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Analysis of the Influence of Policy, Commitment and Financial Factors on Value Engineering – Based Investment Cost in Green Data Center Projects

Eka Rismah Febriyani and Agus Suroso

Department of Civil Engineering, Mercu Buana University, Jakarta Barat, DKI Jakarta 11650, Indonesia

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Value Engineering
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Agency commitment

ABSTRACT

The Global Warming phenomenon caused by the greenhouse gas effect that raises the need for sustainable energy management, especially in the Data Center Industry, which is known to contribute 2% of emissions, because 35% of energy use is for cooling. This study aims to analyze the influence of government policy factors, agency commitments, and finances on investment costs based on Value Engineering in the Green Data Center project, find the dominant factor among the factors assessed, calculate Value engineering on the investment costs of the Green Data Center to calculate the life cycle Cost Analysis. The research method uses a combination of quantitative & Qualitative methods with data collection techniques through Primary Data and Secondary Data, Secondary data is obtained based on project information such as Bill of Quantity, Technical Specifications, and project reports. Primary data is obtained through questionnaires to stakeholders of the Data Center project, as well as multiple linear regression analysis to test the relationship between variables. The results of the study indicate that the factors assessed have a significant effect on the investment costs of environmentally friendly projects. The application of a renewable energy system through the Value Engineering stages has proven effective in optimizing investment costs through identifying the use of an energy-efficient Liquid cooling cooling system for medium-scale Data Centers which results in savings of around 15.34% and increases Energy Use Efficiency (PUE). While Life Cycle Cost Analysis (LCCA) shows long-term operational savings and a return on investment that is considered faster than 3 years, the Green Data Center project is feasible to implement. The most dominant factor is the financial support aspect, followed by government policy and agency commitment. This study reinforces the importance of implementing environmentally friendly concepts to support energy efficiency in supporting climate change control and providing long-term economic benefits.

1. Introduction

The phenomenon of global warming triggered by increased greenhouse gas emissions has become a current issue in sustainable development. One indicator that the earth is changing is characterized by high carbon dioxide (CO_2) in the air that blocks heat from the earth [1]. Data centers as the backbone of global digitalization, contribute to 2% of the world's carbon emissions, with the use of energy for cooling systems from total energy consumption [2][3].

Data center is a facility to place a collection of servers or computer systems and data storage systems (storage) that are conditioned by power supply settings, air settings, fire hazard prevention and usually equipped with physical security systems [4]. Data centers house IT equipment that consumes energy and requires air conditioning 24 hours a day throughout the year [5]. Data center rooms provide the ability to centralize storage, management, networking and data deployment [6].

*Corresponding author.
E-mail: ekarfebriyani@gmail.com

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Along with the development of the need for digital services in Indonesia, the demand for data center construction has increased significantly, also bringing consequences to increased energy consumption and environmental impact. Therefore, to control climate change, the government has ratified the Paris Agreement through (Law no. 16 of 2016) which contains the government's obligation to contribute to reducing greenhouse gas emissions set nationally to limit the increase in global average temperature. Below 2°C – 1.5°C pre-industrialized temperature level, and ensure that the data center is built and operated in a environmental-friendly manner [7]. In general, there is a fairly high cost increase in the implementation of this green project, 5% to higher than conventional projects in addition to the excessively high design costs in the data center, power and cooling costs have become the main contributors to the data center [8].

Value Engineering (VE) is a systematic review of a project, product or process to improve performance, quality and lifecycle costs by a team of independent multi-disciplinary specialists [9]. Life Cycle Cost Analysis on VE is value-based and is used to determine the cheapest option without compromising on quality [8].

In previous research, the application of the environmentally friendly concept in data centers has been discussed, but studies related to the analysis of the influence of government policy factors, agency commitments, and financial aspects on VE-based investment costs on investment costs in this green data center project are still limited.

