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Operational Challenges and Strategic Solutions for Power Distribution in Mendol Island

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ABSTRACT
Purpose: This thesis addresses critical issues within the plant's capacity and operational framework, emphasizing the importance of enhancing the generation system's resilience through the N-1 and N-2 capacity criteria.
Methodology/approach: The research methodology encompasses both qualitative and quantitative data collection methods, including observations, interviews, brainstorming sessions, and document reviews.
Results/findings: The study reveals a four-year gap between target and actual performance, marked by low energy output and unstable fuel use. Applying N-1 and N-2 criteria is key to maintaining system reliability, especially with renewable energy integration.
Conclusions: The Teluk Dalam Diesel Power Plant faces inefficiencies and capacity issues that reduce performance. Applying N-1 and N-2 criteria is essential to improve reliability and ensure long-term operational resilience, especially with renewable energy integration.
Limitations: This study is limited by its focus on a single power plant, which may affect the generalizability of its findings to other facilities. Additionally, some operational data relied on internal reports and may be subject to interpretation or lack independent verification.
Contribution: This research contributes to power distribution management by analyzing challenges at the Teluk Dalam Diesel Power Plant and offering solutions to improve its performance and sustainability.

Keywords: *Initiative Strategic, N-1 and N-2 Criteria, Operational Efficiency, Power Distribution, Renewable Energy*

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1. Introduction

The development of a nation is significantly influenced by its electricity industry (Stern, Burke, & Bruns, 2019). The value of natural resources extends beyond its function as a means of production, enabling the growth of several economic sectors like processing industry, agriculture, mining, education, and health. Additionally, natural resources play a crucial part in meeting the daily social demands of society (Parra, Kirschke, & Ali, 2020). The implementation of infrastructure development or electricity projects is necessary to address the increasing need for electrical energy, while also ensuring the involvement of all relevant parties (Bansard & Schroder, 2021). Development entails the endeavor to generate prosperity and well-being for the populace. Therefore, the outcomes of development should be universally experienced by the entire society, resulting in a fair and equitable augmentation of welfare(Kaliannan, Darmalinggam, Dorasamy, & Pablos, 2022).

Based on the data shown in Table 1.2, we can see the performance and efficiency of the plant over these years. In 2019, the production target was 1788 MWH, but the actual production was only 1399 MWH, resulting in a gap of -389 MWH, and the fuel consumption exceeded the target by Rp 264,552,082. In 2020, the production target was 2684 MWH, but the actual production was 2024 MWH, resulting in a gap of -660 MWH. Despite this, the actual fuel consumption was significantly lower than the target by Rp 3,998,172,223. The trend continued in 2021, where the production target was 4349 MWH, but the actual production was 2814 MWH, creating a gap of -1535 MWH. However, fuel consumption was below the target by Rp 3,772,090,767. In contrast, 2022 showed a smaller production gap of -170 MWH, but fuel consumption exceeded the target by a substantial Rp 5,565,946,460.

Over the four-year period, Teluk Dalam Diesel Power Plant consistently failed to meet its production targets, with shortfalls ranging from -170 MWH to -1535 MWH, indicating persistent underperformance in generating the expected amount of energy. The mixed picture in fuel consumption highlights significant fluctuations, with substantial savings in 2020 and 2021 but overrun in 2022. These trends suggest potential inefficiencies in plant operations (Ghorbanzadeh, Issa, & Ilinca, 2023).

1.1 Problem Identification

The Teluk Dalam Diesel Power Plant, situated on Mendol Island in Riau Province, Indonesia, has been shown to exhibit notable operational inefficiencies that require immediate scholarly and management focus. The plant operates under limited parameters, operating for a mere 14 hours per day. This not only highlights a notable inadequacy in supplying the uninterrupted energy requirements of the Pelalawan Regency but also imposes excessive pressure on the facility's operational capacities during periods of high activity (Riayatsyah, Geumpana, Fattah, & Mahlia, 2022). The static installed capacity of 2.68 MW, reduced from 1.07 MW in 2021 to 0.78 MW in 2022, together with a minor increase in peak load demand, indicates inefficiencies in capacity and load management (Kanoglu, Işık, & Abuşogˇlu, 2005).

The operational issues are exacerbated by financial inefficiencies, which are seen in the insufficient energy output compared to the target (3177 MWH vs 3347 MWH) and the exorbitant fuel expenses exceeding the budget in 2022 by more than Rp 5.5 billion. The concerns are indicative of more extensive systemic challenges, encompassing insufficient maintenance procedures, improper operating scheduling, and inadequate fuel management. The persistent oscillation of this plant between operational states of 'Alert' and 'Deficit', without attaining a state of 'Normal', underscores its susceptibility to disruptions and its incapacity to adequately address power requirements. Consequently, it is imperative to implement comprehensive strategic interventions that can improve both operational effectiveness and financial efficiency (Priasmoro & Utama, 2024).

1.2 Research Questions and Research Objectives

1. Research Questions
   a) What are the primary challenges and inefficiencies in electricity distribution On Mendol Island?
   b) What alternative solutions can be proposed for the sustainability of electricity distribution and the cost-effectiveness of Mendol Island?
   c) How can the alternative strategy be effectively implemented and deployed, considering stakeholder participation and regulatory frameworks for Mendol Island?

2. Research Objectives:
   a) To identify and analyze the underlying problems affecting electricity distribution and service in Mendol Island
   b) To assess the operational feasibility and economic viability of various distribution alternatives for Mendol Island

c) To develop an implementation plan for the the sustainability of electricity Mendol Island

1.3 Research Scope and Limitation

This research has several scopes and limitations. Scopes and Limitation:

1. The scope of this research focuses on electricity distribution On Mendol Island Riau Province
2. This research is bounded by time constraints, of which the research is conducted from Desember 2023 to April 2024, and primary data collection period from January 2021 to Desember 2022.
3. This research is limited in terms of the PT PLN (Persero) Unit Induk Distribusi Riau dan Kepulauan Planning Division's perspective.
4. This research is limited by the current technological, regulatory, and economic landscape, which could evolve after the research period.

2. Literature review and hypothesis/es development

2.1 Stakeholder Analysis

Stakeholder Analysis is a systematic technique employed to identify, evaluate, and address the interests and influence of various parties involved in or affected by a project or business operation. This methodology was comprehensively defined by R. Edward Freeman in his seminal work, "Strategic Management: A Stakeholder Approach" (1984), which posits that organizations should consider the rights and interests of all stakeholders as part of their strategic planning processes. This approach helps to map out the landscape of individuals, groups, and organizations whose interests must be considered to ensure the success of any business endeavor.

