Jurnal Asiimetrik: Jurnal Ilmiah Rekayasa Dan Inovasi
Terakreditasi "**Peringkat 3**" berdasarkan SK Dirjendiktiristek, Nomor: 225/E/KPT/2022
Volume 6 Nomor 1 Tahun 2024, Januari 2024, Halaman 165-174
Website : http://journal.univpancasila.ac.id/index.php/asiimetrik/

p-ISSN 2655-1861
e-ISSN 2716-2923

Soft System Methodology Approach: Case Study of Renewable Energy Development of Wood Pellets as an Implementation of a Circular Economy

Pendekatan Metodologi *Soft System*: Studi Kasus Pengembangan Energi Terbarukan Wood Pellet Sebagai Implementasi Ekonomi Sirkular

Dino Rimantho*
Industrial Engineering Deparment, Pancasila University, Srengseng Sawah, DKI Jakarta, Indonesia

Article information:

Received:
08/12/2023
Revised:
18/12/2023
Accepted:
23/12/2023

Abstract

The development of wood pellets as a sustainable energy source derived from biomass waste has not significantly increased over the past few decades, despite a rise in demand for and sales of its products worldwide. Several variables contribute to the intricate issue of creating wood pellets from biomass waste as a renewable energy source, including the roles and responsibilities of various stakeholders, including the government, financial institutions, academia, the manufacturing sector, and non-governmental organizations. This article uses a waste management model that employs the Soft System Methodology (SSM) approach to assess the challenge of producing wood pellets from biomass waste as a renewable energy source and possible solutions. Data and information on the development of wood pellets as a renewable energy source derived from biomass waste were acquired through a literature review and in-depth interviews with specialists. The study's findings demonstrate that using the SSM technique leads to a conceptual model that depicts the interactions between sub-elements to enhance the development of wood pellets as a biomass waste-derived renewable energy source. This concept was developed to lessen any adverse effects and enhance the processing of biomass waste. The success of goals is determined by the importance of each actor's role and the collaboration of other actors, including local, national, and corporate governments. The Ministry of Environment and Forestry is the primary stakeholder and has a say in policy and program formulation. The Ministry of Industry, Energy and Mineral Resources, financial institutions, and other relevant organizations can help with this effort.

Keywords: wood pellets, renewable energy, biomass waste, SSM, conceptual model.

***SDGs*:**

Abstrak

Pengembangan pelet kayu sebagai sumber energi berkelanjutan yang berasal dari limbah biomassa belum meningkat secara signifikan selama beberapa dekade terakhir, meskipun terjadi peningkatan permintaan dan penjualan produk-produknya dalam skala dunia. Sejumlah variabel berkontribusi terhadap rumitnya permasalahan pembuatan pelet kayu dari limbah biomassa sebagai sumber energi terbarukan, termasuk peran dan tanggung jawab berbagai pemangku kepentingan termasuk pemerintah, lembaga keuangan, akademisi, sektor manufaktur, dan organisasi non-pemerintah. Artikel ini menggunakan model pengelolaan limbah yang menggunakan pendekatan *Soft System Methodology* (SSM) untuk menilai tantangan produksi wood pellet sebagai sumber energi terbarukan dari limbah biomassa dan kemungkinan solusinya. Melalui kajian literatur dan wawancara mendalam dengan sejumlah pakar, diperoleh data dan informasi mengenai pengembangan wood pellet sebagai sumber energi terbarukan yang berasal dari limbah biomassa. Temuan penelitian menunjukkan bahwa penggunaan teknik SSM menghasilkan model konseptual yang menggambarkan interaksi antar sub-elemen untuk meningkatkan pengembangan pelet kayu sebagai sumber energi terbarukan yang berasal dari limbah biomassa. Konsep ini dikembangkan untuk mengurangi dampak negatif dan meningkatkan pengolahan limbah biomasa. Keberhasilan tujuan ditentukan oleh pentingnya peran masing-masing aktor dan kolaborasi aktor lainnya, termasuk pemerintah daerah, nasional, dan perusahaan. Kementerian Lingkungan Hidup dan Kehutanan merupakan pemangku kepentingan utama dan mempunyai suara dalam perumusan kebijakan dan program. Kementerian Perindustrian, Kementerian Energi dan Sumber Daya Mineral, lembaga keuangan, dan organisasi terkait lainnya dapat membantu upaya ini.

Kata Kunci: wood pellet, energi terbarukan, limbah biomassa, SSM, model konseptual.