The study "Analysis of Barriers to Green Data Center Implementation in Malaysia, using Interpretive Structural Modelling (ISM) " identified barriers including communication, information, financial stakeholder awareness and several other barriers that affect spending on green data center energy efficiency [3]. In the study "Toward Sustainable Data Centers: A comprehensive energy management strategy", the results of the study explain that data centers must increase the use of renewable energy, with which energy use will be more optimal [10].

In the research "Green Data Centers: A survey Perspectives, and future Directions" research findings related to energy efficiency: Increased awareness related to the development of green data centers on reducing carbon emissions, challenges in implementation" focus more on energy savings without examining its relationship with investment strategies and supporting national policies [11]. The study, "A Taxonomy and Survey on Green Data Center Network," informed that in energy reduction, recommendations are made to integrate renewable energy sources, such as solar power or wind into data center operations and also to achieve sustainability goals [12]. Then in a study conducted in Indonesia, namely in Bali, "Green Data Center Design of Udayana University" based on PUE 2.51 and entered the inefficient category, while 39% of DCIE calculations are still in the inefficient category, by recommending the use of cables and facilitating checking activities, the use of raised floors based on a cooling system using a 3-phase electrical system to balance the distributed load [13] .

This gap shows the need for comprehensive research that not only reviews technical aspects, but also managerial and policy factors on the cost of implementing Green Data Centers in Indonesia. The objectives of this study are (1) to find out whether aspects of government policies, agency commitments and financial support have a simultaneous effect on the cost of Value Engineering-based investment in the Green Data Center project (2) to find out the most dominant factor among the factors assessed through SPSS statistical data processing (3) to find out the calculation of the application of Value Engineering to the investment cost of Green Data Center (4) Knowing the application of Life cycle cost analysis calculation to Green Data Center investment costs (5) Knowing how the results of Value Engineering and Life cycle cost Analysis calculations are on the investment cost of Green Data Center Projects (6) Knowing the comparison of research results with previous research.

2. Methods

The research method uses a combination of quantitative & qualitative methods with data collection techniques through primary and secondary data. The secondary data obtained was based on project information such as Bill of Quantity, Technical Specifications, and project reports. Primary data obtained through questionnaires to stakeholders of the data center project.

Based on the results of the literature review both nationally and internationally and project studies in the research conducted, it was determined that the independent variables analyzed include government policy factors (x_1), agency commitment (x_2), financial support (x_3) and Value Engineering (x_4), while the dependent variable is Investment Cost (y) and the questionnaire indicators are determined based on the results of the expert validation for further distribution of the questionnaire. The questionnaire results were analyzed using multiple linear regression to see the simultaneous and partial effects between variables. The validity and reliability of the data were evaluated using SPSS 26. The classical assumption test was conducted to ensure the feasibility of the model. To strengthen the cost analysis, Life Cycle Cost Analysis (LCCA) method applied to evaluate long-term cost efficiency after the implementation of the green data center/ environmentally friendly concept.

The respondents involved in this study were stakeholders involved in the data center project. Phase 1 questionnaire conducted to validate experts to determine the variables and indicators that used for project owners, data center consultants, project managers, site managers to HSE data center projects.

The results of the expert validation provided feedback that the implementation of green data centers is not only to save the earth but can significantly reduce operational costs. It may indeed require higher initial investment (CAPEX), but that will be covered by low operating costs (OPEX). For Indonesia and other tropical countries, more attention needs to the achievement of green performance for DC because there are no natural facilities in the form of free cooling in winter. For this reason, GBCI and IPUSTAH-ID (Indonesian Data Center Professional Association) have published a Greenship Data Center assessment tool that pays close attention to the natural and artificial environmental conditions in Indonesia" and a research model was obtained to be carried out in the 2nd stage questionnaire for stakeholders that had been determined in the research. The research model provided in Figure 1.