2.2 Importance in Strategic Planning

Incorporating Stakeholder Analysis in strategic planning is crucial because it enables businesses to gain insights into the priorities and influences of different stakeholder groups. This understanding is vital for formulating strategies that are not only inclusive but also optimized to mitigate potential conflicts(Ikeziri, Souza, Gupta, & de Camargo Fiorini, 2019)For instance, by identifying which stakeholders have the most influence and are most affected by the project outcomes, managers can prioritize these groups to secure project success and sustainability (SALMAN, 2024).

2.3 Mitigating Risks through Stakeholder Engagement

Engaging stakeholders effectively reduces project risks, increases project buy-in, and enhances the sustainability of business initiatives. Acknowledging and addressing the concerns of key stakeholders such as customers, employees, suppliers, and the community can prevent conflicts and foster an environment of cooperation and mutual benefit. This proactive engagement is supported by the theory that stakeholders who feel their interests are considered are more likely to support the project, reducing resistance and enhancing resource flows (Mandasari & Rikumahu, 2024; Ranasinghe, Kumudulali, & Ranaweera, 2019).

2.4 Empirical Evidence and Practical Application

Empirical research underscores the effectiveness of Stakeholder Analysis in improving project outcomes. For example on project management within the construction industry demonstrated that projects employing thorough Stakeholder Analysis techniques significantly outperformed those that did not in terms of stakeholder satisfaction and project timeliness. This finding illustrates the practical benefits of understanding and integrating stakeholder interests into business strategies (Yang & Shen, 2015). In summary, Stakeholder Analysis is an essential component of modern strategic management that assists organizations in navigating complex stakeholder environments. By systematically identifying, understanding, and addressing the needs and potential conflicts among stakeholders, businesses can enhance their strategic outcomes and ensure broader project acceptance and success (Ackermann, Eden, & McKiernan, 2024).

2.5 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a systematic method that utilizes mathematical and psychological principles to effectively organize and analyze intricate decision-making processes. Thomas L. Saaty invented it in the 1970s, and it has since been widely utilized in various sectors, including government, business, industry, healthcare, and education. Thomas L. Saaty, a professor at the University of Pittsburgh, initially created the Analytic Hierarchy Process in the 1970s as a decision-making framework designed to address intricate situations involving multiple criteria. The purpose of its creation was to offer a thorough and logical approach to organizing a decision problem, to representing and measuring its components, to connecting those components to overarching objectives, and to assessing several possible solutions (Kunz, 2010).

The Analytic Hierarchy Process (AHP) has undergone continuous improvement and expansion, making it a globally utilized method in various decision-making scenarios, ranging from product choices to corporate strategy, resource distribution, and conflict resolution (Vaidya & Kumar, 2006). The Analytic Hierarchy Process (AHP) employs a hierarchical framework consisting of multiple levels, including objectives, criteria, sub-criteria, and alternatives. The relevant information is obtained through comparing criteria (or alternatives) in pairs, considering their relationship to the parent node in the hierarchy. Each node is assigned priorities, and a numerical priority or weight is calculated for each choice alternative. These weights can then be used to order the alternatives for decision making (Saaty, 2008).

The approach consists of the following steps:

1. Hierarchical Structuring: The initial phase entails breaking down the decision problem into a hierarchy of smaller, more manageable sub-problems, each of which can be examined separately. The components of the hierarchy can pertain to any facet of the decision problem, whether it is something concrete or abstract, accurately quantified, or informally estimated.
2. Comparative Judgement: After constructing the hierarchy, the decision-makers methodically assess its different components by comparing them in pairs.
3. Establishing Priorities: After making and documenting judgments, the next stage involves assigning weights or priorities to each node in the hierarchy by combining the comparisons. The weights assigned to the options determine the decision.

The Analytic Hierarchy Process (AHP) assigns numerical values (weights or priorities) to these evaluations, which are then utilized to compute a score for each possibility (Saaty, 2008). The pairwise comparisons would entail subjective evaluations of the relative significance of various criteria, as well as the relative efficacy of different options in relation to each criterion. This may entail soliciting advice from various stakeholders, such as technical experts, business management, and client representatives(Maglio & Spohrer, 2008).

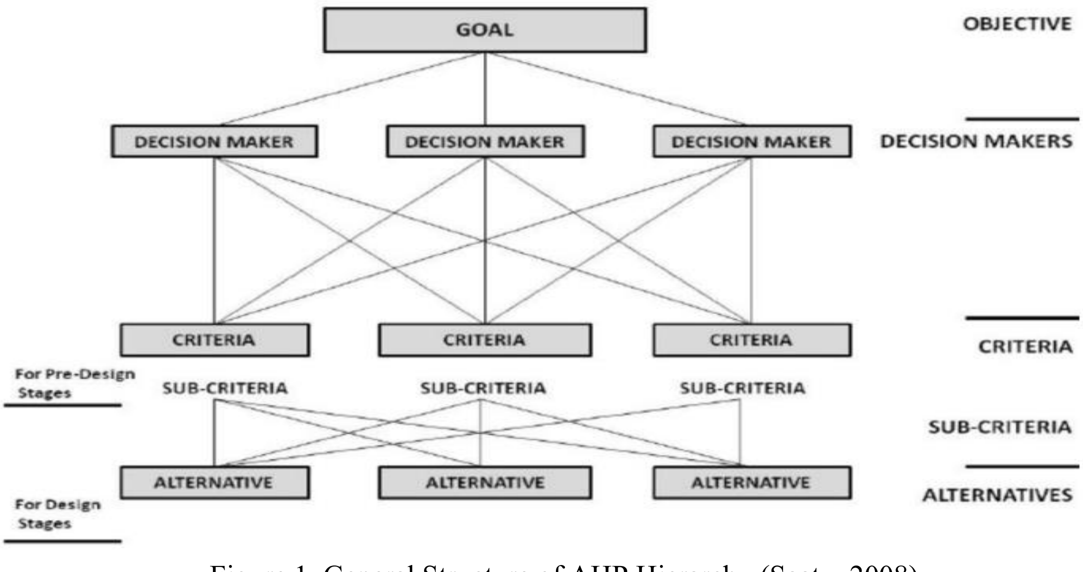

Figure 1. General Structure of AHP Hierarchy (Saaty, 2008)

In the illustration shown in Figure 1, the resulting weights or priorities assigned to each choice would offer a quantitative foundation for determining the most optimal overall strategy for the migration process. It is worth mentioning that although AHP offers a systematic and clear structure for decision-making, it still relies on subjective assessments, and the accuracy and reliability of the outcomes depend on the precision and consistency of these assessments (Vaidya & Kumar, 2006)

2.6 Conceptual Framework

The author aims to develop a framework in the final stage of this project. This framework will provide a comprehensive description of the research methods used to develop an alternative strategy within PLN UID RKR. The framework will incorporate various analytical approach tools and decision-making methodologies based on the literature review.

