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ANALYSIS OF ECONOMIC OBSTACLES AND STRATEGIES FOR THE FIRST PUMPED STORAGE HYDROPOWER PLANTS IN INDONESIA: A CASE STUDY OF UPPER CISOKAN HYDROPOWER PLANTS

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ABSTRACT

This study aims to analyze economic barriers and formulate strategies for developing the first Pumped Storage Hydroelectric Power Plant in Indonesia, focusing on a case study of the Upper Cisokan Pumped Storage Hydroelectric Power Plant under PT PLN (Persero). This study uses a qualitative method with a case study approach. Data were collected through in-depth interviews with officials and employees of PT PLN (Persero) Central Java Development Unit (UIP JBT) who were directly involved in the project. Data analysis methods include data reduction, coding, and data presentation. Conclusions are drawn in a descriptive narrative manner.The results of the study indicate that the main obstacles in the development of the Upper Cisokan hydropower plant include economic factors, such as the complexity of project funding involving administrative requirements and financial commitments from various parties. In addition, technical obstacles were also found, especially related to the dynamics of changes in construction design due to external factors such as geological conditions and government regulations. Based on these findings, this study proposes a development strategy that includes optimizing project governance, diversifying financing sources, and increasing collaboration between stakeholders to support the sustainability of the Upper Cisokan hydropower plant development.

Keywords: Obstacles, Challenges, Economic Aspects and Upper Cisokan Pumped Storage Hydroelectric Power Plant

INTRODUCTION

The leading role of renewable energy as an important instrument to support sustainable economic development. This enables the transition to a new low-emission energy model, there is no doubt. Therefore, a massive development in renewable energy is needed to play a decisive role in the fight against global warming and climate change ("International Renewable Energy Agency", 2020).

Renewable energy comes from natural processes that are continuously replenished (Kasu, 2015), which in its various forms, renewable energy is obtained directly from the sun, or from heat generated deep within the earth. Kasu (2015) further explains that this definition includes electricity and heat generated from solar, wind, ocean, water (hydro), biomass, geothermal, biofuels, and hydrogen resources derived from renewable resources.

Electricity usage is not flat, but fluctuates throughout the day, so daily electricity demand is not constant. Hydroelectric power plants are more efficient at meeting peak power demand during short periods than fossil and nuclear power plants. One way to do this is by using "pumped storage," which reuses the same water more than once (Kasu, 2015). Figure 1 shows a reservoir acting like a battery, storing energy in the form of water during low demand and producing maximum power during daily and seasonal peaks.

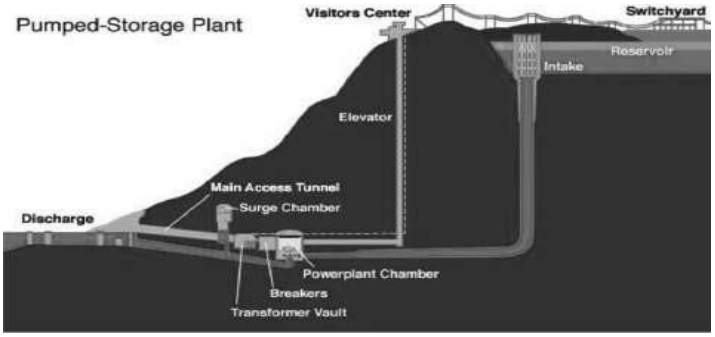

Figure 1. Pumped Storage Hydro Powerplant
Source: Tennessee Valley Authority, 2012

This paper presents an overview of Pumped Storage Hydropower (PSH), which is currently the largest provider of large-scale energy storage in the world's electricity grid with more flexible operational characteristics. This discussion also covers the development and development of Pumped Storage Hydropower technology in Indonesia. The technical capabilities of Pumped Storage Hydropower that can improve the reliability of the electricity grid and help the integration of renewable energy generation will also be discussed.

From an economic perspective, Pumped Storage Hydropower has great potential to provide significant benefits, such as reducing the operational costs of the electricity system through efficient peak load management and energy storage. In addition, the development of Pumped Storage Hydropower also contributes to reducing dependence on fossil fuels, which is in line with the national strategy to reduce long-term energy costs. However, the main challenges in this development include large initial investments, the complexity of project financing, and economic feasibility analysis that requires intensive coordination between stakeholders. Regarding the current status and outlook for Pumped Storage Hydropower in Indonesia, including the identification of economic barriers and development strategies that can support the sustainability of similar projects in the future.

