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Stakeholders' Perceptions of the Peer-to-Peer Energy Trading Model Using Blockchain Technology in Indonesia

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Abstract: The energy transition towards Net Zero Emission by 2060 hinges on the renewable energy power plants in Indonesia. Good practices in several countries suggest a peer-to-peer (P2P) energy trading system using blockchain technology, supported by renewable energy (solar panels), an innovation to provide equal access to sustainable electricity while reducing the impact of climate change. The P2P energy trading concept has a higher social potential than the conventional electricity buying and selling approach, such as that of PLN (the grid management concept), but does not have a sharing element. This model implements a solar-powered mini-grid system and produces a Smart Contract that facilitates electricity network users to buy, sell, and trade electricity in rural areas via smartphones. This study aims to analyze the stakeholders' perceptions of the peer-to-peer (P2P) energy trading model using blockchain technology in Gumelar District, Banyumas Regency, Central Java Province, Indonesia. The stakeholders include households, the Ministry of Energy and Mineral Resources (ESDM), the State Electricity Company (PLN), the Institute for Essential Services Reform (IESR), Awina Company, and IPB University. The strength factors of this model are the freedom to generate and sell electricity (0.1) and transparency in electricity usage and sales by disclosing the amount, duration, and price of electricity (0.1). Regarding weakness factors, this model is primarily suitable for the lower middle class residing in rural or remote areas (0.02). Additionally, the intermittent electricity production to meet the substantial demand is a weakness (0.03). The opportunity factor for the model is the increase in public awareness and cooperation in using environmentally friendly, pollution-free electricity (0.12). Furthermore, there is an opportunity for additional income (0.12) and new business investment (0.12). Regarding threat factors, the model faces significant threats from the implementation aspect involving multiple parties (0.04). There is a potential threat in the form of losses for state utilities such as PLN or individuals who have already established electricity infrastructure if this program is implemented on a large scale (0.04). This model is located at the coordinate point (-0.40; 0.31), placing it in quadrant II. This indicates that the model should apply the Stability Strategy and focus on the Selective Maintenance Strategy for improvement. The stability strategy goal is to maintain the current situation by leveraging opportunities and addressing weaknesses. For effectiveness and efficiency, the strategy emphasizes fostering collaboration with PLN, which holds the legal authority as the sole utility company in Indonesia with an extensive electricity network, as well as advocating for regulations that support the independent purchase and sale of solar-powered electricity, particularly in areas without PLN network coverage.

Keywords: blockchain; energy trading; peer-to-peer; net zero emissions; stakeholders' perceptions

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1. Introduction

The energy transition towards Net Zero Emission by 2060 hinges on the renewable energy power plants in Indonesia. The Indonesian government has set ambitious targets for increasing the usage of renewable energy. Their goal is to reach 23% renewable energy usage by 2025 and 31% by 2050 to align with the objectives of the 2016 Paris Climate Agreement and reduce greenhouse gas emissions. However, based on data from PLN's Electricity Supply Business Plan (RUPTL) until the end of 2020,

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it is estimated that the portion of new renewable energy in Indonesia stands at around 11.51%, which falls short of the target of 13.4%. Indicates the need for more substantial efforts to achieve the 23% target by 2025. According to the 2019 IRENA publication, the country has only installed solar panels at a rate of 0.55%, equivalent to around 80 MWp. These installations include small solar panel setups in remote areas and 1 to 5 MW grids connected in Kupang, East Nusa Tenggara. The Indonesian government's 2019 RUPTL targets solar energy development to reach 6,500 MWp by 2025.

Solar energy in Indonesia offers great potential for renewable energy capacity. Future of Renewable Energy Roadmap (REMap) identified the potential for an installed capacity of 47 Gigawatts by 2030. This includes plans to use solar energy to provide electricity to nearly 1.1 million households in remote areas without electricity. Furthermore, solar energy is expected to be used on a significant scale by 2030 in three ways: large utility-scale, on residential and commercial rooftops, and off-grid to replace expensive diesel power plants. This potential is assumed to be developed by 2030 through the efforts of the government and the State Electricity Company [1]. Several studies and practices in several countries suggest switching to a peer-to-peer (P2P) energy trading system based on blockchain technology supported by the use of renewable energy, in this case, solar panels as one of the innovations in equalizing access to electricity that uses renewable energy while reducing the impact of climate change. Some of these examples are Piclo in the UK, Vandebron in the Netherlands, Sonnen Community in Germany, and Yeloha and TransActive Grid in the USA [2–6].

In various Southeast Asian countries such as Thailand, Malaysia, and Singapore, previous trials of peer-to-peer (P2P) energy trading have been carried out. Specifically in Malaysia, P2P energy trading utilizing blockchain technology was implemented, involving four producers and eight consumers under the leadership of the Sustainable Energy Development Authority (SEDA) 2022. The project's initial phase involved a centralized approach, with SEDA overseeing the energy transactions between producers and consumers. This initiative is aligned with the Renewable Energy Transition Roadmap (RETR) 2035, which aims to foster the growth of the rooftop solar market by exploring P2P energy trading as a potential solution.

In 2018, the Metropolitan Electricity Authority (MEA) of the Thai government collaborated with Power Ledger on a blockchain-based P2P energy trading pilot project. The pilot project involved a dental clinic as the sole consumer, with a local mall, school, and apartment complex acting as additional large prosumers. A 635 kWP solar panel was installed on the roofs of the mall, school, and housing complex to generate renewable energy for the pilot project. The MEA, as the energy utility company, devised a centrally designed P2P marketplace for this initiative. In the Alpha phase, Electrify developed a pilot retail P2P energy trading platform in Singapore. The marketplace had 15 members in Singapore’s national grid, consisting of three producers and 12 consumers. It successfully met its technical test objective by simulating the end-use of P2P energy trading in Singapore’s main electricity grid while adhering to the energy regulations.

Energy utilities are increasingly exploring the potential of blockchain to enhance the efficiency of electricity markets. The Russian national grid operator is currently conducting tests on the technology to enhance the efficiency of electricity metering, billing, and payments for end users. This solution will empower consumers to monitor their energy consumption in real time through a mobile app and automate payments within the grid. In addition, cities are also getting involved in this trend. For example, Chuncheon in South Korea is piloting a blockchain platform process that issues tokens for implementing sustainable energy practices, which can be exchanged for various goods and services [7]. Similarly, in Bangladesh, a blockchain-based peer-to-peer energy trading network is being created for rural households to enhance access to sustainable, reliable, and affordable electricity [8].

Blockchain technology and P2P trading have been widely discussed in the context of climate change policy and applied in many different climate-related sectors, from climate investment to carbon pricing. With the falling prices of solar panel modules, the number of households installing solar panel systems has increased; P2P energy trading has become one of the most popular applications powered by blockchain technology. However, there are concerns about the carbon footprint generated by blockchain. Concerns also arise from the transaction fees required to maintain the integrity of a decentralized blockchain. Several studies have embraced mathematical evidence and projected that blockchain emissions could drive global warming and consume more energy than mining minerals to produce equivalent market value [9].

Numerous studies examining the reasons for participating in collective prosumer initiatives have consistently highlighted the significant influence of environmental concerns [10]. For instance, an investigation into the motivations of individuals joining renewable energy cooperatives in Flanders, revealed that the support for renewable energy production outweighs the importance of financial returns or electricity prices as a motivating factor. Similarly, a survey of members of a community-based renewable energy initiative in Germany, demonstrated that participant engagement is primarily driven by environmental considerations rather than financial incentives [11]. Multiple studies have reinforced the idea that environmental benefits are the primary drivers for participation in peer-to-peer electricity markets [12–14]. Furthermore, a motivational psychology framework to peer-to-peer energy trading, aiming to increase prosumer participation. Their findings indicated that the proposed model could potentially reduce carbon emissions by 18.38% and 9.82% during summer and winter, respectively, compared to the feed-in-tariff scheme.

Although peer-to-peer (P2P) trading reduces energy costs for local consumers, the limited energy generation in local microgrids means that the average consumer still needs to purchase energy from the traditional grid. Increase strain on non-renewable energy sources, such as coal-fired or solar power plants, contributing to greenhouse gas emissions. Introducing energy trading between microgrids offers a promising solution to alleviate the reliance on polluting utility grid generation. Previous research has consistently highlighted environmental concerns, particularly the aspiration for a more sustainable lifestyle, as a significant motivator for individuals to invest in renewable energy [15,16].