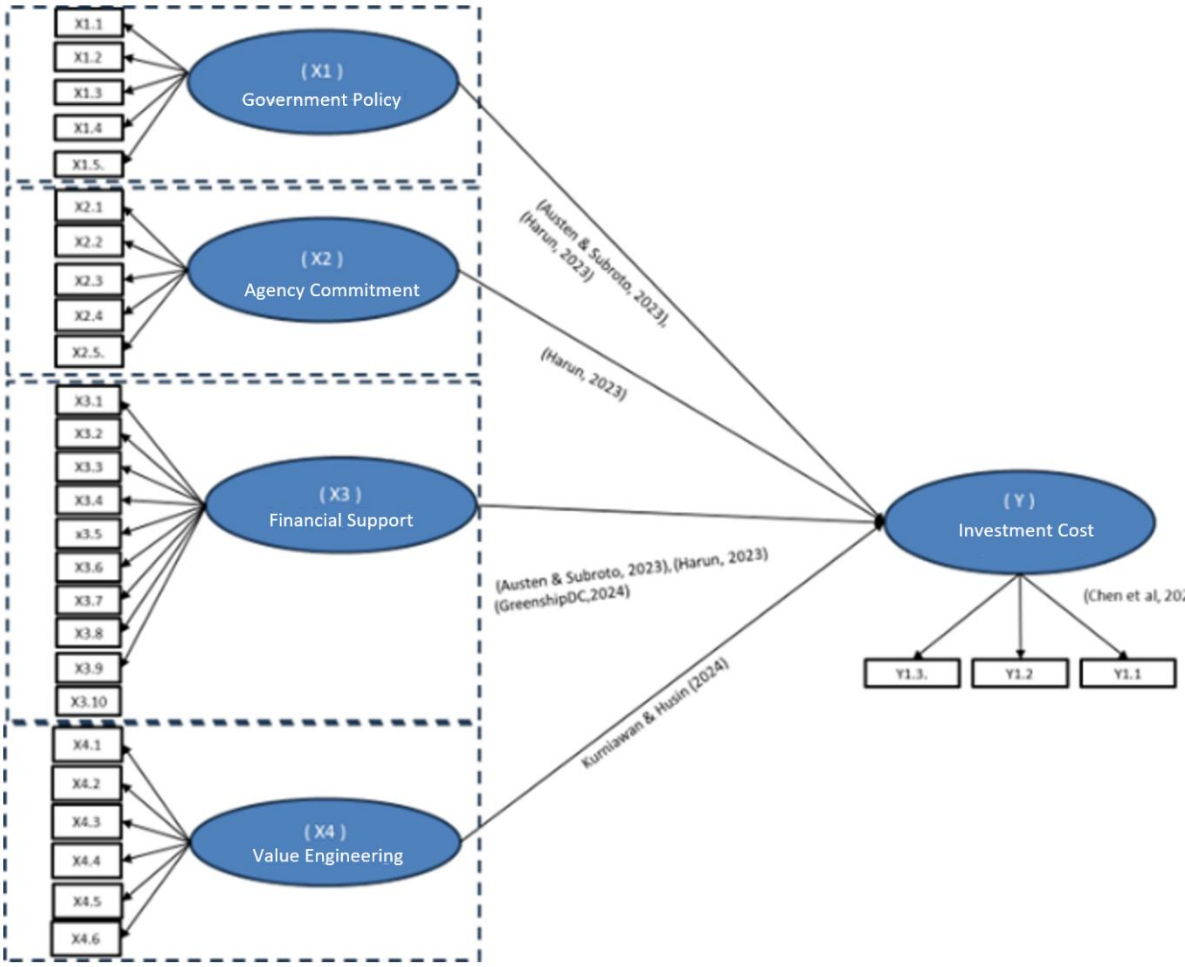


Figure 1. Research model

Phase 2 questionnaire conducted on 67 respondents from the side of contractors, data center consultants, project managers, project control, technician staff, and HSE data centers using 4 sample project data centers located in West Java, DKI Jakarta and Batam. The results of the questionnaire then processed with SPSS 26 statistics. Table 1 provides the profile of respondents based on their position in the project and on average have more than 5 years of experience in a data center project with a bachelor's degree.

