

DIENG GEOTHERMAL POWER PLANT (PLTP) IN THE SUSTAINABLE DEVELOPMENT NARRATIVE: A PHENOMENOLOGICAL STUDY IN PAWUHAN HAMLET, INDONESIA

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Abstract:

The transition toward renewable energy is frequently framed as a pathway to achieving sustainable development and reducing carbon emissions. However, renewable energy projects may generate complex social, economic, and environmental consequences for communities living around energy infrastructure. This study examines how local communities experience the sustainability implications of the Dieng Geothermal Power Plant and explores the interaction between these experiences and the Sustainable Development Goals. Using a qualitative phenomenological approach, the research was conducted in Pawuhan, Banjarnegara, Indonesia. Data were collected through semi-structured in-depth interviews, participant observation, and documentation involving local residents with diverse social and economic backgrounds. Thematic analysis was employed to identify patterns in community experiences across social, economic, and environmental dimensions. The findings reveal that the Dieng Geothermal Power Plant creates economic opportunities through employment, supporting businesses, and increasing land values, although these benefits are unevenly distributed. At the same time, communities experience declining trust, limited participation, perceived environmental risks, and rising adaptation costs related to water, agriculture, and household conditions. The study concludes that geothermal development cannot be evaluated solely through its contribution to clean-energy provision. A sustainable energy transition requires equitable benefit distribution, meaningful community participation, and environmental governance that recognizes local experiences and vulnerabilities. These findings challenge the assumption of an automatic correspondence between renewable energy and sustainable development and demonstrate that an energy transition undertaken as part of sustainable development can also generate new forms of socioeconomic inequality and environmental injustice.

Keywords: Community Experience, Geothermal Power Plant, Sustainable Development, Clean Energy

INTRODUCTION

The climate crisis is one of the major global challenges, driven largely by increasing greenhouse gas emissions resulting from the dominant use of fossil energy sources such as coal, oil, and natural gas (Laskurain et al., 2015; Liu et al., 2024; Mose, 2018; Sovacool & Walter, 2018; Wu, 2023). Dependence on fossil energy not only increases global temperatures and intensifies the climate crisis, but also generates various environmental problems, including air pollution, natural disasters, and disruptions to ecosystem balance (Gan et al., 2023). Accordingly, the transition toward New and Renewable Energy sources has become an important global agenda and a key strategy for reducing environmental pressures, particularly those associated with the climate crisis, while simultaneously meeting the continuously growing energy needs of society (Beer, 2015; Davtyan & Khachikyan, 2024; Dincer, 2000).

The development of New and Renewable Energy has consequently become an important component of the global sustainable development agenda, particularly through Sustainable Development Goal (SDG) 7



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concerning affordable and clean energy (Dincer, 2000; Laskurain et al., 2015). However, the energy transition as part of the sustainable development agenda should not focus solely on shifting from fossil fuels to renewable energy; it must also maintain a balance among social, economic, and environmental dimensions throughout the development process. In line with this principle, geothermal development as one form of renewable energy development needs to be assessed multidimensionally, because the sustainability of an energy industry is determined not only by its contribution to low-carbon energy provision, but also by its capacity to improve community socioeconomic welfare and safeguard environmental sustainability in surrounding operational areas (Anggreta et al., 2022; Shortall et al., 2015).

Geothermal development occupies a strategic position in Indonesia because the country has substantial geothermal potential as part of the Pacific Ring of Fire, placing Indonesia among the countries with the world's second-largest geothermal reserves (Alamsyah et al., 2024; CELIOS-WALHI, 2024). This potential has encouraged the government to position geothermal energy as an important component of the national energy-transition policy and the national renewable energy -mix target. One project representing geothermal-energy development is the Dieng Geothermal Power Plant (PLTP) in Banjarnegara, Central Java, which is managed by PT Geo Dipa Energi, a state-owned enterprise under the Ministry of Finance (CELIOS-WALHI, 2024).

Although the Dieng Geothermal Power Plant is currently positioned as part of Indonesia's national sustainable-development agenda in the energy sector (SDG 7), its existence must be understood within a historical context. The plant has operated commercially since 2002, while the initial development of the Dieng geothermal area took place from the 1970s to the 1990s through cooperation among Himpurna California Energy (HCE), PLN, and Pertamina (Alamsyah, Maratama, Siti, et al., 2024). Thus, the Dieng Geothermal Power Plant was not originally developed as a direct response to global or national energy-transition targets, given that the global sustainable-development agenda through the SDGs began to be implemented in 2016, long after the plant had commenced operations. The Dieng Geothermal Power Plant was subsequently recontextualized as part of renewable energy provision in achieving SDG 7 under Indonesia's National Energy Policy (KEN) (Alamsyah et al., 2024; CELIOS-WALHI, 2024; GDE Report, 2024).

This recontextualization gives new meaning to the Dieng Geothermal Power Plant as part of renewable energy infrastructure within the national sustainable-development agenda. It also indicates a possible gap between sustainable-development policy and the lived experiences of local communities. This change in meaning is important to examine because the sustainability of a renewable energy project should be understood not only through the way the project is constructed within the national policy agenda, but also through how communities that have long lived alongside it experience, interpret, and respond to the social, economic, and environmental changes associated with the project.

The sustainable-development paradigm emphasizes that sustainable development in the energy sector must consider the interrelationships among social, economic, and environmental dimensions in a balanced manner (Elkington, 1998; Ramasubramanian & Ramakrishna, 2023; Shortall et al., 2015; Vargas-Payrera, 1984; Wosiak, 2021; Youth & Camp, n.d.). The social dimension concerns community acceptance, social legitimacy, information transparency, open communication, and meaningful participation; the economic dimension concerns the distribution of employment opportunities, supporting businesses, and asset improvement; and the environmental dimension concerns changes in ecosystems that support communities' daily needs (Abdi et al., 2025; Anggreta et al., 2022; Cook et al., 2019b; Greiner et al., 2023; Ibrohim et al., 2019; Pambudi, 2018; Renoth et al., 2023; Wachowicz-Pyzik et al., 2024; M. N. Wahid et al., 2025). Therefore, geothermal-energy development cannot be understood solely in terms of its contribution to renewable energy provision, but must also be examined through its effects on community welfare, the distribution of economic benefits, and environmental sustainability in surrounding operational areas.

