Simulacra | ISSN: 2622-6952 (Print), 2656-8721 (Online)
https://journal.trunojoyo.ac.id/simulacra

CENTER FOR SOCIOLOGICAL STUDIES AND COMMUNITY DEVELOPMENT
DEPARTMENT OF SOCIOLOGY
FACULTY OF SOCIAL AND CULTURAL SCIENCES
UNIVERSITAS TRUNOJOYO MADURA, INDONESIA

Simulacra
e-ISSN: 2656 8721

UNIVERSITAS TRUNOJOYO MADURA

Volume 9, Issue 1, June 2026 **Page 39–54**

Recognizing women's hidden role in climate action: Lessons from Eastern Indonesia

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DOI: https://doi.org/10.21107/sml.v9i1.32293

Article Info

Keywords:
Feminist Political Ecology
energy justice
household biogas system
gendered energy transition
livestock management

Abstract

The global energy transition is central to addressing climate change and advancing sustainable development. Achieving a just transition requires attention to social and gender dimensions. Yet, in many rural contexts, women are still positioned as passive recipients rather than active contributors to renewable energy initiatives. This study examines women's recognition and inclusion in the development of household-scale biogas systems in Manggarai Regency, East Nusa Tenggara, Indonesia. Drawing on feminist political ecology and the energy justice framework, the research explores how gendered divisions of labor, situated knowledge, and local power relations shape women's participation in renewable energy transitions, particularly in livestock management and household energy practices. Fieldwork in Nenu and Pagal villages used a participatory action research approach, combining in-depth interviews and focus group discussions with women farmers and local stakeholders. Findings show that women's everyday livestock management feeding animals, maintaining stalls, and collecting manure is essential for sustaining household biogas systems. These often-invisible forms of labor position women as key actors in maintaining biodigester feedstock. The study contributes by integrating feminist political ecology and energy justice framework to understand better how gendered labor, knowledge, and power shape participation and recognition in renewable energy initiatives.

Citation suggestion:
Sardjo, S., Nugraha, E. Y., & Koopman, J. (2026). Recognizing women's hidden role in climate action: Lessons from Eastern Indonesia. *Simulacra, 9*(1), 39–54. https://doi.org/10.21107/sml.v9i1.32293

Received 31 October 2025; Received in revised form 28 March 2026; Accepted 11 April 2025; Published online 25 June 2026.

Introduction

Energy is a major driver of climate change, and continued dependence on fossil fuels without effective mitigation will intensify the crisis; global warming will accelerate, disasters will occur more frequently, and the impacts on people and nature will become increasingly severe (WEF, 2023). Scientific reports from the United Nations and the Intergovernmental Panel on Climate Change emphasize the urgent need for climate action, and countries worldwide must meet their energy and climate targets for 2030 and 2050 (Heffron and Sokolowski, 2024). Accelerating renewable energy innovation is therefore essential to achieving global climate goals (Rose, 2024). Human society has undergone three major energy transitions: the shift from firewood to coal, from coal to oil, and from fossil fuels to clean, renewable energy. The current wave of low-carbon energy transition anticipates an energy production and consumption pattern dominated by clean electricity to achieve net-zero emissions by 2050 (Yang et al., 2024). These clean energy provisions offer new opportunities for previously marginalized societies, including large corporations and entire economic sectors (Hackforta et al., 2025). By applying energy justice principles across the energy sector, this transition can take place within a more secure, just, and inclusive framework.

This should be a shared global goal, as ongoing energy policy failures affect us all as global citizens striving for a better future (Heffron and Sokolowski, 2024). In recent years, a growing number of studies on green technology development have been published, focusing on the technological aspects of green innovation for industry (e.g., Barakat et al., 2026; Park et al., 2026; Sen et al., 2026; Liu and Taleghani, 2026). There are also publications that address the social dimensions of green technology development, particularly regarding gender in the Global South. Women have been underrepresented in environmental management, including access, participation, control, and benefits (Oktarina and Yulianti, 2022).

