al. (2024) [38]	Y	N	Y	N	Case study analysis	China
5	Anna Janda & Weronika Urbańska (2024) [36]	N	Y	N	Y	Policy Analysis	Poland
6	Robi Fajerin Darmawan & Bambang Sudarmanta (2024) [30]	Y	N	Y	N	Techno-Economic Analysis	Indonesia
7	Suherman Yahya et al. (2024) [27]	Y	N	Y	N	Cost-Benefit Analysis	Indonesia
8	Maria Margarida Mateus et al. (2023) [35]	Y	N	Y	N	Circular Economy Assessment	Portugal
9	I Made Wahyu Wijaya et al. (2023) [34]	N	Y	Y	N	Experimental analysis	Indonesia
10	Diananto Prihandoko et al. (2022) [29]	N	Y	N	Y	Techno-economic analysis	Indonesia
11	Mochamad Arief Budihardjo et al. (2022) [37]	Y	N	Y	N	RDF Characterization	Indonesia
12	Putu Chandra Mandala et al. (2022) [43]	Y	N	Y	N	Waste composition analysis	Indonesia
13	Khadija Sarquah et al. (2022) [1]	Y	N	Y	N	Waste Characterization	Ghana
14	Tiammanee Weerasak & Sompop Sanongraj (2021) [40]	Y	N	Y	N	Waste Composition Analysis	Thailand
15	Gabriel Andari Kristanto & E Rachmansyah (2020) [33]	Y	N	Y	N	Simulation analysis	Indonesia
16	Mudassar Azam et al. (2019) [32]	Y	N	Y	N	Combustion Testing	Austria
17	Piotr Krawczyk et al. (2018) [31]	Y	N	Y	N	Comparative analysis	Poland
18	Jordy Charly Isidore et al. (2015) [39]	Y	N	Y	N	Literature review and survey analysis	Madagascar

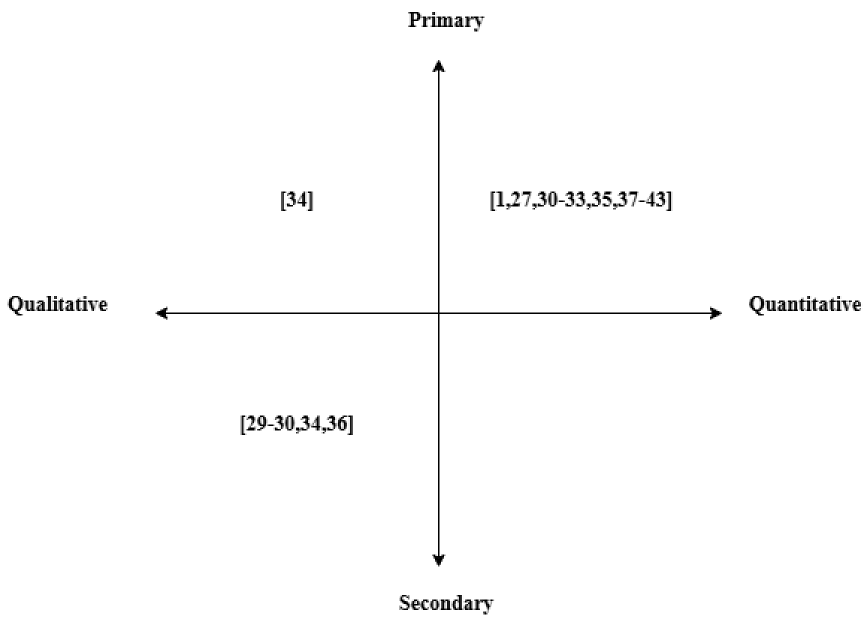

Figure 2. Schematic diagram

Table 2 summarizes various findings related to RDF processing and utilization, as well as its contributions to waste management and the sustainability of green production systems, as outlined by the relevant authors.

Table 2. Summary of authors' findings on RDF technology and its applications**.**

No.	Author(s) (Year)	Response
1	Robi et al. (2025)	Investigates the application of RDF biomass pellets in a gasification process to produce syngas for dual-fuel diesel engines, evaluating technical performance, economic feasibility (payback period under two years), and CO_2 emission reduction for electricity generation [30]
2	Natvaree Chommontha et al. (2024)	Investigates co-gasification of RDF, offering insights into optimizing RDF for higher energy yields [42]
3	Do-Won Shun et al. (2024)	Analyzes RDF combustion in fluidized boilers, highlighting technological and environmental benefits [41]
4	Ting Li et al. (2024)	Examines RDF integration in industrial waste management, focusing on technical and policy challenges [38]
5	Anna Janda & Weronika Urbańska (2024)	Case study on RDF production in Poland, exploring energy recovery and landfill waste reduction [36]
6	Robi Fajerin Darmawan & Bambang Sudarmanta (2024)	Presents techno-economic analysis of biomass waste conversion into energy, contributing to RDF and renewable energy integration [30]
7	Suherman Yahya et al. (2024)	Analyzes financial feasibility of RDF in cement production, highlighting economic and sustainability considerations [27]
8	Maria Margarida Mateus et al. (2023)	Analyzes RDF's role in circular economy, focusing on waste reduction and energy transition in production processes [35]
9	I Made Wahyu Wijaya et al. (2023)	Investigates RDF production from temple and coconut waste, focusing on sustainable energy and waste management practices [34]