The Upper Cisokan Pumped Storage (UCPS) Power Plant 4x260 MW project will be the first pumped storage hydropower plant (PLTA sistem pompa) built in Indonesia. In short, Upper Cisokan Pumped Storage (UCPS) is a major part of the Indonesian government's future energy plan in the National Energy General Plan (RUEN), where an indicative 23% of Indonesia's total energy needs will come from renewable energy.

From an economic perspective, this project has great potential to have a positive impact on the energy sector and the national economy. As a hydroelectric power plant with an energy storage system, UCPS can reduce the need for fossil fuel power plants, which in turn can reduce national energy operating costs. In addition, the existence of UCPS allows for more efficient peak load management, thereby stabilizing electricity production costs and reducing the risk of electricity tariff spikes for consumers.

The Upper Cisokan Pumped Storage (UCPS) project has a long history as seen in the chronology in Table 1.

Table 1. Chronology of Construction of the Upper Cisokan Pumped Storage Project

No	Activity Description	Duration
1	*The Upper Cisokan Pumped Storage Hydroelectric Power Development Project in the Republic of Indonesia (Feasibility Study*	October1992sd March1995
2	*Engineering Services for Upper Cisokan Pumped Storage Hydroelectric Power Plant Project (Detailed Design)*	August1999sd May2002
3	*Engineering Services for Java Bali Power Restructuring and Strengthening Project for Upper Cisokan Pumped Storage Hydro Power Plant Project (Supplementary Study)*	April2006until March2007
4	*Engineering Services for Pre-Construction and Construction Phases of Upper Cisokan Pumped Storage Power Plant Project (Implementation Study)*	December2012sd September2017
5	*Engineering Services for Updating Detailed Design and Preparing Construction Drawing of Upper Cisokan Pumped Storage Power Plant Project (DD Update)*	May2019up to now

Source: PLN Technical Consultant Report (NEWJEC's weekly report), 2024 Based on Table 1.it is explained that the Upper Cisokan Pumped Storage

(UCPS) Project started from an initial feasibility study in 1995, with a detailed design conducted in 2002, and a supplementary design conducted in 2007. The project was funded by the World Bank as part of an effort to support the development of renewable energy in Indonesia. However, in early 2016, several landslides occurred that damaged the Permanent Access Road (PAR). This damage required significant repair work, causing a complete delay in the implementation of the project. As a result, the existing loan agreement with the World Bank was eventually canceled, creating new financial pressures for the sustainability of the project.

From an economic perspective, project delays not only increase operational and construction costs due to inflation and changes in material prices, but also have the potential to disrupt the projection of long-term economic benefits expected from the project. Uncertainty in funding also increases investment risks, affects stakeholder confidence, and complicates efforts to find new sources of financing. With these challenges, a more comprehensive economic analysis is needed to evaluate the impact of project delays on financial feasibility and alternative financing strategies. This approach is important to ensure that the project can continue with minimal risk and provide optimal contributions to the national economy.

Based on the previous explanation, this phenomenon shows the existence of a gap phenomenon in identifying more deeply the obstacles and constraints that prevent developing countries such as Indonesia from joining the global effort to promote renewable energy through the development of Pumped Storage Hydroelectric Power Plants. These challenges include complex technical, regulatory, and project management aspects, as well as significant economic challenges.

From an economic perspective, the main obstacles include the high initial investment requirements for the development of Pumped Storage hydropower infrastructure, limited access to financing with flexible schemes, and financial risks due to project uncertainty. Project delays caused by technical factors such as damage to infrastructure access also increase construction costs and reduce the economic efficiency of the project.

In addition, this phenomenon reflects the need for innovative financing strategies and collaboration between stakeholders to reduce the burden of financing on the government and increase the attractiveness of projects to investors. This study seeks to provide practical answers by proposing an economic analysis-based approach, such as optimizing fund allocation, diversifying financing sources, and establishing incentive policies to accelerate the development of similar projects in the future. By providing solutions that combine economic and technical aspects, this study is expected to help overcome the difficulties that hinder the development of renewable energy, especially Pumped Storage Hydroelectric Power Plants, in developing countries such as Indonesia.

Several previous studies related to barriers to renewable energy development have been conducted by experts in various countries, with varying results, resulting in a research gap. From an economic perspective, this gap includes a lack of in-depth analysis of the impact of funding limitations, financial risks, and long-term economic feasibility in the development of renewable energy projects, especially Pumped Storage Hydroelectric Power Plants in developing countries. The following table shows the differences in research results (research gap) from previous studies.

