The Autonomy Measurement Index on Indonesian Solar Power Plant

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Abstract

Background: Energy autonomy refers to the guaranteed energy availability by maximizing domestic potential. The success of the energy autonomy target requires dimensions of indicators for measurement, assessment, and evaluation. The purpose of the study is to determine the autonomy of Solar Power Plant management in Indonesia through indexing and to develop improvement strategies for management autonomy located in Jakarta, Bandung, and Yogyakarta.

Methods: This research applied qualitative methods. The data from the informants were collected to obtain management autonomy measures that used scores and weights. A Strengths Weaknesses Opportunities and Threats matrix analysis establishes a strategy to increase autonomy.

Results: The results showed that the value of the management autonomy index score was 2.79 ((from a maximum scale of 4.00), which was reasonable enough and equivalent to level three in the Capability Maturity Model. This level shows the capability to define the running process. It requires two steps of improvement or a strategy to achieve the optimal level, being able to perform process optimization for autonomy management (level 5). Based on the matrix analysis results, the appropriate approach is a strategy that improves weaknesses by maximizing opportunities in a quadrant III turn ground.

Conclusios: The strategy was done by developing policies to enhance solar power plant stakeholder synergy in Indonesia and facilitate technology transfer to international solar power plant component producers. Autonomy in the management and control of solar power plants is essential so that there is no disruption on energy security in Indonesia. This study recommends evaluating or measuring the autonomy index for other energy sectors, especially to support the achievement of the energy mix target, which in turn aims to increase national energy autonomy and security.

Background

Introduction

The Indonesian Government has decided to make the primary energy mix consisting of 25% petroleum, 22% natural gas, 30% coal, and 23% renewable energy in 2025 (Figure 1). The percentages in the energy mix, both in primary energy and in the electricity sector, are set to support energy security targets in Indonesia. The energy mix, however, is different from energy autonomy because the energy mix goal does not require the use of domestic power [1, 2]. For example, the mixed energy target has been achieved with renewable energy by 23% and using human resources and technology from outside, while the target of energy autonomy has not. Autonomy can be accomplished by utilizing domestic resources to the fullest extent possible through human resources, technology, and natural resources [3]. The national energy security index includes many factors, such as quality, accessibility, and acceptability. The parameters and weighting results are not yet in the autonomy index, so working on the autonomy index is essential to assess and prepare energy autonomy strategies.

Fossil energy dominance has traditionally led to renewable energy plants as an alternative source of energy, and the potential can not be optimized [4, 5, 6]. However, after the National Energy Policy published in 2014, the renewable energy industry has become an energy development priority in borders, remote, and outermost regions that are not accessible to the National Electricity Company (PLN). Indonesia has plenty of renewable energy sources for power generation with an approximate capacity of 443 GW. One of the potentials is solar energy, with a potential of up to 207 GW. Solar energy from solar plants could be used in many countries, and this performance could serve as a reference point for the potential supply of electricity in Indonesia [2]. The solar energy collected can be used as solar thermal energy for heating (for room and water) and solar photovoltaics for electricity generation [7, 8]. The captured solar power is transformed into electricity by photovoltaic cells that are semi-conductive (solar) materials. The solar energy conversion level depends on the number of solar panels used and the strength of solar energy shining in solar panels [1, 9, 10]. Despite the enormous global demand for renewable energy and the rise in dependence on electricity, environmental concerns are that in terms of energy supply to minimize greenhouse gas emissions [11, 12]. The Indonesian Government also undertook to reduce greenhouse gas emissions by 29% with its efforts and 41% with foreign aid and partnership at the World Climate Change Summit in Paris by COP 21. Based on the commitments made, the Indonesian Government's 2016 greenhouse gas emissions have been reduced by 31,60 million tons due to enhanced use of existing and renewable energy plants [13].

Solar energy is one of the potential future energy sources to establish reliable and affordable renewable energy sources, particularly for people in remote areas [11]. Indonesia's solar energy potential has encouraged the company to build many solar power plants all over Indonesia (Figure 2). The Government has installed over 100 solar power plant systems from a targeted 1000 solar power plant system for 1000 islands starting in 2013. In their Electricity Supply General Plan, PLN has targeted 1047 Mega Watt peak (MWp) of solar energy usage in Indonesia in 2025, far from being used in 2018, which was only 94.42 MWp. However, the existence and development of solar power plants still face challenges, particularly in terms of the autonomy of human resources in terms of planning, construction, operation, and maintenance [14].

Autonomy challenge is caused by limited human resources, particularly in terms of technical mastery, budget management, and time. The lack of qualifications for solar power plant operators has resulted in a limited standard of operator awareness in operating and maintaining solar power plants [15, 16]. The challenge of the autonomy of human resources in solar power plants has made the measurement of management autonomy index as an essential element in the assessment of evaluation and planning of strategies for increasing the autonomy of energy management for solar power plants [17]. However, the Autonomy Index for Energy Management has not yet been available in Indonesia. It is different from some developed countries, where the evaluation of human resource management has been standard by using several human resource management theory-based analyses. One of which is the Capacity Maturity Model (CMM) with the measurement tool maturity level. The Maturity Level Analysis Tool is a standard evaluation system used to determine human resource skills and how it implements the best industry-based organizational or project management [18, 19]. Indicators to obtain management autonomy index are obtained by assessing the organization's maturity or readiness to construct and operate a solar power plant in Indonesia, and experts' opinions on the appropriate indicators are appropriate for calculating the management index .

Some previous solar power plant studies were more concerned with optimization and technical calculations [20, 21]. The others haven't discussed the qualitative understanding of different aspects of solar power plant social and management. The results of this study were expected to provide an output of management autonomy index value in solar power plant, so that it can be used as a reference for evaluations and basis for future energy planning and to meet the target of the renewable energy mix in 2025 of 23%. This study aims to: 1) examine the key achievements and constraints of the autonomy management of solar power plant; 2) evaluate the results of weighting and autonomy index evaluation indicators in Indonesia solar power plant; 3)establish strategies to increase the autonomy of solar power plant management in Indonesia; 4)determine the relationship between increased management autonomy in solar power plants with increased autonomy and national energy security.

Methods

This research has been located in Jakarta, Tangerang, Bandung, and Yogyakarta in the following categories: Department of the Assessment and Application of Technology (BPPT); PT Lembaga Elektronika Nasional (PT LEN) and PT Surya Energi Indotama (PT SEI); Baron Technopark and Pantai Baru Yogyakarta; National Electricity Company (PLN). The data were collected through direct observation and detailed interviews with informants to determine and assess or value each of those indicators and achieving the order of the indicators to evaluate an autonomy index for the solar power plant. In addition, informants were asked to acquire external and internal environmental factors needed in the SWOT analysis to achieve strategic alternatives to improve the autonomy of solar power plant management. Informers and analysis sites were specially selected and entirely designed. Secondary data was collected by literature and journals and by documentation on the Indonesian nation's capacity and autonomy in the design, development, operation, maintenance, and implementation of the solar power plants. The supporting data were obtained from study-related focus group discussions.