*Correspondence Author
email : dino.rimantho@univpancasila.ac.id

1. INTRODUCTION

The concept of a circular economy (CE) is becoming increasingly popular in business. To maximize resource efficiency and minimize waste, this economic paradigm replaces the conventional "take, create, and throw away approach with a new reduce, reuse, and recycle strategy. Companies that use circular economy models save money, increase resilience, and reduce environmental impact (Sassanelli *et al.*, 2019). Similarly, the business world now understands that the energy and natural resources used as operational materials are limited and cannot be renewed. Therefore, the business world needs to use renewable energy sources and minimize the carbon footprint produced (Sassanelli *et al.*, 2019; Belhadi *et al.*, 2022; Hasheminasab *et al.*, 2022).

The circular economy concept is not limited to recycling materials and energy used in production. Businesses everywhere must embrace closed production and build it into their business plans to continue making money while protecting the environment. To achieve environmental sustainability goals, the business world must adopt a circular economic system, especially if they want to use renewable energy sources as their primary energy source (Patwa *et al.*, 2021). To achieve optimal value creation in a circular economy, producers must minimize energy input, especially that from non-renewable elements. This will allow materials to remain in the production cycle for as long as possible, reducing waste generation (Olabi, 2019).

Stakeholders involved in the circular economy can achieve environmental sustainability through energy management using clean and renewable energy sources during production. Using renewable energy sources, such as wind, solar, hydrogen, biomass, and wood pellet power, has been proven to significantly reduce greenhouse gas emissions, especially carbon dioxide emissions and other harmful gases from production. This reduces air pollution in the environment over time (Lima *et al.*, 2020; Wang *et al.*, 2021; Bello and Solarin, 2022).

In the process of transitioning to sustainable energy, initiatives to improve energy efficiency along the value chain are also an excellent example of the circular economy concept. To analyze the amount of energy used at each stage of the value chain, as well as the amount of energy and materials that are wasted or used incorrectly in the process, businesses must carry out integrated energy audits and evaluations (Cavicchi, Oppi and Vagnoni, 2022). Reducing waste and the amount of non-renewable energy used in the production process can also be done through symbiosis and vertical and horizontal integration between businesses involving the exchange of materials, energy, and by-products (Kristia and Rabbi, 2023).

The business world must prepare processes to convert waste materials from production and consumption into energy sources to integrate renewable energy into the circular economy model. The reuse and recycling of waste from consumer consumption processes—a process known as waste-to-energy conversion—as well as the processing of material scraps and energy wasted during production, are important components of the cradle-to-cradle system (Malinauskaite *et al.*, 2017). One of the waste materials that can be used in renewable energy is biomass.

The development of biomass as a renewable energy source holds significant potential in Indonesia. The anticipated capability for generating biomass energy is 50 GWe, however the current installed capacity for biomass energy in Indonesia is approximately 1600 MW (Pradnyaswari *et al.*, 2022). Biopellets are a type of biomass product that is derived from sawdust waste and transformed into tiny alternative fuels, distinct from briquettes. With an energy density of 4,280 kcal/kg, bio pellets have the potential to substitute LPG gas as a cooking fuel (Hoefnagels, Junginger and Faaij, 2012; Proskurina *et al.*, 2019).

In addition to its increased efficiency, the utilization of biopellets as a fuel offers greater economic benefits, as well as improved cleanliness and ease of use for both home and power generation applications. Furthermore, biopellets have a reduced carbon content compared to LPG.

Consequently, it is strongly advised to utilize biopellets as a source of fuel in Indonesia. Biopellets are classified as reclaimed wood fuels, which are biomass derived from socio-economic activities unrelated to the forest and wood processing industries. The process of pellet production involves the application of a densification approach, which can enhance the calorific value per unit volume. This method also presents a promising and competitive solution for alternative cooking fuels (Rimantho *et al.*, 2023). Furthermore, wood pellet stoves emit less smoke compared to cooking facilities fueled by firewood, which can result in a reduced workload (Pradnyaswari *et al.*, 2022).

A number of studies have tried to explain this gap by identifying barriers to CE implementation (Kirchherr *et al.*, 2018; Bocken and Geradts, 2020), with a primary focus on firms' external barriers (Grafström and Aasma, 2021). Therefore, comprehensive knowledge of the reasons behind and mechanisms of firms' internal barriers that hinder CE implementation is still insufficient.

Previous research shows that cultural (Kirchherr *et al.*, 2018), economic (de Jesus and Mendonça, 2018), or cultural-cognitive (Ranta, Aarikka-Stenroos and Mäkinen, 2018) factors are the main elements that hide internal barriers. Grafstrom and Aasma emphasize how important it is for businesses adopting CE to identify barriers from their perspective in order to reduce business risks (Grafström and Aasma, 2021). Additionally, previous research has mainly concentrated on individual barriers, ignoring the way these barriers interact (Bening, Pruess and Blum, 2021).

