

Model of Community Ecosystem Through Intercropping Pattern of Energy Crops With Design Thinking Approach

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ABSTRACT

Environmental and sustainability issues are currently important in economic activities. One of the widely discussed environmental and sustainability issues is air pollution from coal burning in power plants (PLTU), which is not environmentally friendly or renewable. Besides the benefits felt, especially in electrical energy, it has negative economic, social, and environmental impacts, especially for local communities. Therefore, solutions are needed to minimize the negative impacts. The first three stages of design thinking, empathize, define, and ideate, become the initial stages to validate the ideas generated before further implementation. Literature study results show that idea generation is done using an empathy map in the empathize stage. The empathize stage indicates that handling air pollution from coal burning in PLTU is not yet optimal, causing public anxiety due to the resulting impacts. Therefore, efforts are needed to minimize the negative impacts. The define stage explains that emissions contributed by coal-fired power plants amount to 35%, and the sustainability of coal fuel is still questionable, thus requiring other fuel sources and a concept to obtain this biomass. The ideate stage produces a community ecosystem model through an intercropping pattern of energy crops that offers increased economic, social, and environmental benefits and reduces the negative impacts of air pollution from coal burning.

Keywords: Community Ecosystem Model, Design Thinking, Energy Crops, Intercropping.

I. Introduction

In current economic activities, environmental and sustainability issues are critical. Using resources without considering sustainability in linear economic activities causes significant negative impacts such as climate change, loss of biodiversity, environmental pollution, and others. To reduce emissions, Indonesia's Minister of Energy and Mineral Resources (ESDM) has set the Enhanced-Nationally Determined Contribution (E-NDC), where carbon emission reduction by 2030 is 32% or 912 million tons of CO₂. In the energy sector, Indonesia's emission reduction target by 2030 is 358 million tons of CO₂ through developing renewable energy, energy efficiency, low-carbon fuels, and clean coal technology.

Global warming and increasing greenhouse gas emissions have become major environmental problems that potentially threaten human life and ecosystem sustainability worldwide. Given that coal-fired power plants (PLTU) are still the primary choice to meet energy needs in Indonesia, coal burning is the primary

source of carbon dioxide (CO₂) emissions from fossil fuels, including coal. However, coal burning produces significant pollutants, contributing to high levels of CO₂ and other greenhouse gases in the atmosphere. Health risks such as respiratory and cardiovascular diseases are often associated with air pollution generated by PLTU, as well as a decrease in the community's quality of life. In addition, increased greenhouse gas emissions exacerbate climate change, which impacts extreme weather patterns, food security, and soil quality in agricultural areas near industries (Sanderson et al., 2013).

Several studies involve the use of nature-based plants, such as plants that can absorb CO₂ (Wang et al., 2022). Intercropping is planting two or more types of plants on the same plot of land simultaneously. Compared to monoculture planting, intercropping aims to maximize all production factors owned by farmers, including limited land, labor, and working capital; more efficient use of fertilizers and pesticides; land conservation; soil biological stability; and increased total production (Raditya Warman & Kristiana, 2018). To support the Indonesian government's efforts to achieve a 23% new and renewable energy mix by 2025 and a 29% reduction in greenhouse gas emissions by 2030, Kaliandra was chosen as biomass due to its high calorific value and rapid growth. This makes it suitable as a substitute for coal in the PLTU combustion process (Darmawan et al., 2023). By applying this pattern to community land, it is hoped that CO₂ absorption will increase and economic opportunities will arise for local communities. This intercropping method not only aims to reduce carbon dioxide emissions but also to increase farmers' income. The energy crops planted can produce additional products, such as wood or biomass, that can be processed into alternative fuels, such as biomass pellets. Several studies show that using biomass pellets from energy crops can reduce our dependence on coal, provide a more environmentally friendly alternative, and support energy sustainability (Sanderson et al., 2013). In this case, the design thinking-based approach involves understanding community needs comprehensively (empathize), defining key problems related to emissions and welfare (define), and developing ideas and solutions through intercropping patterns (ideate). In the ideation stage, in addition to intercropping patterns, developing derivative products from energy crops is identified as a solution to increase the economic value of communities around PLTU. The community ecosystem model actively involves local communities in economic and environmental management. This intercropping pattern is also part of this model. The community, government, and private sector work together to plant, maintain, and process energy crop yields to maintain environmental balance.