The method of data collection in research allowed direct observations to give the researcher a clear view of how the solar power plant works and the managers of the solar power plant do their job. To provide answers to the formulation of the issues under investigation, the researchers conducted detailed interviews with research subjects. Before interviews, the criteria for interviews were developed based on the capabilities and capacity of the expected informants. A recording system was also used to facilitate the interview process. The questions given to the informants were in the form of closed questions, to obtain weighted value and measurements, and open-ended questions to gain further insight into the informants' ideas regarding the research object. To support the legitimacy of the data collection process, the authors have recorded the outcomes of interviews with informants in the form of an image, videos, and voice recording devices—observation and interviews during and before the study process. In order to perform literature studies, researchers should collect qualitative records of public documents (magazines,

magazines, public broadcasting, etc.) and in private documents (diaries, office-based reports, letters, etc.). The data validity in qualitative research needs to be measured to ensure the accuracy of data from researchers, sources, and views. During and after the study, the researcher tested the validity of the data by triangulating data supplied by one source toward data provided by other sources at different institutions. The researcher often measures the informants' information with actual data from observations and secondary data collected by the researcher. The Maturity Level Analysis Approach is the data analysis methodology used for measuring and analyzing the indicators accomplished [22]. The purpose of the research expected from the data collection was the energy autonomy indicators of the solar power plant, which are then required by the speakers with the guidance of standardized questions embedded in the Capability Maturity Model (CMM) guideline, to be examined (Figure 3). Through analysis, external and internal environmental data that influence solar power plant management strategy were then be processed with the SWOT matrix to create appropriate strategic alternatives.

Results And Discussion

Overview upon Solar Power Plant Autonomy

The definition of autonomy is the maximum possible use of domestic potential and practical implementation in several laws and regulations, one of which is the Domestic Component Level (DCL). The domestic component level is the value for a combination of goods and services in a series of domestic components, including commodities in the form of raw materials, design, and engineering containing local experts' manufacturing, assembly, software, and services [23]. For the solar power plant, by regulation of Minister of Industry number 54 of 2012, the minimum DCL of goods, services, and combined goods and services are 25.63%, 100%, and 43.85%, respectively. The Government of Indonesia has regulated the use of DCL as an electricity infrastructure development 43.85%.

Besides the DCL value, the autonomy aspect of solar power plant management in planning, building, operation, and maintenance is also visible. The human resource factor is one of the major factors deciding the progress of the planning for the upkeep of the solar power plant in Indonesia. The standard and the amount of staff required for autonomy are calculated by the level of education, level of economics, level of skills, number of jobs, and workload [24].

In general, the autonomy of human resources in solar power plant management has a reasonably good effect in planning, construction, and operation based on secondary data tracking and discussions with resource persons, but not in maintenance. The value is good, nearly all implementers and decision-makers are from Indonesia and have observed the planning guidelines and rules applicable. Meanwhile, the maintenance and repair aspect has a low value because the human resources who manage solar power plants in Indonesia are generally not equipped with adequate skills and training to solve the problem of damaged or stalled components.. The low value of maintenance and repairs can mainly be seen when introducing the Solar Home System (SHS) plan for non-governmentally electrified areas. The program run by the Ministry of Energy and Mineral Resources has only been a temporary project as a solution fo the areas which will get The PLN service within 3-4 years. As a temporary program, the Government's training and budget for the maintenance of the SHS were not provided. Besides the low maintenance capacity, human resources are limited to the production of solar power plant components, where major solar power plant components, such as solar cells and batteries, still have to be imported from outside.

The researchers had managed to summarize the autonomy of solar power plant management in Indonesia from secondary information and discussions with information sources. The planning section includes several points. First, the price of the finished product for the solar power plant and the raw material components of imported origin is lower in price than the domestic products. Second, research and development costs for raw materials and components of solar power plants are highly valued and unstable due to market instability. This condition causes the majority of domestic producers to think that conducting research and production of solar power plant products is not feasible in business. Third, there is a lack of initiative from the Government in providing incentives and promotions for domestic investors and producers to produce the key components of the solar power plant. Fourth, there is also a lack of government support in funding research and development for key components of the solar power plant. In the Development section, 1) There is still a contradiction between the target given by the Government to PLN to increase the electrification ratio with adjustments to the energy mix target (solar energy) from the RUEN and the target given by the Government to PLN as a State-Owned Enterprise to increase profits.; 2) There is a lack of government involvement of contractor who produces solar power plant, particularly in Eastern Indonesia so that the quality of the solar power plant construction often differs from the variety of the solar power plant planned at the beginning; 3) Even though the use of domestic human resources is 100%, technology for development still uses key components imported from abroad. The ability of Indonesian producers to produce solar power plant is still limited to the assembly level.

The operation section includes: 1)the distribution of solar power plant operators training quality in Indonesia is still uneven. The quality of their training in western Indonesia differs from the quality of instruction in eastern Indonesia. Likewise, the quality of staff who carry out solar power plant operations in Indonesia is not yet equally allocated in particular in terms of easy access to standard education; 2) there is no standardization of solar power plant operations in Indonesia, which means that sometimes operators operating one solar power plant may not necessarily work solar power plant elsewhere; 3) The Government's monitoring and evaluation program has not yet been implemented to manage the solar power plant established by national budget allocation (APBN) or regional budget allocation (APBD). The maintenance and repair section includes: 1) Based on the information provided by sources from the Ministry of Energy and Mineral Resources (through Dirjen EBTKE), the operating and maintenance budget of the solar power plant is transferred from the Ministry of Energy and Mineral Resources to the regions only for one year and after one year, if solar power plant damages, the maintenance budget shall be maintained. Many SHS or solar power plants are no longer operating due to corrosion, and there is no budget to carry out repairs and maintenance. Secondly, domestic human resources have not been able to repair damaged solar power plant components. The repair needs either technician from foreign manufacturers or new components and products. Thirdly, solar power plant and SHS programs launched by the Government are generally not long-term programs.