In the depicted image shown in Figure II.4, the conceptual framework for enhancing the dependability, operational hours, and efficiency of Teluk Dalam Diesel Power Plant in Mendol Island centers on discerning alternative strategies by comprehending and optimizing the interaction among different factors. The variables that are not influenced by other factors in this framework are the integration of renewable energy and the deployment of modern technology (Aščerić & Čepin, 2025). Renewable energy integration refers to the degree to which renewable energy sources, such as solar and wind power, are integrated into the existing system that relies on diesel as its primary source of energy. Advanced technology deployment involves the implementation of intelligent grid technologies and diagnostic tools to monitor, control, and improve the functioning of a system (Adeyinka, Esan, Ijaola, & Farayibi, 2024).

The independent variables have a direct impact on the dependent variables, which include the reliability, operational hours, and efficiency of electricity distribution. The reliability of power distribution is assessed based on the frequency and length of power outages. Operational hours pertain to the duration of uninterrupted operation, whereas efficiency is evaluated by the extent of decreased energy losses during the process of transmitting and distributing. The correlation between the independent and dependent variables is influenced by two factors: system modernization and staff training and competency. System modernization entails enhancing and renovating the grid infrastructure to enable the smooth incorporation of renewable energy and sophisticated technology. Employee training and competency are crucial factors that determine the expertise and skill level of operational staff. These factors have a substantial influence on the successful implementation of new technologies and procedures.

In addition, the framework considers two moderating variables: government policy and support, as well as community acceptance. Government policy and support refer to the regulatory and financial aid provided by the government, which can have an impact on the effectiveness of integrating renewable energy and advancing technology in this field. The extent of local support for the development and operation of new systems is reflected in community acceptability, which can significantly impact their success(Hashemizadeh, Ju, & Abadi, 2024). Furthermore, the framework regulates external variables such as market conditions and environmental conditions. Operational expenses and investment decisions may be influenced by market variables such as fuel costs, the availability of technology, and economic stability. Environmental circumstances, such as meteorological and topographical considerations, can impact the dependability of power generation and distribution networks.

This conceptual framework examines the connections between independent, mediating, moderating, and dependent variables, while also considering control variables. The goal is to isolate the impacts of strategic changes and gain a thorough understanding of how different factors interact within the operational environment of Teluk Dalam Diesel Power Plant in Mendol Island. This strategy seeks to provide strategic interventions to improve the plant's performance in terms of the reliability of energy distribution, operational hours, and efficiency(Namazi & Namazi, 2016).

3. Methodology

3.1 Research Design

At this stage, it is necessary to identify the variables to be examined and establish the methodology for their measurement. Furthermore, the careful selection of representative samples is a crucial element in guaranteeing the integrity and reliability of research findings. Subsequently, the gathering of data can be conducted by diverse methodologies, including surveys and observations. Once the data has been gathered, the subsequent phase of analysis can be conducted utilizing statistical methodologies that are suitable for the specific nature of the acquired data. The objective of this analysis is to examine hypotheses and address research problems that have been previously identified. Furthermore, the findings of the research can be utilized to derive valuable conclusions and provide recommendations for alternate strategies.

3.2 Data Collection Method

The utilization of data gathering methods is crucial in acquiring precise and dependable information for diverse research and analytical objectives. Choosing suitable data gathering methods guarantees the integrity and accuracy of the gathered data, ultimately resulting in significant comprehension and well-informed alternatives strategy. Data collection for this study was carried out in the period January 2021 –Desember 2022 within PLN UID RKR, which is one of the project business units of PT PLN (Persero). Data collection for addressing the operational and financial inefficiencies at the Teluk Dalam Diesel Power Plant is designed to be comprehensive. The author will use a variety of data collection mix methods techniques in this study.

3.3 Primary Data Collection

3.3.1 Observation

1. Define Objectives: Identify the specific aspects of plant operations to be observed (e.g., workflow, equipment usage, maintenance practices).
2. Develop Checklist: Create a structured checklist to ensure consistency in observations across different parts of the power distribution.
3. Conduct Observations: Systematically observe and record the operations, noting any inefficiencies or issues.
4. Document Findings: Maintain detailed records of observations, supported by photographs or videos if necessary.

3.3.2 Interviews and Brainstorming

1. Identify Participants: Select individuals with comprehensive knowledge of the research subject, including employees, management, local community leaders, and other stakeholders.
2. Design Interview Questions: Prepare structured, semi-structured, or unstructured interview questions that cover the key research topics.
3. Plan Brainstorming Sessions: Organize brainstorming sessions with selected participants to generate ideas, solutions, and insights regarding the plant's operational inefficiencies.
4. Schedule Interviews and Brainstorming Sessions: Arrange convenient times for both interviews and brainstorming sessions, ensuring participants are well-informed about the purpose of the research.
5. Conduct Interviews: Engage participants in discussions, recording their responses accurately.
6. Facilitate Brainstorming Sessions: Guide participants through structured or unstructured brainstorming sessions, encouraging them to share ideas freely without criticism.
7. Document Responses and Ideas: Record interview responses and ideas generated during brainstorming sessions verbatim, ensuring all relevant information is captured.
8. Analyze Responses and Ideas: Review and categorize the data collected from interviews and brainstorming sessions to identify common themes, insights, and potential solutions.

3.3.3 Data Reports and Archives Review

1. Identify Relevant Documents: Determine which past performance reports, maintenance logs, financial records, and compliance documentation are necessary for the research.
2. Collect Documents: Gather all relevant historical data and archival materials.

3. Review and Analyze: Examine the documents to identify trends, benchmarks, and areas requiring improvement.
4. Document Insights: Record key findings and insights that will inform the research analysis.