P2P energy trading is currently in an experimental and pre-competitive phase. The regulatory approach adopted around this model will determine its future success. According to IRENA and personal research, to date, the countries that have involved state and private institutions in piloting P2P energy trading schemes are Australia, Bangladesh, Colombia, Germany, Japan, Malaysia, Thailand, Singapore, the Netherlands, Spain, the United Kingdom, and the United States. Most of these [1] countries do not have regulations on P2P energy trading. Only a few of the above countries have touched the regulatory stage, even if only superficially. In contrast, more countries, including the UK, Japan, and the Netherlands, are embracing a regulatory sandbox approach. This approach permits governments to experiment with innovative concepts that are not yet regulated for a limited duration to gain insights. Regulatory sandboxes present an ideal platform for regulatory authorities and innovators to engage in dialogue and experimentation, enabling mutual learning and the exchange of ideas on a product before its approval for general public use. Currently, trials for peer-to-peer energy trading, often leveraging blockchain technology, are being conducted under regulatory sandboxes in the UK and the Netherlands.

The concept of P2P energy trading has a greater social potential compared to the traditional electricity trading methods, like those used by PLN (incorporating grid management principles such as direct load control and time-varying tariffs). However, P2P electricity trading lacks a sharing element. It has the potential to generate compelling narratives, such as the notion of buying and selling electricity in underserved communities, remote islands, and beyond. Nevertheless, further in-depth research is essential to validate these ideas. Therefore, the potential for developing a P2P energy trading model based on blockchain technology appears promising for exploring alternative solutions to improve the quality of electricity access in Indonesia, with a focus on low emissions and fairness, particularly to enhance the quality of life for the Indonesian people.

2. Literature Review

Over the past few decades, there have been several proposals for improving the quality of electricity access in Indonesia. Pekik Argo Dahono, a Professor from the Bandung Institute of Technology, has gained attention for promoting the "Nusantara Supergrid" concept, which involves connecting the large islands in Indonesia to the electricity network with a focus on renewable energy sources [17]. This concept, commonly known as Supergrid, involves the large-scale transmission of renewable electricity over long distances. Indonesia has substantial potential for renewable energy, which could potentially meet the country's electricity needs. However, the sources are not evenly distributed across the islands. In alignment with the 2060 Net Zero Emission Targets, the Ministry of Energy and Mineral Resources plans to gradually transition to renewable energy by creating a roadmap for "Energy Transition Towards Carbon Neutral". As part of this plan, the government intends to establish a "Super Grid" for interconnecting the islands using renewable energy sources, with the initiative set to begin after 2025. The government emphasizes that the implementation of this plan will require private sector involvement due to the limited state finances.

In recent years, peer-to-peer energy trading using solar power has emerged as an alternative for prosumers (producers and consumers) to actively participate in the energy market. This has been driven by the growing popularity of solar power worldwide [18]. P2P enables prosumers to trade excess energy production with their neighbors through microgrids, thereby increasing consumer profits. P2P energy trading offers greater flexibility to end users, more opportunities to utilize clean renewable energy, and contributes to reducing greenhouse gas emissions in the context of climate change. Furthermore, it brings additional benefits such as reducing peak electricity demand, lowering maintenance and operating costs, and enhancing the reliability of the electricity system [5,19].

1.1. Microgrids and Consumer-Centric Markets

Local-based energy projects and microgrids are expected to play an increasingly important role in the energy system. Local-scale energy projects have great potential to provide socio-economic and environmental benefits to the communities involved [20]. In a microgrid, distributed generators, storage devices, and uncontrolled and controlled loads form an interconnected system that can operate in synchronization with the main grid or full autonomy if operating in island mode [21]. From a control perspective, a microgrid acts as a single system that has a different electrical boundary from the main grid [22]. In addition to the formal definition, virtual microgrids can also be considered, providing aggregate control over supply and demand beyond the electrical and physical boundaries. Microgrids promote local-scale energy production and consumption, which can lead to significant reductions in distribution and transmission losses [23]. When combined with sustainable resources, microgrids can further enhance the integration of renewable energy power generation [24].

Local-scale microgrids can improve grid resilience, providing additional services such as frequency and voltage support to aging power systems with the potential to defer expensive grid upgrade investments. They can also provide energy services to consumers in cases of grid contingencies. The efficient operation of microgrids at a technical level, such as optimal control strategies and system architectures, has been extensively studied [25–30].

Peer-to-peer energy trading in local markets can provide socio-economic incentives that promote local renewable generation and therefore can form an alternative incentive for potential prosumers [4]. Consumers who are unable to invest in renewable energy generation, either due to limited capital or space, can purchase certified green energy at affordable prices. However, consumers are often willing to pay a premium for green energy, but currently, there is no guarantee about the origin of the purchased energy, and most likely, the energy used by the end consumer still comes from the nearest fossil fuel power plant [31]. Community-based microgrids based on blockchain essentially enable local energy trading between consumers, which is recorded in a secure and transparent manner.nd tamper-free manner.

1.2. Peer-to-Peer (P2P) Energy Trading

Peer-to-peer energy trading in local markets has the potential to create socio-economic incentives that encourage local renewable energy generation. This can offer an alternative incentive for potential prosumers who are unable to invest in renewable energy due to limited capital or space. By enabling consumers to purchase certified green energy at affordable prices, it addresses the demand for green energy. Currently, consumers are often willing to pay a premium for green energy, but there is no guarantee about the origin of the purchased energy, and it likely still comes from the nearest fossil fuel power plant. Community-based microgrids based on blockchain technology facilitate local energy trading between consumers in a secure and pre-determined manner, free from interference. Similar to an open market economy, suppliers seek the highest possible price, considering costs and benefits, and consumers choose the lowest possible price based on their needs and preferences. In the traditional model, consumers purchase electricity from a utility at a fixed tariff or time-of-use tariff, while prosumers can sell excess electricity back to the grid at a buyback rate that is generally much lower than consumer tariffs. The implementation of the peer-to-peer model will have a significant impact on society, affecting lifestyles and cultural practices related to electricity supply and demand. It will also create local training and employment opportunities for administrative and maintenance work within the peer-to-peer system. Additionally, it will foster greater social trust, increase transparency in transactions, and reduce fraudulent activities. Ultimately, fostering greater community engagement will create a more direct connection among participants, enhancing their sense of belonging to the community. They will encourage them to coordinate with each other to optimize their profits [32]. Due to these and other advantages, numerous projects worldwide are dedicated to P2P energy trading. Notable initiatives include Piclo in the UK, Vandebron in the Netherlands, Sonnen Community in Germany, and Yeloha and TransActive Grid in the United States America [4–6].

1.3. Indonesian Context of P2P Energy Trading Using Blockchain Technology

The Center for Innovation Policy and Governance has proposed a set of principles and policy recommendations on Big Data, Artificial Intelligence, Blockchain, and Financial Technology in Indonesia for the Directorate General of Informatics Applications, Ministry of Communication and Informatics. It is noteworthy that in Indonesia, Blockchain is still primarily associated with Bitcoin and is often misunderstood due to the misuse of Bitcoin for illicit activities reported in the media. Moreover, there is limited involvement from key stakeholders such as universities and research institutions in blockchain research, and the country's supporting industries, particularly the electronics and telecommunications sectors, have not been optimally engaged in addressing blockchain-related issues. While the Indonesian government informally acknowledges the potential of blockchain in supporting a sustainable and democratic energy network by eliminating intermediaries and fostering trust between networks, there has been no formal policy or strategy developed for P2P energy trading or blockchain. The absence of a domestic track record of blockchain utilization has hindered the formulation of appropriate policies and regulations, thereby impeding the potential benefits of P2P energy trading and blockchain technology for Indonesians.

The National Research and Innovation Agency (BRIN) is a governmental organization established to succeed the Ministry of Research and Technology. BRIN operates as a non-ministerial institution accountable to the President. President Joko Widodo created this agency through Presidential Regulation Number 74 of 2019. Its primary responsibilities include conducting research, development, assessment, and implementation, as well as promoting integrated inventions and innovations. It remains uncertain whether the inclusion of P2P energy trading and blockchain technology is a prominent topic within the agenda of the BRIN institution.