No.	Author(s) (Year)	Response
10	Diananto Prihandoko et al. (2022)	Discusses RDF technology for municipal waste management, focusing on environmental and economic benefits, and its role in sustainable supply chains [29]
11	Mochamad Arief Budihardjo et al. (2022)	Studies RDF from landfill waste, emphasizing renewable energy potential and environmental benefits [37]
12	Putu Chandra Mandala et al. (2022)	Optimizes RDF production at landfills, addressing environmental, economic, and policy aspects [43]
13	Khadija Sarquah et al. (2022)	Studies RDF valorization from municipal solid waste, focusing on technological, environmental, and economic benefits [1]
14	Tiammanee Weerasak & Sompop Sanongraj (2021)	Focuses on municipal waste composition for RDF production, highlighting raw material quality for green production [40]
15	Gabriel Andari Kristanto & E Rachmansyah (2020)	Studies RDF production from commercial waste for cement, reducing CO_2 emissions and evaluating sustainability [33]
16	Mudassar Azam et al. (2019)	Analyzes RDF combustion, providing insights into energy content and environmental benefits compared to traditional fuels [32]
17	Piotr Krawczyk et al. (2018)	Investigates RDF co-combustion with lignite, offering environmental comparisons and advantages over traditional fuels [31]
18	Jordy Charly Isidore et al. (2015)	Discusses gasification of household waste, focusing on process complexities and RDF's role in energy recovery [39]

3.1. *Technological aspects of RDF production*

Refuse-Derived Fuel (RDF) production is a multistage process that transforms municipal solid waste (MSW) and other types of waste into usable fuel for energy generation, especially in energy-intensive industries such as cement manufacturing and power generation. The technological processes involved in RDF production are crucial for determining the fuel quality, energy yield, environmental impact, and economic feasibility.

At its core, RDF production begins with waste collection and segregation, where recyclable and non-combustible materials, such as metals, glass, and inert materials, are removed. The remaining waste, typically composed of plastics, paper, cardboard, and organic residues, serves as the feedstock for RDF. The quality of this feedstock significantly affects the efficiency and performance of RDF as an energy source. Weerasak and Sanongraj emphasized the importance of analyzing municipal waste composition to ensure the raw material's suitability for RDF production, as higher calorific values are typically associated with plastic and paper-rich waste streams [40]. Figure 3. depicts the waste management practices implemented on campus.

Following segregation, waste undergoes mechanical processing, which includes shredding, drying, and sometimes pelletizing. Drying technology plays a critical role in this stage. The moisture content of RDF must be reduced to enhance its calorific value and combustion performance. As described by Zamrudy et al. [30] optimized drying techniques are essential for making RDF viable for use in cement kilns, where consistent fuel quality is crucial for process stability and emissions control. In addition, RDF biomass pellets produced through optimized drying and pelletizing can also be utilized in gasification processes to generate syngas as an alternative fuel for dual fuel diesel engines, supporting waste-to-electricity applications and promoting decarbonization efforts [44].

Another technological pathway explored in RDF research is gasification, a process in which organic waste is thermochemically converted into synthetic gas (syngas) through controlled oxygen or steam conditions. This gas can then be used for electricity generation or as a precursor in other chemical processes. Budihardjo et al. and Chommontha et al. highlighted how co-gasification — the simultaneous gasification of RDF with other fuels or biomass — can improve energy efficiency and reduce the environmental footprint of waste management systems [37, 42]. Gasification offers a cleaner alternative to direct combustion by producing fewer harmful emissions, provided that the process is carefully controlled.

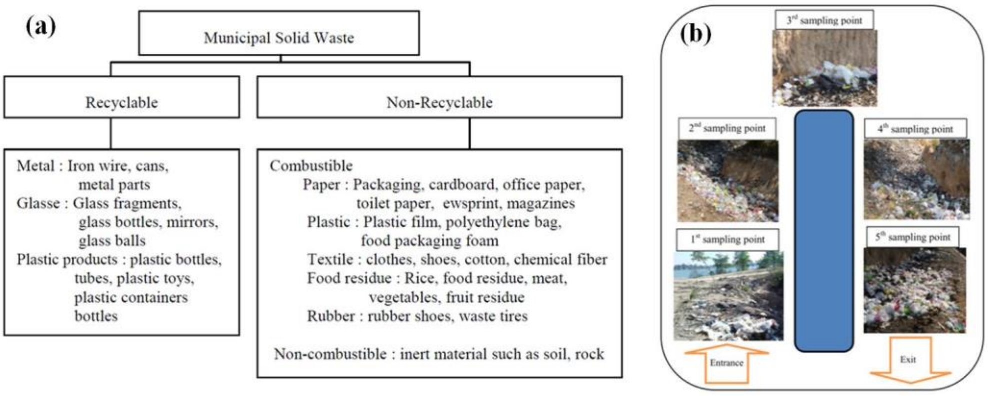

Figure 3. Waste management practices at Rajamangala University of Technology Isan, Surin Campus, Thailand: (a) municipal solid waste classification system; (b) open dumpsite and sampling location. Adapted from [40].

Combustion technologies have also been widely applied and studied. RDF is often burned in industrial boilers or cement kilns to replace traditional fossil fuels, such as coal. Studies such as those by Mudassar Azam et al. and Do-Won Shun et al. examined how RDF combustion in fluidized bed boilers can achieve higher combustion efficiency and more stable thermal performance due to better mixing and heat transfer [32, 41]. The volatile matter content in RDF, which is higher than that in conventional coal, contributes to more complete combustion and can result in lower emissions of certain pollutants, assuming optimal combustion conditions are maintained.

Simulation technologies and techno-economic analyses also play important roles in RDF technology development. Researchers like Gabriel Kristanto & Rachmansyah used simulation methods to evaluate the efficiency of RDF production from commercial waste streams and its integration into existing energy systems [33]. These analyses help stakeholders predict the performance and economic outcomes of RDF projects prior to implementation.