External And Internal Environmental Aspects

Human resources are closely related to the organizational environment and the solar power plant. The entire process from planning, development, operation, and maintenance can cover existing organizations or stakeholders or cover just one or two aspects of them [25]. It is essential to analyze external and internal environmental factors within the organization because it provides an overview of opportunities and benefits that can be used to develop an overview of the threats that need to be avoided to achieve objectives properly [26, 27]. The economic, socio-cultural, political, juridical, technological, and other organizations' competitive strengths play a role in the analysis of threats. Based on secondary data studies and discussions by resources, external factors affecting the autonomy of solar power plant management are as follows: Economic aspects include: supply and demand in Indonesia for solar power plant and SHS; industrial growth; domestic macro-economic conditions (inflation, inflation, deflation, export-import, monetary policy); domestic micro-economic conditions (APBN, APBD, manufacturing, and consumption); Socio-cultural aspects include population growth rate, household growth rate, energy conservation, and diversification information and culture; renewable energy information and culture; infrastructure design; electrical terms (electrification ratio); Political and legal aspects include: Domestic Political Condition, Renewable Energy Policy, and Rules; Renewable Energy Policy and Regulations of Local Government; Renewable Energy Policy of PLN; Regional Defense and Security Conditions; Competitive aspects include: renewable energy produced power prices compared to fossil electricity prices; solar power plant infrastructure price compared with other power stations; component prices compared to local or auto manufactured component prices; solar power plant electricity performance compared with electricity generated by other electricity plants; the area necessary to operate solar power plant is compared to the area needed for solar power plant.

On the other hand, the internal factors that affect the autonomy of solar power plant management are the following: Funding and planning aspects include the cost of investing in building a solar power plant system; solar power plant administrative, and financial systems; existing and non-current property; human resources; materials availability; and stakeholder coordination [28]. The next is manufacturing and operational aspects include human-made tools for production and operations, production and operating owned technology; processes/sops in solar power plant development and operating processes; collaboration with stakeholders; running costs. Lastly, maintenance and repair aspects include maintenance and repair personnel, maintenance, and repair technology [18, 28].

Indicators affecting the autonomy index of solar power plant management in Indonesia

The purpose of this study is to identify indicators used to measure autonomy management in Indonesia. Researchers divide the indicators and then break each of them down into four aspects, namely, aspects of planning, construction, operation, and maintenance. The method used in the indicator identification process is obtained by analyzing the internal and external environment, which raises external and internal variables from various aspects of solar power plant management. Based on secondary data, current and actual conditions in the field as well as information on the results of discussions with the speakers, then indicators are obtained regarding the autonomy of solar power plant management. After getting indicators regarding the autonomy management index for the solar power plant, the next step is to determine the ranking, which is carried out to determine the level of management autonomy according to each source. Assessment to determine the ranking is done by asking the resource person to fill out a questionnaire. The median obtained from the value given by the resource person will then be used to determine the score for each variable at the weight calculation stage. That indicator will then be weighted by making a paired comparison based on the preferences provided subjectively to the value of each indicator by each source. This weight calculation uses a pairwise comparison matrix that compares the two indicators relative to the autonomy of solar power plant management. The variables or indicators in the matrix are represented by capital letters. The pairwise comparison matrix of each of these variables is then processed and recapitulated from all sources. Then the results of the weighting of each resource are then processed and recapitulated and averaged so that the weight of each indicator is obtained. In the appendix to this report, we will see the complete collection and analysis of data from these sources. After knowing the rating and weight value, the next step is to calculate the score by multiplying the weight's rating value. The objective of scoring the score and index is to determine the position of the current autonomy management of solar power plants. The results of the score calculation can be seen in table 1.

After obtaining this index, the position of autonomy in the management of solar power plants can be identified as material for evaluating human resource management. The Management Autonomy score for planning amounts to 3,08 out of the maximum scale of 4.00, is 2.83 out of the maximum scale of 4.00 for growth, is 2.64 out of 4 for operations, and is 2,59 out of the maximum scale of 4.00 for maintenance and repairs. When combined, the scores showed the autonomous management index for solar power plants at 2.79 out of a maximum level of 4.00. Based on the score calculation, it is known that the planning aspect has the highest score compared to the other three aspects, where it reaches a value of 3.08 from a maximum score of 4.00. This score was also following discussion results with several resource persons who indicated that in addition to the technical mastery of the crucial components of solar power generation, almost all aspects of solar power plants had reached a good level of autonomy. Human resources from Indonesia have mastered the planning stages and have followed the SOPs. The development aspect is in the next rank with a score of 2.83 from a score of 4. This score indicates a good level of autonomy. Several informants said that development in Indonesia is almost entirely carried out by domestic human resources, although they still depend on foreign technology. The third rank is the operational aspect, with a score of 2.64 from a maximum score of 4. This score still indicates quite a good autonomy aspect. The domestic human resources involved have mastered technology enough to operate and have followed the SOPs given. However, the operational aspect still has shortcomings in the limited training and monitoring and evaluation processes that have not been carried out. The last ranking is in the aspect of maintenance and repair with a value of 2.59. The score still shows a positive value, but based on discussions with resource persons, the elements of maintenance and repair have the most significant obstacles, especially in terms of mastery of technology to make repairs and limited funds for maintenance.

Previous research on Indonesia's energy security index by National Energy Councill (DEN) in 2015, Indonesia has reached a score of 7.518 from a maximum score of 10, meaning that the level of energy security is good in terms of established indicators. This score shows the results that are relatively the same as the autonomy value obtained in this study. However, this study focuses on the scope of autonomous management of solar power plants rather than covering all energy in Indonesia. Although the indicators and calculation scores used are different, the energy security index issued by DEN can be used as a reference for researchers to evaluate the autonomy of solar power management based on Indonesia's energy security position.

The Maturity Level analysis method is one of the standard assessment methods used to measure human resources' capabilities and how an organization implements operational management or project management based on industry best practices. Executive management must have three main capabilities, namely, management capability, sponsorship capability, and organizational capability. Management Capability is the ability to manage costs, product quality, safety, job performance, and others. Sponsorship capability is the ability to ensure that the products produced are products that are following the market and organizational desires. Organizational capability is the capability to ensure that the project portfolio is developing the corporate strategy, and the resources devoted to completing it are following its purpose [19]. This study determined five levels of maturity, which are one of the theories used in evaluating management autonomy. The indicators arranged are a description of the maturity level model. The score obtained in this research can illustrate the level of the autonomy management of solar power plants towards the five levels of the maturity model. The score that reaches 2.79 (from a maximum scale of 4.00) indicates that in the capability maturity model, the autonomy position of solar power plant management reaches level three. This level shows the capability to define the running process. It requires two steps of improvement or a strategy to achieve the optimal level, being able to perform process optimization for autonomy management (level 5).