In Indonesia, the current electricity solution adopted by PLN involves constructing medium-large scale power plants, which is expensive and ineffective in ensuring equal distribution of electricity. The geographical challenges, with over 17,500 islands and more than 6,000 inhabited islands, make creating an electricity network on each island a formidable task in terms of cost, ecosystem, and technology. According to the World Resources Institute, Indonesia is among the largest greenhouse gas (GHG) emitters globally. Over the past two decades, GHG emissions have increased across various sectors, including land use, energy, agriculture, industry, and waste. Currently, land use and energy sectors contribute 80 percent of greenhouse gas emissions in Indonesia.

The Constitutional Court, in a Judicial Review decision, invalidated Article 10, paragraph 2, and Article 11, paragraph 1, of the 2009 Law on Electricity, which emphasized the state's dominance, particularly that of PLN, in controlling electricity. The Court emphasized that the decision should not be interpreted as a reduction of the state's role. The coordination of electricity provision and distribution will continue to be managed by the government through state-owned enterprises (BUMN) operating in the electricity sector, such as PLN, and should not be unbundled. However, providing equitable and quality access to electricity in eastern Indonesia seems to be a challenge for PLN. Tri Mumpuni, also known as Ibu Puni, an entrepreneur and environmental activist, has been instrumental in bringing electricity to at least 61 remote villages in Indonesia, including isolated villages in NTT and eastern Indonesia, through the Institute for People's Business and Economics (IBEKA) since the 1990s. Mumpuni and her husband, through IBEKA, have established Micro-Hydro Power Plants (PLTMH) to provide electrical energy to areas not covered by PLN, using water and turbine energy sources. One of the crucial aspects of lighting up remote villages is the acknowledgment of electricity as a form of social capital rather than just infrastructure or a commodity. Additionally, investments need to be made in partnership with the community, a concept referred to as community partnership investment [33].

In the context of an archipelagic nation, off-grid peer-to-peer (P2P) electricity trading combined with blockchain technology is highly significant. A secure blockchain can eliminate intermediaries, replacing them with a distributed network of users who collaborate to validate, consolidate, and synchronize data in a ledger through a consensus mechanism. Smart contracts enable automatic execution under specific conditions [9]. The potential of blockchain can be fully realized when combined with data from Internet of Things (IoT) devices and analyzed using machine learning or artificial intelligence techniques. In regions such as the Indonesian islands, the potential of the blockchain market in the mini-grid market is nearly as substantial as the mini-grid market itself, particularly given Indonesia's rapid economic growth among G20 countries and the accompanying rise in energy demand. Demonstrating the effectiveness of blockchain here creates enormous opportunities for scalability across mini-grid and micro-solar systems of all sizes and geographic distributions, as the technology can be applied to any smart meter network.

3. Materials and Methods

The project involves the installation of solar panels to create microgrids in the Gumelar District, Banyumas Regency, Central Java. The research commenced in March 2022, involving relevant stakeholders such as the Blockchain Climate Institute and local research institutions. A blockchain-based application will facilitate P2P energy trading (buying and selling electricity) among "Prosumers". Interviews were conducted with key stakeholders such as the State Electricity Company (PT PLN Persero), the Ministry of Energy and Mineral Resources (ESDM), NGOs, entrepreneurs, and other experts to analyze the potential impact of P2P energy trading model using blockchain technology. The goal is to improve access to clean and affordable energy for households in Indonesia, aligning with the Sustainable Development Goals. The insights from the interviews were transformed into a SWOT-based questionnaire and used to survey application users, allowing for comparisons of different responses. The study involved various stakeholders related to the operation of a model, including homeowners with solar panels in two locations in Indonesia. Semi-structured interviews were conducted with the following stakeholders:

1. Homeowners (10 households) at one location who are given 3 KWh of electricity to be bought and sold for 30 consecutive days.
2. Regulatory and electricity provider – the Ministry of Energy and Mineral Resources (ESDM).
3. State electricity company in Indonesia – PLN.
4. Non-Governmental Organizations (NGOs) working in renewable energy and community empowerment – Institute for Essential Services Reform (IESR).
5. Private companies engaged in the energy business (IPP) and solar panels – Awina Company.
6. Academics – IPB University.

4. Results and Discussion

4.1. Peer-to-Peer Energy Trading Model by Blockchain Technology

This model implements a solar microgrid system in a rural area in Gumelar, Banyumas, Central Java. The model generates a smart contract that facilitates grid users to buy, sell, and trade electricity through a mobile application. The program examines the impact of the model on users compared to previous electricity access methods, as well as the operation and billing techniques of the mini-grid. At the end of the program, the system is handed over to the local community, and its management is handed over to a cooperative formed to operate sustainably and integrate it with broader community service delivery to maximize sustainable development impact. The ultimate goal is to reach the entire microgrid industry. The users of the model are focusing on low-income households that struggle to access affordable energy and receive minimal fuel subsidies. Additionally, the model aims to assist communities with access to the grid but are experiencing frequent power outages, occurring at least twice a week for approximately 2 hours each time. By examining the impact on these areas, the model seeks to gain a better understanding of the potential for expansion in Indonesia, considering the adaptability of the core technology to various scenarios and operational cases.

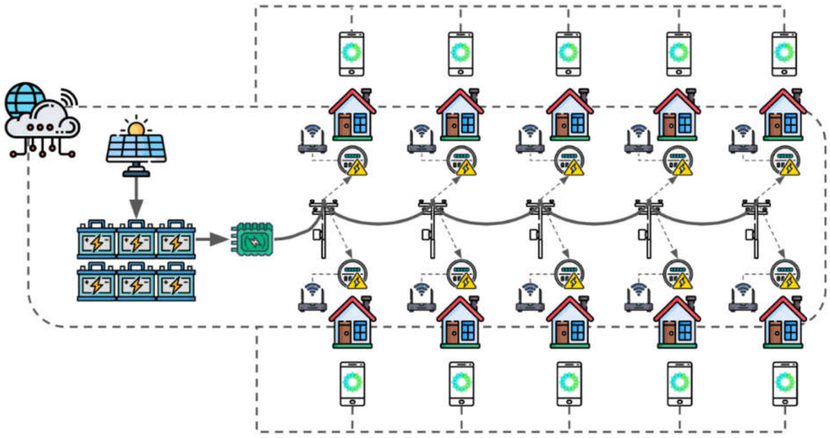


Figure 1. Peer-to-Peer Energy Trading System Design in Gumelar.

4.2. Implementation of a Peer-to-Peer Energy Trading Model Using Blockchain Technology in Central Java

The study involved prosumers from 10 households in Gumelar District who were connected to a single energy supply distributed by solar panels through a battery system. Originally, the plan was to install solar panels on each participating house's roof. However, this plan was changed, and the solar panels were arranged in a community setup placed in the Gumelar Office, to improve the network. This decision was made due to potential political and structural issues that might arise from roof installation and a technical considerations regarding the installation of cables and the overall system cost.

