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NETWORK FOR EQUITY IN TRANSITIONS FROM FOSSIL FUELS

CASE STUDY #4

# MICRO-HYDRO POWER IN INDONESIA

## The Role of Decentralized Energy in Just Transition Strategies

In the face of increasingly frequent climate crises, many countries across the global South, including Indonesia, have adopted a just transition framework to accelerate climate action. Within Indonesia's energy transition strategy, the expansion of Micro-Hydro Power (MHP) has emerged as a key example of decentralized renewable energy implementation. Unlike larger-scale energy infrastructure, many MHP initiatives are developed not only by national and local governments but also by community organizations, NGOs, and private actors. By examining the diverse MHP initiatives, this case study explores the extent to which decentralized renewable energy can advance just transition goals in the global South. The MHP cases analyzed here highlight how reliable, small-scale renewable systems can generate multidimensional benefits while minimizing negative environmental impacts. Yet, persistent challenges remain including gender inclusion gaps, policy fragmentation, and the difficulty of sustaining initiatives overtime. Through a feminist analytical lens, this study shows that sustained implementation depends largely on the extent of community involvement. Inclusive processes build ownership and continuity, while government- or private-led arrangements that limit engagement often result in weaker attachment and reduced durability. These findings offer lessons for achieving more inclusive, participatory, and equitable energy transitions throughout the global South.



## Context: Just Transition and Energy in Indonesia

### Why Just Transition Matters

Energy demand in Indonesia continues to rise alongside rapid economic growth, but the country's energy production is heavily dependent on fossil fuels. Indonesia ranks third on the list of the world's leading coal producers and is also a major consumer. However, the country has also committed to achieving net-zero emissions by 2060 or sooner, with a goal of transitioning to 44 percent renewable energy in the power sector by 2030.

Access to energy is also still a challenge. Although the State Electricity Company (PLN) reports that electrification has reached 99.92 percent of households,<sup>1</sup> this figure obscures significant regional disparities. Many rural and underdeveloped areas still experience limited or unreliable electricity access and are often dependent on kerosene lamps or small diesel generators. The persistence of these gaps underscores the need for an energy transition that goes beyond headline numbers, ensuring equity and inclusion.

A just transition is therefore essential in Indonesia, not only to replace fossil fuels with renewable energy but also to create opportunities for communities historically excluded from development. Renewable energy offers benefits in various ways, yet it can also generate negative socio-economic outcomes that risk reinforcing existing inequalities. The promise of *decentralized* renewable energy lies in its potential to address both energy poverty and social inequality by redistributing control over resources and decision-making.

### Benefits of Micro-Hydro Power in Indonesia's Energy Transition

Indonesia's efforts to reduce dependency on fossil fuels have relied on the development of various kinds of renewable energy production such as hydropower, bioenergy, geothermal, wind, and solar power plants. Among these, Micro-Hydro Power (MHP) has emerged as one of the most promising technologies, particularly for rural electrification. Although the technology was introduced in the late 19th century, its widespread application began more systematically in the mid-2000s.

Since then, MHP has gained traction due to its low cost, environmental benefits and practical feasibility as an option for rural electrification, especially in places disconnected from the PLN grid.<sup>2</sup> Larger hydropower

plants, although capable of providing stable energy generation, are frequently associated with negative environmental and social impacts, including biodiversity loss and community displacement caused by dam construction.<sup>3</sup> In contrast, smaller MHP technologies have relatively limited impacts on both local ecosystems and the climate compared to other renewable energy sources.

Rural areas in Indonesia are often difficult to access, making decentralized MHP a suitable solution for renewable energy implementation. At the household level, the introduction of electricity provides a number of benefits, such as improving access to information, strengthening social interaction, and enabling students to study at night. For women, in particular, MHP can significantly reduce heavy domestic burdens, as it decreases the need to travel long distances to collect firewood or purchase kerosene. Beyond the household level, electrification also enhances community life by powering shared facilities and communication infrastructures.