Previous studies on geothermal power plants have often examined the environmental dimension through geothermal energy's contribution to decarbonization and carbon-emission reduction, while the

economic dimension has been associated with increased investment, job creation, and contributions to regional revenue (Cook et al., 2019; Greiner et al., 2023; Wachowicz-Pyzik et al., 2024; Pusat Studi HAM UII, 2026). In the social dimension, several studies have highlighted spatial conflicts, community acceptance, and concerns regarding environmental and safety risks as well as disruptions to social and spiritual values resulting from geothermal-power development (Ibrohim et al., 2019; SAVIRA, 2023; N. Wahid et al., 2025a). However, these studies tend to identify the impacts and benefits of geothermal plants across separate social, economic, and environmental dimensions and have rarely examined in depth how communities living around operational areas interact with, adapt to, and construct meanings around the presence of geothermal facilities and the accompanying social, economic, and environmental changes.

This study addresses that gap by exploring the experiences of the Pawuhan community in Batur, Banjarnegara, which lives alongside the Dieng Geothermal Power Plant. These experiences are organized into three dimensions—social (people), economic (profit), and environmental (planet)—in accordance with the Triple Bottom Line framework to understand their interrelated dynamics within a sustainable-development project (Elkington, 1998). These three dimensions are not treated as independent elements, but as interconnected components of community experience. The Nilsson Scale is further used to analyze interactions between research findings across the social, economic, and environmental dimensions and the relevant Sustainable Development Goals (SDGs), by identifying interactions that either reinforce or constrain one another (Nilsson et al., 2018). Together, these two frameworks allow the study to place community experience at the center of an exploration of what sustainability means in a geothermal-energy project from the perspective of local communities. In this study, sustainability is defined not merely by success in providing low-carbon energy, but also by balanced improvements in socioeconomic welfare and environmental protection (Elkington, 1998).

On this basis, the study aims to: (1) explore the lived experiences of communities living alongside the activities of the Dieng Geothermal Power Plant, categorized into social, economic, and environmental dimensions; and (2) analyze interactions among findings across these three sustainability dimensions and relevant SDGs using the Nilsson Scale. Practically, the findings are expected to provide a basis for developing geothermal-energy governance that is more participatory, transparent, and equitable for all community members.

METHODS

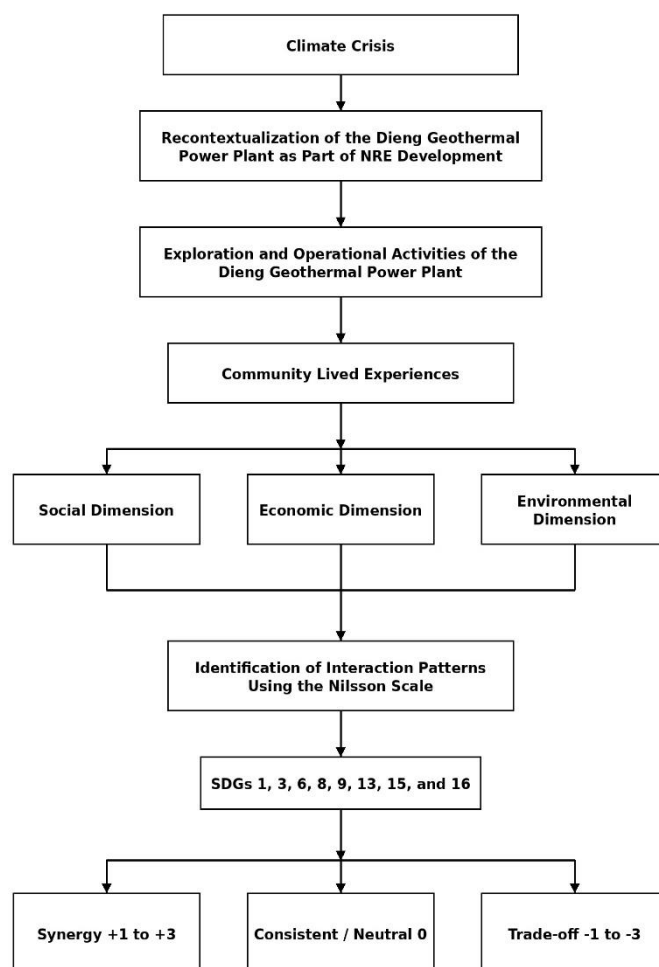


Figure 1. Research Conceptual Framework

As illustrated in Figure 1, the study is built on a conceptual pathway linking the climate crisis to the development of New and Renewable Energy as a form of climate mitigation, represented in this study by the Dieng Geothermal Power Plant. The research framework places social, economic, and environmental dimensions at the center of the analysis of the sustainable-development paradigm surrounding the plant's activities from the perspective of local communities. It then identifies patterns across the three dimensions and relates them to relevant SDG targets using the Nilsson Scale, which classifies interactions into three principal categories: synergy, consistent/neutral, and trade-off.

This study employs a qualitative research design with a phenomenological approach. Phenomenology was selected because it enables social reality to be understood through community experiences, perceptions, and meanings (Husserl, 2001; Tarditi, 2024). It recognizes human experience as a primary and legitimate source of knowledge. Accordingly, the phenomenological approach enables this study to understand the phenomenon contextually through the perspectives of local residents who live alongside geothermal-industry activities.

Within the phenomenological process, the researcher applied bracketing by consciously suspending prior assumptions, knowledge, and judgments concerning the geothermal power plant and its impacts. This was particularly important because the researcher is not a member of the Pawuhan community and the researcher's daily life is not directly connected to the activities of the Dieng Geothermal Power Plant;

consequently, informants' experiences were positioned as the primary source for understanding the phenomenon. Potential bias was reduced through researcher reflexivity during data collection and analysis, by avoiding the imposition of predetermined categories or conclusions, repeatedly reading informants' narratives, and comparing information through source and technique triangulation as applied in this study. Informants' subjective experiences were not merely grouped into themes; they were further analyzed by tracing similarities in experience, experiential structures, context, emotions, and meanings emerging from their narratives in order to identify the essential structure of the community's lived experience of coexisting with the Dieng Geothermal Power Plant.

The research was conducted in Pawuhan Hamlet, Karangtengah Village, Batur District, Banjarnegara Regency, Central Java. The site was selected purposively because it is located near the operational area of the Dieng Geothermal Power Plant and the Pawuhan community has directly experienced the dynamics of daily life associated with geothermal exploration and plant operations for at least two decades. Site selection also considered the community's relationship with the three sustainability dimensions that form the focus of this study: social, economic, and environmental.