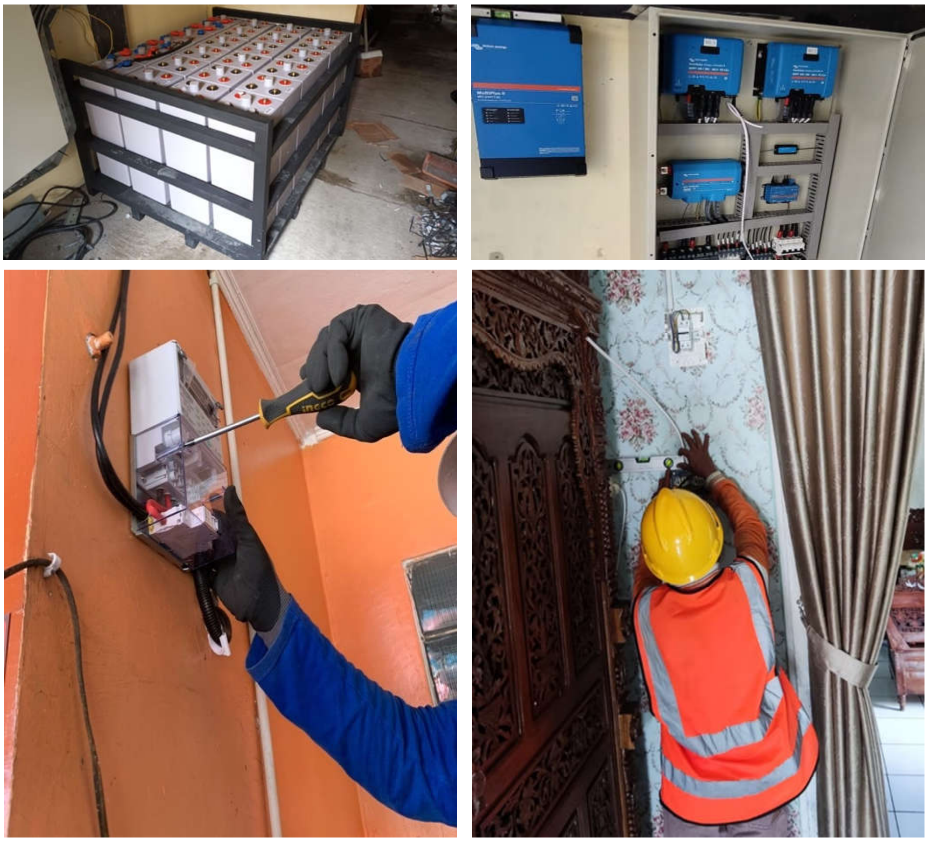
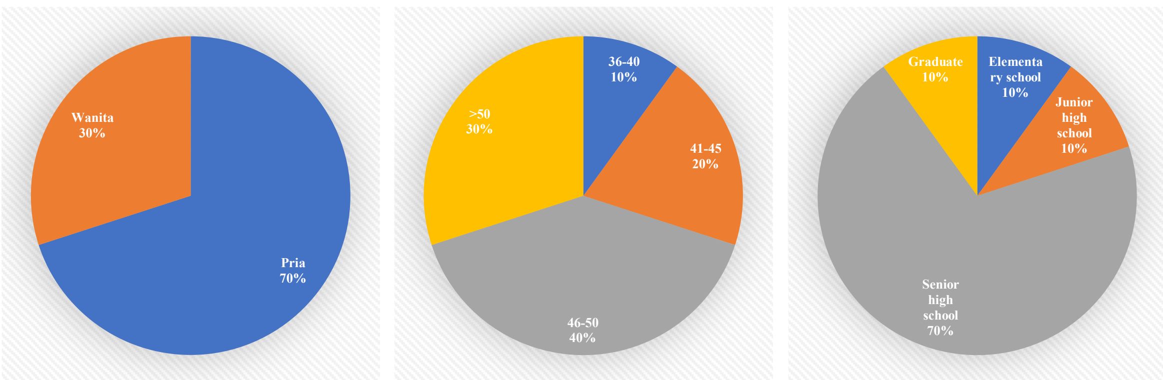


Figure 2. Implementation of a peer-to-peer energy trading model using blockchain technology. In Gumelar, Banyumas, Central Java

4.3. Stakeholders' Perceptions

The model trial was conducted twice: (a) from December 15, 2023, to January 13, 2024, and (b) from January 15 to February 13, 2024. A perception test was carried out on 10 prosumers in Gumelar District. They were asked to complete a questionnaire and then participate in a semi-structured interview to ensure that all questions were answered properly and correctly. The questionnaire filled out by the prosumers and expert users was then tested for validity and reliability. The results were analyzed using four methods: (a) IFE/EFE Matrix, (b) IE Matrix, (c) SWOT Matrix, and (d) SPACE Matrix to assess the results and their suitability with each other. Through the analysis of these various matrices, the stakeholder's perceptions will be assessed to understand the potential development of P2P energy trading using Blockchain technology and the factors that affect it.



a. Gender category b. Age category c. Education category

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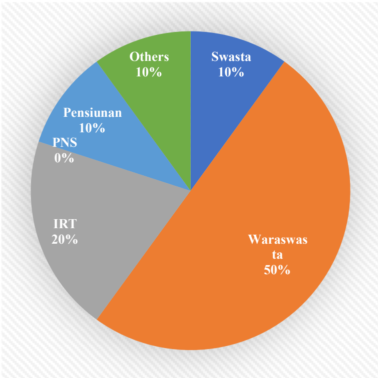
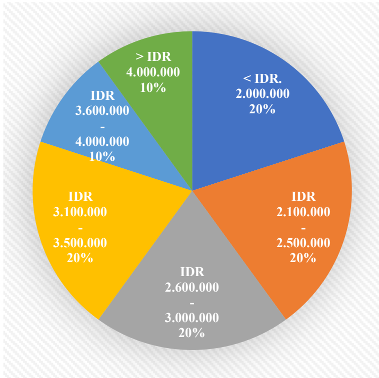


d. Work category



e. Income category

Figure 3. Participants Profile.

The survey participants were predominantly male, accounting for 70% of the total respondents (7 people). There were three female respondents, comprising 30% of the total. Notably, these three women were using an electricity buying and selling application on behalf of their absent husbands. The highest number of respondents, four people (40%), fell within the 46-50 age range, followed by three people (30%) in the over 50 age range. Additionally, two people (20%) were in the 41-45 age range, while a person (10%) fell in the 36-40 age range. It's important to mention that there are few young people in Gumelar District (aged 18-35) as most individuals in this age range work as Indonesian Migrant Workers abroad. The majority have a high school education, comprising 70%. Additionally, there is a person (10%) with an elementary school (SD), junior high school (SMP), and bachelor's degree (Sarjana). It is noteworthy that although most of them have a high school education, on average they are former Indonesian Migrant Workers who have worked abroad. Their level of technological literacy and software usage is quite promising. Providing training to each of these individuals should not take long. According to the survey, the majority of respondents, five people (50%), are self-employed. Additionally, two respondents work as housewives. The following categories are private employees, retirees, and others, represented by a person (10%). It's worth noting that many of the respondents were former Indonesian Migrant Workers abroad who, upon returning to Indonesia, tended to start their businesses or become small entrepreneurs contributing to their respective regional economies. The respondents have varying income levels. 10% of respondents earn below Rp. 2,000,000, while another 10% earn above Rp. 4,000,000. The majority, which is 20% of the respondents, earn between Rp. 2,100,000 and Rp. 3,500,000, with two people falling into this category.

4.4. Internal Factors Evaluation and External Factors Evaluation Matrix Analysis

Identification of internal and external factors was carried out to obtain information related to the Strengths, Weaknesses, Opportunities, and Threats factors in this model. This identification was carried out using in-depth interviews or brainstorming from various sources who meet the stakeholder's criteria related to the model, including the following parties:

1. Regulatory and electricity provider – the Ministry of Energy and Mineral Resources (ESDM).
2. State electricity company in Indonesia – PT PLN Persero.
3. Non-Governmental Organizations (NGOs) working in renewable energy and community empowerment – Institute for Essential Services Reform (IESR).
4. Private companies engaged in the energy business (IPP) and solar panels – Awina Company.
5. Academic – IPB University.

The next step involves assigning weights and ranks to each variable. The findings from the IFE and EFE analyses are then organized into a matrix for assessing the key factors influencing the model. This provides a clear understanding of the model's current position and serves as valuable input for devising an effective strategy for its implementation.

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4.5. Internal Factors Evaluation Analysis

Identification of the internal factors of this model involves assessing its strengths and weaknesses, assigning them weights and ratings, and then processing them to obtain a score on the IFE Matrix. The IFE matrix identification is detailed in the table below.

Table 1. Internal Factors Evaluation Matrix.