The literature suggests that transitions from traditional to renewable energy sources, such as biogas, solar stoves, and improved biomass stoves, provide tangible benefits for women across a wide range of dimensions (Cellini et al., 2025). Several studies examine technology adoption and household preferences for green technologies, particularly in Africa and Asia (Ding et al., 2014; Chicombo & Musango, 2022; Singh, 2023; Yasmin, 2020). Women are often relieved of the burden of collecting firewood following the adoption of renewable energy technologies, including biogas digesters, energy-efficient biomass stoves, and solar cookers (Ding et al., 2014). However, women often have limited access to extension services related to health, education, and agriculture, which undermines recognition of their significant contributions. This reflects a broader trend across rural Asia, where women farmers play a critical role in agricultural adaptation yet remain excluded from training opportunities and decision-making platforms (Khatri-Chhetri et al., 2020; Rodgers et al., 2024; Koopman, 2026).

Energy transition and gender remain highly relevant today. Unfortunately, even after the introduction of rural gas programs, firewood remains the dominant cooking fuel for households and small-scale industries in many developing countries, where women bear a disproportionate burden (WEF, 2023). In Indonesia, although 86.1% of households use LPG, 9.82% still rely on firewood, with the figures reaching 63.77% in Papua and 68.11% in East Nusa Tenggara (BPS, 2023). Many rural households use both fuels due to economic constraints, cultural preferences, and availability. In many traditional communities, firewood also retains cultural

value and is believed to enhance food flavor, despite the health risks faced by women who cook for long hours. Evidence indicates that biomass consumption has a disproportionate impact on women. Their needs are often overlooked during policy design, and they have yet to fully benefit from the outcomes of these policies (Chicombo & Musango, 2022). In East Nusa Tenggara, eastern Indonesia, energy poverty remains acute, yet women's roles in fuel collection and cooking are rarely acknowledged in energy transition programs. Although initiatives such as the Green Microfinance Program (GMP) link women to renewable energy (Atahau et al., 2021), no mainstream government policies directly position women as primary beneficiaries. Inspired by Rocheleau (1996) and Harcourt (2019), this study addresses these gaps by employing Feminist Political Ecology (FPE) as an analytical framework to examine women's experiences within biogas initiatives in Manggarai, emphasizing a relational approach as a key dimension. Whereas hegemonic patriarchal models of development are often grounded in domination, conflict, and the exploitation of bodies, cultures, and nature, FPE advocates transformative pathways rooted in the everyday practices and knowledge of women, men, and their communities to sustain ecologically viable livelihoods (Harcourt et al., 2022).

This paper contributes to the literature by examining how women are recognized and included in biogas programs, using an FPE perspective to analyze how household biogas initiatives in Manggarai position women as key actors in operating and maintaining biodigesters. Energy programs often claim "time-saving benefits" without measuring women's real labor. This raises critical questions: How is the division of labor in household energy use structured? Who has access to and control over technology? How is knowledge and decision-making regarding biodigesters shared between men and women? And how do power relations shape women's engagement with biodigester technology?

Women's contributions are often undervalued in rural development programs, which tend to prioritize men as holders of authority and formal technical knowledge. This paper also applies the energy justice framework to examine how biogas adoption relates to issues of fairness, recognition, and participation in local energy systems (Sovacool and Dworkin, 2015; Sovacool et al., 2017). This study argues that the success of household biogas initiatives in Manggarai relies heavily on women's everyday labor and knowledge in livestock care and waste management. These contributions remain largely invisible within formal renewable energy programs, reflecting issues of fairness, recognition, and participation, as well as the hegemonic patriarchal model of development often grounded in everyday practices. By combining Feminist Political Ecology with the energy justice framework, this study reveals how distributive, procedural, and recognition injustices shape women's participation in and benefits from rural energy transitions.

Method

The study specifically examined the intersection between women's labor in livestock management—particularly in pig farming—and its contribution to biogas production as a renewable household energy source. The researcher was stirred to write this article as a critical reflection on household-level biogas development programs that prioritize men as beneficiaries. However, behind these initiatives are women who spend most of their time caring for pigs, the primary source of manure for biodigesters that produce biogas.