By combining intercropping patterns, people will see better air quality and a greener environment, and be healthier through the derivative products that can be purchased. Collaboration with the government through incentives or technological support is also needed so that the community can access adequate equipment and knowledge to manage energy crops. This will encourage the community to keep their land productive for food and energy crops, improving environmental quality and economic stability.

II. Literature Review and Hypothesis Development

2.1. Design Thinking

Problem-solving can be achieved using the application of design thinking. This method combines aspects of creativity to obtain an alternative solution. A characteristic of the design thinking method is that the selected solution is obtained by utilizing user needs and meeting technical and economic requirements (Pande & Barathi, 2020). Design thinking is utilized by analyzing a problem, obtaining a solution, and implementing it in the form of a prototype or proposed idea. Because user needs must be considered, the problem analysis process must go through observation stages and relevant interview results (Skaggs, 2018). The design thinking process has five main stages: empathizing, defining, ideating, prototyping, and testing (Chasanidou et al, 2015).

2.1.1. Emphatizing

In this stage, observations are made to find out what problems are experienced by users. To get valid problems, interviews can be conducted with stakeholders. In this stage, a creative thinking approach is used to analyze and digest information more deeply (Khodaei et al., 2023).

2.1.2. Defining

In this stage, the problem definition is obtained according to the persona approach from each stakeholder's perception. The results of this persona approach will then be used to obtain solutions from each perspective (Isadora et al., 2021). A critical thinking approach is also used in this stage to ensure a relevant problem definition.

2.1.3. Ideating

In this stage, solutions are formulated by applying creative thinking. To formulate solutions, brainstorming is also conducted with experts and stakeholders to generate alternative ideas to solve problems. In formulating solutions, it is as much as possible to prioritize usefulness and eliminate weaknesses or disadvantages (Sarooghi et al., 2019).

2.1.4. Prototype

This stage involves creating a model design as a form of solution implementation. In this stage, user flow creation, case implementation, and prototype design are usually carried out. Prototype creation must prioritize desirability, feasibility, and sustainability (Dennehey et al., 2019).

2.1.5. Testing

The final stage is testing the implemented prototype. In this stage, a series of tests are carried out to ensure the effectiveness of the prototype implementation. In this stage, it is also decided whether the solution obtained from the application of design thinking can be continued, updated, or improved.

2.2. Intercropping

Intercropping is a plant cultivation method where several types of plants are grown on the same land simultaneously. According to Mulyono (2019), the intercropping method has advantages such as increased land efficiency, energy savings, reduced land management costs, reduced fertilization costs, reduced pest control costs, and diverse harvests. Intercropping methods carried out consistently for 3-4 years based on Wang et al. (2014) research show better soil fertility improvement compared to monoculture methods. However, this method must consider planting patterns to avoid competition between plants. Despita et al. (2020) explain that planting distance is one of the success factors of intercropping. In addition, selecting appropriate commodities must also be considered to obtain positive relationships between plants (Suryanto, 2019).

III. Research Method

This research was conducted from September to October 2024, sourced from primary and secondary data. Primary data was obtained through FGDs with the community and local government agencies, and secondary data was obtained through literature studies of various related journals and articles. The data

obtained were then processed and analyzed using a qualitative approach and descriptive analysis techniques. According to Broberg et al. (2020), descriptive analysis is used in discussions related to events experienced by individuals or groups of individuals. Descriptive analysis is used to explain each stage of design thinking, namely 1) Empathize, 2) Define, 3) Ideate, 4) Prototype, and 5) Test. However, this article's scope is limited to only the first three stages of the design thinking approach: 1) Empathize, 2) Define, and 3) Ideate.