As a result, there is a lack of a comprehensive framework that explains how CE barriers interact and relate at both internal and external organizational levels (Tura *et al.*, 2019). Finally, previous research has not produced specific strategic advice for businesses on how to impact and overcome CE barriers. Here are the ways this research fills the gaps in the literature mentioned above: First, this research pinpoints the internal barriers to CE implementation. Second, it provides a better understanding of exterior obstacles and their possible configurations. Third, this study examines the relationship between external and internal barriers. Finally, they use the insights gained to create strategic management suggestions for business executives who wish to implement CE in their companies.

Based on the description above, a separate strategy is needed because of the complexity of implementing a circular economy. The aim of this article is to build a circular economy model that considers the role of institutions, actors, and rules of the game in the development of renewable wood pellet energy by a soft system methodology approach.

2. METHODOLOGY

One way to overcome unstructured problems is to use systematic thinking techniques, or systems thinking. This methodology can offer a synopsis of the correlation between variables and actions carried out, along with interested parties from input to final product. This method also makes it possible to identify interactions between the various parts, subsystems and elements that make up a system. The systems thinking approach considers a number of factors, including goals, outcomes, and current goals and ambitions (Rimantho, 2020).

This research applies the Soft System Methodology (SSM) method as a systems approach in developing wood pellet renewable energy. The systems approach is a new approach to problem solving that considers problems holistically and not part by part. To overcome certain problems using SSM as a method for evaluating renewable energy development, systems thinking emerged—a transdisciplinary field—as an answer to the limitations of technical approaches in reduction process.

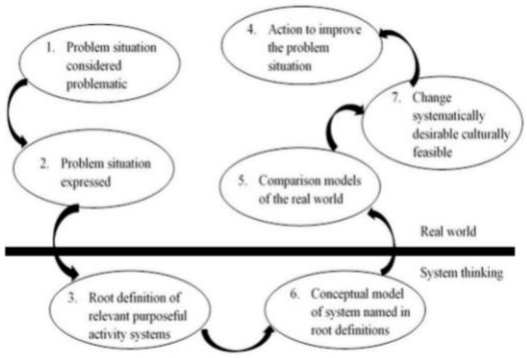

Figure 1. SSM protocol by Checkland (Checkland, 1999).

SSM works effectively to assess unstructured problem scenarios that are difficult to determine at the moment (Cavana and Maani, 2000). This approach stems from the belief that the basis for developing a system must focus more on problems that have ambiguous or abstract characteristics. In addition, Checkland implemented the SSM approach in seven stages, as depicted in Figure 1 (Checkland, 1999).

This article explains the seven steps taken to prepare a sustainable electronic waste management strategy in DKI Jakarta, referring to the Checkland Protocol.

1) Analysis that outlines appropriate conditions or arrangements from the perspective of developing wood pellets as renewable energy. The first stage is to ask about the problems that need to be resolved regarding the development of renewable energy, with an emphasis on its impact on the environment, society, and the economy.
2) Be aware of the problems faced by each stakeholder. This understanding includes the requirements that stakeholders have. Apart from that, the understanding is based on the capabilities and accountability of the parties involved. The result of this understanding is sometimes called a rich image, namely a picture of the participation of several stakeholders.
3) Apply the CATWOE technique (Client or Customer, Actor, Transformation, Weltanschauung, Owner, and Environmental Constraint) to gain an understanding of the perspective of each stakeholder.
4) Produce conceptual or virtual designs that explain how different operations or activities depend on each other. The correlation between the intake, process, and output of an activity with other activities is shown through this virtual design.
5) Prepare a schedule of tasks to be carried out and generally draw parallels between the transcendental plans that have been made and the actual situation.
6) Checking possible variations. At this stage, disputes between specialists may arise. Several things may change. This includes policy strategies, changes in composition, and the potential transformation of culture and values in the form of a movement towards presumptive rules.
7) Carry out modifications to the designed layout.

3. RESULTS AND DISCUSSION

3.1. Analyze The Situation

Even though there are laws or regulations governing the development of renewable energy in Indonesia, this is still not going well. Therefore, this can lead to many complicated problems. Apart from that, various factors, including market potential, income level, culture, education level, and culture, influence the growth of wood pellets as a renewable energy source. A comprehensive identification process is needed to be able to produce wood pellets as a renewable energy source. A framework for the development of wood pellets as renewable energy will be provided by understanding the features of this process. Apart from that, this will also provide information support to relevant stakeholders regarding who might produce wood pellets as a renewable energy source. Additionally, characterization can be used to measure environmental impacts and balance the effectiveness of management actions.