Table 1. Measurement Of Scores For Autonomy Management Of solar power plant Indicators

Planning		Weight	Rating	Weight x Rating
1	Autonomy in the design process and component manufacturing	0,143	3	0,43
2	Knowledge sharing or transfer of technology carried out by foreign producers in the component production process and domestic solar power plant installation	0,125	2,5	0,31
3	Compliance with applicable planning criteria and legislation and control of risks and adjustments	0,219	4	0,88
4	Accuracy standard of solar power installation planning in Indonesia	0,181	3	0,54
5	Considering economic issues, social and environmental	0,110	3	0,33
6	Coordination and communication from cross-sectional planning of solar power plant sectoral	0,148	3	0,45
7	Evaluation and monitoring methods useful in planning solar power plant installation	0,074	2	0,15
Total		**1,000**		**3,08**
Development		**Weight**	**Rating**	**Weight x Rating**
1	The level of autonomy in the construction of a solar power plant installation	0,203	3	0,61
2	Fulfillment of solar power plant development standards in Indonesia	0,193	3	0,58
3	Competence and experience of human resources in Indonesia in building solar power plant installation	0,236	3	0,71
4	Adjustments contained in the development process	0,097	3	0,29
5	Cross-sector coordination in the construction of a solar power plant	0,103	3	0,31
6	The development has followed guidelines on financial issues, environment and social	0,087	2	0,17
7	Domestic funding for the construction of a solar power plant	0,081	2	0,16
Total		**1,000**		**2,83**
Operation		**Weight**	**Rating**	**Weight x Rating**
1	The level of autonomy in operating the solar power plant installation	0,171	3	0,51
2	Level of training for solar power plant operator and	0,171	3	0,51

	management in Indonesia			
3	Monitoring and evaluation process in operation	0,130	2	0,26
4	The effectiveness of the financial administration system in operation solar power plant	0,117	2.5	0,29
5	Coordination and communication across sectors in the operation of a solar power plant	0,107	2.5	0,27
6	Funding in operation	0,117	2	0,23
7	SOP in operation	0,186	3	0,56
Total		**1,000**		**2,64**
Maintenance and Repair		**Weight**	**Rating**	**Weight x Rating**
1	The level of autonomy in the maintenance and repair of solar power plant installations	0,218	3	0,65
2	Operator and management training in performing maintenance a solar power plant in Indonesia	0,220	3	0,66
3	Periodic monitoring, SOP and allocation of resources carried out in the maintenance of solar power plant	0,155	3	0,46
4	Domestic funding for maintenance and repair of solar power plant	0,133	2	0,27
5	Risk management for a solar power plant in Indonesia if it occurs damage	0,139	2	0,28
6	The role of stakeholders in Indonesia in overcoming the solar power plant stalled due to damage	0,136	2	0,27
Total		**1,000**		**2,59**

SWOT matrix analysis to find strategies for increasing management autonomy

Table 2. SWOT Matrix for Autonomy solar power plant Management

	STRENGTH (S)	WEAKNESS (W)
	1. Support the national energy mix program 2. Supports quality improvement 3. Reducing government subsidies 4. Availability of materials 5. Availability of land and resources (abundant sunlight and massive radiation) 6. Adequate quality of human resource education (Western Indonesia) 7. Operating costs are cheap and do not require a lot of workforces 8. solar power plant technology is easy to implement in a hybrid manner with other power plants	1. solar power plant is dominated by new technology that is not yet known by the Indonesian people 2. Huge initial investment costs 3. Indonesia's geographical conditions make it difficult for infrastructure development 4. Unequal quality of human resources (especially in Eastern Indonesia) 5. The absence of a standard operating and administrative system from the Government 6. Imported components are cheaper than making your own 7. There is no incentive for domestic production and RnD 8. Difficulties in coordinating among stakeholders 9. Insufficient operating and maintenance budget 10. Lack of workforce training 11. There is no ongoing monitoring and evaluation
OPPORTUNITIES (O)	SO STRATEGY	WO STRATEGY
1. Growing new jobs 2. Increase in population 3. High demand because it is a new technology that is environmentally friendly 4. Cooperation with foreign parties is more open due to environmental emission factors	1. Increase the development of PV mini-grid by involving local community organizations so that the quality of PV mini-grid management can increase (S2, S6, S7, O1, O7, O9, O10) 2. Make policies to facilitate business entities or government agencies in disseminating and educating the public to increase interest and use of solar power plant nationally (S1, S2, S6, O6, O7, O8)	1. Make policies to improve the synergy of solar power plant stakeholders in Indonesia, so that the quality of human resources in solar power plant and the use of solar power plant nationally can be increased (W1, W5, W8, W10, W11, O2, O3, O8) 2. Making government policies to promote the transfer of technology to foreign solar power plant component manufacturers doing business in Indonesia (W6, W7, W9, O4, O6, O8)

5. There is a feed-in tariff from the Government for energy from EBT 6. Business opportunities for national solar power plant companies 7. Public education opportunities related to clean energy 8. State capital participation as well as foreign capital to strengthen business entities in the solar power plant sector 9. Increasing the quality of human resources 10. Reducing the state budget and energy subsidies for the Indonesian Government		
THREAT (T)	ST STRATEGY	WT STRATEGY
1. Changing government policies on EBT 2. Indonesia's old and complicated bureaucracy concerning investment 3. The threat of an embargo on the critical components of solar power plant 4. Defense and security conditions in border, outermost and remote areas	1. There is a need for bureaucratic reform regarding increasing domestic investment so that the autonomy of solar power plant management can increase (S1, S2, S3, T1, T2) 2. Utilizing available land in the outer and remote border areas to support defense and security in the area and vice versa (S4, S5, S8, T4, T5, T7)	1. There needs to be a research and development policy for the critical components of solar power plant (W1, W2, W6, W7, T3, T8, T9) 2. There needs a synergy policy between solar power plant stakeholders and agencies in the field of defense and security so that the threats that are concerned can minimize (W3, W4, W8, T3, T4, T5, T6, T7, T8)

5. Social threats from people who are not ready to accept solar power plant technology. 6. Threats to the national electricity infrastructure 7. Friction and jealousy among PV mini-grid stakeholders in Indonesia 8. Dangers of practical political interests 9. Market and economic uncertainty for solar power plant producer.	