IV. Results and Discussion

Based on design thinking theory, the analysis results obtained are presented according to the following stages:

4.1. Empathize

Empathizing is the initial stage of the design thinking concept. An empathy map is a tool used to deepen understanding of users/customers from the perspective of behavior, attitudes, and desired needs, and it is very helpful in decision-making (Amaliani Putri et al, 2022). This allows researchers to feel the user's perspective. The empathy map comprises six dimensions: what the user/customer thinks, feels, sees, says, and does. Next, I will find out the pain and gain experience from the community. The explanation for each dimension is presented in this paper. In the "what is thought" dimension, it is concluded why air pollution handling is still not optimal, what are the proper steps to handle air pollution, how to reduce the negative impacts of environmental pollution, what is the sustainability level of coal use as PLTU fuel, and whether there is a more sustainable and environmentally friendly substitute for coal fuel.

The empathize stage was obtained through interviews with the surrounding community and discussions with local government agencies/village officials through FGDs. In the "what is felt" dimension, it can be concluded that the community feels anxious because the air quality is deteriorating, affecting the health of the community around the PLTU. In addition, the community wants better air quality, but dependence on electrical energy is still high, and the community wants a better quality of life. In the "what is seen" dimension, it is concluded that coal burning in PLTU is one of the leading causes of air pollution, the amount of coal is decreasing and not renewable, and the community's welfare around the PLTU is still low. In the "what is said and done" dimension, it is concluded that replacing PLTU raw material sources with more environmentally friendly and sustainable ones is highly necessary. Cooperation with the community through the community concept in producing biomass raw materials, such as PLTU raw material sources, can provide opportunities to improve community welfare. Based on this, pain and gain can also be identified, where the pain felt is the negative impacts experienced by the community from social, economic, and environmental aspects. In addition, dependence on electrical energy is very high in every aspect of life, so electricity use cannot be avoided, and the use of coal substitute raw materials and information on the use of biomass as PLTU raw materials are still low, as is community involvement in industrial processes. Meanwhile, the gain felt is that using wood biomass as a partial substitute for coal in the PLTU combustion process can minimize the impacts felt and create business opportunities with community involvement as producers of wood biomass, a raw material source for PLTU combustion.

4.2. Define

The define stage is the next stage after the empathize stage, which shows the stage of describing ideas or people's views to form the basis of the product to be made (Amaliani Putri et al, 2022). Based on literature studies, coal burning is the most significant contributor to air pollution after emissions generated by transportation. Coal burning produces various emissions, namely CO₂, SO₂, particles, and dust. According to the Director General of Mineral and Coal of the Ministry of Energy and Mineral Resources (ESDM) (2021), out of 1,262 Gigatons of CO emissions produced in Indonesia, 35% comes from coal-fired power plants. In

addition, according to the Director General of Mineral and Coal of the Ministry of Energy and Mineral Resources (ESDM) (2021), Indonesia's current coal reserves reach 38.84 billion tons. With an average coal production of 600 million tons annually, the coal reserve life is still 65 years if no new reserves are found. Therefore, other types of raw materials that are more environmentally friendly and sustainable need to be sought. One source of raw material that is more environmentally friendly and sustainable than coal is biomass. In his study by Leif Kinderberg (2010), the use of biomass as a bioenergy raw material is considered more environmentally friendly because biomass uses the photosynthesis process in plants to capture solar energy by converting carbon dioxide (CO₂) from the air and water (H₂O) into complex fibers that can be used as a substitute for coal with high calorific value. Burning biomass in the energy conversion process causes biomass to return some carbon dioxide and water and release solar energy. Because plants can store and release energy, they can be said to be natural batteries.