Table 1. Research Responden

Position	Numb	Percentage (%)
Owner	2	2.7
Project Manager	7	9.3
Site supervisor/Technician	50	66.7
HSE	3	4.0
DC Consultant	1	1.3
Staff & Designer Contractor	12	16.0
Total Respondents	75	100.0

3. Results and Discussion

This research conducted to answer the purpose of the research, so that the discussion of the results of this research divided based on the formulation of the research problem. The data from the questionnaire stage 2 processed and analyzed using SPSS (Statistical Package for the Social Sciences) statistics which supports correlation tests and regression analysis, allowing researchers to investigate complex relationships between variables. Figure 2 provides stages in answering research questions in RQ (Research question 1 & 2).

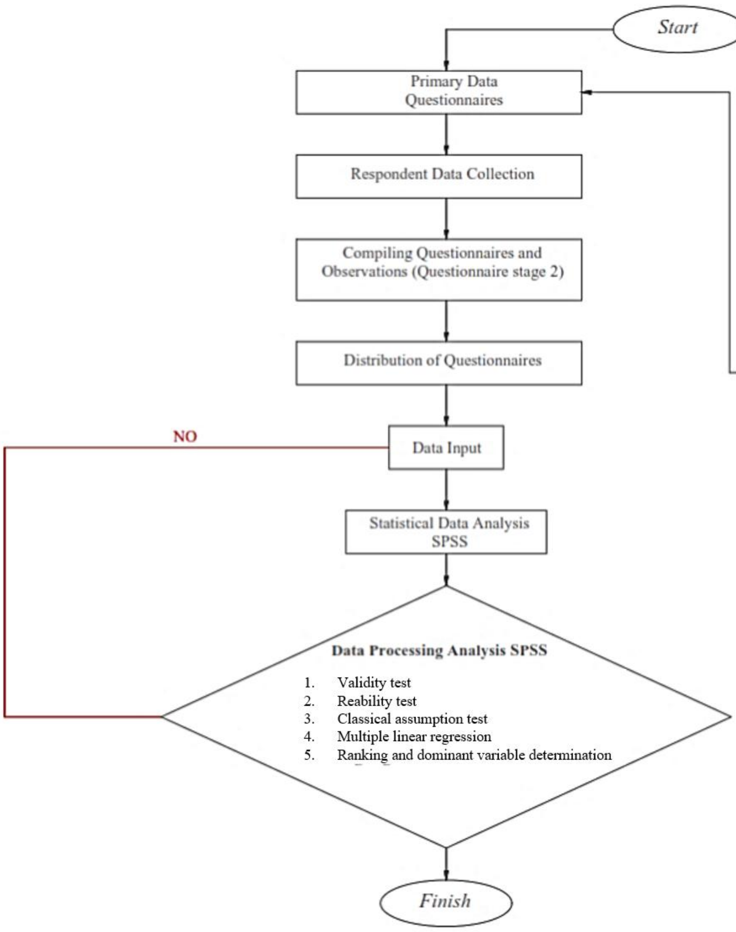


Figure 1 . Statistical Data Collection and Process Flow

Research Question 1. The data from the phase 2 questionnaire processed and analyzed using SPSS (Statistical Package for the Social Sciences) statistics that supported correlation tests and regression analysis, which allowed researchers to investigate the complex relationships between variables. The stages in answering research questions in RQ (Research questions 1 & 2) provided as follows.

a) The results of the validity test showed that all variable indicators had an R value calculated > an R value, so that the questions on the questionnaire were declared Valid.
b) The results of the Reliability Test, 4 independent variables studied showed a Crobach's Alpha value of > 0.6. so that the measuring tool in this study was declared reliable or could provide consistent results.
c) The results of the classical assumptions test show that the residual in the regression model is normally

distributed. The Multicollinearity test indicates a Tollerance value of > 0.01 and has a VIF value of < 10.00, then Multicollinearity does not occur.