Figure 2. Wood pellet from biomass.

The aim of developing renewable wood pellet energy is to utilize biomass for renewable energy. Management of biomass waste as raw material for wood pellets can be said to be good if the production process does not endanger the environment or human health. To support the sustainability of renewable energy in Indonesia, it

is necessary to create a circular economic model for the development of wood pellets to maximize the development of biomass as a raw material. Referring to the previous explanation, Figure 2 illustrates the development of wood pellets as a renewable energy source leading to a conclusion.

Uncertainty regarding the future financial viability of wood-based biomass production has reduced the interest of wood suppliers (loggers, forestry officers) in wood-based biomass harvesting on private land and the ability of landowners to access these markets. The costs of harvesting and transporting biomass to pellet mills, price competition from other wood products, and low biomass prices have reduced the potential rate of wood-based biomass harvesting on private forest lands. Additionally, price competition from fossil fuels and other renewable energy sources has limited wood pellet production to supply the domestic market, meaning that available wood-based biomass is not being used to meet fossil fuel needs. Furthermore, the price of wood-based biomass is still unable to compete with alternative energy sources, and wood pellet production will likely remain dependent on international demand, meaning that sustainability standards must be met to guarantee biomass production in the future. The low interest of investors in developing wood pellets also has the potential to result in the suboptimal use of biomass waste as raw material for wood pellets.

3.2. Root Definition Problem

From an environmental, social, and economic perspective, the issue of making wood pellets to support renewable energy has emerged, largely due to the impacts it causes. This impact may have a significant impact on the growth of renewable energy sources in Indonesia which is less than ideal and may also increase the possibility of conflict and institutional chaos. Based on this, relevance between stakeholders will be used to describe how existing challenges relate to each other.

The CATWOE approach can be used to ascertain and explain the importance of each participant in the conversion of biomass waste into wood pellets. A comprehensive explanation of this process is given in the next section.

a. ***Clients*** can consist of the community, other stakeholders involved in the development of wood pellets from biomass waste, and end users of wood pellets are considered clients or customers. The groups affected by the development of renewable wood pellet energy are the community and other stakeholders.
b. ***Actors*****,** which are the part that plays an important role in producing consequences in the social, political, and economic fields, are actors. This component includes environmental non-governmental organizations (NGOs), the informal sector, and institutions/organizations that develop wood pellets from biomass waste. This group is aware of the possibility of differences of opinion originating from differences in the interests of all parties involved.
c. ***The transformation*** process requires an agreement regarding the development of wood pellets derived from biomass waste as renewable energy that considers issues of social, environmental, and financial sustainability.
d. ***Weltanschauung*** is German, which serves as a basis for developing appropriate and meaningful definitions given the situation. There is no common understanding that can provide balance for each stakeholder in facing competing interests related to finance, energy, and the environment. Therefore, coordination and regulations are needed that can balance the interests of all stakeholders.
e. ***Owner*****,** includes every element of government administration, including the Ministry of Trade, Industry, and the Environment. The Forestry Service and the Industrial Trade Service are the two management agencies involved in developing wood pellets from biomass waste at the regional or provincial level. The main responsibility of this group is to create implementation stages and regulations for the development of wood pellets from

biomass waste that are related to sustainability considerations.

f. ***Environmental*** constraints are factors that might make it difficult for each stakeholder to carry out their activities. The level of understanding is the main barrier. Due to the lack of socialization from the government, each stakeholder's understanding is different. As a result, the regulations set do not function optimally.

3.3. Conceptual Model

The conceptual model shows how the roles and activities of each stakeholder interact with each other to achieve goals. There is a relationship between each function that covers the gaps left by the other functions. Figure 3 and Figure 4 depict the conceptual model and relationships between various stakeholders in the development of wood pellets made from biomass waste as a renewable energy source.

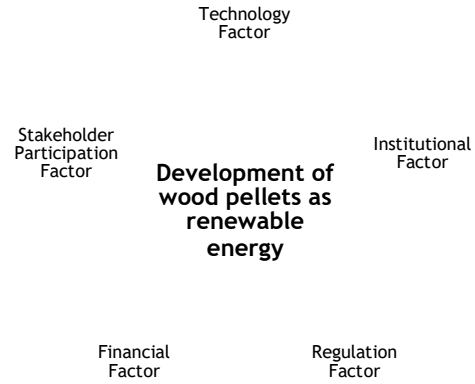

Figure 3. Factors in the development of wood pellets as renewable energy.