3.4 Data Analysis Method

The data analysis for this study utilizes a combination of qualitative and quantitative approaches, offering a full comprehension of the power distribution process:

1. Qualitative Data Analysis: The qualitative data obtained from interviews, brainstorming sessions, and document review, conducts thematic analysis. This process entails encoding the data, discerning patterns, evaluating these patterns, establishing and labeling the themes, and ultimately generating the report. Thematic analysis enables a comprehensive investigation of the data, providing valuable understanding of the participants' experiences, perceptions, and decision-making processes.
2. Quantitative Data Analysis: The acquired quantitative data, obtained from corporate reports, power distribution catalogs, and product specifications, is examined using the statistical methods of the Analytic Hierarchy Process (AHP). Descriptive statistics are utilized to provide a concise summary of the data, while inferential statistics are employed to ascertain connections between variables and evaluate hypotheses. Quantitative analysis offers a numerical representation of the facts.

The combination of qualitative and quantitative data analysis techniques enables a thorough and robust study of the data, hence improving the dependability and accuracy of the research findings.

4. Results and discussion

4.1 Analysis

4.1.1 Business Issue Exploration

The Teluk Dalam Diesel Power Plant, located on Mendol Island in Riau Province, Indonesia, plays a crucial role in meeting the energy needs of Pelalawan Regency. Although the plant holds great importance, its operational constraints, particularly its limited running hours of approximately 14 hours per day, present significant obstacles to the region's growth goals. This exploration seeks to analyze the operational difficulties that affect the plant, thereby establishing a framework for sustainable operational enhancements.

Operational Challenges and Their Implications:

1. Capacity and Demand Discrepancies: The Teluk Dalam facility has exhibited a decline in installed capacity, from 1.07 MW in 2021 to 0.78 MW in 2022, against a backdrop of marginally increasing peak demand. This capacity-demand mismatch is a primary driver of the plant's frequent operational states of 'Alert' and 'Deficit', signaling an urgent need for capacity enhancement strategies to stabilize its operational status. The persistent inability to meet peak demands not only compromises the reliability of power supply but also hinders economic activities dependent on consistent energy availability.
2. Financial and Operational Inefficiencies: The plant's operational inefficiency is worsened by its excessive fuel consumption compared to electricity output. The fuel expenses have exceeded the budgeted amount by more than Rp 5.5 billion in 2022. The facility's budget for essential maintenance and infrastructure upgrades is limited due to significant financial losses. This perpetuates a cycle of inefficiency, which hinders economic viability and operational sustainability.
3. Environmental Concerns and Regulatory Compliance: The plant’s operational inefficiency has broader implications, including increased environmental impact due to excessive fuel consumption. Such inefficiencies may lead to breaches of environmental regulations, potentially attracting penalties or enforced operational shutdowns that could further destabilize the plant’s operations.
4. Stakeholder Impact and Trust: The operational shortcomings of the Teluk Dalam Diesel Power Plant significantly impact stakeholder satisfaction and trust. Inconsistent power supply erodes consumer confidence and may complicate regulatory and community relations, essential for the plant’s long-term operational approval and tariff support.

4.1.2 Stakeholders Analysis

This analysis is necessary for defining the roles, influences, interests, and impacts of each stakeholder group, which is critical for ensuring the success and long-term viability of the Teluk Dalam Diesel Power Plant project. The purpose of the stakeholder analysis is to identify and understand the impact that various stakeholders have on the operational practices and outcomes of a project. This study is helpful in the strategic planning and implementation stages of the project.

In this stakeholder analysis not only highlights the complex interdependencies and varying influences among stakeholder groups but also underscores the necessity of strategic stakeholder management to enhance operational efficiency and ensure project success. This comprehensive analysis serves as a foundation for addressing potential conflicts and leveraging synergies, ultimately guiding the Teluk Dalam Diesel Power Plant project towards achieving operational excellence and strategic goals.

Table 1. Stakeholder Analysis Teluk Dalam Diesel Power Plant Project

Stakeholder Group	Interests	Power/Influence	Potential Impact	Engagement Strategy
Management And Employees	Successful implementation, Reducing operational inefficiencies and improving system reliability	High	Direct and Significant	Regular briefing sessions, strategic alignment workshops, and decision-making meetings.
Shareholders and Lenders	Ensuring it contributes positively to the company's profitability, stability, and sustainability commitments	High	Direct	Regular financial reports and discussions on potential risks
Customers	Service quality, reliability, 24 hours operation time	Medium to High	Direct	Community meetings, public feedback channels, and transparency in operations and impacts
Government Regulatory Bodies	Ensuring that energy distribution meets legal standards and supports regional development sustainably	Very High	Direct	Regular updates, compliance reports, and collaborative meetings to discuss regulatory impacts and project support
Consultant	Reputation and effectiveness are measured by their impact on project success	Medium	Direct	In-depth workshops, strategic advisory roles, and continuous involvement in assessment and redesign phases
Suppliers and Contractors	Maintaining contracts and delivering according to specifications	Medium	Direct	Supplier development programs, performance evaluations, and strategic partnerships

Following the stakeholder analysis approach presented, here is an explanation of the analysis for each stakeholder group in relation to the Teluk Dalam Diesel Power Plant project, as displayed in Table 1:

1. Management and Employees (PLN UID RKR)
The project's successful implementation is a primary concern for both management and employees. Their goal is to minimize operational inefficiencies and improve the reliability of the system. They have significant authority and influence because they directly manage project operations and choices. Their influence on the project is both immediate and substantial, as their everyday actions and decisions play a crucial role in determining the project's success. Regular briefing sessions, strategic alignment workshops, and decision-making meetings are essential to guarantee that project goals are met and operational concerns are immediately addressed.

2. Shareholders and Lenders
The company's long-term viability relies heavily on its interest in both the financial rewards and the sustainability contributions of the project. They possess considerable influence on financial tactics, rendering their assistance crucial for the project's continuation. This group is kept well-informed and actively involved in decision-making processes through regular briefings on financial performance and discussions on potential hazards.

3. Customers
The project's output has a significant impact on customers, who demonstrate a keen interest in the quality, dependability, and consistency of the power supply. Although not completely dominant, their power is significant, as they exert influence through market demand and public opinion, which in turn impacts the project's public perception and operational legitimacy. Engagement techniques, such as community meetings, public input channels, and transparency initiatives, guarantee ongoing support and satisfaction from the public.

4. Government Regulatory Bodies
Government Regulatory Bodies oversee the project to guarantee adherence to legal norms and promote sustainable regional development. They wield significant authority because of their regulatory power and ability to ensure adherence or grant crucial authorizations. Periodic updates, compliance reports, and collaboration meetings are carried out to ensure that the project is in line with regulatory standards and to obtain continuous governmental support.