This paper was developed as a focused discussion on gender issues, drawing on insights from a multidisciplinary research team comprising experts in sociology, animal husbandry, and agriculture who collaborated throughout the study. Before data collection, the research team completed the necessary ethical procedures by obtaining permission from relevant authorities in the research area and consulting with community leaders to explain the study's objectives and procedures. Informed consent was obtained from all participants before conducting interviews.

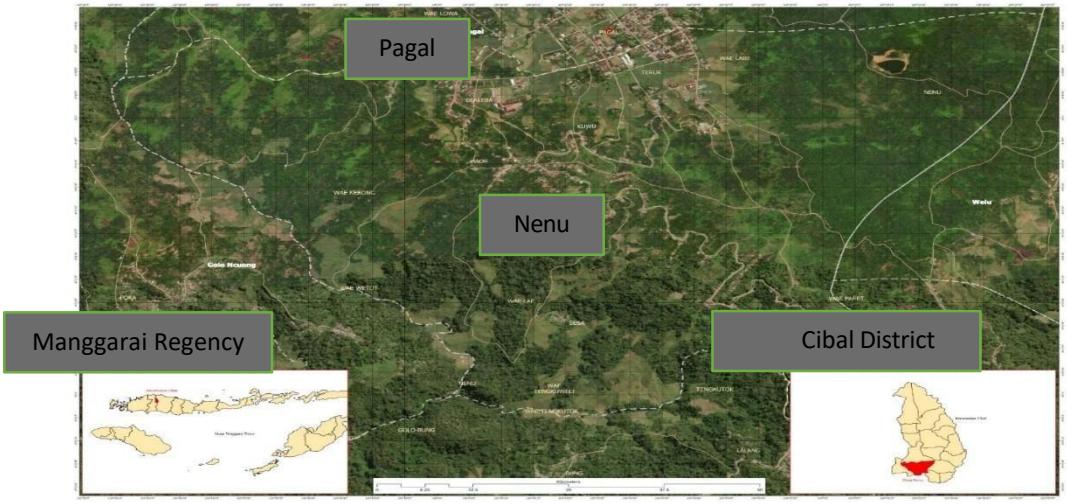
This research was conducted from May 29 to July 17, 2024, in Nenu and Pagal villages, located in Cibal Subdistrict, Manggarai Regency, East Nusa Tenggara, Indonesia. The research sites were selected in areas where a pilot project on household-scale biodigesters had been implemented. Both villages represent typical rural communities in which livestock—particularly pigs—play a significant role in household economies and where access to modern energy services remains limited.

The study employed participatory action research (Stoeker & Falcon, 2022) as the primary approach to explore women's involvement in the household biogas development program. This approach was chosen to ensure that local knowledge, experiences, and aspirations were integrated into the research process. Three primary data collection techniques were used: in-depth interviews, focus group discussions, and observation.

In-depth interviews were conducted to capture diverse perspectives from various stakeholders (Creswell & Poth, 2018; Miles et al., 2014). Through these interviews, the researchers gained deeper insights into gender relations following the implementation of the biogas development program, including practices related to maintaining healthy livestock to support biogas production. The in-depth interviews involved 16 participants, including village leaders (2), livestock owners (3), veterinarians (2), pig farmers (6), a biogas technician (1), a community leader (1), and a municipal officer (1).

Focus group discussions (FGDs) were conducted with 16 women farmers across the two villages. The FGDs explored women's daily activities, their roles in livestock

Figure 1: Research Sites



(Source: ArcGIS Pro Base Map)

management, their perceptions of biogas, and their aspirations regarding energy transitions.

Following Creswell & Poth (2018), the study applied common validation strategies, including triangulation using multiple data sources (interviews, FGDs, and field notes), member checking by returning findings to participants for feedback, and researcher reflexivity. Data analysis followed an iterative spiral process comprising five core stages: (1) organizing the data through transcription and memo collection; (2) data immersion to build familiarity with context; (3) coding by labeling text segments to generate categories; (4) developing themes regarding women's roles in pig farming; and (5) constructing thematic narratives to address the research questions.