In summary, RDF production is a technologically intensive process involving multiple stages, from waste segregation and drying to combustion or gasification, each requiring careful optimization. Advancements in these technologies not only improve fuel quality and energy efficiency, but also support environmental goals, such as greenhouse gas reduction and landfill diversion. The integration of RDF into industrial energy systems reflects the intersection of engineering innovation, environmental management, and circular economy principles.

3.2. *Integration of RDF into supply chain processes*

The incorporation of Refuse-Derived Fuel (RDF) into industrial supply chains, particularly in sectors such as cement manufacturing and thermal energy generation, has been recognized as a strategic pathway for enhancing sustainability and resource efficiency. RDF serves as a partial substitute for conventional fossil fuels, especially coal, which remains the primary energy source in many industrial applications. Empirical findings by Krawczyk et al. [14]. and Kristanto & Rachmansyah [16] demonstrate that the co-combustion of RDF in cement kilns and power plants can significantly reduce lignite or coal consumption without compromising thermal performance or energy output.

This substitution is not merely a technical improvement but a systemic shift in how industrial operations manage their inputs and outputs. In cement production, RDF integration supports both the thermal energy requirements of kilns and environmental performance goals. When properly managed, the combustion of RDF emits fewer greenhouse gases than coal, thereby contributing to lower carbon footprints and helping industries meet climate targets. Moreover, the high-temperature environment in cement kilns ensures the safe thermal destruction of potential contaminants in RDF, minimizing risks to air quality and public health [45-47].

Beyond environmental advantages, RDF integration plays a crucial role in closing material loops, which is a foundational concept in the circular economy. By diverting large volumes of municipal and commercial waste from landfills and converting them into fuel, RDF production transforms waste into a valuable resource. Maria Margarida Mateus et al. emphasized this role, noting that RDF promotes waste valorization and supports the shift from a linear to a circular production model, particularly in industrial processes where waste-to-energy pathways are viable [35].

However, infrastructure readiness and stakeholder coordination are essential for the successful integration of RDF into supply chains [48]. First, upstream systems, such as waste segregation, sorting, and collection, must be well established. Effective segregation at the source—whether at the household, commercial, or municipal level—ensures that the RDF feedstock has a high calorific value and minimal contamination. Following collection, waste must undergo mechanical treatment processes, such as shredding, drying, and sometimes pelletizing, before it becomes suitable for use in industrial settings.

The integration process also necessitates investments in technology and logistics, including RDF production facilities, storage systems, transportation networks, and combustion technologies adapted to RDF characteristics. Industries must upgrade or retrofit their boilers, kilns, or incinerators to accommodate RDF's variable composition of RDF, which differs significantly from that of traditional fossil fuels in terms of moisture, ash content, and volatile matter.

Furthermore, collaboration among stakeholders is critical to achieve this goal. Local governments must enact supportive policies and regulations that promote the adoption of RDF while ensuring environmental safety. Waste management companies play a central role in maintaining consistent RDF quality and supply, and industries must commit to adopting and investing in RDF-compatible technologies. These collaborations ensure not only the technical feasibility of RDF integration, but also its long-term economic and environmental sustainability.

3.3. *Environmental and economic benefits of RDF utilization*

RDF offers notable environmental and economic advantages [49]. From an ecological and environmental perspective, RDF utilization reduces dependence on landfilling and significantly mitigates methane emissions, a greenhouse gas with a global warming potential far greater than that of CO_2. Moreover, the displacement of conventional fossil fuels, particularly in cement production, contributes to substantial reductions in CO_2 emissions, aligning with broader climate change mitigation goals [33].

Economically, RDF enhances resource efficiency by transforming municipal waste into marketable fuel alternatives. The financial viability of RDF has been affirmed by Yahya et al.[27] and Sarquah et al. [1], who report favorable cost-benefit outcomes in energy recovery and fuel substitution scenarios. Moreover, RDF adoption reduces dependence on conventional landfill systems, thereby lowering disposal costs and supporting the advancement of circular economy practices [35, 50, 51].

3.4. *Challenges and policy implications*

Despite these benefits, there are several challenges to the widespread adoption of RDF. One major issue is the variability in waste composition, which can affect the quality and calorific value of the RDF. This challenge necessitates advanced sorting and pretreatment processes, which require additional investment in technology and infrastructure [23]. Furthermore, the regulatory framework surrounding RDF production and utilization is still developing, particularly regarding quality control, environmental standards, and waste segregation policies [26].

Policy implications are also critical for supporting RDF development. Governments must provide clear regulations and incentives to encourage the adoption of RDF in industrial processes. This includes supporting technological advancements in waste segregation, treatment and quality control. Additionally, policies that promote the use of renewable energy and reduce reliance on fossil fuels can enhance the integration of RDF into green production systems [11].

3.5. *Comparative analyses with traditional fuel or waste management systems*

RDF demonstrates clear advantages over conventional waste management and fossil fuel-based energy systems. RDF offers a more sustainable alternative to fossil fuels by reducing the reliance on coal and lowering the environmental impact of waste disposal. Krawczyk et al. [31] and Mudassar et al. [32] emphasized the environmental benefits of RDF compared to traditional fuels, including reduced CO_2 emissions and lower energy consumption in certain industrial applications. Notably, the heating value of RDF closely matches that of low-rank coal, whereas municipal solid waste (MSW) exhibits significantly lower calorific potential [31]. The ultimate analysis also showed a high sulfur content in the coal sample. Figure 4 illustrates the potential energy recovery from 5,000 tons/day of MSW and RDF in Lahore, underscoring RDF's role of RDF in narrowing the city's energy supply demand gap through waste-to-energy conversion.