The existence of a high demand and dependency scenario in the development of wood pellets made from biomass waste as a sustainable energy source is a problem that arises.

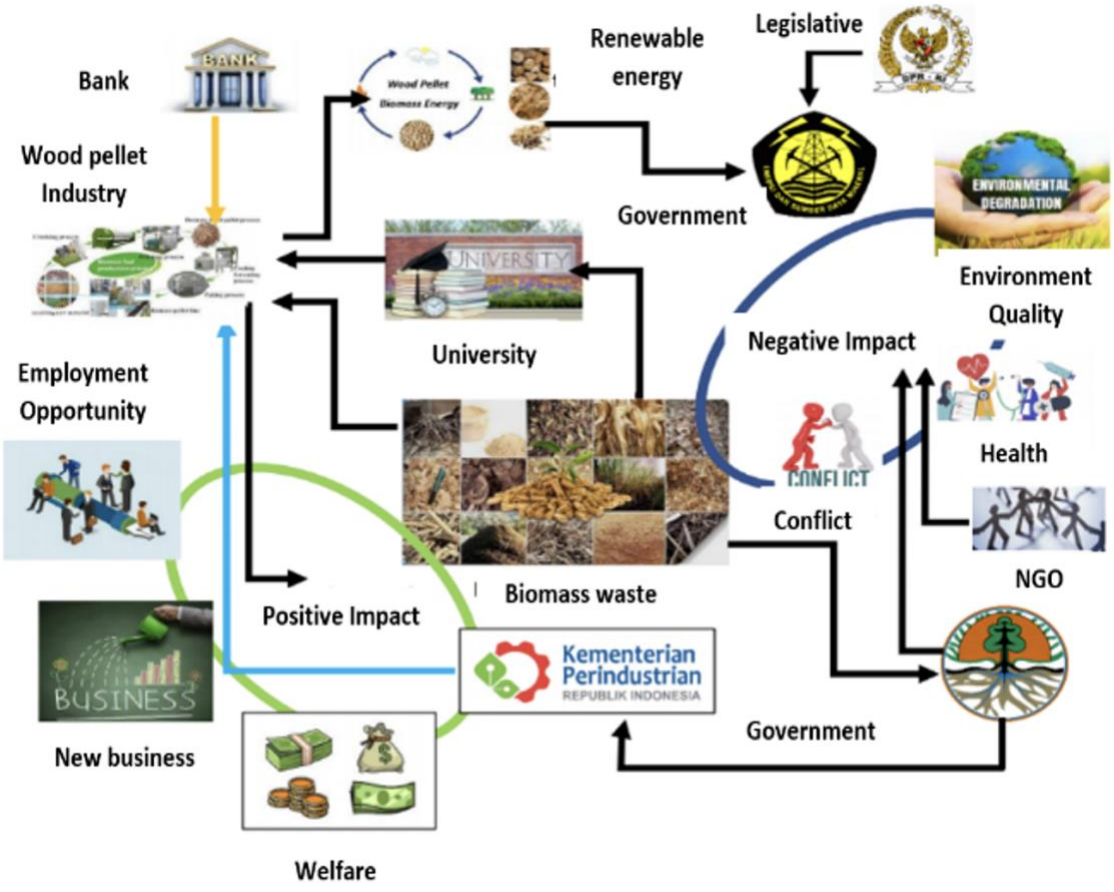

Figure 4. Rich picture of the development of wood pellets as renewable energy.

Additionally, there is no official oversight of these activities. On the other hand, there is usually an increase in demand for wood pellet products in the international market.

Efficient implementation of the major contributions of each stakeholder is necessary. The government has an important role in developing and implementing policies and regulations that prioritize the welfare of all sectors of society, while also considering environmental, economic, and social sustainability. It will serve as a comprehensive guide for all individuals involved in environmental regulation and the development of wood pellets as renewable energy. Actors such as small industry and other stakeholders have a role in implementing policies. Monitoring and control can be carried out collaboratively with various stakeholders, including government representatives in the environmental sector, NGOs, academics, and environmental observers.

To develop wood pellets as a renewable energy source originating from biomass waste, all stakeholders must take concrete actions and monitor the implementation of regulations. Therefore, criteria for the level of implementation of each stakeholder's functions—which relate to the three aspects of management, namely efficacy, efficiency, and effectiveness—must be established. These specifications will act as a roadmap for implementing continuous process improvements. Apart from that, there are five factors that need to be considered in developing wood pellets as a sustainable energy source originating from biomass waste: institutional support, financing, legal regulations, operational technical elements, and community involvement. When used, these five elements will be able to overcome problems that may arise from an economic, social, and environmental perspective as shown in Figure 4.