The role of the community is vital in producing this biomass. This is because the community has land that can be optimized for its utilization. 2 (2) types of community land management can be used as sources of biomass production: Alley Cropping and Enrichment Planting. In both patterns, several plants can be planted on one plot of land, also known as the intercropping method. The literature study explains that the intercropping method has advantages, especially in increasing land efficiency, diverse harvests, and soil enrichment. By applying the intercropping concept, the community can plant staple crops that are usually done and energy crops as biomass producers, without damaging or disturbing their main crops. Thus, biomass planting can provide additional income besides what is obtained from the main crops. Based on this explanation, involving the community in producing biomass as a raw material source can increase income and social benefits by providing related job opportunities, such as direct biomass sellers and other derivative products. Indirectly, environmental benefits are also obtained, where, according to the literature, the intercropping method of planting is more fertile for the soil than monoculture planting. This indicates that the concept of a community ecosystem in producing biomass through community empowerment can significantly impact economic, social, and environmental aspects.

4.3. Ideate

In the ideate stage, solutions to problems are described by evaluating and combining design creativity. The authors brainstormed to determine the right ideas for the existing problems. In the initial idea presentation to the community and relevant agencies through FGDs, several alternative planting methods were discussed: monoculture planting of energy crops and intercropping patterns. Monoculture planting was considered less profitable for farmers because it only produced one garden product, while farmers still needed their land to meet daily needs. Therefore, intercropping is the most suitable planting pattern for producing biomass. Another effort that can be made to reduce air pollution is the use of other renewable energy sources. However, implementing other renewable energy sources requires significant investments, and community empowerment may not be possible. Sustainable land management methods are considered the best solution because they address environmental problems and provide economic, social, and long-term sustainability benefits. This method integrates efficient land resource use with local community empowerment to create comprehensive solutions to reduce the negative impacts of coal burning in power plants (PLTU). Methods such as supplementary planting and intercropping allow the same land to be used for various crops without damaging the main harvest. Studies show that these techniques increase land productivity while maintaining the ecosystem. Intercropping can increase land efficiency and reduce the need for inputs such as fertilizers and pesticides. Thus, intercropping provides economic and environmental benefits at the same time (Wang et al., 2022). In a sustainable model, energy crops are planted to absorb carbon dioxide (CO₂), which reduces the impact of emissions from power plants (PLTU). The biomass produced can also replace some coal, thereby reducing air pollution. Studies show that agroforestry approaches can increase the capacity of plants and soil to absorb carbon (Sanderson et al., 2013). This method involves local communities in land management, increasing income through biomass and by-products such as organic fertilizer and animal feed. Studies show

that community models using energy crops such as gamal and kallaracha can create new jobs and local business opportunities (Darmawan et al., 2023).

This method improves soil quality by combining complementary plants. Studies show that over several years, intercropping practices improve soil fertility compared to monoculture methods, thanks to plant interactions that reduce erosion and increase soil organic matter content (Raditya Warman & Kristiana, 2018). This allows communities to produce biomass sustainably without disturbing the local ecosystem. The community ecosystem model, supported by the private sector and government, ensures that the program runs well and does not experience problems. Studies show that empowering communities to manage sustainable resources increases a sense of ownership and responsibility for the environment (Amaliani Putri et al.).

Based on the explanation in the define stage, the community ecosystem model through intercropping of energy crops is an idea offered to produce biomass as a substitute for non-renewable and unsustainable coal raw materials and as a contributor to reducing air pollution. In this ideate stage, 4 points are used to generate ideas: enhance, replace, reuse, and limit (Amaliani Putri et al., 2022). Enhance explains the value and novelty offered by the proposed idea. Through the intercropping of energy crops, the community ecosystem model provides sustainability value for the raw materials produced. Through the continuous planting process, the sustainability of biomass as a raw material is more guaranteed because it is easy to do and continuous. Community empowerment provides value in terms of economic, social, and environmental aspects. Economic value is obtained through increased income due to the intercropping produced. Social value is obtained from the emergence of job opportunities. An environmental value is obtained from the intercropping method of planting energy crops. Biomass in bioenergy also provides an environmentally friendly value because it replaces environmentally unfriendly fossil raw materials.