The primary unit of analysis is the lived experience of the Pawuhan community in encountering the activities of the Dieng Geothermal Power Plant in everyday life. The units of observation include individuals and community groups with direct experience of social, economic, and environmental changes perceived to be associated with the plant. Informants were selected through purposive sampling according to several criteria: they had lived or conducted daily activities around the Dieng Geothermal Power Plant area for at least the previous 15–20 years and had experience of social, economic, and environmental changes perceived to be related to the plant's activities. Informants with diverse socioeconomic backgrounds were selected to obtain varied perspectives on community experiences across the three dimensions and to identify potential patterns of inclusion and exclusion (Creswell, 2017). The profiles of informants from different backgrounds are presented below:

Informant Code	Gender	Age	Primary / Secondary Occupation	Informant Position and Perspective
PR-01	Male	54 years	Farmer; secondary activities as a used-car broker and boarding-house owner	Resident affected by the Dieng Geothermal Power Plant who provides perspectives on social, economic, and environmental dimensions
BM-02	Female	50 years	Farmer, homemaker, and boarding-house business owner	Resident affected by the Dieng Geothermal Power Plant who provides perspectives on social, economic, and environmental dimensions
PW-03	Male	46 years	Farmer and on-call construction laborer (casual worker)	Resident affected by the Dieng Geothermal Power Plant who provides perspectives on social, economic, and environmental dimensions
MR-04	Female	27 years	Homemaker	Member of a farm-laborer household who provides perspectives on household economics, women's

				participation, and the social, economic, and environmental impacts of the geothermal plant
BS-05	Female	60 years	Farmer and homemaker	Resident affected by the Dieng Geothermal Power Plant who provides perspectives on social, economic, and environmental dimensions
PG-06	Male	35 years	Head of Pawuhan Hamlet	Head of Pawuhan Hamlet who provides perspectives on general community conditions, community forums, complaint mechanisms, and relations with the company
PRN-07	Male	62 years	Farmer	Farmer affected by the Dieng Geothermal Power Plant who provides perspectives on changes in agriculture and other social, economic, and environmental changes
PT-08	Male	59 years	Farmer	Neighborhood-unit head and farmer who provides perspectives on community conditions, community forums, the articulation of aspirations, and relations with the company
PS-09	Male	55 years	Farmer	Resident affected by the Dieng Geothermal Power Plant who provides perspectives on social, economic, and environmental dimensions
MA-10	Male	24 years	Tourism-sector worker	Young person working in tourism and active in a religious organization, providing perspectives on youth roles, social activities, and employment opportunities outside agriculture
MF-11	Male	29 years	Leader of an anti-geothermal movement	Leader of opposition to geothermal development who provides perspectives on the history of resistance, community aspirations, and barriers to organizing collective action
MD-12	Male	25 years	Leader of an anti-geothermal movement	Leader of opposition to geothermal development who provides perspectives

				on community movements, perceived risks, and efforts to advocate for affected residents
PB-13	Male	45 years	Head of a farmer group	Farmer-group leader who provides perspectives on agricultural activities perceived to be associated with geothermal operations, compensation claims, and the distribution of compensation
PWZ-14	Male	38 years	Farmer	Resident affected by the Dieng Geothermal Power Plant who provides perspectives on social, economic, and environmental dimensions
SPT-15	Female	36 years	Farmer	Resident affected by the Dieng Geothermal Power Plant who provides perspectives on social, economic, and environmental dimensions

Data were collected through semi-structured in-depth interviews, participant observation, and documentation. In-depth interviews were conducted using an interview guide developed from the research objectives and lasted approximately 45–90 minutes. A semi-structured format was used so that the researcher maintained a clear direction for questioning while allowing informants sufficient space to describe their experiences and perspectives in greater depth.

In addition to interviews, participant observation was used to obtain a direct understanding of community life. The researcher engaged with the community's social environment to observe daily activities, social conditions, economic activities, agricultural practices, environmental conditions, and the ways in which residents interpreted the presence of the Dieng Geothermal Power Plant. Observation served as supporting evidence so that interpretation was not based solely on informants' statements but also on conditions encountered in the field. Documentary analysis complemented the research data through field notes and archival documents related to the study site and the activities of the plant. Documents analyzed included records from local and central government institutions as well as reports issued by PT Geo Dipa Energi as the operator of the Dieng Geothermal Power Plant.

Data were analyzed using thematic analysis through several stages: repeated reading of the data, coding, grouping codes into themes, defining themes, and constructing interpretive narratives concerning relationships among themes (Braun & Clarke, 2024). The thematic coding process combined deductive and inductive approaches. The deductive approach referred to the three Triple Bottom Line dimensions – social, economic, and environmental – so that community experiences were initially organized into these categories. Within the interview data, the researcher identified quotations related to major themes such as social acceptance, community participation, distribution of benefits and burdens, economic opportunities, household expenditure, agricultural change, water quality, soil conditions, air quality, and environmental safety. At the same time, the inductive approach was used to identify patterns, experiences, and meanings emerging from informants' accounts without restricting analysis to the three predetermined dimensions.



The study was conducted throughout 2025–2026. The research stages included a literature review, preliminary observation of the site and research themes, preparation of research instruments, field data collection, informant interviews, environmental observation, data analysis, and preparation of the research findings. Data credibility was strengthened through source and technique triangulation by comparing information obtained from interviews, observations, and documentation, thereby producing a more comprehensive understanding of local community experiences regarding the presence of the Dieng Geothermal Power Plant.

RESULTS AND DISCUSSION

This study involved 15 informants from diverse socioeconomic backgrounds. They included farmers, homemakers, casual daily laborers, tourism-sector workers, hamlet officials, neighborhood-unit leaders, a farmer-group leader, and residents who had previously participated in initiating opposition to activities of the Dieng Geothermal Power Plant because these activities were perceived to threaten the environmental sustainability of their living area. All informants lived and carried out their daily activities in Pawuhan Hamlet, Karangtengah Village, Batur District, Banjarnegara Regency. This diversity enabled the study to capture community experiences from different social positions, particularly in relation to dependence on economic access and resources, social involvement, and proximity to geothermal activities. Community experience was therefore not treated as uniform, but as lived experience shaped by each informant's position and background.

The analysis was organized into three principal dimensions: social, economic, and environmental experience. In the social dimension, community experience was characterized by latent opposition, fragmented participation, perceptions of injustice in the distribution of benefits and burdens, and deteriorating relations between residents and the company operating the Dieng Geothermal Power Plant. The economic dimension revealed new opportunities through employment, supporting businesses, and rising land values; however, these benefits coexisted with increased household expenditure, constraints on livelihood diversification, and unequal access to economic opportunities. The environmental dimension emerged through perceived changes in water quality and agricultural soils, odor disturbances, corrosion of household materials, and growing uncertainty regarding the safety of the living environment. These three dimensions are interconnected: environmental changes experienced by residents may develop into greater economic burdens and subsequently influence social relations, including community acceptance and the social legitimacy of geothermal activities.