## A Feminist Analysis of Micro-Hydro Power Expansion in Indonesia

MHP projects in Indonesia have been initiated by a range of actors, including local communities, non-governmental organizations (NGOs), government, and the private sector. In order to analyze the impacts, opportunities and challenges associated with MHP in Indonesia, we first conducted an extensive literature review in English and in Indonesian of publications found in academic and policy outlets. We identified a total of eleven cases of MHP documented in this literature, and categorized them according to the 4 sectors listed above: community-led (three cases), NGO-led (three cases), private sector-led (two cases), government-led (three cases). Even though in practice the boundaries are often blurred (community initiatives frequently rely on donor or NGO support, and NGO projects often involve public-private collaboration, etc.), these categories are useful for comparative analysis, as elaborated below.

We then made use of a feminist analytical framework adopted from Bell et al. (2020), which outlines four dimensions of feminist energy systems including political (decentralized, democratic), economic (well-being and biodiversity more than profit), socio-ecological (transparent and relational), and technological (community-directed).<sup>4</sup> This framework helps interpret the impacts of MHP

expansion in Indonesia, beyond a simple calculation of how many households gain access to electricity. Feminist approaches like this one have been adopted in environmental and climate change research, particularly for their ability to highlight how power relations shape access, decision-making, and control within energy systems.

Our analysis shows that the effectiveness of MHP initiatives depends significantly on the degree of community engagement across political, economic, socio-ecological, and technological dimensions. When communities are treated not only as beneficiaries, but as active decision-makers, the systems tend to be better maintained and more resilient over time. In contrast, more centralized arrangements often reduce local accountability and limit the social conditions needed for stable and equitable energy access. Below we unpack in detail the dynamics of MHP expansion in Indonesia along these four dimensions.

### Political Dynamics

Bell et al. define political dynamics as the extent to which energy systems are publicly accessible, democratically governed, and structured to support decentralized control.<sup>5</sup> In Indonesia, the political dynamics of MHP initiatives demonstrate that decentralization in energy projects enables local participation, which is one of the keys to sustaining renewable energy initiatives. Decentralized governance allows local actors to co-manage energy systems, which can improve accountability, adaptability, and social ownership. Yet, the degree of community involvement varies across cases. Some communities maintain full authority, while others are limited to maintenance roles or are excluded from decision-making altogether.

Community-initiated MHP often demonstrates the most direct form of decentralized energy governance, where locals hold full control over maintenance, operation, and decision-making. In Gunung Sawur, decentralization creates strong social participation through the Women's Association, which manages operations, distribution and electricity sales.<sup>6</sup> Similarly, in Gununglurah, a local cooperative manages finances, technical operations, and maintenance. There, when the facility experienced severe damage, residents collectively raised funds and restored the MHP plant. Here we see the benefits of local participation. These cases suggest that decentralized systems enhance resilience, as local ownership and engagement enable communities to

respond effectively to unforeseen challenges and sustain MHP projects over time.

NGO-initiated MHP projects share similar participatory goals but often begin with less local readiness. In Kalimantan, the Environmental Education Center (PPLH) initially managed operations because the community had limited technical capacity, but the absence of shared responsibility meant that river blockages were unaddressed, eventually causing the system to fail.<sup>7</sup> Through community development programs, Paguyuban MHP Kalimantan (PKM) was established to take over management and successfully expanded the system to connect with the PLN. A similar transition took place in Cinta Mekar, where the NGO, the People Centered Economic and Business Institute (IBEKA) managed social engagement, capacity building, and cooperative formation, enabling residents to lead the maintenance, billing, and governance.<sup>8</sup> In contrast, the Qaryah Thayyibah Farmers Union (SPPQT) held full control over the Banyu Biru's operations. Despite receiving technical training from IBEKA, the organization encountered coordination failures and unclear ownership. The complicated bureaucratic process further delayed commissioning, leaving the plant inactive and eventually caused its failure.<sup>9</sup> These cases highlight that decentralization succeeds only when supported by transparent roles, capacity building, and shared responsibility.