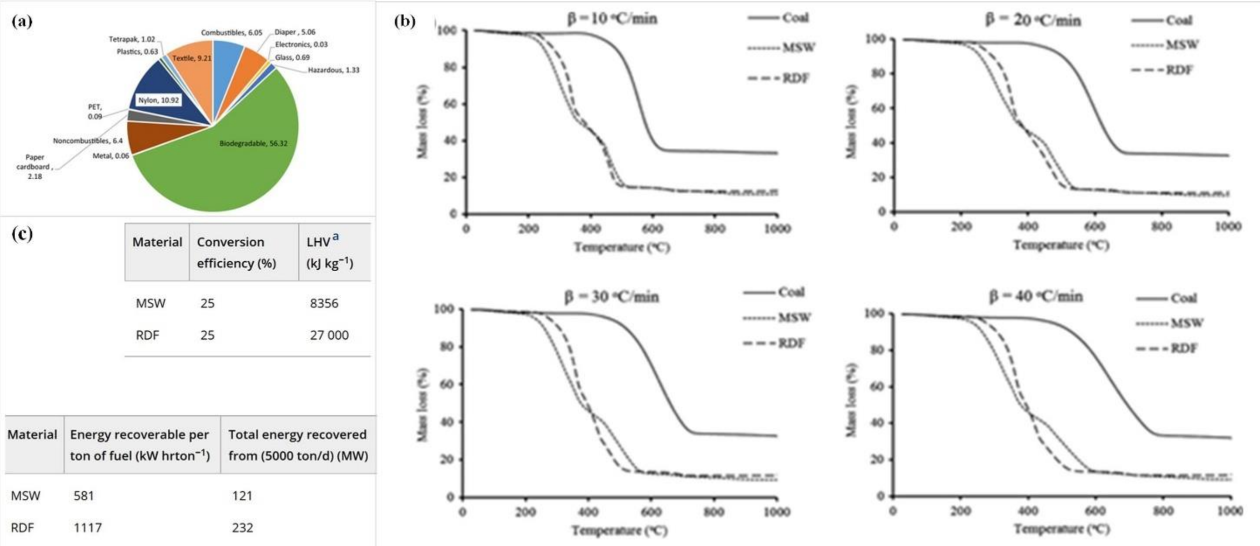

Figure 4. Combustion comparison of coal, MSW, and RDF: (a) average composition of Lahore MSW; (b) TG curves at four heating rates; (c) energy recovery potential via incineration. Adapted from Ref. [40].

RDF's role of RDF in replacing or complementing traditional waste management systems is also significant. Traditional methods, such as landfilling or incineration without energy recovery, contribute to environmental degradation. In contrast, RDF utilizes waste as a resource, converting what would otherwise be discarded into an energy source. This not only addresses waste disposal challenges but also contributes to a more sustainable and economically viable waste management system [1].

3.6. *Future directions and recommendations*

While this study highlights the potential of integrating refuse-derived fuel into sustainable supply chain practices, further empirical validation and large-scale pilot projects are needed to confirm its feasibility and scalability across diverse industrial contexts. Future research should explore advanced waste characterization methods to improve feedstock quality, as well as policy and economic incentive models to encourage broader adoption. In line with the global trend toward digitalization and Industry 4.0, advanced technological tools such as artificial intelligence (AI) are increasingly relevant for enhancing green supply chain strategies and optimizing waste-to-energy processes, including refuse-derived fuel (RDF) production. Additionally, the implementation of artificial intelligence–driven methods — such as AI-powered sorting systems, predictive analytics, and machine learning — has shown the potential to significantly improve waste-to-energy conversion efficiency and operational performance in solid waste management systems, achieving accuracy rates up to 99.95% and reducing costs by over 13% [52, 53]. By leveraging these digital tools, stakeholders can achieve higher levels of operational performance, circularity, and environmental impact minimization in the construction industry. Future investigations integrating these advanced approaches will provide valuable insights into sustainable production, waste management, and green supply chain innovations. Figure 5 shows the future direction of RDF integration in green supply chains.