No.	Internal Factors	Weight	Rating	Score
	Strengths			
1	The model gives you the freedom to choose to generate and sell electricity.	0.03	3.70	0.10
2	The model can improve your ability to manage electricity.	0.03	3.20	0.08
3	The model can send electricity from areas with excess to areas with electricity shortages.	0.02	3.40	0.08
4	The model creates clarity and freedom in direct electricity buying and selling (without intermediaries).	0.02	3.70	0.09
5	The model eliminates PLN's monopoly as an electricity provider.	0.03	3.30	0.09
6	The model makes it easy to manage your electricity usage and buying and selling.	0.02	3.60	0.09
7	The model increases your electricity savings.	0.02	3.70	0.09
8	The model is environmentally friendly and has pollution-free electricity.	0.03	3.40	0.09
9	The model eliminates centralized electricity management in urban areas.	0.02	2.70	0.07
10	The model will become a solution for remote communities with difficulty accessing electricity and finances.	0.03	3.50	0.09
11	The model creates transparency such as the amount of electricity, duration, usage, and selling prices.	0.03	3.50	0.10
12	You are used to using the internet or Smartphone as a tool to implement the model.	0.02	3.60	0.06
13	The requirements for installing the model are easy to become a producer or consumer of electricity.	0.03	3.40	0.09
14	The electricity usage rate on the model is more stable.	0.02	2.60	0.06
15	The model complements the existing PLN electricity.	0.02	3.30	0.08
	Subtotal of Strengths	**0.37**		**1.26**
	Weakness			
1	Lack of knowledge to implement the model.	0,02	3,10	0,07
2	The model produces limited electrical energy during the day.	0,02	2,40	0,05
3	The high cost of installing technology in the model.	0,02	2,90	0,07
4	There are no examples of other areas implementing this model.	0,02	3,70	0,09
5	The electricity-generated model is not sufficient for household needs or sales.	0,02	2,90	0,06
6	The regional data center does not regulate household electricity usage.	0,02	3,30	0,08
7	You find it difficult to adapt to using the digital application/platform model.	0,02	3,10	0,06

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No.	Internal Factors	Weight	Rating	Score
8	The installation of the model is subject to high costs.	0,02	2,10	0,05
9	The sun does not shine brightly all year round in your area.	0,02	1,60	0,04
10	The installation of the model requires a large place/room.	0,02	2,20	0,04
11	The model is only suitable for lower-middle class society who live in areas far from the city center or rural.	0.02	1.20	0.02
12	You do not mind the instability of the electricity received.	0.02	2.80	0.06
13	Your area finds it difficult to implement the model because of the large electricity needs.	0.02	1.80	0.04
14	The electricity-generated model cannot be produced continuously.	0.02	1.80	0.04
15	The electricity generated from the model tends to be small and large expenditures.	0.02	3.30	0.07
16	There are no regional regulations regarding the implementation of the model.	0.03	3.50	0.09
17	Your motivation for buying and selling electricity from this program is personal gain.	0.02	2.90	0.06
18	The uncertainty of the model is both from the electricity generated by the seller and that requested by the buyer.	0.02	2.70	0.06
19	The costs set by the model are only suitable for some groups of electricity buyers.	0.02	3.00	0.07
20	There is no legal regulation to protect model users.	0.02	2.90	0.07
21	The electricity availability model is small, so wait to become a user.	0.02	3.30	0.07
22	The more model users there are, the more difficult it will be to manage.	0.02	1.50	0.03
23	The function of the model used is still not optimal and has many shortcomings.	0.02	3.50	0.07
24	The residential area has little internet network, and few people have smartphones.	0.02	1.90	0.04
25	The internet connection in your place of residence is poor (weak).	0.02	2.60	0.06
26	The electricity generated from the model is only for household scale.	0.02	2.80	0.06
27	The electricity price from the old model will become more expensive over time.	0.02	2.50	0.05
28	Implementing the model will make it difficult for PLN electricity users, especially for PLN customers.	0.02	2.40	0.05
29	Do not have electrical knowledge and skills.	0.02	2.50	0.05
	Subtotal of Weaknesses	**0.63**		**1.66**
	Total (Strengths + Weaknesses)	**1.00**		**2.92**

There are fifteen significant strength factors and twenty-nine key weakness factors that influence this model. The IFE matrix indicates a score of 2.92. According to the IFE Matrix, the main strength factor crucial to this model is the freedom to generate and sell electricity (0.1). This factor introduces transparency in the electricity usage and sales by disclosing the amount, duration, and price of electricity (0.1). This internal advantage is highly influential in driving the adoption of this model by stakeholders. The concept of transparency is at the core of Blockchain technology, enabling public participation in the electricity trading process without fear of deception due to the recording of all transactions in the application. Regarding weakness factors, the IFE matrix suggests that this model is primarily suitable for the lower middle class residing in rural or remote areas (0.02). Additionally, the intermittent electricity production to meet the substantial demand is a major weakness (0.03). Furthermore, the weak and relatively expensive internet network, low penetration of sophisticated mobile phones, and complex system management contribute to a negative impact on the model's adoption. Currently, P2P energy trading using blockchain technology remains at the level of simulation and has not involved large prosumers (more than 100 people). The prospect of simulations involving numerous participants and advanced technology is indeed intriguing.

4.5. External Factors Evaluation Matrix Analysis

Identification of external strategy factors includes opportunity and threat factors that influence the strategy of this model. The results are then processed to obtain a score on the EFE matrix.

Table 2. External Factors Evaluation Matrix.

No.	External Factors	Weight	Rating	Score
	Opportunities			
1	The model creates electricity distribution.	0.03	3.30	0.11
2	The model increases public awareness and cooperation in using environmentally friendly electricity (pollution-free).	0.03	3.50	0.12
3	The model opens up new business opportunities.	0.03	3.50	0.11
4	The model becomes additional income.	0.03	3.40	0.12
5	The model opens up opportunities for new business investment.	0.03	3.40	0.12
6	The model increases community income.	0.03	3.30	0.10
7	The model managed efficiently by the community.	0.03	3.50	0.11
8	The model sends electricity and stores electricity usage data via smartphones.	0.03	3.40	0.11
9	The community is empowered in business and socially with the model.	0.03	3.40	0.10
10	The model provides electricity for public facilities (mosques, roads, etc.).	0.03	3.30	0.10
11	The model creates benefits at the community level (RT/RW).	0.03	3.40	0.10
12	The model fosters public interest in using renewable energy (environmentally friendly).	0.03	3.50	0.11
13	The model helps solve the problem of the limited reach of the PLN electricity network.	0.03	3.30	0.09
14	The model used can create employment opportunities for the community.	0.03	3.50	0.11
15	The behavior of the community working together in meeting electricity needs makes it easier to implement the model.	0.03	3.50	0.10
16	The electricity sales system to PLN increases the use of the model.	0.03	3.20	0.09
17	PLN's high electricity load increases public interest in using the model.	0.03	3.40	0.10
18	PLN's plan to reduce its business area is an opportunity for the community to switch to the model.	0.03	3.20	0.09
19	The limitations of fossil fuels can increase the use of the model.	0.03	3.40	0.10
	Subtotal of Opportunities	**0.58**		**1.97**

No.	External Factors	Weight	Rating	Score
	Threats			
1	Weather conditions have a major impact on electricity production in the model.	0.03	3.00	0.09
2	There are no laws and regulations governing the transfer of PLN electricity customers to the model.	0.03	2.80	0.09
3	Concerns about the security and confidentiality of personal data, if they become model users.	0.03	2.20	0.06
4	No government assistance or private investment in the model.	0.03	2.10	0.06
5	The danger of customer data theft reduces interest in using the model	0.03	2.30	0.06
6	The model is highly dependent on the availability of smartphones and internet connections.	0.03	2.60	0.08
7	The installation of the model must not exceed the size of PLN's installed power.	0.03	2.20	0.06
8	The procedures for trading (buying and selling) electricity from the model are not properly regulated.	0.03	1.70	0.06
9	The implementation of the model involves many parties.	0.03	1.60	0.04
10	PLN's free electricity service program for public facilities hinders the implementation of the model.	0.03	2.10	0.05
11	Bad relationships between neighbors can hinder the model.	0.03	2.10	0.06
12	The wasteful behavior of people using electricity can threaten the sustainability of the implementation of the model.	0.02	2.50	0.06
13	The losses of people who have installed PLN electricity infrastructure hinder the implementation of the model.	0.03	1.40	0.04
14	People who fail to pay for electricity hinder the development of the model.	0.03	1.80	0.05
	Subtotal of Threats	**0.39**		**0.86**
	Total (Opportunities + Threats)	**0.97**		**2.83**

There are 19 key opportunity factors and 14 threat factors that significantly influence this model. The IFE matrix results indicate a total score of 2.83. According to the EFE Matrix, the opportunity factors for the program is the increase in public awareness and cooperation in using environmentally friendly, pollution-free electricity (0.12). Furthermore, there is an opportunity for additional income (0.12) and new business investment (0.12). This particular opportunity factor is crucial as it can expand market share and generate public interest in the model. Regarding threat factors, the EFE matrix indicates that the model faces significant threats from the implementation aspect involving multiple parties (0.04). Additionally, there is a potential threat in the form of losses for state utilities such as PLN or individuals who have already established electricity infrastructure if this program implemented on a large scale (0.04). A threat poses to the sustainability and profitability of PLN's state utility business and could impede the implementation of this model.