Private sector- and government-initiated MHP projects are generally more focused on generating profit, research, technological development, and grid integration and are mostly centralized. Limited community involvement diminishes a sense of ownership and decreases long-term resilience. In Panji Muara Bali, 98 percent of operators and workers are local people, yet they are excluded from strategic decisions. Similarly, In Kunci Putih MHP shifted from Adi Banuwa Company to Kunci Hidro Energi Company with little evidence of local participation in governance. Government-led MHP projects under the Ministry of Energy and Mineral Resources (ESDM) show similar issues. The Igirklanceng MHP project initially engaged local experts through the Sinar Harapan organization, but without sustained financial and technical support, the project ceased operations.

Across these cases, decentralization aims to transfer authority to local actors, but its outcomes depend on how participation is structured and supported. Community-led projects tend to succeed

when they emerge from genuine local needs and existing organizational capacity, while projects treating communities as passive beneficiaries often struggle to sustain operations.

### **Economic Benefits**

In Bell et al. a feminist view of economic benefit emphasizes energy systems that prioritize well-being and biodiversity over profit, distribute benefits and burdens fairly, and support livelihoods rather than extract value.<sup>10</sup> Decentralized energy generation provides diverse economic opportunities beyond supplying electricity to households previously excluded from PLN grid. It supports local economic growth by providing lower electricity costs, creating jobs, improving quality of life, and enabling local business and educational advancement. Yet, the extent of these benefits varies depending on who initiates and manages the project. Projects grounded in community participation tend to produce more equitable and durable economic outcomes, while externally driven initiatives often yield benefits that are less embedded in local development.

In community-led MHP projects, electricity is sold through community cooperatives with revenue reinvested into operations, maintenance, and development. These projects show that decentralized energy governance can have far-reaching benefits beyond affordable electricity. In Mbakuhau, for instance, the availability of reliable electricity attracted a Base Transceiver Station (BTS) tower, allowing connectivity and communication.<sup>11</sup> Once the system was up and running, several micro-enterprises emerged, especially led by women. In Gunung Sawur, access to affordable electricity enabled women to establish a local food-processing business that created jobs and strengthened the village economy.<sup>12</sup>

However, electrification also introduces new social challenges. The increased access to media and communication technologies has, in some cases, encouraged more consumptive behavior and reduced social interaction within communities.<sup>13</sup> Furthermore, MHP is not a silver bullet solution, as output depends on water flow and capacity remains insufficient for larger appliances and to support the full extent of villagers' aspirations upon gaining access to electricity. In Gunung Sawur, residents now rely on both MHP and PLN to meet energy needs.<sup>14</sup> As consumption patterns and social relationships change, social awareness and adaptive governance are needed to address the emerging challenges.

NGO-initiated projects often mirror the community-led model but in some cases offer stronger institutional support for local economic development and related activities. In Kalimaron, electrification from MHP created jobs and diversified local livelihoods through small-scale industries and eco-tourism, including a women-managed paper recycling enterprise that reaches export markets. In Cinta Mekar, revenue-sharing agreements balanced community empowerment and investor returns by allocating half of the profits to the Mekar Sari Cooperative for community empowerment, while the rest went to the private sector partner PT Hidro Piranti. Additionally, 120 low-income residents received free meters and were exempted from paying for electricity usage. Improved local employment opportunities even encouraged women who had previously migrated for work to return to their village.<sup>15</sup>

By contrast, company-led and government-led MHP projects tend to deliver centralized benefits, with only limited advantages for locals. In Panji Muara, local farmers and ranchers benefited from a more reliable power supply, and the repurposed filtered water for a local bathing area indirectly boosted tourism. In other private-led cases such as Kunci Putih MHP, electricity was sold primarily to PLN, with local involvement largely limited to security or minor operational roles. Government-initiated projects typically provide fewer economic benefits at the local level. Limited documentation in the literature may also reflect their centralized governance that is mostly handled under the Ministry of ESDM and tends to focus on technical research and grid integration rather than local empowerment.

Overall, community- and NGO-initiated MHP projects generate economic benefits that tend to stay within the community. When local groups guide decision-making, the resulting opportunities are more likely to support village livelihoods. By contrast, private sector- and government-led initiatives tend to deliver fewer local community gains, even when they expand access to electricity.