Data analysis began with identifying women's everyday activities and workloads, as well as their knowledge systems related to pig farming and maintaining healthy livestock, which are essential for biodigester operation and biogas energy production. We then examined how these activities are divided between men and women and how gender gaps emerge across the entire process. We also analyzed women's perceptions of biogas technology in relation to men's roles.

Results and Discussion

Transforming livestock waste into energy

According to the 2022 national census, Manggarai's population of 317,600—equivalent to approximately 52,933 households, with an average of 6 members per household—relies predominantly on small-scale, family-based pig farming, with only 2 large commercial enterprises operating in the region. The sector is economically sustained by consistent demand for pork, driven by both cultural ceremonies and daily consumption. Pig farming is among the most prominent livestock practices in Nusa Tenggara Timur (NTT), supported by pigs' high reproductive rates, adaptability to diverse feed sources, and relatively high market value in both domestic and international markets (Tukan et al., 2023).

Despite its economic significance, the sector presents notable environmental challenges. Free-ranging pig-rearing practices remain widespread, and unmanaged manure contributes to methane emissions, environmental degradation, and public health risks. Biodigesters offer a promising renewable energy solution, identified as one of eight key green technologies for climate resilience in Indonesia (Rose, 2024). At the household level, biodigester use aligns with circular economy principles by enabling resource recovery and waste minimization while contributing to climate change mitigation. These systems also reflect broader carbon management strategies, including Carbon Capture, Utilization, and Storage (CCUS), which could capture and store over 7 gigatons of CO_2 annually by 2050 (Rose, 2024).

In Manggarai, pig care carries a dual meaning: it is both a technical and economic practice and a deeply cultural one, embedded in ideas of exchange, ritual, and moral responsibility. Recognizing and integrating this body of local expertise into livestock development and biogas initiatives is crucial. By linking traditional practices with improved veterinary services, training in safe feed management, and greater awareness of biosecurity measures, programs can strengthen household resilience and improve the sustainability of pig-based biogas systems. The symbolic meaning of pigs also reflects a philosophy of work and the intimate relationship between people and the land. Because pigs forage by rooting in the soil (*hang tana* or *oncor tana*), they symbolize diligence and the farmer's

obligation to "eat the soil"—that is, to break, turn, and cultivate it. In local expression, a hardworking person is praised as *ata hang tana* (a person who "eats the soil"), underscoring how labor, creativity, and fertility are grounded in the act of working the land.

Pig farming remains central to rural livelihoods in Manggarai, functioning not only as a source of food and income but also as a means of saving and building social capital. Pigs are indispensable in ritual exchanges associated with weddings, funerals, dowries, and agricultural festivals, serving as markers of kinship solidarity and social identity. More than a material asset, the pig functions as a *cultural asset* that embodies values of creativity, fertility, and prosperity. In Manggarai cultural idioms, the pig is closely associated with femininity and fertility: a young woman is poetically referred to as *ela mbara* ("young pig"), connoting readiness for reproduction and continuity of life (Tukan et al., 2023; Dalle et al., 2023). Pig farming is thus not merely a livelihood strategy but also a symbolic practice that embodies women's labor, creativity, and role in sustaining both households and the wider community. Recognizing these cultural dimensions is essential for designing biogas interventions that are not only technically feasible but also socially resonant (Mittal et al., 2018).

Beyond these roles, pigs represent a strategic resource for renewable energy production. Each animal generates substantial amounts of manure, which, when properly managed, can serve as a reliable feedstock for household-scale biodigesters (Situmeang et al., 2022). Unlike firewood, which requires continuous, labor-intensive collection, pig manure is a by-product of routine livestock management, offering an energy source integrated into existing household practices. Interviews with livestock officers and veterinarians indicate that pig populations in Manggarai have increased steadily over the past decade, with many households raising between three and ten animals—sufficient to sustain domestic biogas systems. Additionally, the slurry by-product can be used as organic fertilizer, further enhancing agricultural productivity. Biogas is generated by anaerobic fermentation of organic matter, including livestock manure and household waste, by methanogenic bacteria that produce methane (CH_4) as the primary product. In Manggarai, pig manure represents a substantial yet underutilized resource for biogas production. Biodigester technology converts this waste into renewable energy and has been shown to improve household welfare and environmental management. Field observations indicate that biodigesters are commonly constructed from locally available materials and maintained through shared technical knowledge, resulting in relatively low operating costs. Informants further noted that biogas production is generally sufficient to meet daily cooking needs, particularly in households with three to five pigs.

