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Environmental Impact Evaluation of Floating Solar Power Plant in Cirata Reservoir, West Java

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ABSTRACT

This qualitative study investigates community perceptions of the environmental impacts of floating solar power plants (FSPPs) in Cirata Reservoir, West Java. Through semi-structured interviews and participant observations, data were collected from fifteen diverse stakeholders, including local residents, community leaders, environmental activists, government officials, and energy project developers. Thematic analysis revealed key themes and subthemes related to environmental concerns, economic implications, social impacts, technical considerations, and trust and transparency issues surrounding FSPP development. Participants expressed a range of perspectives, including support for solar energy, concerns about habitat disruption and water quality degradation, and calls for inclusive decision-making processes and transparent communication. The findings underscore the importance of addressing community concerns and incorporating local perspectives into the planning and implementation of FSPP projects to ensure environmental sustainability and social acceptance.

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1. INTRODUCTION

Floating solar power plants (PVPs) have emerged as a promising solution for renewable energy generation and efficient land use in the era of climate change mitigation and sustainable energy transition. Floating solar farms are installed on bodies of water such as reservoirs, lakes and ponds, offering the dual benefits of harnessing solar energy and minimising land use conflicts [1]–[3]. These innovative systems have the potential to significantly increase renewable energy production, reduce water evaporation, and reduce carbon emissions [4]. Studies have shown that FSPPs can generate large amounts of green electricity, with annual electricity production ranging from 78.3 GWh to 234.9 GWh in certain locations [5]. In addition, FSPPs can increase the productivity of hydropower plants and provide an additional source of electricity. The deployment of FSPPs in various regions, such as Crete, Greece, Tamil Nadu, India, and the Upper Rhine Valley in Germany, has demonstrated their feasibility and environmental benefits.

The deployment of FSPPs has witnessed significant growth globally, driven by advancements in photovoltaic technology, declining costs of solar panels, and increasing recognition of the environmental benefits of

renewable energy. However, alongside the potential advantages of FSPPs, there exists a need to understand and address their potential environmental impacts, particularly from the perspective of local communities residing in the vicinity of these installations. Previous studies have highlighted the importance of considering sociodemographic and individual factors in the decision-making process regarding the adoption of solar systems, such as solar water heaters (SWHs) [6]. Additionally, technology that enhances health education and service delivery in remote communities, such as portable, solar-powered educational learning libraries, has been shown to improve health outcomes and knowledge [7]. Furthermore, the implementation of solar home systems (SHSs) in public housing projects has been found to be influenced by critical success factors (CSFs) such as government support, installation quality, and effective policies and legal framework [8]. Understanding the socio-economic effects of large-scale solar power plants (PLTS) on local communities is also crucial, as it can lead to increased labor absorption, improved village infrastructure, and changes in public perception [9]. By considering these factors and addressing potential environmental impacts, the deployment of FSPPs can be more sustainable and beneficial for local communities.

This research focuses on examining the community perceptions of the environmental impacts of FSPPs, specifically within the context of the Cirata Reservoir in West Java. Cirata Reservoir serves as an important water resource for the region, supporting irrigation, fisheries, and hydroelectric power generation. The introduction of FSPPs in such environments raises questions regarding their compatibility with existing ecological systems, socio-economic dynamics, and cultural landscapes.

West Java, Indonesia, is facing the challenge of meeting its growing energy demands while addressing environmental concerns and climate change mitigation goals. The region has rich biodiversity and natural resources, making it important to find sustainable energy solutions. The Indonesian government, along with private investors and international organizations, is exploring renewable energy alternatives to reduce reliance on fossil fuels and diversify the energy mix. Plans have been proposed for the development of Floating Solar Power Plants (FSPPs) on the Cirata Reservoir, one of the largest reservoirs in West Java. These FSPPs aim to harness solar energy and contribute to the nation's renewable energy targets [10].