3.4. Comparison of Model and Reality

A more comprehensive comparative analysis stage is needed between predicted system goals and actual situations in the real world to identify the implementation of the system design created. Various methods can be applied, including:

a. Simply record the conclusions drawn from the comparisons made.
b. Establish formal comparison criteria; This is followed by activities to study and assess goal differences.
c. Carry out a system simulation. Prepare a plan that has been implemented previously, then implement the plan based on the designed layout, and finally carry out an analysis of the layout.
d. Pay attention to whether the design created can help achieve the desired results.

3.5. Improvements to The Model

The aim of modifying the systems thinking model is to bring design and the real world closer. The adjustments made are related to the level of existing gaps. In addition, the model design needs to be modified to suit the actual situation. Additionally, the goal of design modification is to produce something that is culturally feasible and logical. These two requirements imply that a design must be able to offer reasonable resolution and incorporate appropriate values from the real world (Figure 5).

3.6. Model Application

Once the design is based on logical requirements and suitability, the optimal solution to meet each goal is found through implementation. By changing perceptions and offering interpretations from all parties involved in the development of wood pellets as a renewable energy source originating from biomass waste, this activity can be implemented and overcome significant impacts on the environment, economy, and society. Government regulations are then implemented, and each stakeholder provides direction and assistance as needed. Creating a predictive design that anticipates problems that might give rise to misunderstandings that may arise at the final stage of implementing the rules is the final step. This difference of opinion could arise because each participant has a different level of understanding. Therefore, if a dispute arises, steps to resolve the problem need to be decided together.

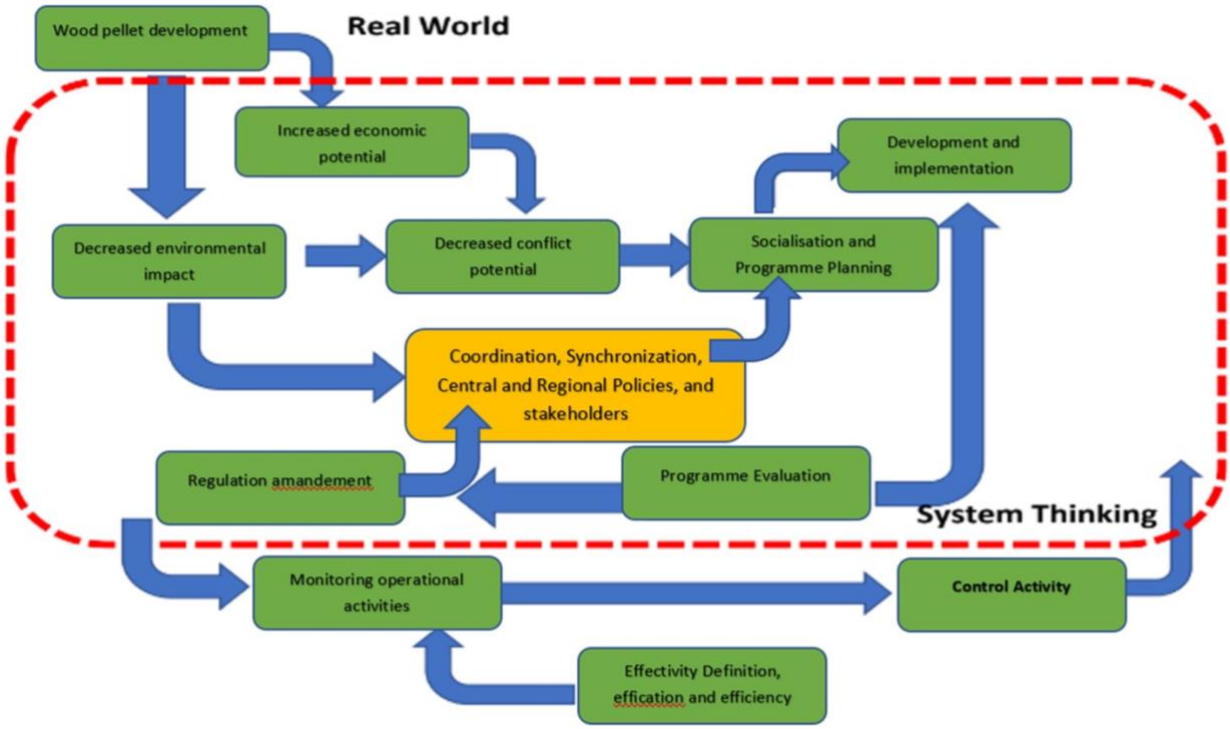

Figure 5. Conceptual model for developing wood pellets as renewable energy.