Replace explains what makes the idea of the community ecosystem model through intercropping of energy crops less attractive. What makes it less attractive is if the price of the biomass product produced does not match the community's wishes. However, if biomass can match coal's price, this becomes a beautiful concept for the community. Reuse explains whether other products have used the concept built from existing ideas. So far, PT is also exploring the concept of a community ecosystem model through the intercropping of energy crops. PLN Persero in obtaining biomass as a substitute for coal. This concept is also being developed with researchers at IPB. Limit is the negative impact of implementing the community ecosystem model idea through the intercropping of energy crops. No adverse impacts have been found so far. However, if linked to the concept of providing biomass products as a substitute for coal, the off-taker cannot meet the community's wishes, so the ecosystem cannot run.

The idea of a community ecosystem model through intercropping of energy crops is implemented by empowering local communities to produce energy crops through the intercropping method, in which energy crops are planted between food crops/staple crops that have been cultivated and energy crops. Community empowerment is carried out by activating KTH (Community Forest Groups), BUMDES (Village-Owned Enterprises), and village officials as actors who will run the community ecosystem. The planting results through the intercropping pattern will produce energy crops whose wood will be used as biomass to be sold to the PLTU. Using biomass as a substitute for coal can reduce emission values, be more environmentally friendly, and maintain energy sustainability. The leaves of energy crops can be used as animal feed. This becomes another added value, where many livestock are raised in rural areas. The animal waste produced can also be an added value by processing it into organic fertilizer. Wood biomass can also be further processed into wood chips/sawdust. Woodchip or sawdust is a finished product ready for PLTU to consume as a substitute for coal. This becomes another opportunity to increase income and open up job opportunities related to wood processing. If this model can be implemented, it will be an excellent concept for reducing the negative impacts of environmental pollution due to coal burning and increasing the economic, social, and environmental value for the surrounding community.

The final stages in the design thinking concept are the prototype and test stages. The prototype stage is the stage for implementing the model created realistically and its application steps. At this stage, a value

proposition canvas and BMC can be used. The test stage is the testing stage with the target audience. However, this paper only discusses the developed model's ideation stage. The role of the community is vital in implementing this model. Model for developing intercropped garden produce in a community ecosystem.

V. Conclusion

The community ecosystem model through intercropping of energy crops is a community empowerment model in a place to produce energy crops through the intercropping method to produce biomass without damaging other plants. This idea was created from a solution-oriented mindset to solve problems and reduce the negative impacts of environmental pollution due to coal burning using the design thinking process. The focus of the discussion in this paper is to empathize, define, and ideate. In the empathize stage, it shows that handling air pollution due to coal burning in PLTU is not yet optimal, causing the community to feel anxious about the resulting impacts. Therefore, efforts are needed to minimize the negative impacts. In the define stage, it explains that emissions contributed by coal-fired power plants amount to 35%, and the sustainability of coal fuel is still questionable, thus requiring other fuel sources and a concept to obtain this biomass. In the ideate stage, a community ecosystem model is generated through an intercropping pattern of energy crops that offers increased economic, social, and environmental benefits and reduces the negative impacts of air pollution from coal burning. The biomass products produced from this community ecosystem can have higher value if further processed into derivative products, ready to be processed by PLTU and other derivative products such as animal feed, organic fertilizer, and increased livestock weight. The suggestion proposed in this paper is that further research needs to be carried out up to the prototype and test stages to apply the model in various areas around the PLTU. This will minimize the negative impacts of coal burning and improve the welfare of the surrounding community.

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