5. Consultants
Consultants are hired for their specialized knowledge and ability to impact the project's strategic course and operational efficiency. While their authority in decision-making is limited, their influence on the project is substantial since their expert recommendations can result in substantial alterations to project design or strategy. For optimal utilization of their knowledge, it is essential to engage in comprehensive workshops and maintain constant involvement in project assessments and redesign phases.

6. Suppliers and Contractors
Suppliers and contractors have a vested interest in maintaining their contractual agreements and delivering goods or services according to specifications to ensure ongoing business. Their impact on the project's operational efficiency is considered minimal, but their labor has a large direct effect on project deadlines and quality. Engagement techniques, such as supplier development programs, performance reviews, and strategic collaborations, are crucial for meeting project needs and standards.

4.2 Analytical Hierarchy Process (AHP)
The Teluk Dalam Diesel Power Plant project, which aims to enhance power distribution efficiency and reliability in Mendol Island, serves as an ideal candidate for the application of AHP due to its multi-faceted decision criteria involving economic, environmental, technical, and social factors. The AHP framework for this project commences by setting a key objective: enhancing the efficiency and reliability of the electricity distribution system. The goal encompasses three primary criteria: Economic Viability, Environmental Impact, and Technical Feasibility. Several factors represent complex issues that require careful consideration due to their implications on the overall decision. Here are a few of those complex factors and an explanation of each:

1. Initial Investment: The initial investment, particularly the construction cost and the Levelized Cost of Energy, are significant as they directly affect the project's upfront financial burden and ongoing cost-effectiveness. The construction cost involves complexities related to logistics, material sourcing, labor, and the integration with existing infrastructure, while LCOE is crucial for assessing the long-term economic sustainability of the power generation option.
2. Ecological Impact: The ecological impact, especially land use and waste production, is a complex issue because it involves the environmental footprint of the power solution. Land use affects biodiversity, local ecosystems, and community land rights, while waste production concerns the disposal and potential environmental contamination, which must be managed sustainably to avoid long-term ecological damage.
3. Technical Feasibility: Reliability is a complex factor as it encompasses the consistency and dependability of the power supply. High reliability is essential to avoid outages and ensure stable power delivery, which impacts industrial productivity, residential comfort, and overall safety. The complexity arises from the need to integrate advanced technologies and maintain them effectively within the existing infrastructure.
4. Economic Return: Economic return captures the financial viability of the project over its lifespan, including the potential for revenue generation through selling excess power or receiving subsidies, and cost savings compared to other energy sources. This factor is complex due to the fluctuating nature of energy markets, policy changes, and technological advancements that can drastically alter expected returns.

These complex matters necessitate the use of interdisciplinary methods to examine and incorporate diverse viewpoints from stakeholders and expert opinions. To choose the most suitable and long-lasting power distribution method for the Teluk Dalam Diesel Power Plant project, it is important to thoroughly assess and analyze these elements.

4.3 Criteria Definition

To initiate the AHP framework, the initial task is to establish the criteria that will be used to assess potential power distribution systems. The criteria for this study have been determined based on Economic Viability, Environmental Impact, and Technical Feasibility. Every criterion is essential to ensure that the chosen potential power distribution solutions are in line with the company's strategic objectives and operational requirements within the context of power distribution. To initiate the AHP framework, the initial step is to establish the criteria that will be used to assess the power distribution alternatives. The criteria for this study have been determined based on technological compatibility, operational efficiency, and financial sustainability. Every criterion is essential to ensure that the chosen power distribution system is in line with the company's strategic goals and operational needs.

The Economic Viability criterion is central, divided into Initial Investment, Operation & Maintenance Costs, and Economic Return. Each category evaluates the financial aspects of potential power solutions Photovoltaic Solar Plant, Diesel-Solar Hybrid Power Plant and 20 kV Submarine Cable Grid through sub-criteria like Construction Costs, LCOE, ROI, Fuel Costs, and Routine Maintenance. This structured approach ensures the selected power solution is economically feasible from inception through long-term operation, assessing upfront costs, ongoing operational expenses, and potential financial returns, thereby facilitating a comprehensive financial analysis to guide optimal decision-making.

The Environmental Impact of different power generation alternatives for the Teluk Dalam Diesel Power Plant project. The group criterion, Environmental Impact, is divided into three main categories: Emissions, Resource Sustainability, and Ecological Impact. Each category is further broken down into sub-criteria: Emissions include CO2 emissions, particulate matter, and nitrogen oxides; Resource Sustainability is assessed through renewable energy utilization and energy efficiency; Ecological Impact is analyzed via land use and habitat disturbance, along with waste production and management. These sub-criteria are used to evaluate three alternatives: a Photovoltaic Solar Plant, a Diesel-Solar Hybrid Power Plant, and a 20 kV Submarine Cable Grid. This framework facilitates a detailed comparison of how each power solution affects the environment, guiding decision-making towards the most sustainable option.

The Technical Feasibility of alternative power solutions for the Teluk Dalam Diesel Power Plant project, focusing on three primary criteria: Implementation Complexity, Scalability, and Reliability. Implementation Complexity is assessed through sub-criteria such as Technical Integration, Technological Maturity, and Specialized Skill Requirements, which gauge how well new technologies can be incorporated within the existing infrastructure and the level of expertise needed for operation and maintenance. Scalability is evaluated through Modular Design and Demand Responsiveness, crucial for future expansions and the system's ability to adapt to changing power demands. Reliability is considered via Operational Stability and Maintenance Frequency and Complexity, ensuring the system operates consistently under varying conditions and maintenance is manageable. These criteria are analyzed against three power generation alternatives Photovoltaic Solar Plant, Diesel-Solar Hybrid Power Plant, and 20 kV Submarine Cable Grid to determine which option best meets the project's technical requirements and future growth needs.

4.4 Priority Trade-offs

The method of pairwise comparison is essential for assessing the different criteria and options. This method is an essential feature of AHP, enabling a methodical comparison of the items in the decision matrix to determine their respective priority or weights. This method enables an impartial assessment of intricate choices by dissecting them into smaller, easier-to-handle binary comparisons. We performed a thorough Analytic Hierarchy Process (AHP) to establish the order of importance for the factors used in selecting power distribution. We have conducted a systematic comparison of possibilities by categorizing them into a hierarchy, evaluating their relative significance through the assignment of numerical values, and determining priority weights by calculation.