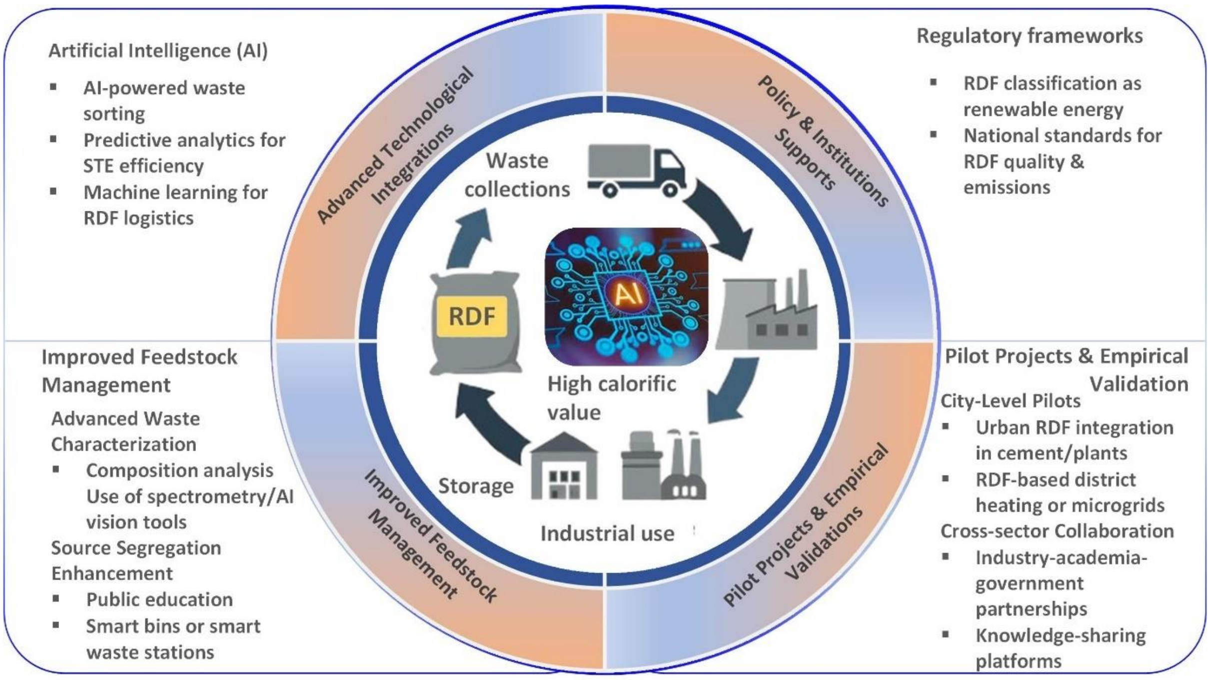

Figure 5. Future directions for RDF integrations in green supply chains

4. Conclusions

Based on the integrative review, the integration of Refuse-Derived Fuel (RDF) into sustainable supply chain management demonstrates significant potential in supporting green production through environmental, economic, and technological benefits. RDF not only reduces reliance on fossil fuels and mitigates greenhouse gas emissions, particularly in energy-intensive industries such as cement production, but also contributes to circular economy practices by converting municipal solid waste into valuable energy sources. Despite these promising advantages, challenges such as inconsistent waste composition, technological requirements, and underdeveloped regulatory frameworks must be addressed through coordinated stakeholder collaboration and supportive policy interventions. Overall, RDF presents a viable and sustainable alternative that, when effectively integrated into supply chain processes, can enhance energy efficiency, reduce environmental impact, and promote more resilient and eco-friendly industrial systems. Future studies should explore the optimization of RDF production technologies and develop comprehensive policy frameworks to facilitate wider adoption. In addition, examining consumer acceptance and market readiness is recommended to ensure the successful implementation and long-term sustainability of RDF within green supply chains.

Author's Declaration

Authors' contributions and responsibilities

LD Muhammad Raldi: Conducted the integrative literature review, performed thematic analysis, developed the conceptual framework, and wrote the original draft. **Setia Damayanti**: Supervised the research, guided the conceptual framework and methodology, and reviewed and edited the manuscript. **Ridwan**: Contributed to the data analysis discussion, provided additional input, and assisted in the final manuscript revisions as per the supervisor's instructions.

Acknowledgment

The authors would like to express their gratitude to Pancasila University, especially to Dr. Setia Damayanti for her invaluable guidance and continuous support throughout the research process. Appreciation is also extended to Ridwan for his collaboration and contributions to Gunadarma University.

Availability of data and materials

All data supporting the findings of this study are available from the corresponding author upon reasonable requests.

Competing interests

The authors declare no conflicts of interest related to this study.

References

[1] K. Sarquah *et al.*, "Characterization of Municipal Solid Waste and Assessment of Its Potential for Refuse-Derived Fuel (RDF) Valorization," *Energies (Basel)*, vol. 16, no. 1, p. 200, 2022, doi: https://doi.org/10.3390/en16010200.

[2] C. Vlachokostas, "Closing the Loop Between Energy Production and Waste Management: A Conceptual Approach Towards Sustainable Development," *Sustainability*, vol. 12, no. 15, p. 5995, 2020, doi: https://doi.org/10.3390/su12155995.

[3] S. Y. S. Rahayu, "Sustainable Development of Refuse-Derived Fuel (RDF) for Alternative Fuel Use in Cement Factories," *IOP Conf Ser Earth Environ Sci*, vol. 1482, no. 1, p. 012056, 2025, doi: https://doi.org/10.1088/1755-1315/1482/1/012056.

[4] M. Sarkar and Y. W. Seo, "Biodegradable Waste to Renewable Energy Conversion Under a Sustainable Energy Supply Chain Management," *Mathematical Biosciences and Engineering*, vol. 20, no. 4, pp. 6993–7019, 2023, doi: https://doi.org/10.3934/mbe.2023302.

[5] S. Suganal and G. K. Hudaya, "Bahan bakar co-firing dari batubara dan biomassa tertorefaksi dalam bentuk briket (Skala laboratorium)," *Jurnal Teknologi Mineral dan Batubara*, vol. 15, no. 1, pp. 31–48, 2019, doi: https://doi.org/10.30556/jtmb.Vol15.No1.2019.971.

[6] B. H. M. Zahir, R. Nurcahyo, F. Farizal, and A. D. Wibowo, "Economic Assessment of Refuse-Derived Fuel (Rdf) Production as Waste Management Strategy and Alternative Fuel in Cement Kilns," *Journal of Law and Sustainable Development*, vol. 12, no. 2, p. e3220, 2024, doi: https://doi.org/10.55908/sdgs.v12i2.3220.

[7] Y. D. Prastika, M. Ulya, and M. F. F. Mu'tamar, "PENENTUAN PENERAPAN PRODUKSI BERSIH TERBAIK DI UKM KUE SERABI 'APEN JULIT GETTAS' KARANGANYAR-SUMENEP DAN ANALISIS NILAI TAMBAHNYA [Determination of the Best Application for Clean Production in the SME of Pancake 'Apen Julit Gettas' Karanganyar-Sumenep and Its Value Added Analysis]," *Jurnal Teknologi & Industri Hasil Pertanian*, vol. 24, no. 1, p. 31, Mar. 2019, doi: https://doi.org/10.23960/jtihp.v24i1.31-38.

[8] M. Švažas, V. Navickas, E. Krajňáková, and J. Nakonieczny, "Sustainable Supply Chain of the Biomass Cluster as a Factor for Preservation and Enhancement of Forests," *Journal of International*

Studies, vol. 12, no. 2, pp. 309–321, 2019, doi: https://doi.org/10.14254/2071-8330.2019/12-2/20.