Community Social Experiences: Erosion of Trust and Low Social Acceptance of Dieng Geothermal Power Plant Activities

The lived experiences of Pawuhan residents demonstrate that geographical proximity to the Dieng Geothermal Power Plant does not necessarily produce harmonious social relations with the operating company. Although residents have lived alongside geothermal exploration and operations for a long period, their experiences indicate a widening social distance. Four major patterns emerged within the social dimension: latent opposition to plant operations after repeated frustrations in conveying aspirations; fragmented community participation; perceptions of injustice in the distribution of benefits and burdens; and deteriorating relations between residents and the company. These patterns are interconnected and collectively form a sequence of experiences that has gradually reduced community trust in the activities of the Dieng Geothermal Power Plant.

In recent years, community opposition has not always taken the form of demonstrations or open mobilization. Many Pawuhan residents have chosen silence, resignation, and withdrawal from actively voicing complaints. Within a phenomenological approach, this attitude must be understood in relation to the experiences that produced it. Silence does not necessarily signify acceptance; in this case, it reflects the

opposite. Residents became silent after perceiving that previously expressed aspirations had failed to generate meaningful change. This experience is illustrated by the following statement:

"We actually do reject it. We are just silent. What else can we do? We do not have the capacity to protest." (PR-01, Pawuhan Hamlet, 20/6/2026).

Another informant described a similar experience.

"Yes, what can we do? We simply resign ourselves to it. Complaining feels pointless; no matter how serious the complaint is, it is ignored." (MR-04, Pawuhan Hamlet, 20/6/2026).

This fatigue was not merely an individual experience; it was also linked to collective experiences in previous years. One informant explained that residents had previously voiced their concerns together with academics, civil-society organizations, and activists and had undertaken various forms of opposition, but those experiences ultimately created negative memories for the community, as reflected in the following account:

*"We are already fed up; physically and emotionally, we no longer want to engage. Talking here and there produced no results. Around 2015 there was a forum where many people spoke up, but we were ignored. At that time we were assisted by students from *** [a well-known university] and by community organizations, yet the study findings were rejected outright by Geo Dipa. Then the men who were vocal in demonstrations were directly offered permanent jobs by Geo Dipa. As a result, people are now much less active in voicing complaints and demonstrations have become rare." (PT-08, Pawuhan Hamlet, 21/6/2026).*

These experiences show that latent opposition is not merely a passive form of disagreement, but reflects exhaustion after residents repeatedly expressed aspirations without receiving responses they considered adequate or satisfactory. In their experience, speaking out was no longer perceived as capable of influencing company action, and resignation emerged as a form of withdrawal from a communication process that had lost meaning for some residents. Thus, the important social experience is not only the existence of opposition, but also its transformation from open resistance into a more concealed form.

Community participation also displayed a fragmented pattern. Social forums such as routine religious gatherings continued to take place, but issues related to the geothermal power plant were not discussed consistently. Conversely, forums initiated by the company were perceived by residents as being held only at certain times, particularly when the company had specific needs or agendas requiring formal community legitimacy. As a result, no regular and independent space for dialogue had developed through which residents could collectively articulate their experiences and aspirations.

"People in Pawuhan actually still oppose it. The problem, as I see it, is that there is no forum, and most residents are reluctant to speak out on their own." (MF-11, Pawuhan Hamlet, 24/6/2026).

The limitations of available forums were also reflected in patterns of interaction that remained divided across particular social groups.

"Here, solidarity tends to exist within each neighborhood unit. Even religious gatherings are sometimes divided into two groups: RT 1 to RT 3 and RT 4 to RT 5. We are not very cohesive." (BM-02, Pawuhan Hamlet, 20/6/2026).

Meanwhile, one informant considered communication with the company to intensify primarily when particular interests were involved.

"Before the planned Dieng 2 drilling in Karangtengah, there was a lot of socialization and every neighborhood unit was gathered. After that was finished, there was nothing anymore. People here are never approached unless the company needs something." (PR-01, Pawuhan Hamlet, 20/6/2026).

These experiences indicate that residents do not fully understand participation as a process that gives them the capacity to influence decisions. Participation is more often experienced as temporary involvement whose timing is largely determined by the company's agenda. The absence of regular social forums or dialogue spaces keeps individual community experiences separated, thereby limiting the formation of a collective voice. This condition also helps explain why opposition persists but does not always develop into open collective action.

The social dimension was also shaped by perceptions of injustice in the distribution of benefits and burdens. Residents live in very close proximity to geothermal infrastructure but do not directly experience the energy benefits of the power plant located alongside them. According to several informants, the electricity used by the community comes from the Garung Hydroelectric Power Plant, approximately 30 km from Pawuhan. Even public facilities such as hamlet street lighting and cemetery lighting, although connected to electricity associated with the Dieng geothermal system, must still be fully paid for using hamlet funds.

"Yes, that is correct. The electricity here has indeed come from the Garung Hydroelectric Power Plant for a long time."
(PG-06, Pawuhan Hamlet, 20/6/2026).

This experience became more striking when residents compared their very close geographical proximity to the Dieng Geothermal Power Plant with the absence of direct electricity benefits from it.

"We asked for electricity because that place is a power plant. Geothermal energy produces electricity. We only asked for electricity for public facilities, but it was not provided. For example, the cemetery is directly opposite the Geo Dipa office; the cable would not even need to run 50 meters, but they still did not provide lighting for the cemetery. In the end, it is supplied through our own hamlet prepaid meter, together with the streetlights in the alley. We pay for it ourselves every month using hamlet funds for those public facilities." (PW-03, Pawuhan Hamlet, 20/6/2026).

Perceived injustice also emerged in the distribution of compensation and company programs. Several informants believed that proximity to the company or to local elites could influence access to benefits. These experiences subsequently fostered suspicion regarding the transparency of assistance distribution.

"That is how compensation is handled. The company relies on certain local individuals who are close to the company. For example, if Rp100,000 comes from the central level, by the time it reaches us it may be only Rp10,000 or Rp1,000. It is like flowing water; much is left behind along the way. For example, after the Pad-30 blasting in 2016, each person received compensation of Rp500,000. Later we found out that the actual compensation was larger than that amount, but because of what I described, the amount that reached residents was not what it was supposed to be." (PT-08, Pawuhan Hamlet, 21/6/2026).