3.7. Discussion

Study by Coelho introduces a system dynamics-based method to provide a framework for decision support in energy planning problems in an urban context (Coelho, Antunes and Martins, 2010). The goal is to lay the foundation for the creation of multi-criteria decision analysis (MCDA) tools that can assess different courses of action. The SSM study has been utilized to precisely describe the decision problem scenario, accurately identify the primary players and their relationships, and determine the pertinent criteria for each of them. The structuring phase emerges from the collective interests, desires, and concerns of the key stakeholders, as well as their power dynamics. Subsequently, this data is utilised to establish the decision support phase, specifically in relation to creating suitable criteria trees for assessing interventions in integrated urban energy planning. Performance measures will be established for the fundamental objectives, and the stakeholders' perspectives on important value trade-offs among the fundamental objectives will be clarified. The evaluation of potential strategies for urban energy planning will be conducted using a sorting approach. This means that the strategies will be categorized into predetermined ordered groups based on their overall effectiveness.

The use of soft systems techniques has been used to create a conceptual model of energy management in the steel sector (Ats-Tsauri, Wilarnugroho and Purba, 2022). The goal is to understand and organize complex real systems into practical models. Furthermore, this study has undergone validation and assessment by representatives of experts in the steel sector, senior management, and policy makers. Although it seems easy, experts argue that this final analysis can effectively overcome the persistent obstacles associated with energy management in the steel industry. However, this research is still incomplete. At this time, SSM Phase 7 cannot be implemented due to investment and change management required. This is because its implementation requires data connectivity and data analysis capabilities.

Formulation and setting of a set of important objectives to encourage innovation within the framework of policy projects and incentive measures for technological innovation in the electricity sector in Brazil (Antunes *et al.*, 2016).

The process involved conducting literature reviews, conducting technical visits, and utilizing Soft Systems Methodology (SSM) resulting in various characteristics that were initially identified as potential problems and evaluation criteria. Structured approach. Categorizing these items facilitated the creation of a compilation of seven fundamental objectives that align with the priorities for technical progress in the energy industry. Following the bottom-up technique, a top-down approach is subsequently applied to systematically divide each goal targeting into sub-goals, thereby providing a clear understanding of the issues involved from multiple perspectives. This effort is very important for the initial stages of evaluation model development. The model aims to define performance indicators for each target and determine how to combine them to produce concise recommendations.

4. CONCLUSION

In Indonesia, the growth of wood pellets as a sustainable energy source made from biomass waste has not yet shown a clear pattern. From an environmental, economic, and social perspective, renewable energy is developed sustainably by utilizing a soft system methodology approach. From the design of making wood pellets as a sustainable energy source made from biomass waste, it is known that there are variations in the objectives and roles of various stakeholders. Conflicts of interest between actors and stakeholders can arise from the growth of wood pellets as a renewable energy source made from biomass waste, production processes, lack of financial capital, and the absence of regulations and regulatory bodies. To create wood pellets from biomass waste, there must be a program scenario that addresses a minimum of five factors: technology, institutions, financing, regulations and legislation, and stakeholder involvement.

ACKNOWLEDGMENTS

This research is supported by the Institute for Research and Community Service (LPPM) Pancasila University, Indonesia, with contract number 0040/LPPM/UP/V/2023.

REFERENCES

Antunes, C.H. *et al*. (2016) 'An Application of Soft Systems Methodology in the Evaluation of Policies and Incentive Actions to Promote Technological Innovations in the Electricity Sector', *Energy Procedia*, 106, pp. 258–278.

Ats-Tsauri, M.I., Wilarnugroho, B. and Purba, H.H. (2022) 'A conceptual model for energy management in the steel industry: A Soft System Methodology (SSM) approach', *SINERGI*, 26(3), pp. 319–326.

Belhadi, A. *et al*. (2022) 'A self-assessment tool for evaluating the integration of circular economy and industry 4.0 principles in closed-loop supply chains', *International Journal of Production Economics*, 245, p. 108372.

Bello, M.O. and Solarin, S.A. (2022) 'Searching for sustainable electricity generation: The possibility of substituting coal and natural gas with clean energy', *Energy & Environment*, 33(1), pp. 64–84.

Bening, C.R., Pruess, J.T. and Blum, N.U. (2021) 'Towards a circular plastics economy: Interacting barriers and contested solutions for flexible packaging recycling', *Journal of Cleaner Production*, 302, p. 126966.