The management measurement results are then used as a metric to assess the Indonesian Government’s strategic role as a regulator and stakeholders in increasing the autonomy of solar power plant management. The Determination of the Government’s strategic position is carried out using the SWOT matrix analysis method (Strength - Weakness - Opportunities - Threat). The SWOT matrix consists of mapping internal and external factors that affect the autonomy of solar power plant management. Based on the weight consideration obtained from interviews with informants, it is found that the most suitable strategy for increasing autonomy is the WO strategy because the position of autonomy in the SWOT quadrant is located in quadrant III, as shown in figure 4. The current position of management autonomy in Indonesia for internal factors is more dominant, showing weakness than strength. This current position is mainly highlighted by the incapability of human resources to critical technologies, the uneven quality of human resources in Indonesia, and the limited budget. However, increased autonomy opportunities are more comprehensive than existing threats, mainly because the solar power plant is an environmentally friendly future technology.

Then for the details of what strategies can be generated from each quadrant, a SWOT matrix is carried out, as shown in table 2. In each quadrant, two alternative procedures are designed to increase the autonomy of solar power plant management. There are a total of 8 strategies, with the priority strategy being the alternative WO (Weakness - Opportunity) strategy from quadrant 3 (figure 4).

SO (Strengths - Opportunity) utilize internal strength in the form of domestic potential in Indonesia to get opportunities both domestic and abroad. This strategy increases the development of solar power plants by involving local community organizations so that the quality of the autonomous management of solar power plants can be improved (S2, S6, S7, O1, O7, O9, O10). The Indonesian people's ability to form influential community organizations must be utilized as much as possible with the potential for policies to increase the development of a solar power plant. The greater the role of community organizations in the area of origin in management and maintenance, the higher the level of autonomy in management and maintenance. Even in the future, these community organizations can also be involved during development and planning so that that autonomy can be more optimal. One example is the solar power plant in the Yogyakarta area under the guidance of the Dinas Energi Sumber Daya Mineral (ESDM) Yogyakarta, which was handed over to local community organizations. This solar power plant has given suitable training and mentoring for several years, so it has been able to autonomously manage and even carry out minor repairs and maintenance, although not yet ready to make a thorough repair. In addition to increased autonomy in management and maintenance, by expanding the role of community organizations in managing solar power plant, the multiplier effect of the existence of the solar power plant in the community can occur. Increased exposure to existing power plants provides specific functions and opportunities for improvement. Several types of businesses related to solar power generation have even emerged, such as tourist attractions or manufacturing companies in battery repair, or solar power generation modules. Examples can be seen in the solar power plant managed by Baron Technopark BPPT and the solar power plant on the New beach of Yogyakarta, which has become a technology tourism object that provides a multiplier effect for the surrounding area.

Strategies for policymaking facilitate business entities or government agencies in disseminating and educating the public to increase interest in and use of solar power plants nationally (S1, S2, S6, O6, O7, O8). The Government's energy diversification and conservation policies have been implemented in recent years through various campaigns and outreach. However, the socialization was deemed inadequate because only the Government, represented by the Ministry of Energy and Mineral Resources and their regional agencies, carried out the socialization. Suppose that the Government will, of course, collaborate with other solar power plant stakeholders, such as producers and contractors of solar plants and solar power plant operators and non-governmental organizations, to socialize and educate the growing population. In that case, the interest in using solar power plants will grow in the community. The dependence of socialization on the Government creates problems in budget constraints. Collaborating with other parties can reduce budget constraints so that people who get information about solar power plants will also be more comprehensive.

The WO (Weakness - Opportunity) strategy is applied to minimize and change internal weaknesses in the country in Indonesia by maximizing the opportunities that exist both domestically and abroad. The Government has made a policy to increase the synergy of solar power plant stakeholders in Indonesia so that the quality of human resources in solar power plant and the use of solar power plant nationally can be increased (W1, W5, W8, W10, W11, O2, O3, O8). One of the obstacles encountered in the management of the solar power plant is the absence of standardization for the solar power plant and the uneven quality of solar power plant management human resources. This obstacle is especially real in Eastern Indonesia. Many of the SHS and solar power plant tools provided are damaged and stalled because the human resources which have been handed over the mechanisms have not been able to carry out operations and are maintained adequately. This case is due to the inequality of information and training received by human resources in various regions in Indonesia. As the regulator and implementer, the Government must cooperate with other solar power plant stakeholders to create a balance in providing information and training for human resources in various regions, especially in the Outermost, Frontier, Remote (3T) areas. This synergy can be done by issuing regulatory policies, cooperation contracts, and providing incentives so that these stakeholders are willing to cooperate with the Government. The Government can also assign BUMN stakeholders of the solar power plants, such as PLN, to further improve the quality of human resources in these problematic areas.

Besides, there is a government policy to promote the transfer of technology to foreign solar power plant component producers doing business in Indonesia (W6, W7, W9, O4, O6, O8). One of the obstacles to the autonomy of solar power plant management is that industrial technology in Indonesia cannot produce the main components for the development of solar power plant infrastructure. Almost every informant think it is too late to start the research because industries in other countries can produce this technology on an industrial scale economically. According to resource people Agus Salim Dasuki from BPPT and Abdurrahman Saleh from the DEN, Indonesia will adopt a "starting from the end and finishing from the beginning" strategy of purchasing and reverse engineering licenses and technology transfer for Indonesia to manufacture these goods economically and then market the product [14]. Reverse engineering and transfer of technology are carried out as concessions because the foreign component manufacturers are already able to do business and take profits in Indonesia.

ST (Strengths – Threats) strategy can optimize Indonesia's internal strength to reduce risks at home and abroad. There is a need for bureaucratic reform regarding increasing domestic investment so that the autonomy of solar power plant management can increase (S1, S2, S3, T1, T2). One of the problems in the operation and maintenance of the solar power plant is the limited domestic budget. This budget limitation is because most of the solar power plants only rely on the Anggaran Pendapatan Belanja Negara (APBN) and Anggaran Pendapatan Belanja Daerah (APBD) from the Government. Investments from the private sector are especially needed, but they are constrained by a reasonably complicated bureaucracy and less attractive profit projections for investors. Reducing the administration, especially for investment licensing, is critical to ensure that investors are interested in investing from the bureaucratic side.

Ensuring investors are interested in investing in bureaucratic convenience is a potential benefit in the future. These potential benefits can be provided to investors by making economic policies that will generate profits by investing in solar power plants. Prioritized investment, namely investment, also encourages domestic autonomy.

Solar power plants can also be strategic in the border, outermost, and remote areas to support defense and security in these areas and vice versa (S4, S5, S8, T4, T5, T7). The defense and security threats faced in the border, the remote, and the outermost (3T areas) have caused many Tentara Nasional Indonesia

(TNI) bases to be established to minimize this threat. TNI bases in these areas need energy supply support provided by solar power plant because it is portable and is compatible with the abundant resources in Indonesia, namely the sunlight. The causal relationship between energy supports defense and defense recommends this energy to be increased due to the availability of sufficient land and the potential for sunlight, which is quite abundant in some areas.