"There used to be compensation once. It happened around the time of the village-head election. Each household received 50 sheets of roofing material, but that was all. It was not sustained." (PB-13, Pawuhan Hamlet, 21/6/2026).

From a phenomenological perspective, these issues show that justice is not interpreted solely in terms of the amount of assistance received. For residents, justice also concerns transparency, continuity of benefits, equal access, and recognition of their position as the group living closest to geothermal-industry activities. When burdens and losses perceived to result from the operation of the Dieng Geothermal Power Plant continue to be experienced while benefits are considered unevenly distributed, residents construct an understanding that the development relationship has not been fully equitable.

The accumulation of these experiences was reflected in the deteriorating relationship between residents and the company. Some informants perceived the company as more active when it required community support for project activities, whereas residents' complaints did not always receive responses considered adequate.

"Regardless of how much risk the community feels, complaints are not responded to. Problem after problem, even when it eventually leads to demonstrations, produces no result." (PW-03, Pawuhan Hamlet, 20/6/2026).

Tensions also arose during the submission of claims for agricultural damage. Residents considered company assessments not always consistent with the calculations they submitted.

"When farmers submit damage claims, they bring data and photographs. If the damage is 100%, the company usually calculates compensation for only around 25% to 30%. Payment can also take five to seven months, even though farmers need working capital quickly." (PG-06, Pawuhan Hamlet, 20/6/2026).

The findings show that communication between Pawuhan residents and the company still exists, but it does not always generate a sense of being heard, understood, or trusted. The deteriorating relationship was not produced by a single incident, but by an accumulation of experiences over at least two decades of living alongside the Dieng Geothermal Power Plant. Latent opposition, weak participatory forums, perceptions of injustice, and complaints considered unresolved gradually accumulated and contributed to the erosion of community trust in geothermal-industry activities and in the company operating the plant.

Previous research on geothermal-energy development shows that the presence of New and Renewable Energy industries does not necessarily produce harmonious relationships with local communities, even when such projects are presented as sustainable development that is socially, economically, and environmentally beneficial. Social conflict in energy projects often emerges not simply because energy infrastructure exists, but because communities experience an imbalance between the benefits they receive and the risks they bear and because they are excluded from decision-making processes (Anggreta et al., 2022; SAVIRA, 2023). The experiences of the Pawuhan community around the Dieng Geothermal Power Plant reveal a similar pattern, in which residents perceive a gap between their position as those living closest to energy activities and their capacity to influence how the project is managed.

This phenomenon can be analyzed through the perspective of energy justice (Jenkins et al., 2016). Energy justice emphasizes that an energy transition is not only concerned with the provision of clean energy but must also address social justice throughout project development and operation. It encompasses three dimensions: distributional justice, concerning the fair distribution of benefits and burdens; procedural justice, emphasizing community involvement in decision-making processes; and recognition justice, which acknowledges the experiences, needs, and vulnerabilities of affected groups. From this perspective, the success of an energy project cannot be assessed solely according to its contribution to low-carbon energy provision. It must also be evaluated according to whether local communities receive benefits that are equitable in relation to the risks they bear, have meaningful opportunities to participate, and receive recognition for their experiences of living alongside energy infrastructure.

In the Pawuhan context, the findings indicate problems across all three dimensions of energy justice. In terms of distributional justice, residents perceive an imbalance between the benefits and burdens generated by the Dieng Geothermal Power Plant: communities living closest to the energy facilities have not experienced comparable direct benefits, while bearing part of the risks and adaptation costs in everyday life. In terms of procedural justice, opportunities for participation are limited because communication with the company has not fully enabled residents to influence decisions concerning plant activities; consequently, some residents have chosen silence after concluding that their expressed aspirations did not produce meaningful change. In terms of recognition justice, residents feel that their concerns regarding the environment, agriculture, and the sustainability of their living space have not been fully acknowledged in energy-project management. These experiences show that social issues surrounding the Dieng Geothermal Power Plant concern not only the existence of an energy project, but also how residents perceive their position in the distribution of benefits, decision-making processes, and recognition of the vulnerabilities they experience.

The accumulation of these experiences of injustice subsequently affects social relations between the community and the company. Under Social License to Operate (SLO) theory, social acceptance of a project is determined not only by formal permits, but also by levels of acceptance ranging from withheld/withdrawn, to acceptance, approval, and psychological identification (Boutilier & Thomson, 2011; Gehman et al., 2017). Higher levels of acceptance require social legitimacy, perceptions of fairness, tangible benefits, and interactional trust between companies and communities. Accordingly, the low level of social acceptance among Pawuhan residents toward activities of the Dieng Geothermal Power Plant can be understood as a consequence of accumulated experiences of injustice.

When interpreted through SLO theory, the experience of the Pawuhan community tends to fall within the withheld or withdrawn level. Silence cannot be interpreted as acceptance because it emerged after repeated failures of communication. Some residents who obtained jobs or boarding-house business opportunities may be positioned at the most basic level of acceptance, but these experiences do not represent the condition of the community as a whole. Thus, the central issue within the social dimension is not merely low acceptance of the Dieng Geothermal Power Plant, but an ongoing erosion of trust rooted in experiences of injustice.

The practical implication of the social dimension is that management of the Dieng Geothermal Power Plant needs to strengthen more equitable energy-governance mechanisms through regular dialogue forums, transparent information distribution, fair distribution of benefits, and community involvement in decision-making. Rebuilding community trust cannot rely solely on compensation programs; it also requires recognition of community experience as an important component of the sustainability of New and Renewable Energy projects within the broader sustainable-development agenda.

Livelihood Vulnerability and Uneven Economic Benefits

The economic experiences of Pawuhan residents reveal two sides of the same coin. On the one hand, the Dieng Geothermal Power Plant has created opportunities through employment, boarding-house businesses, and rising land values. On the other hand, residents also face increasing household costs, limited access to new opportunities, and continued strong dependence on agriculture. The presence of economic opportunities therefore cannot automatically be interpreted as an overall improvement in community welfare. More important is how these benefits are distributed and the extent to which residents are able to sustain their livelihoods amid ongoing change.

Increased household expenditure is among the most tangible economic experiences. Residents must allocate income to needs that could previously be met at lower cost, particularly water, maintenance of pipeline networks, home repairs, and other domestic necessities. Several informants described these changes as follows:

"When mountain water is unavailable, we buy bottled water for drinking. Well water is used only for bathing and washing because it no longer tastes good." (BM-02, Pawuhan Hamlet, 20/6/2026).