d) The Heteroscedasticity test showed a significant value > 0.05, then Heteroscedasticity did not occur.

e) Multiple Linear Analysis, the results of the T-test show that the variables assessed have a significant effect on the investment cost.

f) The results of the F-test are known that the value of F is calculated = 78,601 > f table = 2.50 with a significance value of 0.000 <0.05. This means that together, Government Policies (x_1), Agency Commitments (x_2), Financial Support (x_3) and Value Engineering (x_4) have a significant effect on Investment Costs (y). It can also be concluded that the regression equation is good (good of fit) and the predictive value can explain the actual situation.

g) The mathematics model is obtained as Equation 1.

$$y = -0.067 + 0.189\, x_1 - 0.295\, x_2 + 0.203\, x_3 + 0.243\, x_4 \quad (1)$$

with x_1 as Government Policy, x_2 as Agency Commitment, x_3 as Financial Support, x_4 as Value Engineering, and, y Investment Cost.

h) The value of R square is 0.818, so the influence of the free variable on the bound variable is 81.8%, and 18.2% is influenced by other factors outside this study. Table 2 summarized the coefficient of determination test result model.

Table 2. Coefficient of determination test result model

Model	R	Rsquare	Adjusted R Square	Std. Error of the Estimate
1	0.904[a]	0.818	0.807	0.95522

Research Question 2. This regression model is statistically significant both simultaneously (F test) and partially (t-test). The variables with the greatest influence are presented in Table 3.

Table 3. The Rank of independent variables

Variable	Coef Beta	Pearson Corr	Sig <0.05
Financial Support (x_3)	0.668	0.857	0.002
Value Engineering (x_4)	0.426	0.810	0.000
Government Policy (x_1)	0.347	0.625	0.000
Agency Commintment (x_2)	-0.548	0.577	0.000

Based on the results of the analysis obtained (pearson correlation) and a significant value of <0.05. The verifiable rating that most affects the investment cost of the Green Data Center Project The Financial Support Variable (x_3) is the most dominant factor in influencing the cost efficiency of the Green Data Center project, followed by Value Engineering (x_4), Government Policy (x_1), and Agency Commitment (x_2). Although the Agency Commitment has a negative direction, it actually indicates that the increase in Agency Commitment has an impact on reducing costs, which is in line with the project's efficiency goals.

Research Question 3. Applying the concept of Green Data Center Implementation based on Value engineering and LCCA methods to achieve Green Investment Costs so that it is not considered too high in its implementation. LCCA, which is a critical requirement in sustainable procurement, is a key tool for evaluating economic efficiency for a project's total lifecycle budget. In the value engineering stage, it is carried out through several stages starting from the collection of information, project cost calculation, and Pareto analysis.

The information collect from a data center located in the West Java, Indonesia. It have a medium 50-100 server rack with a capacity of 6kWh/racks. The ventilation / air conditioning system is still using the conventional one, namely with a PAC system and flow AC under raised floor. The existing PAC cooling system illustrated in Figure 3.

Figure 3. The existing PAC cooling system

The next stage is the project cost calculation. The results of data collection regarding construction costs were obtained based on the technical design that had been carried out previously. It is known that the cost of system cooling is the most dominant cost in Data Centers, with the change of conventional system (PAC) to an environmentally friendly system (Immersion Cooling) there is an increase in cost of more than / > 4.5% of the value before the replacement of components.