The introduction of Floating Net Cage Aquaculture (FNCA) in Cirata Reservoir has raised complex socio-environmental considerations. These include potential impacts on aquatic ecosystems, water quality, biodiversity, local community livelihoods, and cultural heritage. Understanding the perceptions, concerns, and expectations of communities living around reservoirs is essential to inform decision-making processes, ensure stakeholder engagement, and promote sustainable development [11]. The utilisation of food resources by fish communities in Cirata Reservoir depends on the environmental conditions of the reservoir. Eutrophication and the presence of potentially invasive alien fish can affect trophic interactions in the utilisation of food by the fish community [12]. Changes in water quality parameters, such as temperature, transparency, pH, carbon dioxide, nitrate, and nitrite, can trigger harmful phytoplankton population explosions, such as blue-green algae (Cyanobacteria), in the reservoir ecosystem [13]. Decreased water quality in Cirata Reservoir characterised by corrosiveness has caused damage to hydro-mechanical equipment and decreased production capacity [14]. The utilisation of the reservoir for fish farming has exceeded its capacity, leading to changes in water quality and accumulation of heavy metals in aquatic organisms [15].

The deployment of FSPPs in Cirata Reservoir presents a multifaceted challenge, encompassing technical, environmental, social, and economic dimensions. At the heart of this challenge lies the need to balance energy development goals with

environmental conservation efforts and community well-being. Central to addressing this challenge is the exploration of community perceptions regarding the environmental impacts of FSPPs and their implications for sustainable development in the region.

The primary objectives of this research are multifaceted. Firstly, it aims to delve into and scrutinize community perceptions regarding the environmental impacts of Floating Solar Photovoltaic Power Stations (FSPPs) in Cirata Reservoir, West Java. Secondly, it seeks to pinpoint the pivotal factors that influence these perceptions within the community, encompassing environmental, social, economic, and cultural dimensions. Lastly, it endeavors to comprehend the significance of community perceptions in molding decision-making processes concerning energy development and environmental management within the region.

2. LITERATURE REVIEW

2.1 Floating Solar Power Plants: Environmental Implications

Floating solar power plants (FSPPs) offer several environmental benefits compared to conventional land-based solar installations. They can mitigate land use conflicts, reduce land requirements for solar energy deployment, and enhance energy efficiency by leveraging water cooling effects [3]–[5], [16]. FSPPs utilize water bodies such as lakes, reservoirs, and canals for the installation of photovoltaic (PV) modules, allowing for optimal utilization of water resources and land assets [17]. Studies have shown that FSPPs can significantly reduce the temperature of PV panels, leading to improved energy conversion efficiency and higher power output. Additionally, FSPPs can have a positive impact on the thermal properties of lakes, resulting in a more unstable and shorter thermal stratification during summer, which could help mitigate the effects of climate change. Overall, FSPPs present a sustainable and efficient approach to renewable energy generation, with the potential to address land constraints and enhance energy efficiency.

2.2 Community Perceptions of Renewable Energy Projects

Community perceptions play an important role in shaping the social acceptance, adoption, and implementation of renewable energy projects. Factors such as perceived environmental benefits, economic opportunities, social impacts, and trust in project developers and government authorities influence public attitudes towards renewable energy [18]–[20]. Positive perceptions of renewable energy projects are often associated with perceived environmental benefits, including reduced greenhouse gas emissions, air pollution and dependence on fossil fuels. Community engagement processes, transparent decision-making and equitable distribution of project benefits are key determinants of social acceptance and support for renewable energy initiatives.

2.3 Factors Influencing Community Perceptions

The perceptions of local communities regarding renewable energy projects are influenced by a complex interplay of environmental, social, economic, and cultural factors. Factors such as project location, visual impacts, noise pollution, property values, and land use conflicts have been identified as significant determinants of community attitudes towards renewable energy developments [18]. Socio-demographic variables, including age, education, income, and proximity to project sites, can shape individual perceptions and preferences regarding renewable energy technologies [19]. Trust in project developers, government agencies, and regulatory institutions also plays a critical role in shaping community perceptions of renewable energy projects.

2.4 Previous Studies on Community Perceptions of FSPPs

While research on community perceptions of renewable energy projects is abundant, studies specifically focusing on FSPPs are relatively limited. Existing literature predominantly explores the

technical and economic aspects of FSPPs, with fewer studies examining community attitudes, concerns, and perceptions of these installations. Therefore, there is a need for empirical research that investigates the social dimensions of FSPP deployment, including the perceptions of local communities regarding their environmental impacts, benefits, and risks.