"When the mountain water does not flow, we buy bottled water at the shop. One Rp20,000 gallon lasts only one day, and the next day we exchange it again. When the pipeline from Mount Prau to Pawuhan was built, the company provided two rolls of pipe, but each household was still asked to pay Rp100,000 for installation and connection costs." (BS-05, Pawuhan Hamlet, 25/6/2026).

"Drinking water is brought from far away on Mount Prau. We pay Rp5,000 per cubic meter." (PRN-07, Pawuhan Hamlet, 25/6/2026).

In addition to water, the cost of maintaining household materials has become part of residents' everyday economic experience.

"Around here, corrugated-metal roofs generally corrode quickly. At least once a year we have to repaint the metal with an asphalt-based material to prevent corrosion." (PB-13, Pawuhan Hamlet, 21/6/2026).

Additional costs are even experienced in simple domestic activities.

"When washing clothes, even if we use a lot of detergent, it still does not foam. The same happens when washing dishes; glassware does not feel properly clean or dry." (SPT-15, Pawuhan Hamlet, 21/6/2026).

These experiences demonstrate that environmental changes perceived by residents have concrete economic consequences. Such additional costs are not entirely productive investments, but rather adaptive expenditure required to maintain basic needs. At the household level, this means that part of household income must be diverted from savings or productive needs toward additional adaptation expenses.

Nevertheless, the presence of the geothermal plant has also generated economic opportunities. Renting rooms or boarding houses to project workers is one form of benefit that has emerged. However, these opportunities are more readily utilized by residents who already possess assets, capital, or social networks.

"In addition to farming and working as a broker, this boarding house is also a source of supplementary income." (PR-01, Pawuhan Hamlet, 25/6/2026).

"There are also permanent company employees here who additionally own quite a number of boarding-house units." (PG-06, Pawuhan Hamlet, 25/6/2026).

"There is also a village official who works as the treasurer and runs a boarding house occupied by quite a number of geothermal-company workers; the family is also known to be close to the company." (SPT-1, Pawuhan Hamlet, 21/6/2026).

These quotations show that economic opportunities do exist, but access to them is uneven. Ownership of housing and land, initial capital, and social networks create different capacities among residents. For groups lacking these forms of capital, the emergence of new economic opportunities or activities does not necessarily transform their livelihood structure.

Barriers to livelihood diversification further reinforce the community's dependence on a single livelihood sector. Most Pawuhan residents still depend on agriculture. Limited education and skills restrict access to new economic opportunities, including industrial employment and tourism-related occupations.

"Most people here, including me, do not have a high level of education. To work there or become a permanent employee [at the geothermal company], you need certification. For example, jobs in machinery, welding, or piping require that. They need specialized skills." (PW-03, Pawuhan Hamlet, 21/6/2026).

Similar barriers were encountered when residents attempted to enter the tourism sector.

"There used to be tourist Jeeps, and one trip could earn around Rp600,000 to Rp1,000,000. My husband had already bought a Jeep for tourism, but it turned out we were not allowed to join. When we tried to enter the community, we were not permitted to register and the process was made difficult. That is how it is here, because they feel tourism in Dieng should be for people from Dieng and outsiders should not participate. So even though we own a Jeep, it is still difficult to enter because of community restrictions and local licensing." (MR-04, Pawuhan Hamlet, 22/6/2026).

These experiences demonstrate that geographical proximity to an economic center does not necessarily translate into equal economic access. Education, certification, skills, social networks, community membership, and territorial identity all influence residents' ability to enter new economic opportunities or livelihoods. Consequently, many residents remain dependent on agricultural work, including farm labor, motorcycle transport for fertilizer and harvests, and seasonal trading of agricultural produce.

Rising land values represent a more complex form of economic benefit. Some residents benefit because land located near geothermal infrastructure continues to appreciate in value.

"Land values are high, especially in nearby or strategic locations. Land close to Geo Dipa is also expensive. If the company needs it, they will acquire it regardless of the price. Land near the wells [wellpads] is especially expensive. When expansion is required, Geo Dipa does not set a target price. However expensive it is, if they need it, they will buy it. Land farther away is actually cheaper." (PR-01, Pawuhan Hamlet, 20/6/2026).

Another informant described a substantial change in land prices.

"In 2010, it was around Rp500,000 per square meter. Now residents can ask for Rp5 million per square meter." (PWZN-14, Pawuhan Hamlet, 21/6/2026).

However, rising land values do not necessarily generate benefits for all residents. The experience of a tenant farmer illustrates another side of this issue.

"I rent land annually at Rp1 million per keranjang. I rent three keranjang, so I pay Rp3 million per year. That is expensive because the price depends on access to water. The land I rent used to be close to water, but now the agricultural reservoir at Zibido has been polluted after the Pad-28 leak, and small craters have appeared around Zibido. So I lose out: the rent is already expensive, but the reason it was expensive in the first place is no longer there." (PW-03, Pawuhan Hamlet, 21/6/2026).

Rising land values are therefore ambivalent. Owners of strategically located land may obtain substantial benefits, while residents without land do not receive comparable gains. Increasing land prices may even reduce younger generations' ability to purchase farmland or land for housing and other businesses. These experiences show that growth in asset values is not necessarily equivalent to an equitable improvement in welfare.

The unequal distribution of benefits became even more apparent when residents compared economic opportunities with the burdens they experienced.

"Community welfare is far from reality. Compensation has never been sustained. When Zibido became polluted, the company once agreed to build drilled wells for agriculture. But the water from those wells had the same smell. Now there is no compensation that actually solves the water-pollution problem. It feels as if the company pays no attention to the community." (PW-03, Pawuhan Hamlet, 21/6/2026).

"Lower- and middle-income residents generally oppose the project, while many people from the upper-middle group work at Geo Dipa." (MF-11, Pawuhan Hamlet, 24/6/2026).

"Ordinary residents without influence have applied for jobs many times but received no response. Those with internal connections are more easily accepted." (SPT-15, Pawuhan Hamlet, 21/6/2026).

These quotations do not imply that all economic opportunities are enjoyed only by particular groups. Phenomenologically, however, informants' experiences reveal a perception that capital, assets, and social relationships play important roles in determining the distribution of benefits. Consequently, the presence of the geothermal plant may be interpreted as an opportunity by some residents but as a source of pressure by others.