### **Socio-Ecological Impacts**

In this framework, socio-ecological impacts refer to how energy systems interact with their surrounding environments and communities, including the transparency of resource use and the protection of social and ecological well-being. A feminist lens highlights the need for community authority, ecological stewardship, and accountability across the entire life cycle of energy technologies.<sup>16</sup> The

introduction of MHP plants often raises concerns among rural communities regarding water availability, as most villagers rely on rivers for agriculture and daily household needs. The use of river water to operate MHP turbines has therefore led to fears that it might reduce water availability. During the early stages of the Cinta Mekar MHP project, some communities initially opposed construction. In practice, however, the operation of the MHP plant did not affect water availability. In Gunung Sawur, a community-initiated project encouraged residents to protect their watershed areas, engage in reforestation and manage local forest resources to sustain river flow. Similarly, the NGO-led Kalimaron project established collective ownership and motivated villagers to actively conserve forests, safeguard recharge zones and river ecosystems to maintain stable water discharge. As a result, the previous practice of illegal logging and deforestation was eliminated, and forest and river conservation became integral to community activities.<sup>17</sup>

Private sector-led MHP can also result in environmental co-benefits. At Panji Muara Bali, the water used in power generation is partially repurposed for a local bathing area, with the majority redirected into a reservoir and the remaining flow distributed to the locals' subak (traditional Balinese irrigation system). The project has also been associated with improved oxygen levels in the surrounding river ecosystem. By contrast, little information is available on socio-ecological outcomes from government-led initiatives, which may reflect the centralized nature of their management and the limited local engagement in resource monitoring.

Despite mature technology and being relatively stable, MHP projects remain vulnerable to climate change. Prolonged droughts or floods can significantly disrupt turbine operations and reduce energy output. For example, during an extended drought in North Bali in 2020, Panji Muara Bali MHP operations were forced to limit production to a single turbine, reducing the capacity to only 420 kW, which is far below the ideal level.<sup>18</sup> This nearly led to the plant's shutdown until rainfall patterns increased, allowing the system to recover and continue living up to expectations to this day.<sup>19</sup>

In sum, collective ownership of MHP projects reinforces socio-ecological outcomes by building a sense of responsibility and accountability. Communities maintain and protect both technology

and surrounding ecosystems because they directly benefit from its sustained operation, which creates a self-reinforcing link between energy access and environmental stewardship.

### **Technology Transfer**

Achieving a just energy transition through a decentralized system requires effective technology transfer to prepare local communities for long-term management. Technological transfer involves developing and implementing innovations in close collaboration with the communities they serve, ensuring that technology aligns with local economic, social, political, and ecological contexts.<sup>20</sup> In community-initiated projects such as Mbakuhau, IBEKA provided hands-on training for residents to be actively involved from the early stages. The MHP revenue was reinvested in scholarships for electrical training with the aim of preparing local residents to serve as system operators.<sup>21</sup> In Gunung Sawur, the village established a workshop space that allows students to come and learn about MHP systems, while in Gununglurah, the ministry of ESDM and the Central Java Provincial government organized technical workshops to support operational capacity.

In NGO-led initiatives such as the Kalimaron MHP, PPLH's technical monitoring allowed villagers to gain technical expertise in daily maintenance and troubleshooting, reducing reliance on external experts. This enabled the expansion of the MHP project, Wot Lemah, within the same river basin, which reflects the scalability and replicability of the system. The PKM association supported by PPLH further facilitated knowledge-sharing with neighbouring villages. Similarly, in Cinta Mekar, the Mekar Sari Cooperative played a key role in transferring technical and managerial knowledge to local operators.<sup>22</sup> In the initial stages of construction of Banyu Biru MHP, SPPQT provided basic training, although the aim was more to obtain local permits and ensure project security rather than to develop long-term technical capacity.<sup>23</sup>

In the case of private sector-led initiatives, the local employers working on the MHP Banyu Biru project received on-the-job training. The projects are also often used as field learning for visiting students. In contrast, government-led MHPs showed limited involvement of local experts in project planning and maintenance. Although there was local enthusiasm for adopting MHP as new technology, this lacked institutional support for technical upkeep or environmental management.

These cases suggest that effective technological transfer is crucial for sustaining MHP operations, and projects that integrate communities from the outset build local technical capacity, reduce dependence on external actors, and enable scalability and replication.