Table 2. Research Gap

Findings	*Research Gap*	Location	Researcher (year)
Economic Barriers and SolarEnergy Developmentin Developing Countries	Researchobject: solar energy	Mexico and Egypt	Trujillo,Bruno Bernal (2021)
Advancedpumped storage hydropower value modeling and analysis	Research methods: simulation and modeling	Jnited States of America	V. Koritarov et al. (2014)
Economic Opportunities and Barriers to Pumped-	Scope of research: study of 5 (five) PS hydroelectric	Jnited States of America	CJ. Yang et al. (2011)
Hydro Energy Storage and Energy	power plants in the developed country of the US		
Electric Storage Equipment Drivers and the Economics of Modern Pumped Storage	Research method: comparative study	Jnited States and Europe	RK Fisher et al. (2012)
Environmental and economic impact analysis of Hydroelectric Power Plants (PLTA)	Research method: literature review	ɔuntries in Europe	lnabooee, ADA (2023)
Analysis of conditions affecting the economic competitiveness of PumpedStorage Hydroelectric Power Plants	Research variables: economic competitiveness	Egypt	Abdellatif et al, (2018)
Economic Impact Assessment an d Sustainable Benefits of Hydroelectric Power Projects	Research method: literature review	Hydroelectric power plants around the world	Himanshu Nautiyal et al. (2020)
The Role of Hydroelectric Power Plants (PLTA) for Sustainable Energy Economy an d Development	Research method: literature review	Türkiye	Mehmet Bilgili et al. (2018)
Economic Gap Analysis and Strategic Direction for Sustainabl e Hydropower Utilization	Research method: literature review	Brazil	Simone Athayde et al. (2019)

Source: Published journal

Based on the gaps identified in Table 2, this study contributes in three ways. First, it focuses on

the renewable energy sector in Indonesia. Second, this article analyzes the obstacles faced in the development of renewable energy projects for pumped storage hydropower in Indonesia. Third, from an economic perspective, this study explores financial challenges, such as funding constraints, economic impacts due to project delays, and investment risks that affect the feasibility of developing pumped storage hydropower. Through these experiences, the authors identify and describe the obstacles encountered, both from technical and economic aspects, to provide comprehensive insights into the development of pumped storage hydropower in Indonesia.

The novelty of this research, referring to the existing literature, is that in describing the obstacles to clean energy development through Pumped Storage Hydroelectric Power Plants in Indonesia, documentation on the topic of Pumped Storage Hydroelectric Power Plants will be presented by combining information from the literature and direct experience from PT PLN (Persero) Central Java Development Unit (UIP JBT) through interviews conducted with representatives from the sector. From an economic perspective, this study also highlights financial barriers, such as challenges in securing funding, managing investment risks, and evaluating the economic feasibility of Pumped Storage Hydroelectric Power Plant projects in Indonesia. By combining technical and economic insights, this study provides a comprehensive understanding of the economic barriers to the development of this renewable energy infrastructure.

FORMULATION OF THE PROBLEM

Based on the background that has been discussed, understanding the technical and non-technical obstacles and challenges faced in the development of Pumped Storage Hydroelectric Power Plants in Indonesia is very important to formulate effective strategies and encourage the development of Pumped Storage Hydroelectric Power Plants in Indonesia. Therefore, the formulation of the problem can be stated in the following research questions:

1. What are the obstacles and challenges faced in the development of Pumped Storage Hydroelectric Power in Indonesia?
2. How do these obstacles and challenges affect the development of Pumped Storage Hydroelectric Power Plants in Indonesia?
3. What strategies can be implemented to overcome these obstacles and challenges and encourage Pumped Storage Hydropower to develop effectively in Indonesia?
4. How do economic barriers, such as funding limitations, investment risks, and economic feasibility evaluations, affect the development of Pumped Storage Hydropower in Indonesia?

LITERATURE REVIEW

Overview of Pumped Storage Hydropower in Indonesia

Despite the various potential obstacles and challenges that have been explained in the previous sub-chapter, Hydroelectric Power Plants (PLTA) will still have a significant impact on the renewable energy landscape in Indonesia. Hydroelectric power plant construction technology has developed to minimize the ecological impacts caused by hydroelectric power plant construction, one of which is Pumped Storage Hydroelectric Power Plant. The concept of Pumped Storage Hydroelectric Power Plant is relatively new in Indonesia. As of September 2021, the World Bank has approved a loan for the construction of the first Pumped Storage Hydroelectric Power Plant in Indonesia. This step is in line with the Indonesian Government's commitment to climate change and energy transition. As seen in the earth map screenshot Figure 2. below.