The overarching priority in the decision-making process focuses significantly on Economic Viability with a weight of 0.544, indicating a strong preference for ensuring that the project is financially sustainable. Technical Feasibility follows with a weight of 0.346, underscoring the importance of a technically robust system that ensures reliability and operational efficiency. Environmental Impact, though less prioritized at 0.11, still plays a critical role in ensuring that the project aligns with environmental standards and practices, reflecting a balanced approach towards sustainable development. The consistency ratio for these overarching priorities is calculated at 0.046, which is significantly below the threshold of 0.10, indicating a high level of consistency and reliability in the pairwise comparisons made among these criteria.

Technical Feasibility gives paramount importance to Reliability (0.648), specifically emphasizing Operational Stability (0.8). This is indicative of the project's emphasis on ensuring an uninterrupted power supply, which is crucial for economic and social stability. Lesser weights for Implementation Complexity (0.122) and Scalability (0.223) indicate that while these factors are important, they are subordinate to the primary need for reliability. The very low consistency ratio of 0.0032 for Technical Feasibility speaks to the exceptional agreement among the evaluative judgments, enhancing the credibility of these findings.

The detailed application of AHP in this study demonstrates how priority weights and consistency ratios can effectively guide decision-making in complex infrastructure projects. By quantifying the relative importance of diverse criteria and ensuring that the evaluations adhere to a logically consistent framework, the AHP methodology aids in selecting a power distribution system that is economically viable, technically sound, and environmentally responsible. This rigorous approach ensures that the decision-making process is not only systematic and transparent but also aligned with the strategic objectives and sustainability goals of the Teluk Dalam Diesel Power Plant project.

4.5 Pairwise Comparisons of Option for Criteria

Within the framework of the Analytic Hierarchy Process (AHP), the options were compared in pairs to assess the alternatives in relation to one another. The data presented in Table 2 is as follows:

Table 2. Attributes Pairwise Comparison

Criterion	Photovoltaic Solar Plant	Diesel-Solar Hybrid Power Plant	20 kV Submarine Cable Grid
Construction Costs	0,163780664	0,297258297	0,538961039
LCOE (Levelized Cost Of Electricity)	0,16984127	0,387301587	0,442857143
ROI (Return On Investment)	0,163780664	0,297258297	0,538961039
Fuel Costs	0,159259259	0,251851852	0,588888889
Routine Maintenance	0,197619048	0,311904762	0,49047619
Operation Costs	0,197619048	0,311904762	0,49047619
Revenue Generation	0,197619048	0,311904762	0,49047619
Cost Savings	0,197619048	0,311904762	0,49047619
(CO2) Emissions	0,197619048	0,311904762	0,49047619
Particulate Matter (PM)	0,197619048	0,311904762	0,49047619
Nitrogen Oxides (NOx)	0,231082375	0,103847382	0,665070243
Renewable Energy Utilization	0,197619048	0,311904762	0,49047619
Energy Efficiency	0,197619048	0,311904762	0,49047619
Land Use and Habitat Disturbance	0,197619048	0,311904762	0,49047619
Waste Production	0,197619048	0,311904762	0,49047619
Technical Integration	0,197619048	0,311904762	0,49047619
Technological Maturity	0,197619048	0,311904762	0,49047619
Specialized Skill Requirements	0,197619048	0,311904762	0,49047619
Modular Design	0,197619048	0,311904762	0,49047619
Demand Responsiveness	0,197619048	0,311904762	0,49047619
Future Compatibility	0,197619048	0,311904762	0,49047619
Operational Stability	0,141558442	0,333766234	0,524675325
Maintenance Frequency and Complexity	0,333766234	0,524675325	0,141558442

The alternatives assessed include the Photovoltaic Solar Plant, Diesel-Solar Hybrid Power Plant and the 20 kV Submarine Cable Grid. The analysis involves pairwise comparisons across various criteria, systematically evaluated to derive priority weights and assess the consistency of the judgments. The complete table refers to Appendix C.

Within the Economic Viability criterion, three sub-criteria are considered: Construction Costs, Levelized Cost of Electricity (LCOE), and Return on Investment (ROI). For Construction Costs, the Photovoltaic Solar Plant has a weight of 0.1638, the Diesel-Solar Hybrid Power Plant has a weight of 0.2973, and the 20 kV Submarine Cable Grid has the highest weight of 0.5390, with a consistency ratio of 0.070. This indicates significant initial investment requirements for the Submarine Cable Grid, reflecting its potential for long-term economic benefits. For LCOE, the Photovoltaic Solar Plant, Diesel-Solar Hybrid Power Plant, and Submarine Cable Grid have weights of 0.1698, 0.3873, and 0.4429, respectively, with a consistency ratio of 0.019, indicating the Submarine Cable Grid's higher ongoing energy production costs. For ROI, the Photovoltaic Solar Plant, Diesel-Solar Hybrid Power Plant, and Submarine Cable Grid have weights of 0.1638, 0.2973, and 0.5390, respectively, with a consistency ratio of 0.037, highlighting the Submarine Cable Grid's highest potential returns.

The Environmental Impact criterion includes CO2 Emissions, Particulate Matter (PM), and Nitrogen Oxides (NOx). For CO2 Emissions, the Photovoltaic Solar Plant, Diesel-Solar Hybrid Power Plant, and Submarine Cable Grid have weights of 0.1976, 0.3119, and 0.4905, respectively, with a consistency ratio of 0.046. The Submarine Cable Grid shows superior performance in managing CO2 emissions, highlighting its environmental advantage. For PM and NOx, the Submarine Cable Grid demonstrates better environmental performance, with weights for PM at 0.4905 and NOx at 0.6651, and consistency ratios of 0.046, indicating the reliability of the evaluations.

4.6 Priority Alternatives

After carrying out the Analytic Hierarchy Process (AHP) to choose a power distribution strategy, the priority values for the available options have been calculated. These values indicate the comparative attractiveness of each choice, considering all the criteria and sub-criteria assessed during the decision-making process. The priority values derived from the analysis clearly indicate the 20 kV Submarine Cable Grid as the most suitable option, balancing cost, efficiency, and sustainability. The Diesel-Solar Hybrid Power Plant serves as a strong alternative, particularly where balanced performance across criteria is needed. The Photovoltaic Solar Plant, although cost-effective initially, is less favorable due to its lower long-term benefits. The consistent application of AHP ensures that the selected power distribution system aligns with the project's strategic goals and objectives, reinforcing the reliability and coherence of the decision-making process.