Bocken, N.M.P. and Geradts, T.H.J. (2020) 'Barriers and drivers to sustainable business model innovation: Organization design and dynamic capabilities', *Long Range Planning*, 53(4), p. 101950.

Cavana, R.Y. and Maani, K.E. (2000) 'A Methodological Framework for Systems Thinking and Modelling (ST&M) Interventions', in *Proceedings of ICSTM 2000. 1st International Conference on Systems Thinking in Management*, Australia: World Academy of Science, Engineering and Technology, pp. 136–141.

Cavicchi, C., Oppi, C. and Vagnoni, E. (2022) 'Energy management to foster circular economy business model for sustainable development in an agricultural SME', *Journal of Cleaner Production*, 368, p. 133188.

Checkland, P. (ed.) (1999) *Systems Thinking, Systems Practice*. In: Currie, W.L. and Galliers, B., Eds., Rethinking Management

Information Systems, 1st edition. Oxford ; New York: Oxford University Press.

Coelho, D., Antunes, C.H. and Martins, A.G. (2010) 'Using SSM for structuring decision support in urban energy planning', *Ukio Technologinis ir Ekonominis Vystymas*, 16(4), pp. 641–653.

Grafström, J. and Aasma, S. (2021) 'Breaking circular economy barriers', *Journal of Cleaner Production*, 292, p. 126002.

Hasheminasab, H. *et al.* (2022) 'A circular economy model for fossil fuel sustainable decisions based on MADM techniques', *Economic Research-Ekonomska Istraživanja*, 35(1), pp. 564–582.

Hoefnagels, E.T.A., Junginger, H.M. and Faaij, A.P.C. (2012) *Capacity study for solid biomass facilities - scenarios for supply and demand of solid biomass for electricity and heat generation in north west Europe*. Thesis. Utrecht University.

de Jesus, A. and Mendonça, S. (2018) 'Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy', *Ecological Economics*, 145, pp. 75–89.

Kirchherr, J. *et al.* (2018) 'Barriers to the Circular Economy: Evidence From the European Union (EU)', *Ecological Economics*, 150, pp. 264–272.

Kristia, K. and Rabbi, M.F. (2023) 'Exploring the Synergy of Renewable Energy in the Circular Economy Framework: A Bibliometric Study', *Sustainability*, 15(17), p. 13165.

Lima, M.A. *et al.* (2020) 'Renewable energy in reducing greenhouse gas emissions: Reaching the goals of the Paris agreement in Brazil', *Environmental Development*, 33, p. 100504.

Malinauskaite, J. *et al.* (2017) 'Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe', *Energy*, 141, pp. 2013–2044.

Olabi, A.G. (2019) 'Circular economy and renewable energy', *Energy*, 181, pp. 450–454.

Patwa, N. *et al.* (2021) 'Towards a circular economy: An emerging economies context', *Journal of Business Research*, 122, pp. 725–735.

Pradnyaswari, I. *et al.* (2022) 'Barriers and Opportunities of Bio pellets Fuel Development in Indonesia: Market Demand and Policy', *IOP Conference Series: Earth and Environmental Science*, 997(1), p. 012003.

Proskurina, S. *et al.* (2019) 'Global biomass trade for energy— Part 2: Production and trade streams of wood pellets, liquid biofuels, charcoal, industrial roundwood and emerging energy biomass', *Biofuels, Bioproducts and Biorefining*, 13(2), pp. 371–387.

Ranta, V., Aarikka-Stenroos, L. and Mäkinen, S.J. (2018) 'Creating value in the circular economy: A structured multiple-case analysis of business models', *Journal of Cleaner Production*, 201, pp. 988–1000.

Rimantho, D. (2020) 'Pengelolaan limbah elektronika di DKI Jakarta menggunakan pendekatan Soft System Methodology', *Jurnal Pengelolaan Lingkungan Berkelanjutan (Journal of Environmental Sustainability Management)*, pp. 552–564.

Rimantho, D. *et al.* (2023) 'The strategy for developing wood pellets as sustainable renewable energy in Indonesia', *Heliyon*, 9(3), p. e14217.

Sassanelli, C. *et al.* (2019) 'Circular economy performance assessment methods: A systematic literature review', *Journal of Cleaner Production*, 229, pp. 440–453.

Tura, N. *et al.* (2019) 'Unlocking circular business: A framework of barriers and drivers', *Journal of Cleaner Production*, 212, pp. 90–98.

Wang, J. *et al.* (2021) 'Decoupling and decomposition analysis of investments and CO2 emissions in information and communication technology sector', *Applied Energy*, 302, p. 117618.