[9] H. Kusumo and S. Rakasiwi, "Information System Supply Chain Management with FIFO Perpetual Method," *Advance Sustainable Science, Engineering and Technology*, vol. 3, no. 2, May 2021, doi: https://doi.org/10.26877/asset.v3i2.9722.

[10] A. D. Dwipayana and N. L. Darmayanti, "Green Energy Development Strategy Towards Green Logistics: Case Study At PT. Pelabuhan Indonesia III (Persero) Benoa Bali," *Jurnal Manajemen Industri dan Logistik*, vol. 8, no. 1, pp. 81–96, Sep. 2024, doi: https://doi.org/10.30988/jmil.v8i1.1415.

[11] C. Furqon, M. A. Sultan, H. W. Yuin, H. Hendrayati, and A. P. A, "Green Supply Chain Management Performance Measurement Using the Balanced Scorecard - Analytic Network Process in the Fresh Dairy Industry," *Jurnal Manajemen Industri dan Logistik*, vol. 6, no. 2, pp. 297–308, May 2023, doi: https://doi.org/10.30988/jmil.v6i2.1308.

[12] Jusuf Haurissa and Helen Riupassa, "ANALISA KONVEKSI PAKSA (PEMAKSAAN UDARA MASUK) PADA PROSES PEMBAKARAN BRIKET AMPAS SAGU".

[13] Jususf Haurissa, Helen Riupassa, Hendry Y. Nanlohy, and Suyatno, "PENGARUH PENAMBAHAN ADJUSTER PADA KOMPOR BRIKET TERHADAP JARAK PEMBAKARAN DAN LAJU PERPINDAHAN PANAS KONDUKSI".

[14] A. Z. Abidin *et al.*, "Comparative Analysis of Waste Management Between Masaro and Refuse-Derived Fuel (RDF) Technologies in West Java," *E3s Web of Conferences*, vol. 519, p. 04004, 2024, doi: https://doi.org/10.1051/e3sconf/202451904004.

[15] A. Priyo Dwiarso, U. Marius Siahaan, and S. Maya Damayanti, "Project Identification And Selection to Prioritize the Best Alternative Project in the Context of Cement Manufacturing," *Journal of Engineering and Management in Industrial System*, vol. 13, no. 1, pp. 1–13, 2025, doi: https://doi.org/10.21776/ub.jemis.2025.013.01.1.

[16] Y. S. Kurniawan, H. O. Lintang, and L. Yuliati, "Preparation of green-emissive zinc oxide composites using natural betacyanin pigment isolated from red dragon fruit," *Indonesian Journal of Chemistry*, vol. 21, no. 1, pp. 57–65, Feb. 2021, doi: https://doi.org/10.22146/ijc.52351.

[17] N. Widha Setyanto, L. Riawati, R. Prasetyo Lukodono, and R. Ardianwiliandri, "PENENTUAN SETTING LEVEL OPTIMAL UNTUK PEMBUATAN BRIKET BERBAHAN BAKU LIMBAH DAUN PENYULINGAN NILAM," 2016. [Online]. Available: http://Jemis.ub.ac.id

[18] Siti Ajizah, Nur Hidayat, and Sri Surhatini, "Modelling Green Production Process in the Natural Dyes Batik Industry Using Cleaner Production Options".

[19] S. Peningkatan Produktivitas dan Kualitas Kedelai Lokal, N. Siswi Indastri, I. Yuliasih, G. Pramuhadi, B. Pengkajian Teknologi Pertanian Banten Jl Ciptayasa Km, and C. Serang, "STRATEGIES FOR INCREASING LOCAL SOYBEAN PRODUCTIVITY AND QUALITY WITH A GREEN PRODUCTIVITY APPROACH," *Jurnal Teknologi Industri Pertanian*, vol. 28, no. 3, pp. 342–353, doi: https://doi.org/10.24961/j.tek.ind.pert.2018.28.3.342.

[20] N. Siswi Indrasti, M. Romli, I. Sailah, and A. Permatasari, "CO-COMPOSTING OF BELTPRESS SOLID WASTE AND RICE STRAW BY USING AERATED STATIC PILE."

[21] M. Dahlan, E. Sulfiana, S. Purna yudha, and Muh. N. H. Amaluddin, "STUDI KARAKTERISTIK BRIKET ARANG BIOMASSA BERBASIS SCREW PRESS," *Jurnal Rekayasa Mesin*, vol. 15, no. 3, pp. 1643–1653, Dec. 2024, doi: https://doi.org/10.21776/jrm.v15i3.1824.

[22] Rianto Wibowo, "ANALISIS THERMAL NILAI KALOR BRIKET AMPAS BATANG TEBU DAN SERBUK GERGAJI."

[23] I. Urwatul Wusko, A. Noraidi Maulana, A. Sabitah, and Misbachudin, "UJI KUALITAS BRIKET ARANG DARI SEKAM PADI DAN SERBUK KAYU SEBAGAI BAHAN BAKAR ALTERNATIF," *Jurnal Rekayasa Mesin*, vol. 15, no. 3, pp. 1425–1436, Dec. 2024, doi: https://doi.org/10.21776/jrm.v15i3.1694.

[24] N. O. Solomon, P. Simpa, O. A. Adenekan, and S. C. Obasi, "Sustainable Nanomaterials' Role in Green Supply Chains and Environmental Sustainability," *Engineering Science & Technology Journal*, vol. 5, no. 5, pp. 1678–1694, 2024, doi: https://doi.org/10.51594/estj.v5i5.1136.