4.7 Sensitivity Analysis

Within the framework of the Teluk Dalam Diesel Power Plant project, conducting sensitivity analysis using the Analytical Hierarchy Process (AHP) is essential for comprehending the impact of changes in criteria weighting on the overall ranking of power distribution system alternatives. The evaluated options consist of the Photovoltaic Solar Plant, Diesel-Solar Hybrid Power Plant, and the 20 kV Submarine Cable Grid. Sensitivity analysis is a method used to assess the strength of a choice by examining how the final ranking is affected by variations in the weights assigned to different criteria.

The 20 kV Submarine Cable Grid exhibits significant sensitivity to economic viability, particularly influenced by its substantial construction costs and high return on investment (ROI). This sensitivity underscores the crucial need for meticulous long-term financial planning and substantial investment in large-scale infrastructure projects. The high initial capital expenditure associated with the Submarine Cable Grid is justified by the potential for considerable economic returns over the project's lifecycle. This option's economic sensitivity indicates that any fluctuation in cost-related factors, such as changes in material prices or financial incentives, can profoundly impact its overall prioritization. Thus, strategic financial management and robust economic forecasting are imperative to mitigate risks and optimize the economic benefits of the Submarine Cable Grid.

The Diesel-Solar Hybrid Power Plant demonstrates moderate sensitivity to environmental factors, reflecting its balanced performance in both economic and environmental sustainability. This sensitivity highlights the importance of adopting a holistic approach that integrates environmental considerations into the economic evaluation framework. The Hybrid Plant's ability to moderately manage CO2 emissions and other environmental impacts, while still providing a reliable energy supply, suggests that it can adapt to varying environmental priorities. As environmental regulations and societal expectations evolve, the Hybrid Plant's moderate sensitivity to these factors ensures its continued relevance and acceptability. Therefore, environmental sustainability must be factored into decision-making processes to maintain the Hybrid Plant's viability and stakeholder support.

The Photovoltaic Solar Plant shows notable sensitivity to economic criteria, yet it remains less responsive to changes in technical feasibility. This dichotomy suggests that while the Photovoltaic Solar Plant is an economically attractive option due to its low initial costs and favorable levelized cost of electricity (LCOE), its technical limitations warrant careful consideration in large-scale applications. The relatively lower operational stability and higher maintenance complexity of the Photovoltaic Solar Plant imply that, although it may be cost-effective in the short term, its long-term technical performance could be compromised. Consequently, for large-scale or high-demand projects, the technical feasibility of the Photovoltaic Solar Plant must be rigorously assessed to ensure that its economic benefits are not offset by operational inefficiencies and higher maintenance demands. This underscores the necessity of a comprehensive evaluation that balances economic advantages with technical robustness to achieve sustainable energy solutions (Walker, 2018).

The sensitivity analysis for the Cost Construction criterion revealed a decision change sensitivity of 33.75%. This percentage represents the probability of a change in the preference for power distribution between the 20 kV Submarine Cable Grid and The Diesel-Solar Hybrid Power Plant because of fluctuations in the perceived construction costs. It indicates that by altering the significance attributed to the construction cost of the 20 kV Submarine Cable Grid compared to the Diesel-Solar Hybrid Power Plant, there is a 33.75% chance that the prioritizing of the power distribution option will change.

The sensitivity analysis within the AHP framework for the Teluk Dalam Diesel Power Plant project reveals critical insights into the responsiveness of each power distribution system alternative to changes in criteria weightings. The 20 kV Submarine Cable Grid's economic sensitivity highlights the importance of long-term financial strategies and substantial capital investment. The Diesel-Solar Hybrid Power Plant's moderate environmental sensitivity underscores the need for an integrated approach to sustainability. The Photovoltaic Solar Plant's economic sensitivity, coupled with its technical limitations, emphasizes the importance of a balanced assessment that considers both short-term cost benefits and long-term operational stability. These detailed sensitivity insights ensure that the decision-making process is thorough, adaptable, and aligned with the strategic objectives of the project, providing a robust framework for selecting the most suitable power distribution system (Sawle, Jain, Babu, Nair, & Khan, 2021).

4.8 Business Solution

To address the identified issues at the Teluk Dalam Diesel Power Plant on Mendol Island, a multifaceted solution aimed at improving operational efficiency, financial performance, and regulatory compliance is proposed. This comprehensive solution comprises three strategic initiatives: the development of a Photovoltaic Solar Plant, the implementation of a Diesel-Solar Hybrid Power Plant, and the construction of a 20 kV Submarine Cable Grid (Slabá, 2014).

Development of a Photovoltaic Solar Plant: The primary objective of this initiative is to supplement the existing diesel power generation with renewable solar energy, thereby reducing fuel consumption and emissions. Solar power is abundant and sustainable, providing a reliable alternative during peak sunlight hours, which decreases dependency on diesel generators. This initiative involves the installation of photovoltaic (PV) panels, inverters, and grid integration systems. Additionally, battery storage systems will be implemented to manage energy storage and ensure stability. The monitoring and control systems will optimize the utilization of solar energy. The expected benefits include significant reductions in operational costs due to decreased fuel consumption, a reduction in environmental impact, and improved compliance with regulatory standards. However, challenges such as the initial capital investment for PV panels and associated infrastructure, the need for skilled personnel to manage and maintain the solar power systems, and variability in solar energy generation due to weather conditions must be addressed. Mitigation strategies include securing funding and incentives from governmental and environmental grants, providing comprehensive training for local staff, and implementing robust battery storage solutions to store excess energy for use during low sunlight periods.

Implementation of a Diesel-Solar Hybrid Power Plant: This initiative aims to integrate solar and diesel power generation to create a hybrid system that leverages the strengths of both sources. The hybrid system offers enhanced flexibility and reliability, enabling seamless transitions between power sources and optimizing fuel usage. Key components of this system include the integration of existing diesel generators with new PV panels, hybrid control systems to manage transitions between diesel and solar power, and battery storage systems to manage load and improve reliability. Monitoring and control systems will also be essential to optimize hybrid operation. The expected benefits of this initiative include enhanced reliability and flexibility in power generation, optimized fuel usage leading to reduced operational costs, and improved environmental performance through reduced emissions. Challenges such as the technical complexity in integrating diesel and solar systems, high initial investment costs for hybrid control and battery storage systems, and the requirement for ongoing maintenance and technical support are anticipated. Mitigation strategies involve engaging expert consultants for system integration and technical support, securing financing through partnerships and government incentives, and implementing a robust training program for local operators.