Based on the results of the literature review, conventional systems require large amounts of electricity to turn on air conditioning fans and coolers, on the other hand, these immersion systems operate with much lower energy costs. This system can reduce cooling energy consumption by up to 50% resulting in considerable savings on electricity costs. The use of refrigeration alternatives has a greater initial investment value. The following is the *standard* for calculating PUE (Power Ussage Effectiveness).

$$PUE = \frac{\text{Total Facility power}}{\text{IT equipment energy}} \quad (2)$$

The next stage is Pareto Analysis. Based on the Pareto distribution law, work that has a weight of more than 20% is generally potential for Value Engineering, in order to produce an increase in value or function from the work, so that the total will reduce costs or add functions or value to the entire project.

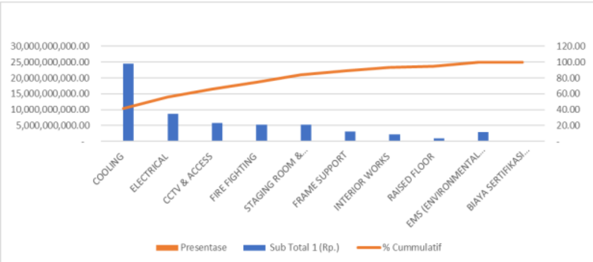


Figure 2. Pareto Diagram Analysis

Based on the Pareto analysis in Figure 4, the most dominant work component can be identified by looking at its cumulative value. The most dominant work is Cooling and. So further analysis is conducted. So, 80% of these problems are priorities that must be handled first.

The previous use of cooling/cooler was in the form of Air Cooling, with high operational and maintenance costs, so savings in operations are needed. Based on the findings of the researcher in the analysis of functions in each existing scope of work, and also with input from the team in an effort to reduce the cost budget on the work components whose functions and values are known to be the most dominant in the implementation of the Green Data center, namely the Cooling Component.

In the Value Engineering creative stage, we consider more efficient and environmentally friendly alternatives to replace or improve conventional PAC systems. While the initial investment in advanced data center cooling technology is much higher, the long-term operational savings often justify such expenses. Reduced energy consumption leads to lower Electricity bills. And the reduced need for extensive air conditioning infrastructure can result in additional cost savings, in addition to improved energy efficiency contributing to a smaller carbon footprint, aligned with sustainability goals globally.

By conducting the Value Engineering process to provide an option for energy-saving components in the cooling system. In the discussion process, calculations made using the power of each PAC (Precision Air Conditioner)/conventional cooling system, Immersion Cooling and Liquid Cooling System.

According to the Uptime Institute, data centers have an average PUE of 2.5, with estimates that most facilities can reach 1.6 PUE if the most efficient data center equipment and best practices are implemented. Data Center Infrastructure Efficiency (DCiE) is a metric used to evaluate the power or energy efficiency of a data center or risk management within a data center. This involves evaluating and calculating energy consumption, specifically how it relates to the energy use of devices and IT. The comparison of conventional system with energy saving provided in Table 4.

Table 4. Comparison of conventional system with energy saving [15][16][17]

Feature	PAC (Conventional)	Immersion Cooling	Liquid Cooled
Energy Efficiency	Low (High power consumption for Fan/fan in AC system).	High - Very High (Approximately 40% reduction in energy consumption).	High (20-40% reduction in energy use).
Maintenance	Frequent (dust buildup on the AC fan).	Low (Closed system, low maintenance).	Minimal (Closed, low maintenance system).
Environmental Impact	High (High Energy Consumption).	Low (Very low energy consumption).	Low (Sustainable Cooling, reducing carbon footprint).
Application	Fully air-conditioned cooling type.	Ideal for high-density power devices, especially extreme environments such as large-scale data centers.	Suitable for small to medium data centers, suitable in all climates.