Biodigester technology was introduced in Manggarai in 2014 by local experts Ir. Adi Lagur and Ir. Yunus Lagur, who developed integrated pig-farming systems combined with biodigester units (interview with Mr. L, June 2024). These initiatives produced lasting results and continue to operate successfully. The Ndajong family pioneered household-scale adoption in the same year. Subsequently, religious and pastoral institutions, such as the Mena Convent and the Ecopastoral Program in Pagal, expanded the use of biodigesters and integrated them with organic fertilizer production. At the provincial level, household-scale biogas development in East Nusa Tenggara began in 2010 through the Biogas Rumah (BIRU) program, initiated by Hivos–SNV in collaboration with Yayasan Rumah Energi (YRE), which introduced

domestic biodigester technology combining technical training, credit schemes through local cooperatives, and community-based capacity building (Yayasan Rumah Energi, 2017). Pig farming in Manggarai therefore operates at the nexus of economic activity, cultural practice, and energy transition, providing households with a multipurpose asset that encompasses income generation, social capital, and renewable energy.

In June 2024, a biogas development program based on pig manure was funded through the corporate social responsibility (CSR) budget of a state-owned enterprise. The program served as a pilot project for a single biodigester installation shared by two households, each required to own at least two healthy adult pigs. The program began by identifying households in proximity to ecopastoral Catholic communities that had already implemented biogas technology. Without accounting for the established division of labor in pig rearing, the project formally granted eligibility to male heads of household. In one instance, the beneficiary was a widow; however, the project still sought confirmation of an adult male relative in the home. Paradoxically, one designated household head was a truck driver who spent little time at home and engaged minimally in pig farming. These responsibilities were carried out daily by his wife; nevertheless, the assistance was formally awarded in his name.

Despite the positive reception, uncertainties persisted regarding the program's sustainability. A representative from the Manggarai District Livestock Office expressed skepticism, noting that many comparable initiatives had ceased after the installation phase and had not progressed to sustained biogas utilization. Drawing on this experience, the biodigester development team formulated an integrated technical assistance model encompassing pig rearing, system installation, and effective biogas utilization. The researcher observed that women's involvement was not considered at any stage of the program's design, with the development team treating women as peripheral actors.

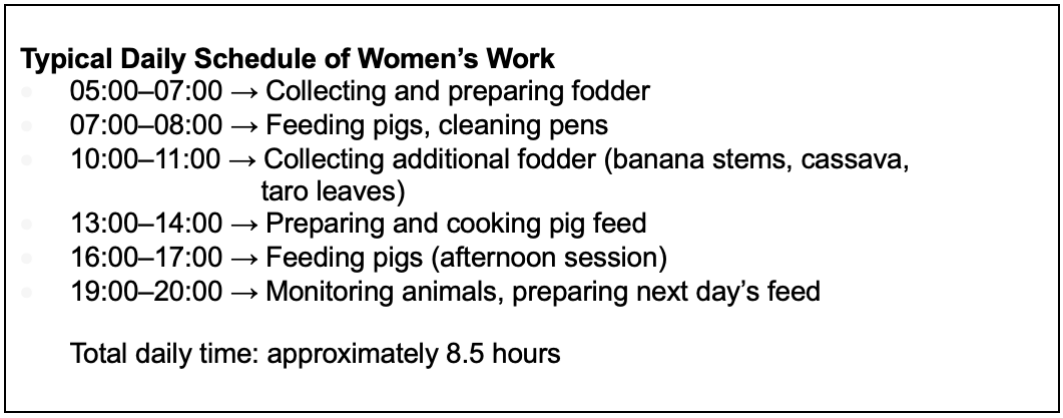
Local knowledge and practices in pig farming

Throughout the Global South, women and girls in rural and peri-urban areas are deeply involved in livestock systems (FAO, 2018). Analysis of women's daily schedules reveals the intensive labor demands of pig farming in Manggarai. Men are generally responsible for occasional tasks such as preparing agricultural land and constructing or repairing livestock pens and other infrastructure. However, these activities are typically carried out only occasionally and are not performed continuously on a daily basis. In contrast, women typically dedicate 8–9 hours per day to livestock-related tasks, interwoven with cooking, childcare, and household chores (Figure 2). The most time-intensive task is preparing pig fodder, which involves collecting, chopping, and cooking feed from cassava, banana stems, or taro leaves. Feeding occurs twice daily, while cleaning pens and monitoring animal health are routine responsibilities.