Within the economic dimension, much of the literature on the geothermal industry emphasizes the role of geothermal power plants in promoting regional economic growth while creating new employment opportunities (Cook et al., 2019b; Greiner et al., 2023; Pambudi et al., 2014; Wachowicz-Pyzik et al., 2024). Other studies, however, show that the economic benefits of geothermal development are not always distributed equitably. At the Sorik Marapi Geothermal Power Plant, for example, although employment opportunities were created for some residents, surrounding communities lost productive land and did not obtain direct access to the electricity generated. This inequality reveals a contradiction among the objectives of low-carbon energy development, the green economy, and social justice (Maisyaroh et al., 2024; Setyowati, 2021). Similar patterns are evident in renewable-energy projects elsewhere in the world that prioritize economic dimensions but do not yet fully account for socio-ecological sustainability because greater emphasis is placed on market efficiency and investment (Akadiri et al., 2023; Portillo et al., 2024). From an

investment perspective, geothermal development faces high exploration costs, substantial capital requirements, and sophisticated technological needs, yet it is also promoted as a potential contributor to regional revenue through the green economy (Raihan, 2025; Vargas-Payrera, 1984).

Several findings concerning the everyday economic experiences of Pawuhan residents living closest to the operational area of the Dieng Geothermal Power Plant can be analyzed using the Sustainable Livelihood Approach (SLA). The SLA framework is illustrated in the following figure (DFID, 2000):

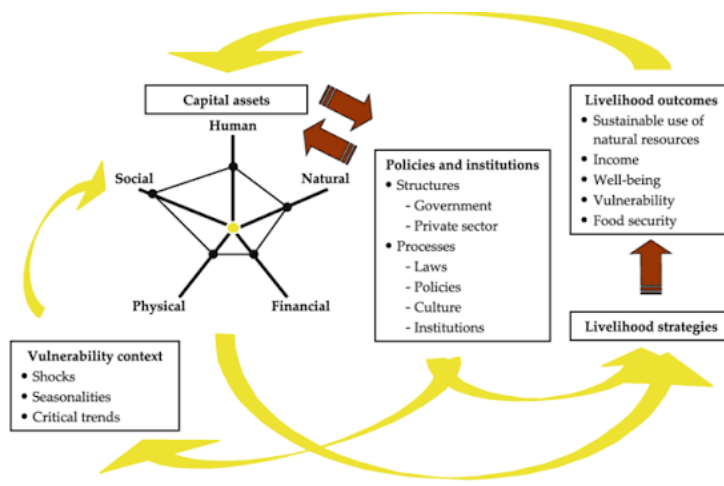


Figure 2. Sustainable Livelihood Approach Framework (DFID, 2000)

The Sustainable Livelihood Approach (SLA) conceptualizes livelihoods through five major forms of capital: financial, natural, human, physical, and social. Among Pawuhan residents, pressure on financial capital is evident when household income must be used to purchase water, maintain water networks, repair homes, and increase agricultural production inputs. Natural capital is under pressure because residents no longer fully trust the water and soil that form the basis of agricultural activities. Human capital is constrained by limited education and skills required to enter employment outside agriculture. With respect to physical capital, houses and land can generate economic opportunities, but these benefits are more accessible to those who already possess assets. Social capital is reflected in the importance of relationships and social networks for accessing some of the new employment opportunities.

These issues are also related to transforming structures and processes. Recruitment mechanisms, compensation arrangements, access to business opportunities, licensing, and institutional networks create differences in residents' capacity to convert assets into livelihood strategies. Residents who possess capital and land have more options, while those with limited capital and assets remain concentrated in agricultural work, which has historically dominated livelihoods in Pawuhan.

Thus, operation of the Dieng Geothermal Power Plant has indeed created several forms of economic diversification, but these opportunities have not been equally accessible to all residents, and broader efforts to strengthen community livelihood resilience have therefore not yet been fully achieved. Employment opportunities and rising asset values occur alongside additional adaptation costs associated with the social, economic, and environmental changes experienced by residents. From an SLA perspective, livelihood outcomes among Pawuhan residents still differ across community groups and have not yet fully resulted in more resilient livelihoods.

The practical implication of these findings is that economic development around the Dieng Geothermal Power Plant should be directed not only toward creating new opportunities but also toward ensuring more inclusive access for Pawuhan residents, particularly groups with limited capital, skills, and social networks.

Community-empowerment programs should focus on capacity building through skills training, access to occupational certification, strengthening local enterprises, and more transparent and inclusive mechanisms for distributing economic benefits. In this way, renewable energy projects can contribute not only to national green-economic value but also to the livelihood resilience of affected communities.

Environmental Change and the Loss of Community Sense of Security

Experiences of environmental change are closely embedded in the everyday lives of Pawuhan residents. The operation of the Dieng Geothermal Power Plant is interpreted through what residents see, smell, feel, and experience in relation to water, agricultural soil, air, household materials, and the security of their living environment. Because this study employs a phenomenological methodology and did not conduct laboratory testing, the environmental changes reported here derive from community experiences and perceptions. The findings are not used to establish direct causal relationships between all reported environmental changes and the activities of the Dieng Geothermal Power Plant. Such relationships would require independent scientific testing.

Changes in water quality are among the environmental experiences most frequently reported by Pawuhan residents. After small craters appeared around the Zibido water source shortly after the Wellpad 28 leakage incident, some residents began to perceive changes in the taste, color, and quality of the water. They subsequently associated these changes with the Wellpad 28 incident. These concerns led residents to stop using local groundwater for drinking, agriculture, and certain everyday domestic needs.

"Water from Zibido can no longer be consumed. It used to be clear and tasted good. It was safe for drinking and agriculture. After the incident, small craters appeared and the water changed; residents no longer dare to use it, even for agriculture. When it is used for washing, even soap does not produce foam." (BM-02, Pawuhan Hamlet, 20/6/2026).

"The well water has become bland and unpleasant, almost like seawater, slightly salty. On the rocks or riverbed, the water leaves a reddish, rust-like color." (SPT-1, Pawuhan Hamlet, 21/6/2026).

The relationship between water conditions and agriculture was also a concern for informants.

"The main factor is water. The water is used to spray potato crops. If the water is polluted, the soil remains less fertile and yields are not optimal even when fertilizer use is maximized." (PW-03, Pawuhan Hamlet, 21/6/2026).

The findings indicate that residents' experiences of changes in water quality have become a source of concern. Residents lack access to the knowledge and social networks needed to understand what is occurring with groundwater in their area. What they know from direct experience is that the quality of local groundwater has declined, creating fear about consuming it.

Experiences of soil change are also closely connected to community life because a large share of residents depend on agriculture. Several farmers reported changes in soil texture, a greater need for fertilizer, and harvest yields that they believed had declined over time.

"Potato yields used to reach 15 kilograms per crate; now they are lower. Less fertile soil also makes the potatoes stunted or smaller. The height of the potato plants has also decreased because of waste and polluted water." (PWZ-14, Pawuhan Hamlet, 21/6/2026).