Figure 2. Location of the Upper Cisokan Pumped Storage Hydroelectric Power Plant Project

Source: PLN Technical Consultant Report (NEWJEC's weekly report), 2024

The project consists of a lower reservoir formed by the Lower Dam located on the Cisokan River and an upper reservoir formed by the Upper Dam located on a tributary, the Cirumanis River. The project consists of two separate waterway systems, each with a water intake structure, a pressure tunnel, a surge tank, a steel-lined pressure tunnel with branches, and a concrete-lined tunnel outlet leading from the underground powerhouse to the lower reservoir.

Economic Aspects of Pumped Storage Hydroelectric Power Plant Development in Indonesia

Pumped Storage Hydroelectric Power Plant as part of renewable energy in Indonesia has great potential in supporting energy security and the transition to cleaner energy sources. However, from an economic aspect, the development of Pumped Storage Hydroelectric Power Plant in Indonesia faces various challenges that require more attention.

a. Investment and Financing Costs

The development of Pumped Storage Hydroelectric Power Plants requires a very large initial investment, especially for the construction of complex infrastructure and technical facilities. Based on existing literature, large projects like this usually require long-term financing involving various sources of funds, including from international financial institutions such as the World Bank.

b. Investment Risk and Economic Uncertainty

Investment risk is an important aspect in the development of Pumped Storage Hydroelectric Power Plants, especially related to energy price uncertainty, regulatory changes, and challenges in achieving financial breakeven in the long term. Project delays such as those that occurred in the Upper Cisokan Hydroelectric Power Plant due to damage to road access infrastructure which resulted in increased construction and operational costs, show the importance of mature risk management in this project. Previous studies have shown that market and regulatory uncertainty can increase high investment risks in renewable energy projects in developing countries.

c. Long Term Economic Impact

From a long-term economic perspective, pumped storage hydropower can provide significant benefits to the economy, especially in increasing the reliability of electricity supply and the integration of renewable energy. The effective development of pumped storage hydropower can reduce the operating costs of other energy plants, as well as reduce dependence on more expensive and riskier fossil fuels. However, these benefits must be carefully viewed in the context of a cost-benefit analysis that includes the impact on the local economy, job creation, and effects on other energy sectors.

d. Economic Policies and Incentives

The Indonesian government has demonstrated its commitment to the energy transition by supporting the development of renewable energy through policies and regulations that lead to carbon emission reduction. However, to support the success of the Pumped Storage hydropower project, a more in-depth policy is needed regarding financial incentives, such as providing subsidies or tax incentives for investors. In a literature review, clear and transparent economic incentives have been shown to encourage investor interest in the renewable energy sector, especially in large, high-risk projects such as Pumped Storage hydropower.

Theoretical Framework of Thought

The research framework can be seen in Figure 3 below.

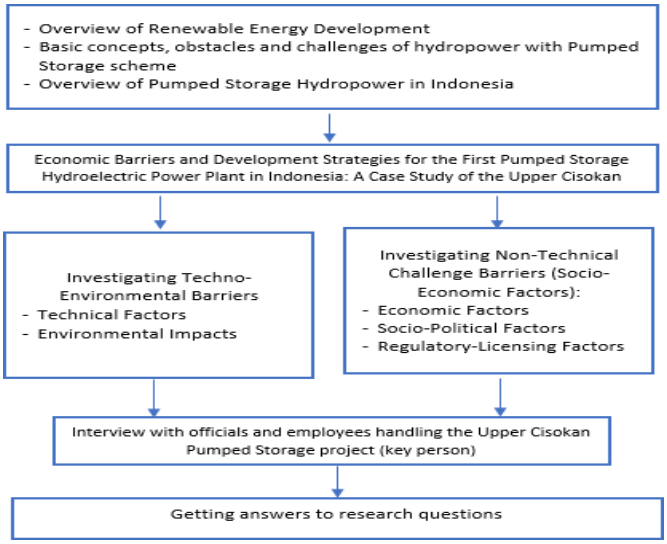

Figure 3. Theoretical Framework of Thought Source: Processed by the author, 2024

RESEARCH METHODS

Research Design

Methodologically, this research is included in the scope of a case study with a qualitative approach, to understand the Upper Cisokan Pumped Storage Hydroelectric Power Plant in depth in terms of obstacles and economic aspects. This allows researchers to explore the interrelation of various factors that influence this large-scale project, as well as understand the perspectives of various stakeholders. The research aims to Analyze Economic Barriers and Development Strategies for Pumped Storage Hydroelectric Power Plants, with the hope of producing findings that contribute to the development of similar hydroelectric power plants in Indonesia.