4.6. Internal-External Matrix Analysis

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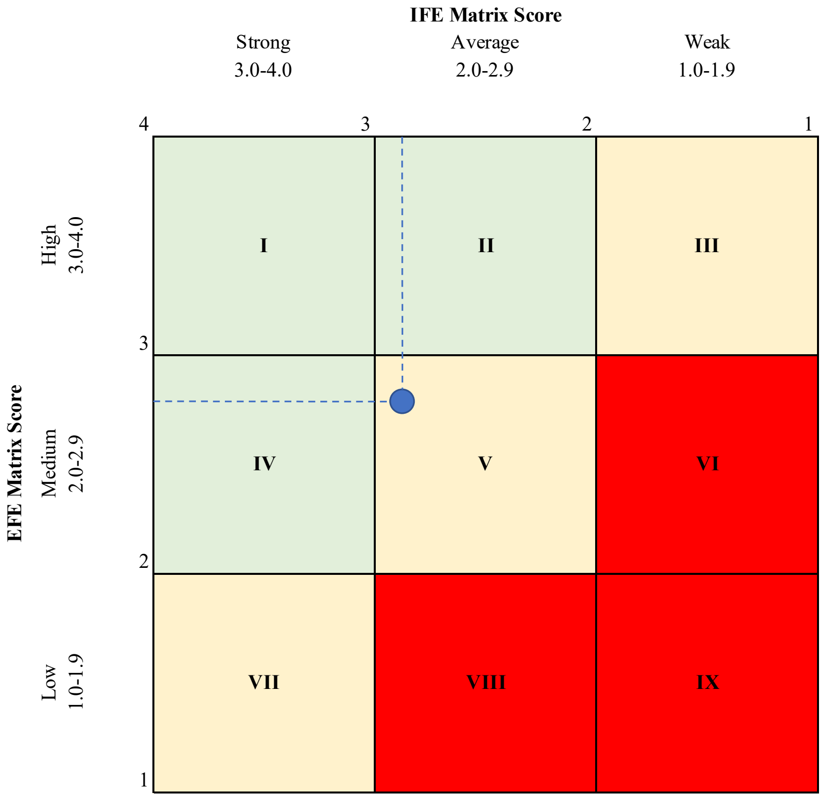

Figure 4. Internal-External Matrix.

For the internal and external results using the IFE-EFE matrix, we obtained an IFE matrix score of 2.92 and an EFE matrix score of 2.83. This places the model in quadrant V in the IE matrix. IE matrix theory, the recommended strategy for quadrants III, V, and VII is the hold and maintain strategy. Based on stakeholder assessments, the suggested strategies for this model are market penetration and product development [34]. Market penetration could involve increasing the number of prosumers from 10 to 100 or 1000, or expanding to one district, or province at a time to assess the effectiveness of systems. Encouraging existing prosumers to buy and sell electricity more frequently is also recommended.

To expand the market share of prosumer products, product development can focus on creating high-selling items. For instance, offering solar panels to urban communities with higher incomes through a program involving PLN as an intermediary, similar to the trial conducted by "Tenaga National Berhad" (TNB), a Malaysian state-owned electricity utility company, can be beneficial. This approach allows the sale of environmentally friendly electricity at a premium price to specific consumer groups. It's important to view this program as a complement to PLN's existing system, rather than a direct competitor. Furthermore, addressing the current issue of power wheeling, where PLN's transmission and distribution networks can be jointly utilized, with a business model like this could be a viable solution. Despite PLN's current reluctance to utilize the concept of power wheeling, this approach holds promise.

4.7. SWOT Analysis

To assess stakeholder perceptions of this model, a SWOT analysis was conducted. The aim is to identify both internal and external aspects of the P2P Blockchain program, mapping out potential opportunities and challenges. This involves taking stock of factors influencing the model within the planning strategy, serving as a foundation for determining necessary corrective actions for future developments. The study's SWOT analysis involved comparing factors impacting the model, comprising Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T). The detailed mapping

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of SWOT factors, derived from the results of brainstorming with expert users as stakeholders, is presented in the following table. The basic concept of SWOT analysis was developed by assessing weighted scores using EFE/IFE analysis. Stakeholders from the government, private sector, academic, non-governmental organizations, and the community act as assessors. They assign a weight of 0.00 to 1.00 to each aspect of SWOT. Each factor (internal/external) is then summed to produce a weight of 1. Once the criteria are weighted, the next step is to rate them to indicate their level of importance (1=less important, 2=quite important, 3=important, and 4=very important). The weighting value is then multiplied by the specified rating. The position of the SWOT quadrant is determined by calculating each factor (internal/external) to produce a diagram indicating the program's future quadrant position. The quantitative SWOT analysis uses results from the IFE and EFE matrix approaches obtained in the previous analysis. Based on the IFE matrix, the total S-W score is -0.40, and the total O-T score is 0.31. The detailed results of the IFE and EFE matrix analysis are presented in the following table.

Table 3. IFE-EFE Matrix Analysis.

Internal Factor	Skor	External Factor	Skor
Strength (S)	1.26	Opportunities (O)	1.97
Weakness (W)	1.66	Threats (T)	1.66
Total (S-W)	-0.40	Total (O-T)	0,31

Based on the analysis results, this model located at the coordinate point (-0.40, 0.31), placing it in quadrant II. This indicates that the model should apply the STABILITY strategy, with a specific focus on the "Selective Maintenance Strategy" for improvement. This involves internal consolidation to address weaknesses and sustain accomplishments. The goal of the Stability strategy is to maintain the current situation by leveraging opportunities and addressing weaknesses.

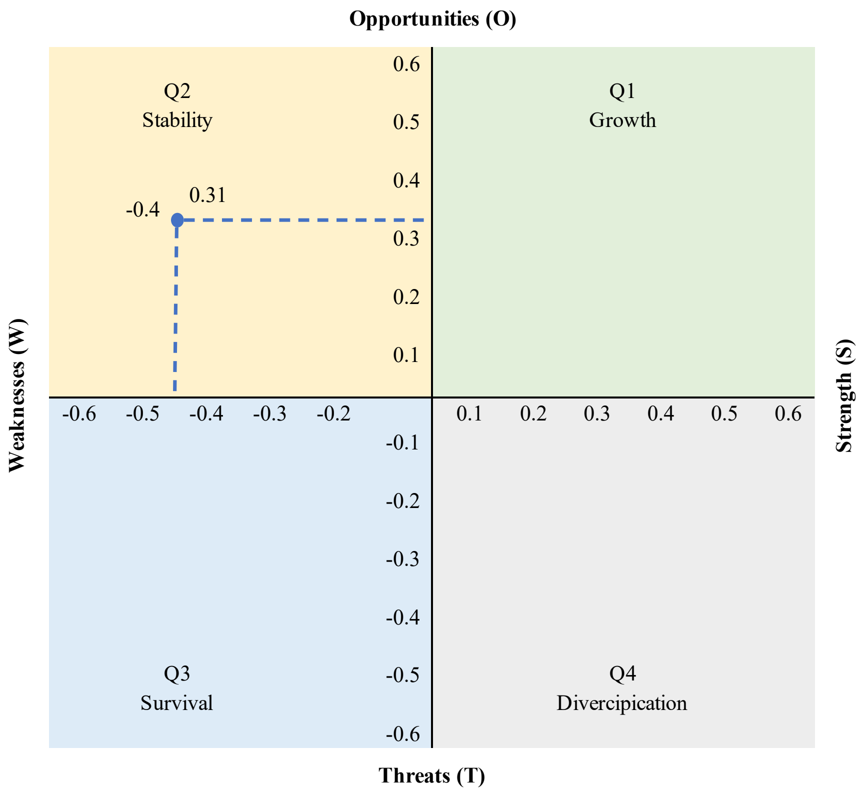

Figure 5. SWOT Matrix.