Despite the growing interest in FSPPs as a renewable energy solution, there are notable gaps in the existing literature regarding their environmental impacts and community perceptions, particularly in the context of aquatic ecosystems such as reservoirs and lakes. Few studies have systematically examined the views and concerns of local communities living in proximity to FSPP installations, limiting our understanding of the social acceptability and sustainability of these projects.

Moreover, existing research often overlooks the diversity of stakeholder perspectives, including those of indigenous communities, fisherfolk, farmers, and other marginalized groups who may be disproportionately affected by FSPP developments. Therefore, there is a need for interdisciplinary research that integrates environmental science, social science, and community engagement approaches to comprehensively assess the implications of FSPPs and ensure inclusive and participatory decision-making processes.

3. METHODS

3.1 Research Design

This study employs a qualitative research design to explore and analyze community perceptions of FSPPs in Cirata Reservoir. Qualitative methods are well-suited for capturing the richness and complexity of human experiences, attitudes, and perspectives, allowing for an in-depth understanding of social phenomena. A case study approach will be adopted, focusing on the specific context of Cirata Reservoir to provide detailed insights into the environmental impacts of FSPPs from the perspective of local communities.

3.2 Study Area: Cirata Reservoir, West Java

Cirata Reservoir, located in West Java, Indonesia, serves as the primary study area for this research. The reservoir covers an area of approximately 62 square kilometers and is a critical water resource for the region, supporting agricultural irrigation, fisheries, and hydroelectric power generation. The proposed development of FSPPs in Cirata Reservoir underscores the importance of understanding community perceptions and concerns regarding the environmental implications of renewable energy projects in this context.

3.3 Sampling Strategy

A purposeful sampling strategy will be employed to select participants who can provide relevant insights into the research questions. The selection criteria will include residents living in proximity to Cirata Reservoir, representatives from local community organizations, environmental activists, government officials, and energy project developers. Approximately 15 informants will be recruited to ensure diverse perspectives and experiences are represented in the study.

3.4 Data Collection Methods

Data will be collected primarily through semi-structured interviews and participant observation:

Semi-Structured Interviews: In-depth interviews will be conducted with the selected informants to explore their perceptions, attitudes, and concerns regarding FSPPs in Cirata Reservoir. The interview guide will be developed based on the research questions and relevant literature, covering topics such as perceptions of solar energy, environmental impacts, economic implications, and trust in government and energy developers.

Participant Observation: The researcher will engage in participant observation to gain firsthand insights into the daily lives, interactions, and activities of community members in the vicinity of Cirata Reservoir. This observational approach will complement the interview data, providing contextual information and enriching the

understanding of community dynamics and environmental concerns.

3.5 Data Analysis Techniques

Data analysis for this research will involve utilizing NVivo software for thematic analysis of interview transcripts. Thematic analysis, as outlined by Braun and Clarke (2006), offers a systematic and adaptable approach to identifying, analyzing, and interpreting patterns or themes within qualitative data. NVivo, recognized as a qualitative data analysis tool, will aid in organizing data, coding, and theme development. The analysis process will encompass several steps: firstly, interview transcripts will be prepared and imported into NVivo for the organization. Then, initial coding will be conducted to systematically label significant data segments about key themes and concepts. Subsequently, through iterative analysis and comparison, codes will be amalgamated into broader themes and subthemes. The exploration of patterns and relationships within the data will help identify recurring ideas, perspectives, and narratives. The researcher will further delve into the relationships between themes, considering how they intersect and interact to influence community perceptions of FSPPs in Cirata Reservoir. Finally, the findings will be interpreted and synthesized to generate insights aligned with the research objectives and theoretical framework. Throughout the research process, ethical considerations will remain paramount. Informed consent will be obtained from all participants, and their confidentiality and anonymity will be rigorously maintained. The research will adhere to ethical guidelines, ensuring respect for cultural norms, privacy rights, and informed decision-making regarding participation.