Reliance on firewood for cooking pig feed compounds women's workload, adding hours of labor each week and exposing them to smoke-related health risks. Women and girls are primarily responsible for gathering wood, reflecting the cultural association of cooking as a woman's duty (Arisanti, 1996). One informant mentioned that although they were accustomed to collecting firewood, the long hours and distances caused fatigue and unease, particularly when entering protected forest zones where collection is restricted (Sardjo et al. 2022; Sardjo, 2023).

Feeding practices reflect both ingenuity and adaptation to local ecological and

Figure 1: Research Sites



(Source: Information from participants)

economic constraints. Women typically prepare feed from crops harvested in home gardens, communal fields, and surrounding forests. Common ingredients include banana stems, cassava leaves, taro leaves and tubers, sweet potato vines, pumpkin, and *daun bunga kuning*. Feed is usually chopped and then either cooked or fermented in water-filled barrels for one day before distribution, a process that extends its usability for several days. Some households supplement these locally sourced materials with purchased inputs, such as commercial pig pellets (IDR 12,000/kg), rice or maize bran (IDR 8,000–11,000/kg), soybeans, leftover fish cooking oil, dried fish scraps, food waste from community feasts, and tofu residue (*ampas tahu*). This flexible mix demonstrates women's detailed knowledge of feed composition while also highlighting economic constraints, as purchased feeds are costly and of variable quality. Importantly, feed is not merely functional; preparing and sharing pig feed sourced from one's own land carries symbolic value, reflecting women's roles as mediators among household subsistence, ritual obligations, and community exchange (Rappaport, 1999; Rodgers, 2024). Culturally embedded approaches such as these enhance community acceptance and strengthen the long-term sustainability of energy transitions (Clancy & Dutta, 2019).

Pen hygiene and animal care vary considerably across households, with women primarily responsible for cleaning pens, bathing pigs, and releasing them into fields using bamboo harnesses (*julu*). However, cleaning often consists only of pouring water rather than thorough scrubbing, and only some households clean pens daily. Limited water availability—especially during the dry season—further constrains regular maintenance. In some cases, women bathe pigs only once every two weeks, occasionally using laundry or dish soap, which can irritate the animals' skin. Moist, uneven, or dirty pens frequently lead to injuries such as foot deformities, skin infections, or wounds. These practices suggest that although women farmers recognize the importance of hygiene, biosecurity awareness remains limited, increasing vulnerability to disease outbreaks (Nugraha et al., 2023).

Women farmers demonstrated extensive experiential knowledge of animal health, although explanations of disease causation remained limited. FGD participants reported gastrointestinal disorders (worms, diarrhea, constipation, and bloating), respiratory symptoms (sneezing and fever), and dermatological conditions such as lice,

piras (white patches), and *pok* (wounds and boils). One participant described her pig's severe health condition, which she believed were tumors. Another reported seizure accompanied by frothing at the mouth, attributed to poisoning from raw cassava or banana stems. Participants also noted the sudden collapse of livestock, with many deaths believed to be caused by viral diseases such as hog cholera and African swine fever (ASF). In the absence of a vaccine or effective treatment, on-farm biosecurity measures remain the only means of control (Dioney et al., 2020).