## Opportunities, Challenges and Future Directions

This assessment of the implementation of MHP initiatives in Indonesia reveals how the level of community engagement and stakeholder involvement contributes to different outcomes. Understanding both enabling and limiting factors provides key insights into how decentralized energy systems can contribute to transitions away from fossil fuels in a way that ensures equitable distribution of benefits and long-term sustainability.

The support from NGOs, private companies, and government institutions in knowledge transfer through forms of capacity building such as training, workshops, and peer-to-peer learning has been instrumental to many projects' success. While external stakeholder involvement is often helpful, most successful cases rely on community engagement throughout all implementation stages. By cultivating local technological and managerial expertise, the community is able to serve as the managing partner and take an active role in both governance and maintenance. Building this capacity is essential to strengthening long-term sustainability and resilience. Empowerment through the facilitation of local ownership and participation in decision-making allows communities to gain greater control over outcomes and ensure that the projects respond to local needs. This sense of ownership motivates communities to maintain the system and even protect their surrounding environment, particularly water sources essential to MHP operation. Additionally, tangible local benefits such as local employment opportunities, small enterprise development, and improved access to education and health services further reinforce community commitment and contribute to the overall success and long-term sustainability of the initiative.

Public consultation helps reduce local concerns, strengthens community attachment, and responsibility for protecting the system and its surrounding environment. However, the community is not a black box. Indeed, attention to the inequalities and power dynamics within

each community is essential to ensuring that MHP projects serve as enablers of more just energy systems. For example, women and other vulnerable groups are often underrepresented in the management, maintenance, and operational systems. And gender inclusion remains a persistent gap across many initiatives. Women's participation is often confined to subsidiary roles, despite their potential to contribute to system management and decision-making. Future initiatives would be improved by integrating gender-transformative approaches that create leadership opportunities for women, thus enhancing equity and social sustainability.<sup>24</sup>

Other challenges faced in MHP implementation come from environmental, institutional, and managerial factors. The failure of several MHP plants can be attributed to environmental instability, inadequate maintenance efforts, limited financial support, and insufficient policy and regulatory backing from the government. Heavy dependence on natural water flows exposes MHP systems to environmental uncertainty. Reduced water supply caused by natural disasters and climate change disrupts electricity generation and can render the system unable to meet energy needs.

Institutional and governance-related barriers further constrain implementation. Although Indonesia's political structure is decentralized, its electrical grid remains largely centralized. The intricacy of Indonesia's multilevel government regulation intensifies the complexity of MHP implementation. This often results in unclear project ownership, fragmented responsibilities, and prolonged administrative procedures that delay project operation or even lead to implementation failures. Another challenge lies in establishing more coherent and continuous support frameworks. Although community-led schemes have shown potential, their sustainability often depends on ongoing assistance from government agencies and development partners. The state's role should extend beyond funding to inclusive capacity building, technical mentoring, and financial facilitation to ensure that local initiatives align with the national standards without sacrificing local autonomy. Pricing mechanisms also requires adjustment, as electricity from MHP systems is often set at a similar rate to the PLN grid, which undermines the economic advantages for rural users. In addition, ensuring the long-term viability of MHP systems requires adapting to environmental and infrastructure changes. Several projects have been abandoned once the

national grid reached their areas, highlighting the need for adaptive strategy that integrates local systems into broader energy networks. For larger-scale or grid-connected MHP projects, coordination with state utilities is essential to maintain stability and optimize resource use.

In short, this evaluation of MHP expansion in Indonesia shows the promising potential of decentralized renewable energy systems as an important element of the transition away from fossil fuels. While the small scale and decentralized nature of such systems offers ecological and social benefits, key to effective implementation and long-term sustainability is a combination of a.) participatory governance that meaningfully involves/is led by the local community (opening space for women and other marginalized groups) that will be served by the installation; and b.) external support in the form of training, funding, infrastructure and coordination with the broader national energy system.

## Footnotes

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## About this Case Study

This case study examines gender-transformative approaches to just transitions through grassroots initiatives in the global South. It was produced by UNRISD to demonstrate how centring women's leadership in energy transitions creates more equitable and sustainable outcomes.

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