WT strategy (Weakness-Threats) transforms weakness into a strength to reduce the existing threats. It is necessary to have a research and development policy for the critical components of the solar power plants (W1, W2, W6, W7, T3, T8, T9). Despite promoting the transfer of technology and carrying out reverse engineering, Indonesia needs to start doing its research and development of the critical components of the solar power plant, which runs in parallel. One thing that can be done is to make a roadmap regarding the research and development as a guideline for solar power plant stakeholders to achieve increased self-reliance in solar power plant management. In reaching targets in the roadmap, to be delivered, periodic monitoring and review of its implementation are required.

Furthermore, there is a need for a synergy policy between solar power plant stakeholders and agencies in defense and security so that threats that can be minimized (W3, W4, W8, T3, T4, T5, T6, T7, T8). Defense and security threats can be minimized by the establishment of bases in border areas supported by energy supply from the solar power plant. It can also be reduced by synergizing solar power plant stakeholders with defense and security stakeholders such as the Indonesian Armed Forces (TNI), Indonesian Police (Polri), and local communities. Optimizing autonomy in the management of solar power plant requires improved communication and coordination between solar power plant stakeholders and stakeholders. The lack of good communication and coordination has caused disruption.

The Influence of Increasing Autonomy of solar power plant Management on National Energy Autonomy and Resilience

Increased autonomy management is an essential factor in achieving the energy mix goal and national energy stability. As described in the previous section, management autonomy is currently at a fairly good level, but it can be increased to a more optimal stage with strategies that have been formulated through research and discussion with the research sources. The renewable energy mix target of 23% by 2025 cannot be reached because domestic stakeholders and industries are still not autonomous to leverage technology and human resource resources. This management autonomy must cover all aspects, from planning to maintenance, because even though it has achieved good autonomy in planning, its maintenance and implementation will not run well, resulting in a stalled project [3]. Human capital and technology mastery is the foundation of the autonomy and stability of domestic energy and fosters the national economy [24]. Substantial autonomy is required to sustain optimally, one of which begins with the autonomy management of the solar power plant [29].

The 2025 renewable energy mix goal is 23%, with a 14% share of renewable energy in the solar power plant. Next, this can be done by incorporating as much outside technology as possible to achieve the electrification ratio and the energy mix. Not to mention, imports can make Indonesia can get better and productive technology than being forced to manufacture their products independently. However, the continuous dependence on imported products without having the ability to produce will put Indonesia under the control of these exporting countries. The risk of being deceived by these countries threatens Indonesia to become powerless in the event of a political situation that causes a monopoly, embargo, or an increase in prices for solar power plant components [14]. The sovereignty impotence of Indonesia was seen in previous events where in the 1990s, Indonesia was embargoed by the USA and its western allies, paralyzing the Republic of Indonesia's Armed forces regulated by western defenses. As far as energy management is concerned, Indonesia will, in this case, learn from the incident in the management of solar power plants in order not to encounter the energy industry's powerlessness and stagnation, as in the defense sector in the 1990s. Since the future international political situation is full of uncertainty, Indonesia should be prepared and awaited if the Western restriction situation of the 1990s exists in a political sense close to that of the Western countries. Because of the actual situation in the solar power plant industry, the main components such as solar cells, batteries, controllers, etc. still rely significantly on imported goods, since domestic industry capability is still limited to assembly [15]. Autonomy in solar power plant management and mastery of this technology is critical so that energy security is not disrupted in Indonesia.

Conclusion

Indonesian solar power plants depend on imported products, especially for critical components such as solar cells, batteries, ICs, etc. The solar power plant industry's capacity, both in modules, batteries, controllers, inverters, is still at the assembly stage of the key imported components. Management autonomy in this study consists of aspects of planning, construction, operation, and maintenance, each of which has constraints based on its strategic environment. Based on the results of questionnaires and discussions with competent resource persons in the field of solar power plant management and the Capability Maturity Model (CMM), the autonomy score obtained is equivalent to level three, namely, at the level of being able to define the running process and it requires two more steps to reach the optimized level (level five). Based on the analysis of the strengths, weaknesses, opportunities, and threats of the independent management of solar power plant, there are eight strategies, i.e., two strategies in each of SO, WO, ST, and WT strategy. The best strategy to optimize autonomy is the WO strategy, based on the weight criteria collected from interviews with informants. The place of autonomy in the SWOT quadrant is positioned in a quadrant III turning point (S < W and O > T). Increased management autonomy is an essential factor in achieving national energy autonomy and resilience targets. If Indonesia continues to depend continuously on imported products without the slightest autonomy, whether there is a monopoly, a restriction, or a price increase, it will be attacked with helplessness. Autonomy in the management and control of solar power plant is essential so that there is no disruption to energy security in Indonesia.

This study recommends evaluating or measuring the autonomy index for other energy sectors, especially to support the achievement of the energy mix target, which in turn aims to increase national energy autonomy and security. solar power plant stakeholders can optimize the WO strategy obtained in this study to increase the autonomy of solar power plant management. The WO strategy is applied by implementing policies to improve Indonesia's solar power plant stakeholders' synergy to achieve a national increase in the quality of solar power plant human capital and the use of solar power plant. And to establish government policies to encourage technology transfer to international solar power plant product suppliers operating in Indonesia. The measured autonomy index is limited to human resource management and can look at other topics or sides, such as the DCL aspect. Management autonomy can be seen from another side or use a different human resource theory from the capability maturity model in order to compare and see which measurement method is better. Further research for the strategy obtained from the SWOT analysis can be seen in terms of cost and benefit analysis or by multi-criteria decision making. This further research is needed to support further the credibility of the strategy obtained or as a consideration for other alternative approaches that might have been missed from previous research.

Abbreviations

SWOT: Strength weakness opportunities threats; PLN: Perusahaan listrik negara; COP: Conference of parties; MWp: Megawatt-peak; CMM: Capability maturity model; BPPT: Badan pengkajian dan penerapan teknologi; LEN: Lembaga elektronika nasional; SEI: Surya energi indotama; DCL: Domestic component level; SHS: Solar home system; RUEN: Renca umum energi nasional; APBN: Anggaran pendapatan dan belanja negara; APBD: Anggaran pendapatan dan belanja daerah; EBTKE: Energi baru terbarukan dan konservasi energi; DEN: Dewan ekonomi nasional; ESDM: Energi sumber daya mineral; TNI: Tentara nasional indonesia; ICs: Integrated circuit.

Declarations

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Authors' contributions

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Consent for publication

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Competing interests

The authors declare that they have no competing interests.