Types and Sources of Research Data

a. Primary data sources

Primary data comes from sources, namely a combination of officials and employees at PT PLN (Persero) Central Java Development Unit.

b. Secondary data sources

The researcher obtained secondary data sources from project work reports (feasibility study reports and project progress reports) related to the construction of the Upper Cisokan Pumped Storage Hydroelectric Power Plant.

Method of collecting data

1. Interview

This method is used by researchers to collect data on the general description of the Upper Cisokan Pumped Storage Hydroelectric Power Plant project, aspects that are included as obstacles, challenges and obstacles to the Economy and Development Strategy of the Pumped Storage Hydroelectric Power Plant. This interview will be conducted with 5 (five) sources consisting of a combination of officials and employees of PLN UIP JBT who are key players (key-person) of the project and know the history of the Upper Cisokan Pumped Storage Hydroelectric Power Plant.

2. Documentation

This study uses several types of documents, namely documents obtained directly by the research subjects, such as the feasibility study and progress report of the Upper Cisokan Pumped Storage Hydroelectric Power Plant project, as well as documents created by other parties, such as scientific journal articles on Pumped Storage Hydroelectric Power Plants.

Data Analysis Techniques

Creswell's opinion (2014) explains that data analysis in qualitative research begins with preparing and organizing the collected data, such as interview transcripts, field notes, and documents. At this stage, researchers reread the data carefully to ensure deep understanding, record ideas, thoughts, and initial questions about the data. In this study, data analysis uses data in the form of words or sentences and is separated according to clear and detailed categories.

RESEARCH RESULT

Research result

The results of this study identify various major obstacles and challenges faced in the development of PS hydropower in Indonesia. These obstacles and challenges are categorized based on 2 (two) aspects, namely technical-environmental aspects (Techno-Environmental Barriers), and non-technical aspects (Socio-Economic Factors).

Techno-Environmental Barriers

The Upper Cisokan Pumped Storage Hydroelectric Power Plant is faced with obstacles and challenges from the technical-environmental aspects (techno- environmental barriers). Based on the interview results, it was obtained that this aspect can include: design and construction complexity, environmental issues, and potential impacts on the ecosystem.

Technical Barriers and Challenges

Based on the results of interviews with sources of officials handling the Upper Cisokan PLTA project, information was obtained that there were obstacles and challenges in terms of technical aspects. There are 2 (two) opinions regarding technical factors coming from natural factors and the geological conditions of the earth. This can be seen from the statements of Gagah Nurjaman (NS-1) and Medio Agustian (NS-02) below:

"Yes, if the obstacles from the technical side are like that, one, natural factors, like earthquakes, they shift like that. We have to adjust and want the latest design according to the existing parameters" (NS-01).

"Then also in terms of location, this Upper Cisokan Hydroelectric Power Plant is located in a location that has a very high topography and rainfall intensity. So this is an obstacle and a challenge in completing the project. Then in terms of work, type of work, we know that the Upper Cisokan Hydroelectric Power Plant is dominated by underground work that has a high level of uncertainty." (NS-02).

From the explanation above, it can be concluded that natural factors are the findings of technical obstacles. The threat of earthquakes in the project area is one of the main obstacles. Land shifts due to earthquakes can disrupt the design and construction of the hydroelectric power plant. This requires design adjustments and the use of the

latest parameters to ensure the resilience of the hydroelectric power plant structure (NS-01). The location of the Upper Cisokan hydroelectric power plant also has complex topography and high rainfall intensity. This makes it difficult to access the project location and increases the risk of landslides, thus requiring careful calculation and construction (NS-05).

Impact of Development on the Environment

NS-01 and NS-02 explain that the World Bank has complex environmental requirements, including the preparation of a biodiversity management plan. This reflects the World Bank's commitment to environmental sustainability and minimizing the negative impacts of projects on ecosystems.