[25] Peni Shoffiyati and Fesa Putra Kristianto, "FURNITURE INDUSTRY GREEN SUPPLY CHAIN SUCCESS FACTORS: A SYSTEMATIC LITERATURE REVIEW," *Jurnal Teknologi Industri Pertanian*, vol. 35, no. 1, pp. 95–106, Apr. 2025, doi: https://doi.org/10.24961/j.tek.ind.pert.2025.35.1.95.

[26] A. Muhammad, B. M. Naidu, V. P. K. Sundram, M. Z. S. M. Hussain, L. L. Chew, and F. A. Amirrudin, "Sustainable Waste Management in Malaysia: Leveraging Supply Chain Solutions for a Greener Future," *Information Management and Business Review*, vol. 15, no. 3(SI), pp. 147–154, 2023, doi: https://doi.org/10.22610/imbr.v15i3(si).3469.

[27] S. Yahya, B. Susanti, and H. Fitriani, "Financial Feasibility Analysis Of Urban Waste Processing As Refused Derived Fuel For Cement Company," *Eduvest - Journal of Universal Studies*, vol. 4, no. 6, pp. 5352–5366, Jun. 2024, doi: https://doi.org/10.59188/eduvest.v4i6.1424.

[28] D. Prihandoko, C. W. Purnomo, P. K. Widyaputra, and N. Nasirudin, "Application of Refuse-Derived Fuel (RDF) Plant in Piyungan Landfill Municipal Solid Waste Management," *ASEAN Journal of Chemical Engineering*, vol. 22, no. 2, p. 296, Dec. 2022, doi: https://doi.org/10.22146/ajche.75560.

[29] F. D. Robi, S. Bambang, and M. B. Toriki, "Techno-Economic Study of the Use of Refuse-Derived Fuel (RDF) Biomass Waste Conversion into Electricity Using the Three-Stage Gasification Method and Dual Fuel Diesel Engine on Batam Island," in *Journal of Physics: Conference Series*, Institute of Physics, 2025. doi: https://doi.org/10.1088/1742-6596/2942/1/012023.

[30] Robi Fajerin Darmawan and Bambang Sudarmanta, "Kajian Tekno Ekonomi Terkait Konversi Limbah Biomassa Refuse Derived Fuel (RDF) Menjadi Listrik Melalui Metode Gasifikasi Tiga Tingkat dan Mesin Diesel Dual Fuel di Pulau Batam," *EduInovasi: Journal of Basic Educational Studies*, vol. 4, no. 2, pp. 1331–1361, Jul. 2024, doi: https://doi.org/10.47467/edu.v4i2.4319.

[31] P. Krawczyk, K. Badyda, and A. Mikołajczak, "The environmental impact of refuse derived fuel co-combustion with lignite," *MATEC Web of Conferences*, vol. 240, p. 05013, Nov. 2018, doi: https://doi.org/10.1051/matecconf/201824005013.

[32] M. Azam, S. S. Jahromy, W. Raza, C. Jordan, M. Harasek, and F. Winter, "Comparison of the combustion characteristics and kinetic study of coal, municipal solid waste, and refuse-derived fuel: Model-fitting methods," *Energy Sci Eng*, vol. 7, no. 6, pp. 2646–2657, Dec. 2019, doi: https://doi.org/10.1002/ese3.450.

[33] G. A. Kristanto and E. Rachmansyah, "The application of Refuse Derived Fuel (FDR) from commercial solid wastes to reduce CO_2 emissions in the cement industry: a preliminary study," *IOP Conf Ser Earth Environ Sci*, vol. 423, no. 1, p. 012014, Jan. 2020, doi: https://doi.org/10.1088/1755-1315/423/1/012014.

[34] I. M. W. Wijaya, I. G. N. M. Wiratama, I. K. A. Putra, and N. P. C. D. Atmaja, "Unlocking the Energy Potential of Temple Waste and Coconut Fiber through Refuse Derived Fuel Production toward Sustainable Energy," *Ecological Engineering & Environmental Technology*, vol. 24, no. 7, pp. 19–29, Jul. 2023, doi: https://doi.org/10.12912/27197050/169362.

[35] M. M. Mateus, D. Cecílio, M. C. Fernandes, and M. J. Neiva Correia, "Refuse derived fuels as an immediate strategy for the energy transition, circular economy, and sustainability," *Bus Strategy Environ*, vol. 32, no. 6, pp. 3915–3926, Sep. 2023, doi: https://doi.org/10.1002/bse.3345.

[36] A. Janda and W. M. Urbańska, "CURRENT PROBLEMS IN THE COMBUSTIBLE MUNICIPAL WASTE MANAGEMENT – A CASE STUDY FOR PRE-RDF, RDF AND SRF MANAGEMENT IN POLAND," *Zeszyty Naukowe SGSP*, vol. 2, no. 89, pp. 75–92, May 2024, doi: https://doi.org/10.5604/01.3001.0054.5447.

[37] M. Budihardjo, E. Yohana, B. Ramadan, A. Puspita, S. Adhana, and J. Rizkiana, "Study of Potential

Refuse Derived Fuels as Renewable Alternative Energy from a Jatibarang Landfill," *Pol J Environ Stud*, vol. 31, no. 4, pp. 3013–3020, Jun. 2022, doi: https://doi.org/10.15244/pjoes/145614.

[38] T. Li, W. Li, Z. Lou, and L. Wang, "Comprehensive Analysis of Industrial Solid-Waste-to-Energy by Refuse-Derived Fuel Technology: A Case Study in Shanghai," *Sustainability*, vol. 16, no. 10, p. 4234, May 2024, doi: https://doi.org/10.3390/su16104234.