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Figures

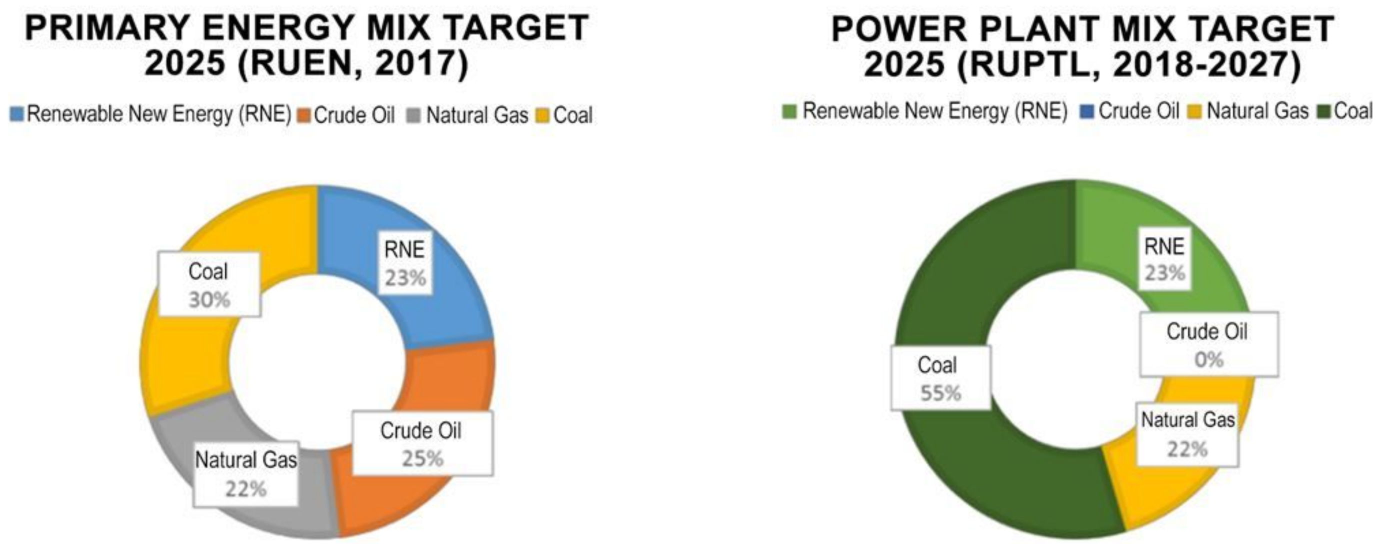

Figure 1

Primary and Power Plant Energy Mix Target

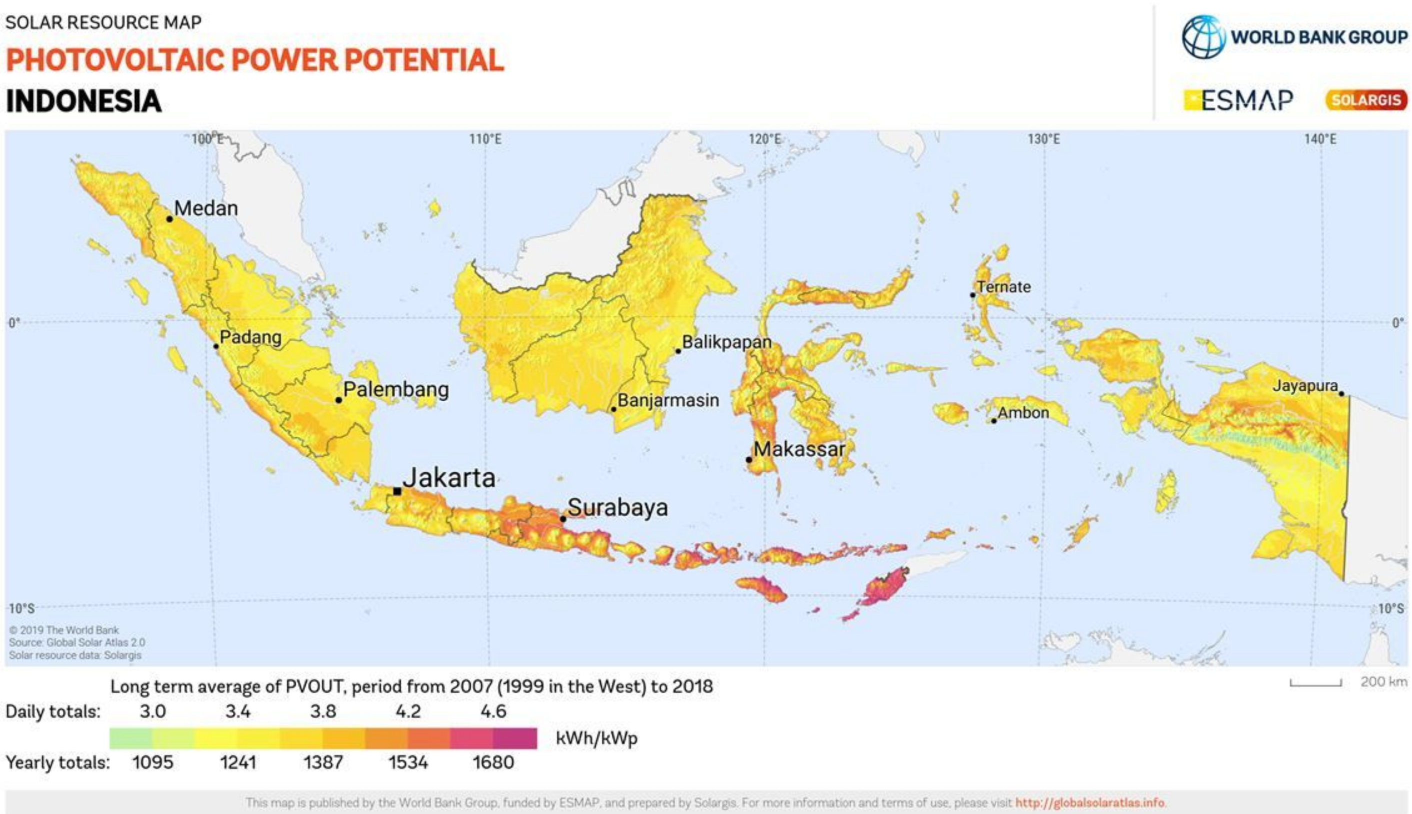

Figure 2

Annual Sunlight Intensity in Indonesia Source: (Solargis, 2019) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