Pig farming also faces reproductive challenges, including stillbirths, premature piglet mortality due to inadequate milk supply, and maternal cannibalism. Locally, such events are interpreted not only as biological stress but also as signs of imbalance in household or communal relationships, reflecting the cultural connection between animal health and human well-being. In the absence of accessible veterinary services, women rely on ethnoveterinary and improvised remedies, such as mixing anthelmintics into feed, administering paracetamol for fever, giving milk to counteract poisoning, and applying coconut oil or Nona Mas balm to skin lesions. Economic constraints often compel women to sell sick pigs through the *julu* system, a traditional collective meat-sharing and marketing arrangement that also functions as a form of community solidarity. However, this practice carries risks of disease transmission, including the spread of ASF (FAO, 2020; Nugraha et al., 2022; Beltrán et al., 2017).

Gendered barriers to biogas adoption in Manggarai

Gender is a critical variable shaping access to and control over resources, interacting with class, culture, and ethnicity to influence ecological change and the prospects for sustainable development (Rocheleau, 1996). Gender–environment relationships operate across multiple scales, playing a crucial role in shaping access to energy, patterns of use, and control (Harcourt, 2019). Ding (2014), studying the gendered impacts of renewable energy in rural northwestern China, showed that although the program aimed to empower women through ownership, training, and access to finance, its impact was constrained by sociocultural boundaries, particularly the divide between public and private spheres.

In Manggarai, women's economic participation extends beyond subsistence to include contributions to customary ceremonies and collective practices such as *gotong royong*, which reinforce social cohesion. Access to financial resources is facilitated through *arisan* (rotating savings groups) and cooperatives, while government initiatives such as PKH (*Program Keluarga Harapan*) and village-level livestock provision programs provide additional support to poorer households, including widows. Women also contribute substantially to household income through agricultural wage labor and small-scale enterprises, such as selling *sopi* or operating coconut and coffee grating services. Their earnings, typically modest (around Rp 50,000 per day), are allocated to daily necessities, including food, water, electricity, and ritual obligations, with rice purchases representing the most burdensome expenditure. When the researcher asked participants why the women worked so hard to earn income and whether their husbands provided financial support, one woman responded, "Husbands give money when they are able. If there are daily needs, we must be prepared—this is normal; it is not a problem." Similar patterns of women's critical economic contributions have been documented in smallholder livestock systems across Asia (FAO, 2018). Furthermore, internalized gender norms

and the ethics of care contribute to women's reluctance to pursue entrepreneurial roles, reinforcing traditional labor divisions and limiting autonomy (Murali & Govindan, 2025).

Women farmers who participated in the FGDs were typically in their mid-thirties to late forties, with most having completed only primary or lower secondary education. Household sizes generally range from four to six members, and most households keep between three and ten pigs, alongside chickens or goats. Livestock contributes to rural livelihoods in multiple ways, including serving as a direct source of nutrition, income generation, capital storage, organic waste for improving soil fertility, and fuel and draft power (Do et al., 2019).

Pig farming constitutes a significant responsibility for women in rural Manggarai, often extending into late night or early morning hours. They regard this work as a customary female responsibility and consider it an essential duty given its economic and cultural significance. A telling expression of this commitment is that women will loudly remind other household members to look after the pigs carefully while they are away—sometimes, it seems, even more carefully than they remind them about the children.

Interviews with several housewives indicate that women play a central role in both the adoption and maintenance of biodigester technology. One woman enthusiastically described how she successfully expanded her pig husbandry and utilized biogas for cooking and lighting. She understood how to operate and regulate the biodigester system and felt fortunate to no longer incur expenses for electricity and cooking. Another informant expressed confidence that she could learn the technology with adequate training, while noting that financial assistance would still be necessary for installation. Community discussions in Nenu and Pagal reveal generally positive perceptions of household biogas, particularly among women, who value its role in reducing costs, easing the burden of firewood collection, and providing organic fertilizer. However, acceptance remains limited, as many people struggle to envision cooking with energy derived from pig waste, which is perceived as dirty. Many also believe that meals cooked over wood-burning stoves possess a distinctive flavor they traditionally value. Adoption thus remains constrained by high upfront costs, safety concerns, and cultural notions of impurity (Mittal et al., 2018).