"Regarding environmental issues, the obstacles are for the Upper Cisokan Hydroelectric Power Plant, we are using a loan from the World Bank, wherethe World Bank has quite complex requirements related to the environment. One example is that we have to prepare a biodiversity management plan, there is something called a biodiversity important area. These are areas that must be treated specifically so that technical implementation continues but the environment that was previously designated also maintains its biodiversity. This is a challenge in itself in the Upper Cisokan Hydroelectric Power Plant area.." (NS-01)

These concerns need to be taken seriously, considering that the biodiversity in the forest area has high ecological value and plays an important role in maintaining the balance of nature. The development of the Upper Cisokan Pumped Storage Hydroelectric Power Plant needs to seriously consider environmental aspects. World Bank requirements and potential impacts on local ecosystems are important factors that need to be addressed through planned and comprehensive mitigation efforts. Cooperation with various related parties is also key to ensuring environmental sustainability is maintained during the construction and operation of the hydroelectric power plant.

Non-Technical Aspects (Socio-Economic Factors)

The Upper Cisokan Pumped Storage Hydroelectric Power Plant is faced with obstacles and challenges from non-technical aspects (Socio-Economic Factors), namely based on the following interview results:

Obstacles and Challenges of Economic Aspects

The Upper Cisokan Hydroelectric Power Plant project has great potential to provide positive impacts to the regional economy. This was emphasized by NS-01 who stated that this project needs to be pursued in order to provide economic benefits to the surrounding community.

"The economic challenges are more about the regional economy, so maybe we also have to pay attention so that the projects we implement also have a positive impact on the regional economy" (NS-03).

NS-03 reiterated that there are local economic challenges that need to be addressed. Efforts are needed to ensure that the project provides economic benefits to the surrounding community. One solution is to involve local entrepreneurs in the project, both in terms of providing raw materials and labor.

However, there were economic constraints faced at the beginning of the project, as explained by NS-04. The project was delayed due to the suspension of funding from the World Bank. Only after funding approval was obtained again, the project could be resumed.

*"From the economic side, then coincidentally, why is it only starting now (the project)? That is because in previous years there were lenders, but they were suspended, so now when there is approval again from the World Bank for the finances, coincidentally the construction is using a budget from the World Bank, right?" (NS-04)*Socio-Political Obstacles and Challenges.

Communities around construction projects generally have a high desire to get jobs. This is because the project presents new economic opportunities, such as job vacancies as laborers, drivers, or other service providers. This desire is in line with the statements of NS-01 and NS-02 which mention the demand for jobs from residents and the many NGOs that help facilitate this.

"If we talk about social matters, that's what I know because I'm on the construction side, which maybe as explained earlier in the social community, there might be a desire to, what is it called, work, because there is a project there, right?" (NS-05)

However, these job opportunities are not always evenly distributed. NS-04 mentioned the many job requests from residents, indicating the potential for competition and social jealousy. The ambiguity in the selection and recruitment process for local workers can trigger tension and dissatisfaction in the community.

"For the social aspect, it may be related to the number of NGOs. The number of requests from residents for work" (NS-05)

ObstacleEconomics in Pumped Storage Hydropower Development

One of the main economic barriers to the development of pumped storage hydropower in Indonesia is limited funding. As a renewable energy project that requires a large initial

investment, the development of pumped storage hydropower faces challenges in obtaining sufficient funding sources. NS-03 stated that despite support from international financial institutions such as the World Bank, the process of procuring project financing is often hampered by complex requirements and dependence on the smoothness of time-consuming administrative procedures.

"For funding, the constraint is indeed the long and sometimes complicated administrative process. Although the World Bank has provided support, the verification and reporting process required is quite time-consuming." (NS-04).

Pumped Storage hydropower projects also face quite high investment risks. NS- 05 emphasized that although the project has long-term potential to provide profits, energy market uncertainty, fossil fuel price fluctuations, and unstable regulations may make investors hesitate to invest in the project.

"The investment risk is very high, especially in the renewable energy sector like this. We don't know for sure what the energy price will be in the future, and government regulations also often change." (NS-05)

The process of evaluating the economic feasibility of the Pumped Storage Hydropower project is also a significant obstacle. NS-02 and NS-03 stated that despite the huge potential of renewable energy, the economic feasibility analysis is often a factor that delays the project. This is due to the high cost of infrastructure development and dependence on external factors, such as geological and environmental conditions, which can affect the results of the economic evaluation.