Table 5. Energy requirement calculation

Category	PAC (kWh)	Immersion Cooling (kWh)	Liquid Cooling (kWh)
IT Load	384	384	384
Cooling System	345.6	230.4	190.08
UPS & Power Distribution	38.4	38.4	38.4
Lighting Interior	10	10	10
CCTV & Security System	5	5	5
Fire Suppression & Monitor	5	5	5

Category	PAC (kWh)	Immersion Cooling (kWh)	Liquid Cooling (kWh)
Total energy	788.00	672.80	632.48
PUE Total	2.05	1.75	1.65
DciE Total	0.49	0.57	0.61
Energy consumption per year	6,902,880.00	5,893,728.00	5,540,524.80
Energy costs per year	9,972,590,736	8,514,668,841	8,004,396,178

Table 6. Comparation of Energy Requirements

Specification	Total Facility Power (kWh)	PUE	DCiE (%)	Annual Energy Consumption (kWh)
(PAC)	345.6	2.05	49	6.902,88
Imersion	230.4	1.75	57	5.893,72
Liquid	190.08	1.65	61	5.540,52

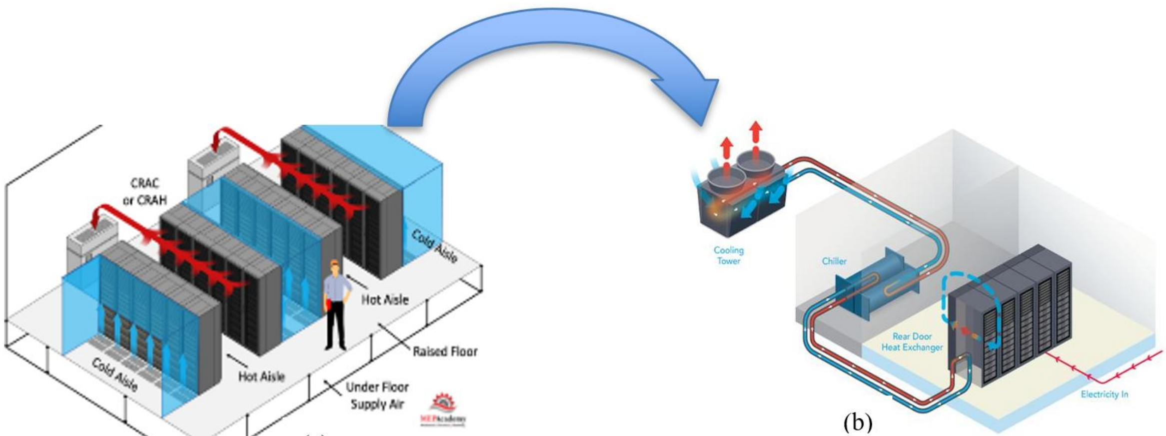
The calculation of energy requirement showed in Table 5. The comparison of energy requirements provided in Table 6. From the results of the comparative analysis of the cooling system operation, an analysis was carried out on the cost of the initial replacement system / initial investment, annual energy costs, maintenance / repair of the cooling system 3 – 4x in 1 year, replacement of IT equipment systems, to the cost of data and physical security maintenance in 1 year. Comparison of PAC, Immersion cooling and liquid cooling.

Table 7. Comparison before and after VE

Cost	Before VE	After VE
Initial Cost	19,355,000,000	15,551,520,000, -
Annual Energy	8,514,668,842	8,004,396,179, -
Annual Operations	13,257,749,610	11,223,994,125, -
Cost - After VE		2,033,755,485.
Savings (%)		15.34%

Table 7 summarizes the comparison before and after value engineering. As a result of the PUE evaluation and calculation stage, Liquid cooling selected as an alternative to the conventional cooling system (PAC). Liquid Cooling uses liquid (usually deionized water or special coolant) to absorb heat directly from server components, such as CPUs and GPUs, through a cold plate or heat exchanger. The heated liquid is then cooled through an external chiller or heat exchanger and returned to the server. The energy efficiency is higher than that of PAC, and is suitable for medium-scale data centers as the case study conducted. Increased power density, allowing for higher server density per rack without overheating issues. Noise reduction, by eliminating or reducing the use of fans on the server PUE is lower compared to PAC. Figure 5 illustrates the system cooling and liquid system cooling.