Despite men's dominance in formal decision-making, their limited engagement in everyday energy use highlights a disconnect between authority and practice. Women's situated knowledge and daily labor make their perspectives central to the effectiveness of biogas initiatives. This tension reflects broader patterns in the literature showing that women's participation enhances clean energy transitions, yet they remain structurally excluded from resource governance (IRENA, 2020; Sovacool et al., 2018; Sovacool, 2016; Moser, 1993; Kabeer, 1999; Benería et al., 2015). In the research sites, men as household heads commonly work as farmers, with a small number employed as teachers or drivers, and more often engage in income-generating activities outside the home. Women are primarily responsible for pig farming and household energy management. This gendered division of labor mirrors findings from Asia, where women dominate daily household activities while men control external income opportunities (Nhung, 2021; Rodgers et al., 2024). In agricultural activities, men typically undertake major tasks such as land clearing, repairing irrigation channels, and constructing animal pens, while women commonly work as agricultural laborers and care for pigs and other livestock. Gender norms and social expectations continue to

restrict women's participation in renewable energy transitions. In the pilot biodigester initiative, the aid package was granted to male beneficiaries, while women—despite their pivotal involvement in pig husbandry—were not considered.

Feminist political ecology emphasizes that such inequalities are structurally embedded in rural development systems that privilege male authority and technical expertise over women's everyday ecological knowledge. The energy justice framework further illuminates how biogas adoption intersects with broader issues of equity and participation (Sovacool & Dworkin, 2015). Furthermore, gender inequality and energy injustice are closely intertwined, particularly in households with low energy consumption. Providing clean cooking solutions and equitable energy access can empower women, improve their quality of life, and advance gender equality (Falcon & Errichiello, 2025).

The Manggarai case therefore calls for a shift from viewing women as passive beneficiaries to recognizing them as key actors in energy transitions. Advancing this goal requires embedding women in decision-making processes, expanding access to gender-responsive financing, and strengthening inclusive training and extension services. Addressing these structural inequalities is essential not only for improving adoption rates but also for advancing more just and sustainable energy systems (FAO, 2018; Rodgers et al., 2024). Sustainable low-carbon pathways must incorporate principles of equity, recognition, and participation to achieve lasting social and environmental outcomes (Johnson et al., 2020). Within the human rights framework, energy justice seeks to ensure universal access to energy for well-being and a healthy environment (Basil & Heffron, 2025). Strengthening women's capacities through targeted training is critical for sustaining and scaling biogas initiatives in Manggarai, consistent with broader evidence linking women's participation to increased renewable energy uptake and improved community well-being (Sovacool et al., 2018; IRENA, 2020; Cellini et al., 2025).

Conclusion

The Manggarai case shows that the household is a critical arena where energy transitions unfold through gendered labor, authority, and everyday practices. Biodigester adoption improved access to affordable energy, reduced reliance on firewood, and lowered women's time burdens, yet access and benefits remain uneven due to livestock ownership, financial capacity, and culturally unequal relations between men and women. Community-based biodigester program implementation reflects participatory governance, but women's central role in everyday energy use does not automatically translate into equal participation in training or decision-making. Although biodigesters align well with local livelihoods and knowledge systems, technical authority remains male-dominated, risking the marginalization of women's experiential knowledge.

The case suggests that energy justice outcomes are inseparable from gendered socio-ecological power relations. Feminist political ecology deepens energy justice by revealing that distributive, procedural, and recognition justice are co-produced within the household and community through gendered access to resources, knowledge, and authority. Distribution is shaped not only by technology access but by gendered assets and social hierarchies. Procedure depends not just on participation, but on who holds influence and technical authority. Recognition requires valuing situated and gendered knowledge within energy

systems. Together, this intersection implies that sustainable energy transitions are not merely technological or economic processes but socio-political transformations. Achieving energy justice therefore requires embedding gender equity into the design, governance, and knowledge systems of energy initiatives—ensuring that women's roles as primary energy users translate into equitable access, decision-making power, and recognition. The key practical takeaway is that energy projects must be designed as social transformation programs, not just technical interventions. Embedding gender equity into financing, training, governance, and knowledge systems is essential for achieving durable and just energy transitions.

Declaration of Ownership

This article is our original work.

Conflict of Interest

There is no conflict of interest to declare in this article.

Ethical Clearance

This study was approved by the institution.

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