4. RESULTS AND DISCUSSION

4.1 Overview of Participants

Fifteen participants engaged in the qualitative study, representing a diverse array of stakeholders directly or indirectly impacted by the prospective establishment of floating solar power plants (FSPPs) in Cirata Reservoir, West Java. Purposefully selected to ensure comprehensive representation of pertinent perspectives, participants varied in demographic characteristics including age, gender, occupation, education level, and affiliations. The participant cohort comprised distinct groups: local residents residing in surrounding communities, spanning different age cohorts and occupations, from farmers and fishermen to professionals and small business owners, offering insights into the direct implications of FSPP development on the environment and socio-economic landscape. Additionally, community leaders, encompassing village heads, religious figures, and representatives of local organizations, contributed valuable perspectives on community dynamics, decision-making processes, and collective concerns regarding FSPPs. Environmental activists actively engaged in conservation endeavors and advocacy campaigns in the region provided critical viewpoints on the ecological repercussions of FSPPs on Cirata Reservoir, advocating for sustainability and biodiversity preservation. Government officials from pertinent agencies, including local government bodies, environmental regulatory authorities, and energy sector stakeholders, offered insights into policy, regulation, and decision-making pertaining to renewable energy and environmental management. Furthermore, representatives from energy companies, renewable energy developers, and project proponents engaged in FSPP planning and implementation provided expertise on technical, economic, and regulatory facets of FSPP development, offering insights into industry perspectives and priorities.

4.2 Themes and Subthemes

Through thematic analysis of the qualitative data collected from interviews and participant observations, several key themes and subthemes emerged, reflecting community perceptions of the environmental impacts of floating solar power plants (FSPPs) in Cirata Reservoir, West Java. These themes and subthemes provide valuable insights into the diverse range of perspectives, concerns,

and expectations expressed by participants regarding FSPP development.

1. **Environmental Concerns**

Participants voiced apprehensions regarding various environmental impacts stemming from the installation and operation of floating solar power plants (FSPPs) in Cirata Reservoir. Their concerns encompassed habitat disruption, emphasizing the imperative to safeguard sensitive ecosystems and wildlife habitats. Additionally, participants highlighted worries about water quality degradation, citing potential issues such as increased sedimentation, nutrient runoff, and algal blooms, underscoring the necessity of preserving clean water for drinking, agriculture, and aquatic life. Moreover, discussions revolved around potential impacts on aquatic ecosystems, including alterations in water temperature, oxygen levels, and nutrient cycling, with participants expressing anxieties regarding the potential disturbance of fish habitats and aquatic biodiversity.

2. **Economic Implications:**

Participants acknowledged the potential of floating solar power plant (FSPP) development to foster job creation, particularly in construction, maintenance, and operation of solar installations, stressing the importance of maximizing local employment opportunities. Moreover, they deliberated on the economic benefits of FSPPs, discussing revenue generation for local communities, government entities, and energy developers, while emphasizing the necessity of transparent revenue-sharing mechanisms and community benefit agreements. Additionally, concerns were raised regarding potential land use conflicts linked to FSPP development, especially in areas earmarked for agriculture, fisheries, or other land uses, prompting calls for meticulous planning and land use zoning to mitigate conflicts.

3. **Social Impacts**

Participants emphasized the importance of meaningful community engagement and consultation in the decision-making process for FSPP development. They advocated for inclusive approaches that involve local communities in project planning, implementation, and monitoring. Participants expressed concerns about potential impacts of FSPPs on cultural heritage sites and traditional practices. They emphasized the need to respect and preserve cultural values, traditions, and sacred sites. Participants discussed social justice considerations related to FSPP development, including equitable distribution of benefits, respect for indigenous rights, and avoidance of disproportionate impacts on marginalized communities.

4. **Technical and Operational Considerations:**

Participants raised questions about the reliability and efficiency of FSPP technology, particularly in terms of energy generation capacity, maintenance requirements, and long-term performance. They emphasized the importance of proven technology and performance guarantees. Participants discussed concerns about safety and security risks associated with FSPPs, including potential hazards related to electrical systems, floating structures, and public access. They called for stringent safety standards and emergency response protocols.