Construction of a 20 kV Submarine Cable Grid: The objective of this initiative is to enhance the connectivity of Mendol Island with the mainland power grid to ensure a stable and continuous power supply. The submarine cable will provide a robust infrastructure for power distribution, reducing the frequency of maintenance and operational disruptions. The components of this initiative include submarine power cables with appropriate insulation and protection, substations at both the mainland and island ends for connection and distribution, and monitoring and control systems to manage the grid connection and power flow. Maintenance and emergency response systems will also be established to ensure continuous operation. The expected benefits include a reliable and continuous power supply to Mendol Island, reduced maintenance and operational disruptions, and enhanced capacity to meet growing power demand and support economic growth. Challenges such as high initial investment costs for submarine cable installation and associated infrastructure, technical difficulties related to laying and maintaining submarine cables, and environmental considerations and regulatory approvals must be managed. Mitigation strategies include conducting thorough feasibility studies and environmental impact assessments, engaging experienced contractors and engineers for cable installation, and collaborating with regulatory bodies to ensure compliance and secure necessary approvals (Simchi-Levi, Kaminsky, & Simchi-Levi, 1999).

The implementation of the 20 kV Submarine Cable Network Development is a significant financial undertaking, encompassing both initial capital expenditure and continuous operational expenses. To successfully tackle these financial difficulties, it is crucial to have a thorough financial plan along with strong risk management measures. This approach will guarantee the long-term financial viability of the project and optimize the return on investment (ROI), while also detecting and minimizing any financial hazards.

5. Conclusion

5.1 Conclusion

This study aimed to address the critical issues of electricity distribution on Mendol Island, focusing on identifying primary challenges, proposing sustainable solutions, and outlining effective implementation strategies. In response to the research question, this study answers as follows:

1. *What are the primary challenges and inefficiencies in electricity distribution On Mendol Island?*
   The Teluk Dalam Diesel Power Plant on Mendol Island faces several significant challenges. The primary issues include the plant's limited operational capacity, which has decreased from 1.07 MW in 2021 to 0.78 MW in 2022, while peak demand has marginally increased from 0.88 MW to 0.94 MW. This capacity shortfall results in frequent operational states of 'Alert' and 'Deficit', severely impacting the reliability of electricity supply. Additionally, financial inefficiencies due to excessive fuel consumption, amounting to Rp 15.25 billion against a target of Rp 9.68 billion, have exacerbated the plant's operational difficulties. The aging infrastructure further contributes to frequent maintenance disruptions, increasing operational costs and reducing system reliability. These factors collectively hinder the plant’s ability to meet both current and future electricity demands effectively.
2. *What alternative solutions can be proposed for the sustainability of electricity distribution and the cost-effectiveness of Mendol Island?*
   To address these inefficiencies, three strategic initiatives have been proposed:

a. Development of a Photovoltaic Solar Plant: This solution aims to supplement the existing diesel power generation with renewable solar energy, reducing fuel consumption and emissions. The integration of solar power during peak sunlight hours will alleviate pressure on diesel generators, promoting sustainability and operational efficiency.
b. Implementation of a Diesel-Solar Hybrid Power Plant: This hybrid system will combine solar and diesel power generation, leveraging the strengths of both sources to offer flexibility and reliability.

The hybrid approach will ensure a stable power supply, optimize fuel usage, and reduce operational costs.

3. *How can the alternative strategy be effectively implemented and deployed, considering stakeholder participation and regulatory frameworks for Mendol Island?*
   The implementation plan for these solutions, based on the 5W + 1H framework, includes specific actions, timelines, locations, responsible parties, reasons, and methods. This plan ensures meticulous planning and execution, aligning with stakeholder interests and regulatory frameworks. Stakeholder participation is critical, involving management and employees, shareholders and lenders, customers, government and regulatory bodies, consultants, and contractors. Regular updates, compliance reports, and strategic engagement will ensure that all stakeholder concerns are addressed, facilitating smooth implementation.

5.2 Recommendation

Based on the study findings and conclusions, several key recommendations are proposed to ensure the successful implementation and sustainability of the proposed solutions at the Teluk Dalam Diesel Power Plant. These recommendations are targeted at different stakeholders involved in the project, emphasizing practical steps to enhance efficiency, compliance, and stakeholder engagement:

1. For Management and Employees: It is crucial to implement comprehensive training programs that equip employees with the necessary skills to manage and maintain the new hybrid systems. This will ensure the sustainable operation of the newly introduced technologies. Additionally, operational efficiency programs should be initiated, including strategic alignment workshops and decision-making meetings, to promptly address any inefficiencies. Regular briefing sessions will keep the management team and employees aligned with the project goals, ensuring smooth execution and continuous improvement.
2. For Shareholders and Lenders: Maintaining transparency in financial reporting is essential. Regular financial reports and discussions on project risks and returns should be conducted to keep shareholders and lenders informed. This approach will ensure their continued support and alignment with the project's financial and sustainability commitments, enhancing overall project credibility and investment attractiveness.
3. For Customers: Community engagement initiatives are recommended to maintain transparency and build trust among customers. Conducting community meetings and establishing public feedback channels will keep customers informed about the project's progress and benefits, enhancing satisfaction and support. This proactive engagement will foster a positive relationship between the power plant and the local community, crucial for long-term success.
4. For Government and Regulatory Bodies: Regular updates and compliance reports are necessary to meet regulatory standards and ensure governmental support. Collaborative meetings with regulatory bodies will facilitate smooth project implementation, securing ongoing support and adherence to environmental and operational regulations. This compliance will also position the power plant as a responsible and sustainable entity within the energy sector.
5. For Consultants and Contractors: Strategic partnerships with consultants and contractors should be developed through workshops and advisory roles to leverage their expertise effectively. Performance evaluation programs and strategic partnerships will ensure high-quality project delivery, meeting the required standards and timelines. Engaging experienced consultants and contractors will also provide valuable insights and innovative solutions, enhancing the project's overall success.

By following these recommendations, the Teluk Dalam Diesel Power Plant can successfully navigate the transition to a more efficient, reliable, and sustainable power generation system. These strategic actions will ensure long-term benefits for all stakeholders involved, aligning with modern energy standards and contributing to the sustainable development of Mendol Island.

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