*"Economic feasibility must be calculated very carefully. Not only in terms of construction costs, but also environmental and social impacts that sometimes cannot be predicted from the start." (*NS-02 and NS-03).

DISCUSSION

Techno-Environmental Barriers

The results of interviews with sources obtained several obstacles and challenges in the development of Pumped Storage Hydroelectric Power Plants in Indonesia from technical and environmental aspects.

The first is the natural factor, namely the threat of earthquakes in the project area, which is one of the main obstacles. Landslides due to earthquakes can disrupt the design and construction of hydroelectric power plants. This requires design adjustments and the use of the latest parameters to ensure the resilience of the hydroelectric power plant structure. Complex topographic challenges and high rainfall intensity also make it difficult to access the project site and increase the risk of landslides, thus requiring careful calculation and construction. Thus, landscape topography has technical and financial implications for the Pumped Storage hydroelectric power plant project (Kucukali, 2014).

Second, the complexity of the multi-package system in the Upper Cisokan hydropower project is one of the main obstacles. Delays in one work package can have a domino effect on other work packages. This is due to the dependency between packages in the construction process, so that delays in one package can hamper the work of other packages. This complexity requires tight schedule synchronization and intensive supervision to ensure the smooth running of the project as a whole.

Third, the engineering process running parallel to construction is a significant challenge. Ideally, the engineering and design process should be completed well before the start of construction. This parallel situation has the potential to create the risk of design errors, mid-way design changes, and delays in construction time. This can result in cost and time inefficiencies, and increase the risk of project failure. Similar problems are found in developing countries such as Nepal, where the lack of integrated planning and decision-making has exacerbated the problems of hydropower project development, as well as wasting social resources (Ghimire and Kim, 2018).

Fourth, the potential impact of project development on the ecosystem because the project location is in the Perhutani area, is feared to result in habitat loss and disrupt the sustainability of endemic flora and fauna in the area.

A study in Turkey labeled the location of a pumped storage hydropower plant as a sensitive area for biodiversity loss and called for ensuring the protection of critical habitats, threatened species, and spawning areas (Kucukali, 2014). A study in Nepal also warned that the flow from the river project could pose a threat to fish migration due to the disruption of river ecology (Suhardiman and Karki, 2019).

One study also warned that pumped storage hydropower could impact bird habitats (Lu et al. 2020), and soil erosion problems due to pumped storage hydropower were reported in another study (Lu et al. 2018). One study noted that the creation of large reservoirs or lakes could change local climate by increasing the lowest temperatures and decreasing the highest temperatures; therefore, the

area would become colder (Gajic et al. 2019).

The issues described in these studies may cause concern among local communities and environmental groups. These concerns need to be taken seriously, considering that biodiversity in forest areas has high ecological value and plays an important role in maintaining the balance of nature.

Non-Technical Aspects (Socio-Economic Barriers).

The results of interviews with sources revealed several obstacles and challenges in the development of Pumped Storage Hydroelectric Power Plants in Indonesia from non-technical aspects (economic, socio-political, regulatory-licensing).

First, there are local economic challenges that need to be considered. Efforts are needed to ensure that this project provides economic benefits to the surrounding community. The economic dimension of the Upper Cisokan hydropower project plays a crucial role. On the one hand, this project has the potential to have a positive impact on the regional economy.

On the other hand, there are various economic constraints and challenges that need to be overcome, such as funding delays, potential cost increases, and bureaucratic obstacles. Careful financial planning and management are needed as well as good cooperation with related parties to ensure the smoothness and success of this project, as well as maximize the economic benefits for the surrounding community. The payback period required to repay the loan is believed to be another obstacle in the development of Pumped Storage hydropower, as it takes at least 2.5-5.5 years (Connolly et al. 2012).

Second, construction projects can also create various social challenges and conflicts, such as job competition, social jealousy, and population relocation. As reported in Nepal (Sovacool et al. 2011), when potential construction sites are located in rural areas with scattered settlements or low population densities, the area will be disturbed for the common good and the community will be forced to relocate. This is often opposed by the anti-dam community. Therefore, it is important for stakeholders, such as project developers, governments, and NGOs, to work together to minimize the negative impacts and maximize the positive impacts of construction projects on the surrounding community.