Research Question 4. In planning a Data Center Project, the owner must be faced with various alternatives in selecting a material, product, equipment or system used. In addition to technical aspects, costs are also an important aspect that needs to be considered. To find out a more efficient alternative, a calculation method is needed, one of which is by using the (Life Cycle Cost Analysis) method. LCCA calculates the total cost starting from the initial cost, maintenance costs, operational and maintenance costs and others. The LCCA method calculates the estimated cost in the nth year in the present value (Present Value). LCCA in this study was carried out on a case study of the implementation of the Green concept in the Data Center. The LCCA calculation result provided in Table 8.



(a) (b)

Figure 3 . (a) System Cooling PAC Data Center (b) System Liquid Cooling PAC Data Center

Table 8. LCCA Calculation Result

Rating item	Assessment Criteria	Result	Information
Benefit Cost Ratio	B/C > 1	4.00	Project Feasible to Implement
Net Present Value	NPV > 0	52 M > 0	NPV with a positive value then the project is profitable
Internal Rate of Return	IRR > DF (Discount Factor)	50.91%>5.75 %	Investment can be accepted
Payback Period (PP)	<3 year = fast 3-5 year = Keep >5 year = slow	1 yr 1 m 12 days	Quick feedback & Projects worth carrying out

Research Question 5. In the application of Value Engineering and Life cycle cost analysis in the Green Data Center project, this approach shows that this approach provides significant benefits in operational cost efficiency and energy consumption reduction. Through the implementation of Value Engineering, energy consumption savings in Data Center cooling systems are obtained by 44% and operational cost savings of up to 37.52% per year compared to Conventional ones.

Meanwhile, the Life Cycle Cost Analysis (LCCA) calculation is carried out to assess the total cost over the life of the project (10 years), including initial investment, annual operational costs, equipment maintenance and energy savings, with BCR Calculation. NPV and IRR that say that the project is feasible and produces a Payback Period in 1 year1 month and 12 days.

Research Question 6. The results of previous research show various findings that are the basis for the development of research in this field. Some studies have also highlighted that there are differences in results based on variables such as location, method, or sample used. However, there are some limitations in previous research, such as limitations in methods, samples, or research scope. Therefore, this study aims to enrich the previous results with a more comprehensive approach and more in-depth analysis.

4. Conclusions

This study has analyzed that the application of Value Engineering (VE) and Life Cycle Cost Analysis (LCCA) can improve energy efficiency and significantly reduce operational costs even though the initial investment is considered higher in the cooling system. With VE carried out on the Cooling system known to have the highest cost influence, Liquid Cooling produces energy efficiency compared to conventional PAC systems with energy savings of up to 40% per year and cost savings of up to 37% per year.

The most dominant aspect he said was that financial support was the most dominant factor in the investment cost of the Green Data Center Project. Stakeholders' awareness of energy efficiency is still a challenge, in contrast to other countries that are more advanced in the application of environmentally friendly technology. Indonesia only has two different seasons from other countries that can implement a free cooling system by taking advantage of the winter season.

The results of the LCCA calculation show that Data Centers in Indonesia are worth starting to transition to Green, with BCR > 1. Positive NPV, and IRR is higher than the Discount rate. The payback period for this liquid cooling system is in the range of less than 3 years of initial investment return.

Based on the research findings, several recommendations are proposed to enhance the successful implementation of Green Data Centers. Stricter energy efficiency standards and regulations are crucial to accelerating the transition toward green systems. In addition, training programs for human resources on liquid cooling technologies and energy-efficient systems can improve operational effectiveness.

Further research is needed to integrate liquid cooling systems with renewable energy sources to improve energy efficiency, particularly within the Indonesian context. The development of location- and scale-based analytical models that consider strategic factors such as energy availability, infrastructure readiness, and disaster risk also recommended. Deeper exploration of the use of artificial intelligence (AI) for energy optimization presents new opportunities, as current applications remain limited to security monitoring systems.

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