This model enables equitable electricity distribution in remote and marginalized areas. Despite PLN's claim that Indonesia's electrification rate is 99%, sporadic power outages persist in Java, including in the Gumelar District. The program aims to achieve two objectives: first, to increase the adoption of this model in energy-deprived areas by focusing on energy quality, reliability, sufficiency, affordability, community acceptance, environmental feasibility, and the multiple socioeconomic benefits of energy access; and second, to allow PLN to act as an intermediary, supplying clean electricity at a competitive price, when targeting urban or industrial areas.

4.8. SPACE Matrix Analysis

The SPACE (Strategic Position and Action Evaluation) Matrix consists of a 2×2 table with four quadrants: aggressive, conservative, defensive, and competitive strategies. The matrix's axes are determined by internal factors such as Financial Strength (FS) and Competitive Advantage (CA), as well as by external factors including Environmental Stability (ES) and Industry Strength (IS). The financial strength factor evaluates all indicators of an organization's financial capability. The environmental stability and industry strength factors analyze their respective content and material. The strategy can formulated as follows: Environmental stability (ES), represented by the highest score of market entry barriers (-4), is a significant concern. The Constitutional Court, through a judicial review decision, annulled Article 10 Paragraph 2 and Article 11 Paragraph 1 of the 2009 Law on Electricity, which further confirms that PLN has control over electricity. The coordination of electricity provision and distribution remains with the government, specifically through state owned enterprise (BUMN) operating in the electricity sector (i.e., PLN) and unbundling. Protective regulations act as the primary barrier hindering the development of this program. And PLN's support for renewable energy, such as solar power, is currently inadequate. The core of this program revolves around the installation of solar panels. PLN's policy prohibiting the direct sale of electricity from solar panels to PLN, in addition to the uncompetitive prices offered to IPP solar panels, pose significant challenges. Moreover, the high initial cost and lengthy payback period deter consumer adoption of solar panels, thus prolonging the decision-making process.

The competitive advantage (CA) of controlling suppliers is rated (-3). This advantage stems from PLN's monopoly over the sale and purchase of electricity, enabling it to offer affordable and uninterrupted electricity to the community by leveraging fossil fuels and an extensive network. The superiority of technology and product quality holds a rated (-3) also. An existing advantage lies in the transparent implementation of a program that allows the community to buy, sell, and track energy transactions, thereby promoting the transition from fossil fuels to clean energy through used solar panels. As for financial strength (FS), the working capital is rated at (+5) due to the substantial initial investment required, balanced by low operational costs and reliance on solar energy for electricity generation. This program is also beneficial for remote areas and only necessitates an application and a smart meter tool for distribution. The return on investment (ROI) similarly rated at (+5). Despite the initial investment, the program's benefits for the community, particularly in areas not covered by PLN electricity, and its positive impact on the environment and society expected to surpass the initial investment value. Regarding industrial strength (IS), financial stability is rated at (+5) owing to the P2P electricity regulation buying and selling program, ensuring the sustainability of the independent system, community empowerment, and environmental benefits from solar energy use.

X-axis = Average CA score + Average IS score = 1

Y-axis = Average FS score + Average ES score = -0.3

Therefore, the coordinate point xy = (1, - 0.3).

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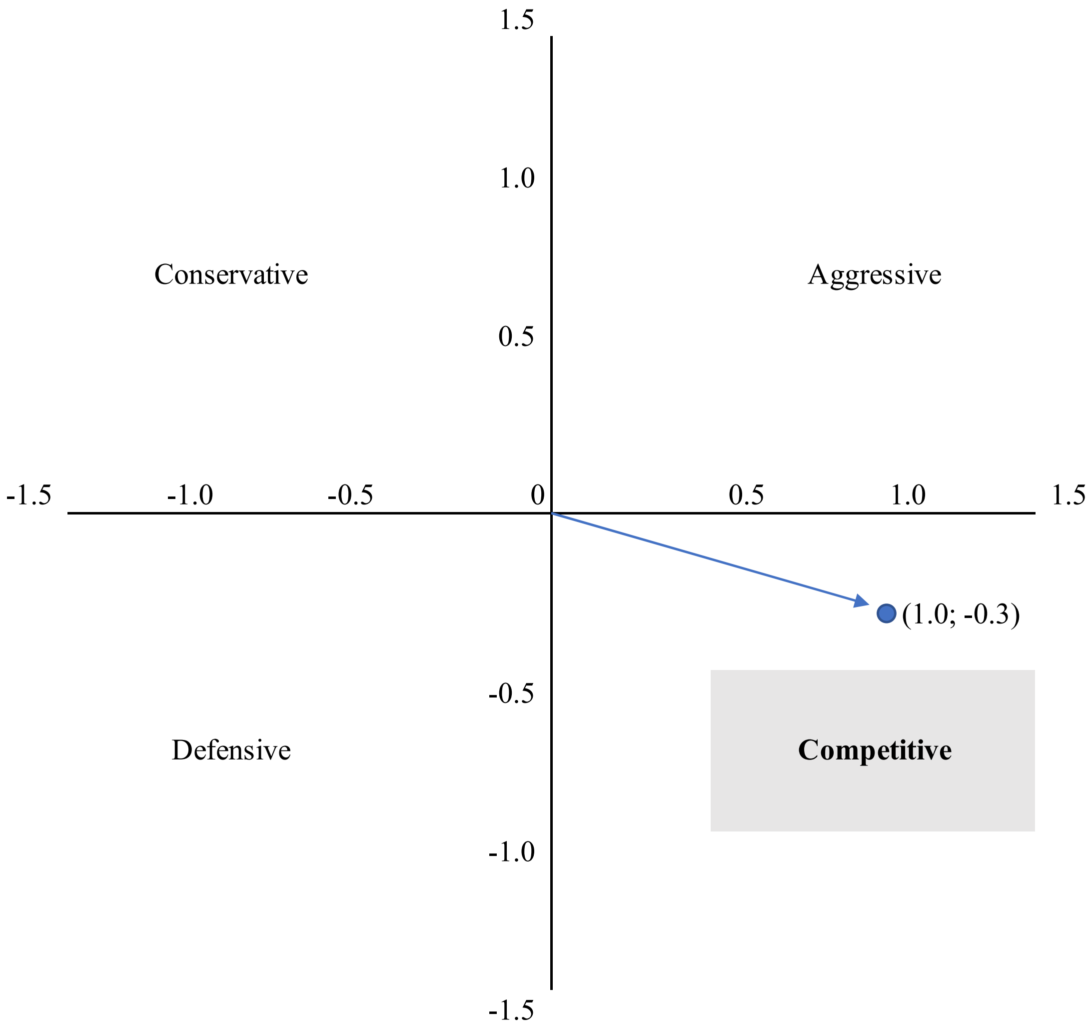

Figure 6. SPACE Matrix.

Based on the SPACE matrix, it is evident that the vector line points towards the COMPETITIVE quadrant (bottom right) of the matrix. Suggests that the model holds the potential for a competitive advantage in its evolving activity type. Consequently, it inferred that the model is well-positioned to capitalize on internal strengths to leverage external opportunities, address internal weaknesses, and mitigate external threats. Collaborating with PLN is a crucial aspect of the widespread adoption of this model, enabling it to operate in areas where the PLN network doesn't reach. The stakeholder perception analysis used the IFE-EFE matrix, IE matrix, SWOT matrix, and SPACE matrix. The conclusion is that the P2P energy trading model, supported by blockchain technology, can grow and evolve by meeting various existing requirements. Additionally, strategic steps for future development, including collaboration with PLN, have been clearly outlined.

4.9. Sustainability Policy Strategies to Model Implementation

The sustainability policy strategies in the model use the SWOT matrix approach. This involves describing the various external and internal factors that impact the model's sustainability, based on EFAS (External Factors Analysis Summary) and IFAS (Internal Factors Analysis Summary) conclusions. The SWOT matrix helps to depict how the model can adapt to external opportunities and threats by leveraging its strengths and addressing its weaknesses.