[39] J. C. I. Rabetanetiarimanana, M. H. Radanielina, H. T. Rakotondramiarana, and D. Morau, "A Survey of the Gasification of Residual Household Waste," *Smart Grid and Renewable Energy*, vol. 13, no. 11, pp. 268–293, 2022, doi: https://doi.org/10.4236/sgre.2022.1311017.

[40] T. Weerasak and S. Sanongraj, "Potential of Producing Refuse Derived Fuel (RDF) from Municipal Solid Waste at Rajamangala University of Technology Isan Surin Campus," *Applied Environmental Research*, pp. 85–91, Jun. 2015, doi: https://doi.org/10.35762/AER.2015.37.2.7.

[41] D.-W. Shun, D.-H. Bae, S.-H. Jo, and S.-Y. Lee, "Combustion Study of 1MWe Circulating Fluidized Boiler for RDF," *Korean Chemical Engineering Research*, vol. 50, no. 5, pp. 837–842, Oct. 2012, doi: https://doi.org/10.9713/kcer.2012.50.5.837.

[42] N. Chommontha, A. Phongphiphat, K. Wangyao, S. Patumsawad, and S. Towprayoon, "Effects of operating parameters on co-gasification of coconut petioles and refuse-derived fuel," *Waste Management & Research: The Journal for a Sustainable Circular Economy*, vol. 40, no. 5, pp. 575–585, May 2022, doi: https://doi.org/10.1177/0734242X211003974.

[43] P. C. Mandala, I. D. A. A. Warmadewanthi, and R. Aniza, "STUDY OF OPTIMALIZATION SOLID WASTE OF REFUSE DERIVES FUEL (RDF) AT LANDFILL GRIYO MULYO, SIDOARJO DISTRICT," *INDONESIAN JOURNAL OF URBAN AND ENVIRONMENTAL TECHNOLOGY*, pp. 30–41, Feb. 2024, doi: https://doi.org/10.25105/urbanenvirotech.v7i1.19315.

[44] W. Zamrudy, S. Santosa, A. Budiono, and E. Naryono, "A review of Drying Technologies for Refuse Derived Fuel (RDF) and Possible Implementation for Cement Industry," *Int J Chemtech Res*, vol. 12, no. 01, pp. 307–315, 2019, doi: https://doi.org/10.20902/IJCTR.2019.120137.

[45] I. A. S. Wulandari, H. C. Wahyuni, I. Mardiyah, and N. R. Hanun, "Environment Performance Index Assessment on Food Production: A Case Study in Indonesia," *Jurnal Teknik Industri*, vol. 23, no. 2, pp. 93–104, Aug. 2022, doi: https://doi.org/10.22219/jtiumm.vol23.no2.93-104.

[46] D. K. Hadi, A. P. Setiawan, O. V. Indrian, and E. F. Rosyid, "Evaluation of Sustainability Supply Chain Performance in the Food Industry: A Case Study," *Jurnal Teknik Industri*, vol. 24, no. 2, pp. 95–108, Aug. 2023, doi: https://doi.org/10.22219/jtiumm.vol24.no2.95-108.

[47] I. A. S. Wulandari, N. R. Hanun, and A. S. Cahyana, "A Model for Enhancing the Environmental Performance by Integrating Lean and Green Productivity Concept: A Case Study of Food Production," *Jurnal Teknik Industri*, vol. 25, no. 1, pp. 83–96, Feb. 2024, doi: https://doi.org/10.22219/JTIUMM.Vol25.No1.83-96.

[48] A. Setiawan Rusdianto, M. Choiron, and N. Novijanto, "KARAKTERISASI LIMBAH INDUSTRI TAPESEBAGAI BAHAN BAKU PEMBUATAN BIOPELLET CHARACTERIZATION OF TAPE INDUSTRY WASTE AS BIO PELLET RAW MATERIAL."

[49] A. S. Rusdianto, F. Septyatha, and M. Choiron, "Analisis Kelayakan Finansial Industri Bio-pellet Kulit Kopi di Kabupaten Jember Financial Feasibility Analysis of Coffee Peel Bio-pellet Industry in Jember Regency," *Jurnal Teknologi dan Manajemen Agroindustri*, vol. 7, pp. 89–94, 2018, doi: https://doi.org/10.21776/ub.industria.2018.007.02.3.

[50] Yusriana, Rachman Jaya, and Meilita T. Sembiring, "EKONOMI SIRKULAR PADA MANAJEMEN RANTAI PASOK AGROINDUSTRI: KONSEPTUAL DAN RANCANGAN IMPLEMENTASI," *Jurnal Teknologi Industri Pertanian*, pp. 196–205, Aug. 2023, doi: https://doi.org/10.24961/j.tek.ind.pert.2023.33.2.196.

[51] Efri Yulistika, Suprihatin, and Purwoko, "POTENSI PENERAPAN KONSEP EKONOMI SIRKULAR UNTUK PENGEMBANGAN INDUSTRI TAHU YANG BERKELANJUTAN,"

Jurnal Teknologi Industri Pertanian, pp. 254–266, Dec. 2023, doi: https://doi.org/10.24961/j.tek.ind.pert.2023.33.3.254.

[52] D. B. Olawade *et al.*, “Smart waste management: A paradigm shift enabled by artificial intelligence,” *Waste Management Bulletin*, vol. 2, no. 2, pp. 244–263, Jun. 2024, doi: https://doi.org/10.1016/j.wmb.2024.05.001.

[53] V. Melinda, T. Williams, J. Anderson, J. G. Davies, and C. Davis, “Enhancing Waste-to-Energy Conversion Efficiency and Sustainability Through Advanced Artificial Intelligence Integration,” *International Transactions on Education Technology (ITEE)*, vol. 2, no. 2, pp. 183–192, May 2024, doi: https://doi.org/10.33050/itee.v2i2.597.