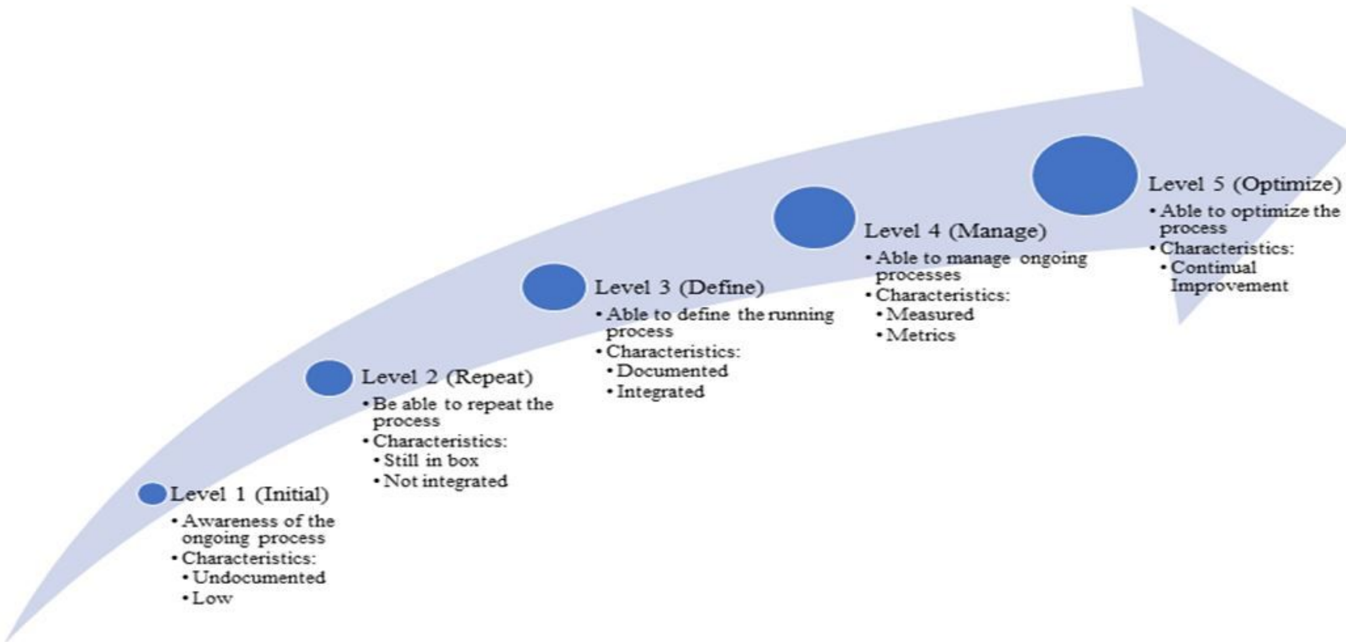

Figure 3

Maturity Levels from the Capability Maturity Model

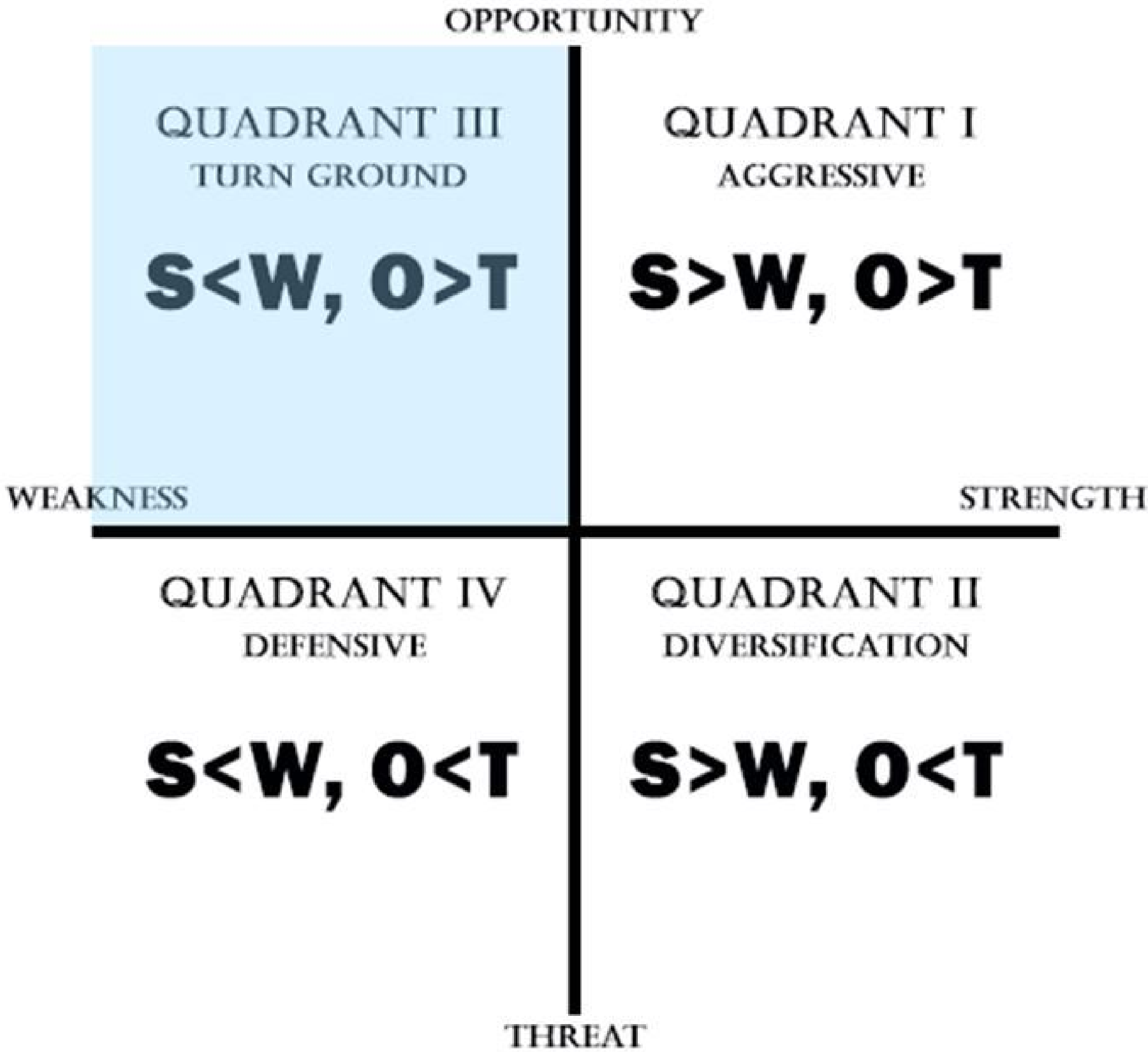

Figure 4

Position of the SWOT Matrix