Economic Barriers to Pumped Storage Hydropower Development in Indonesia

The economic barriers to developing pumped storage hydropower in Indonesia are complex and involve various factors, including funding limitations caused by complicated and time-consuming administrative procedures, which hinder the flow of financing from international and domestic financing institutions; high investment risks due to energy market uncertainty, energy price fluctuations, and instability of government policies related to renewable energy that can affect long-term profit projections; and challenges in evaluating economic feasibility that include analyzing very large construction costs, which not only involve high initial investments but also risks related to fluctuations in operating costs, as well as dependence on external factors that are difficult to predict, such as changes in energy regulations and government subsidy policies. In addition, uncertainties related to the potential social and environmental impacts caused by this large project, such as impacts on surrounding communities and the environment that must be taken into account in the feasibility study, further exacerbate the economic challenges faced. Therefore, to overcome these economic barriers, a more flexible fiscal policy, more attractive incentives for investors, long-term regulatory stability, and a more in-depth and integrated feasibility study are needed, which includes risk analysis, more realistic economic projections, and careful planning to mitigate social and environmental impacts, to ensure that the project is not only economically viable but also sustainable and supports the renewable energy transition in Indonesia.

These findings show that pumped storage hydropower dam projects are embedded in a complex and dynamic regulatory landscape, encompassing economic aspects such as financing uncertainty, very high investment costs, and volatile energy market risks. Effective regulatory navigation, including compliance with design standards, environmental and social considerations, and loan agreement settlement, are key to the smooth and successful implementation of the project, but also affect the economic viability of the project. Other economic aspects, such as reliance on fiscal incentives and long-term energy policy stability, are also determining factors in accelerating or inhibiting the development of the project. The results of this study indicate that the obstacles and challenges to pumped storage hydropower development in Indonesia are similar to those in other countries, especially in terms of financial risk and energy market uncertainty, but there are several differences that need to be considered in formulating policies and strategies for pumped storage hydropower development in Indonesia, such as the readiness of the local financing market, government support in reducing

investment risks, and more efficient cost management.

CONCLUSION

This study concludes that there are technical and non-technical obstacles in the development of Pumped Storage Hydroelectric Power Plants in Indonesia. Technically, the challenges include natural conditions, complex topography, and environmental impacts that cause project delays, increased costs, and community rejection. The proposed strategy is to involve experts for comprehensive seismic studies and project management. Non-technically, the obstacles are related to complicated funding mechanisms, social conflicts, and inefficient regulations, which lead to long bureaucracy and increased construction costs. From an economic perspective, the main problems are financing uncertainty, cost fluctuations, and energy policy instability. Suggested solutions include diversifying funding sources, strengthening social support, and adjusting regulations and fiscal policies to support the development of Pumped Storage Hydroelectric Power Plants.

RESEARCH LIMITATIONS

This study has several limitations. First, it focuses only on the case study of the Upper Cisokan Pumped Storage Hydroelectric Power Plant, so the findings cannot be generalized to other projects in Indonesia. Second, the data were obtained through interviews with informants from the perspective of the project owner, without perspectives from the government, academics, or other parties. Third, it uses qualitative methods, so the findings are descriptive and cannot be quantified. From an economic perspective, another limitation is the lack of quantitative data on cost-benefit analysis and broader economic impacts.

RESEARCH IMPLICATIONS

There are several policy implications that need to be considered to encourage the development of sustainable Pumped Storage Hydropower in Indonesia. Some policy implications to encourage the development of Pumped Storage Hydropower in Indonesia include: first, diversifying funding sources to reduce dependence on the World Bank. Second, increasing HR competency in the field of Pumped Storage Hydropower, from planning to maintenance. Third, strengthening coordination between stakeholders. From an economic perspective, it is important to strengthen fiscal policies, renewable energy investment incentives, as well as transparent economic feasibility evaluations and good financial risk management.

FUTURE RESEARCH AGENDA

Based on the findings and conclusions of this study, here are some future research agendas: First, conducting comparative research to compare the obstacles and challenges of developing Pumped Storage hydropower in Indonesia with other countries that have successfully developed this technology. This can help identify best practices and strategies that can be adopted in Indonesia. Second, conducting a more in-depth financial feasibility study for Pumped Storage hydropower projects, considering various factors such as investment costs, tariff structures, potential profitability, and long-term economic impacts. Third, analyzing fiscal policies and incentives that can increase the attractiveness of investment in the renewable energy sector, as well as identifying more efficient alternative financing mechanisms for Pumped Storage hydropower projects.

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