Table 4. SWOT Matrix Alternatife Strategy.

No.	S-O Strategy	Rank
1	Collaboration with PLN to help meet the electricity needs of remote areas.	1
2	Collaboration with PLN, which has an extensive network.	2
3	Improve the transparency and accountability system for solar panel electricity sales and purchase transactions.	3
No.	**W-O Strategy**	
1	Regulations are needed that support independent electricity sales, especially in areas without PLN networks.	1
2	Increase the number of users of this model en masse.	2
3	Increase public awareness to want to use electricity from this model to improve their family's economy.	3
No.	**S-T Strategy**	
1	Carried out on remote or massive targets.	1
2	The available of internet network technology in unreachable areas (Starlink).	2
3	Increase socialization to the community about the economic benefits of this model.	3
No.	**W-T Strategy**	
1	Investors with a high social entrepreneurship vision are needed to support this model.	1
2	Increase community behavior to use this model.	2
3	Improve the interface system (UI/UX) to make it easier.	3

To determine the priority of each alternative strategy, the researcher utilized the Quantitative Strategic Planning Matrix (QSPM), a highly suitable tool for prioritizing crucial internal, external, and competitive information essential for crafting an effective strategic plan. Then, the decision-making stage relies on the key indicators or factors outlined in the input stage, IFAS and EFAS. These factors prepared an alternative strategy in the second stage (matching stage). Following the QSPM assessment of each alternative strategy, they are sorted from the largest to the smallest value to identify a priority strategy for implementation. A total of 12 vital strategies need to be executed to effectively promote the P2P energy trading model using blockchain technology for systematic development in society. The strategy priorities are shown in the table.

4.10. Peer-to-Peer Energy Trading Model Strategy Priorities

The model is considered economically feasible. On the other hand, the model can effectively reduce CO_2 due to the use of solar panels. Furthermore, this model will work more effectively if it can build cooperation with PLN, which is legally the only utility company in Indonesia that has the largest electricity network. For the initial stage, the Regulatory sandbox model will be an ideal forum to start a dialogue and experiment between regulators and innovators to learn and exchange insights about testing a product before it is suitable for use in the wider community. A trial like this was conducted by "Tenaga Nasional Berhad" (TNB), a Malaysian state-owned electricity utility company, in 2019 on a P2P energy trading model using blockchain technology in collaboration with the renewable energy authority SEDA (Sustainable Energy Development Authority). Thus, this might be an entry point in collaborating with PLN as the electricity sold is environmentally friendly energy and is sold at a higher price to certain consumers by involving PLN as part of its business model. This program should not be considered a competitor to PLN but rather as a complement to the existing PLN system. The energy trading model's twelve priority strategies are represented using the

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triangular relationship between environmental, social, and economic dimensions, which are interconnected and mutually influential.

Table 5. Peer-to-Peer Energy Trading Model Strategy Priorities.

No.	Strategies	Total	Annotation	Priority
1	Collaboration with PLN to help meet the electricity needs of remote areas.	1.92	S-O	1
2	Collaboration with PLN, which has an extensive network.	1.75	S-O	2
3	Regulations are needed that support independent electricity sales, especially in areas without PLN networks.	1.67	W-O	3
4	Investors with a high social entrepreneurship vision are needed to support this model.	1.47	W-T	4
5	Carried out on remote or massive targets.	1.44	S-T	5
6	Increase socialization to the community about the economic benefits of this model.	1.32	S-T	6
7	Improve the transparency and accountability system for solar panel electricity sales and purchase transactions.	1.28	S-O	7
8	Increase community behavior to use this model.	1.27	W-T	8
9	Increase the number of users of this model en masse.	1.26	W-O	9
10	Increase public awareness to want to use electricity from this model to improve their family's economy.	1.15	W-O	10
11	The available of internet network technology in unreachable areas.	0.59	S-T	11
12	Improve the interface system (UI/UX) to make it easier.	0.23	W-T	12

5. Conclusions

This study demonstrates the effectiveness of the microgrid system for peer-to-peer energy trading using blockchain technology in the Gumelar District, Banyumas Regency, Central Java Province, tasted to 10 Prosumers. The results show that this model effectively addresses the challenges of sustainable electricity. The model has proven to be environmentally, economically, and socially beneficial, serving as a valuable reference for addressing energy access inequality comprehensively. Based on the analysis of the IFE-EFE matrix, the strength factors of this model are the freedom to generate and sell electricity (0.1) and transparency in electricity usage and sales by disclosing the amount, duration, and price of electricity (0.1). Regarding weakness factors, this model is primarily suitable for the lower middle class residing in rural or remote areas (0.02). Additionally, the intermittent electricity production to meet the substantial demand is a weakness (0.03). The opportunity factor for the model is the increase in public awareness and cooperation in using environmentally friendly, pollution-free electricity (0.12). Furthermore, there is an opportunity for additional income (0.12) and new business investment (0.12). Regarding threat factors, the model faces significant threats from the implementation aspect involving multiple parties (0.04). There is a potential threat in the form of losses for state utilities such as PLN or individuals who have already established electricity infrastructure if this program is implemented on a large scale (0.04). Based on the SWOT analysis, this model is located at the coordinate point (-0.40; 0.31), placing it in quadrant II. This indicates that the model should apply the Stability Strategy, with a specific focus on the Selective Maintenance Strategy for improvement. The stability strategy goal is to maintain the current situation by leveraging opportunities and addressing weaknesses.

It enhances the quality, reliability, affordability, and energy access while garnering community acceptance and offering multiple socio-economic benefits. Peer-to-peer energy trading using blockchain technology provides greater flexibility for the end users expands opportunities for consuming renewable energy, and contributes to mitigating climate change in Indonesia. For effectiveness and efficiency, the strategy emphasizes fostering collaboration with PLN, which holds the legal authority as the sole utility company in Indonesia with an extensive electricity network, as well as advocating for regulations that support the independent purchase and sale of solar-powered electricity, particularly in areas without PLN network coverage. Regulatory sandbox can be tried at several targeted areas. The potential for blockchain in the mini-grid market is enormous, particularly in Indonesia's island regions, given the country's rapid economic growth and substantial rise in energy demand among the G20 nations. By demonstrating the effectiveness of this approach, there is significant potential for scalability across microgrid systems of varying sizes and geographic distributions, as the technology can implemented across any smart-meter network.

Author Contributions: This study was conducted as main Author by F.Y., doctor candidate at the School of Environmental Science Universitas Indonesia. The Co-Authors R.F.S., P.Y. and T.E.B.S. has contributed in guiding the main Author during his study and provide the editorial and proofreading to the content. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Apendix A

Form 1. Internal Factors Questionnaire (Strengths).

No.	Indicators	Assessment			
		1	2	3	4
1	The model gives you the freedom to choose to generate and sell electricity.				
2	The model is environmentally friendly and has pollution-free electricity.				
3	The model will become a solution for remote communities with difficulty accessing electricity and finances.				
4	The model creates transparency such as the amount of electricity, duration, usage, and selling prices.				
etc.					

Form 2. Internal Factors Questionnaire (Weakness).

No.	Indicators	Assessment			
		1	2	3	4
1	The model produces limited electrical energy during the day.				
2	The installation of the model requires a large place/room.				
3	The model is only suitable for lower-middle class society who live in areas far from the city center or rural.				
4	The more model users there are, the more difficult it will be to manage.				

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No.	Indicators	Assessment			
		1	2	3	4
etc.					

Form 3. External Factors Questionnaire (Opportunities).

No.	Indicators	Assessment			
		1	2	3	4
1	The model increases public awareness and cooperation in using environmentally friendly electricity (pollution-free).				
2	The model opens up new business opportunities.				
3	The model becomes additional income.				
4	The model opens up opportunities for new business investment.				
etc.					

Form 4. External Factors Questionnaire (Threats).

No.	Indicators	Assessment			
		1	2	3	4
1	The implementation of the model involves many parties.				
2	PLN's free electricity service program for public facilities hinders the implementation of the model.				
3	The losses of people who have installed PLN electricity infrastructure hinder the implementation of the model.				
4	People who fail to pay for electricity hinder the development of the model.				
etc.					

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