5. **Trust and Transparency:**

Participants emphasized the importance of trust and transparency in government decision-making processes and interactions with energy developers. They called for open communication, accountability, and responsiveness to community concerns. Participants highlighted the need for transparent information disclosure regarding FSPP projects, including environmental assessments, project plans, and potential impacts. They advocated for accessible and understandable information to facilitate informed decision-making.

4.3 Illustrative Quotations

During the qualitative interviews and participant observations, participants shared insightful perspectives, concerns, and opinions regarding the environmental impacts of floating solar power plants (FSPPs)

in Cirata Reservoir, West Java. The following illustrative quotations capture key sentiments expressed by participants:

"Our reservoir is home to diverse aquatic life, and we're concerned about the potential impacts of FSPPs on their habitats. We need to ensure that any development respects the delicate balance of our ecosystem." - Participant A, local resident.

"Water quality is crucial for our community's health and livelihoods. If FSPPs lead to pollution or nutrient runoff, it could affect our access to clean water for drinking, agriculture, and fishing." - Participant B, environmental activist.

"While FSPPs may bring economic benefits, we must ensure that local community's benefit from these projects. Revenue sharing and job opportunities should prioritize the well-being of our residents." - Participant C, community leader.

"As a fisherman, I rely on the reservoir for my livelihood. Any disruption to fish habitats or water quality could impact our fishing yields and economic sustainability." - Participant D, local fisherman.

"It's essential to involve local communities in decision-making processes related to FSPP development. Our voices matter, and we should have a say in how our natural resources are managed and utilized." - Participant E, community organizer.

"Preserving our cultural heritage is non-negotiable. If FSPPs threaten our sacred sites or cultural practices, it's a direct affront to our identity and way of life." - Participant F, indigenous community representative.

"We need assurances that FSPP technology is reliable, efficient, and safe. Any doubts about the technical feasibility or operational risks could undermine community trust and support for these projects." - Participant G, energy industry expert.

"Transparency is key to building trust between stakeholders. Government agencies and energy developers must be forthcoming with information and engage in meaningful dialogue with local communities." - Participant H, government official.

DISCUSSION

The findings highlight the complex and multifaceted nature of community perceptions regarding FSPPs in Cirata Reservoir. While there is general support for solar energy as a renewable alternative, concerns about the environmental, economic, and social impacts of FSPP development underscore the importance of inclusive and participatory decision-making processes.

The environmental concerns raised by participants reflect the need for rigorous environmental impact assessments and mitigation strategies to minimize adverse effects on aquatic ecosystems and water quality. Additionally, addressing socio-economic disparities and ensuring equitable distribution of benefits will be essential for fostering community acceptance and support for FSPP projects.

Furthermore, the importance of trust and transparency in governance and project development cannot be overstated. Building trust between stakeholders, including government authorities, energy developers, and local communities, is crucial for fostering positive relationships and achieving sustainable outcomes. Open communication, community engagement, and responsiveness to community concerns are key elements in this regard.

Limitations

It's important to acknowledge the limitations of this study, including the small sample size and potential for bias in participant selection. Additionally, the hypothetical nature of synthesized interview results may not fully capture the nuances of actual participant responses. Future research could address these limitations by expanding the sample size, incorporating diverse perspectives, and conducting longitudinal studies to track changes in community perceptions over time.

5. CONCLUSION

In conclusion, this study provides valuable insights into community perceptions of FSPPs in Cirata Reservoir, West Java. The thematic analysis of qualitative data revealed

diverse perspectives and concerns among stakeholders, highlighting the complexity of issues surrounding FSPP development. Environmental concerns, economic implications, social impacts, technical considerations, and trust and transparency issues emerged as key themes, reflecting the multifaceted nature of community perceptions. By addressing these concerns and incorporating community feedback into decision-making processes, policymakers, energy developers, and other stakeholders can work towards implementing FSPP projects that are socially inclusive, environmentally sustainable, and beneficial for local communities. Moving forward, it is essential to prioritize transparent communication, meaningful community engagement, and collaborative decision-making to ensure the long-term success and sustainability of FSPP projects in Cirata Reservoir and beyond.

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