"The crops once dried out and died at that time [during the Pad-30 blasting]. The soil needed more loosening material and fertilizer before crops could grow again. It only began to return to normal roughly two years after the incident." (PR-01, Pawuhan Hamlet, 20/6/2026).

These statements illustrate how farmers experience environmental change through land productivity. For them, soil is not only an element of environmental sustainability but also the foundation of their livelihoods. When soil conditions are perceived to change, these experiences directly affect economic security because farmers no longer have certainty regarding the production outcomes on which they depend.

Environmental change is also experienced through odors at particular times—such as morning, evening, and during foggy weather—and through changes in materials around the home. Residents reported strong odors in their living environment during these periods and perceived corrosion of galvanized metal and iron household materials as evidence of deteriorating air conditions associated with the operation of the Dieng Geothermal Power Plant.

“Corrugated-metal roofs rust quickly. If a roof only needs to be replaced twice in one year, that is already considered durable. To reduce costs, many residents repaint the roofs about every two months using asphalt-based paint.” (MF-11, Pawuhan Hamlet, 24/6/2026).

“Roofs and metal grilles rust and become brittle quickly. Cars that are not kept in garages also lose their color rapidly. There is no routine compensation for replacing roofing sheets. There was compensation once, when each household received 50 sheets, but that happened only that one time and not every year. It also makes us worry: if objects deteriorate that quickly, what might it do to people's lungs?” (BM-02, Pawuhan Hamlet, 20/6/2026).

Within a phenomenological perspective, these experiences are important because residents use signs embedded in everyday life to make sense of conditions that they cannot technically measure themselves. Corrosion of metal roofing, changes in vehicle color, and odors in the air become sensory experiences that shape perceptions of risk. In other words, residents confront not only material environmental conditions but also an interpretive process concerning what these changes might mean for their health and daily lives.

Residents' sense of insecurity is intensified by uncertainty regarding environmental quality. They do not know exactly what substances they are breathing when strong odors appear, whether the water is safe for long-term use, or what factors are responsible for declining agricultural productivity. This uncertainty becomes greater when access to technical information and environmental testing is perceived as limited.

“What we fear is the long-term effect. With the steam and those craters, what will happen to the community in the future? We do not know whether it could cause shortness of breath or other health problems. We have repeatedly submitted complaints to the village office and the company, but there has been no response.” (PT-08, Pawuhan Hamlet, 21/6/2026).

Concerns also relate to the sustainability of agricultural production spaces.

“In the Zibido area, not all of the land can be cultivated anymore. Many potatoes grown near the water become dry and develop holes.” (SPT-15, Pawuhan Hamlet, 20/6/2026).

These two accounts show that community environmental experience extends beyond physical change. More fundamentally, residents have lost certainty about the safety of their living environment. Uncertainty about water quality, agriculture, and the future of the next generation means that the environment is no longer viewed simply as a comfortable place to live, but as a space requiring constant vigilance.

In the environmental dimension, previous studies have shown that geothermal exploration and operational activities may generate significant ecological risks, including land degradation, air pollution, noise from heavy machinery, water pollution, reduced water discharge, drilling-induced seismicity, landscape damage, ecosystem imbalances that may reduce biodiversity or drive wildlife toward settlements, and deterioration in agricultural-land quality (Alamsyah et al., 2024; Mahamoud Abdi et al., 2024; Pambudi, Pramudita, Biddinika, & Jalilinasrabad, 2022; Savira, 2023; Wahid et al., 2025). In Dieng, for example, liquid waste and hot drilling sludge from geothermal activities have the potential to contaminate agricultural land and reduce groundwater quality (Solusi et al., 2022). Hydrogen sulfide (H₂S) emissions from geothermal operations in the Dieng area may also pose health risks and contribute to damage to household materials (Mahdi, 2024). Meanwhile, Environmental Impact Assessment—known in Indonesia as AMDAL—has not always been fully effective in reducing ecological impacts because of weak regulatory enforcement and limited community participation in monitoring processes (Aziz et al., 2025).



Several findings concerning environmental changes perceived by Pawuhan residents as impacts of the Dieng Geothermal Power Plant can be interpreted through Political Ecology (Greiner et al., 2023; Robbins, 2012). Political Ecology asks not only what changes in the environment, but also who receives benefits, who bears burdens, who controls resources, and whose knowledge gains legitimacy in determining whether an impact exists. In the Pawuhan context, community experiences can be examined through four elements: degradation and marginalization; environmental conflict and exclusion; environmental subjects and identity; and political objects and actors.

Degradation and marginalization are evident when perceived changes in water and soil increase the vulnerability of residents who depend heavily on local resources. Farmers are the group most clearly positioned within this vulnerability because water and soil quality directly affect their livelihoods. Environmental conflict and exclusion are visible in the difference between community knowledge derived from everyday experience and technical knowledge that has formal authority to determine impacts. Residents recognize environmental change through odors, water taste, crop conditions, and material corrosion, but determining scientifically whether those changes are related to geothermal activities requires testing systems that lie beyond the capacity of most residents.

At the same time, these experiences shape environmental subjects and identity. Pawuhan is no longer understood only as a place of residence and an agricultural area, but also as a space characterized by uncertainty and the need for vigilance. Water, soil, crops, odors, and household materials become political objects and actors because their condition influences residents' actions. Communities seek alternative water sources, increase agricultural inputs, repair their homes, and question long-term risks. Thus, the loss of a sense of security emerges not only from environmental changes themselves, but also from limited access to information, knowledge, and mechanisms through which residents can obtain certainty about the condition of their living environment.

From a Political Ecology perspective, the environmental sustainability of the Dieng Geothermal Power Plant cannot be assessed solely on the basis of geothermal energy's status as a low-carbon energy source. Sustainability must also consider how risks and benefits are distributed, how community experiences are recognized, the extent to which environmental information is accessible, and residents' ability to participate in decisions that directly affect their living environment.

The practical implication of these findings is that environmental management in the operational area of the Dieng Geothermal Power Plant needs to strengthen transparent monitoring mechanisms and involve communities as part of the oversight process. The provision of accessible technical information, periodic environmental-quality testing, and public disclosure of monitoring results are important for reducing uncertainty and rebuilding residents' sense of security. In addition, complaint-handling mechanisms related to environmental change need to be improved so that communities are not merely recipients of information but also participate in safeguarding the sustainability of living spaces surrounding geothermal-energy infrastructure.

Analysis of Sustainability Interactions Using the Nilsson Scale

SUSTAINABILITY INTERACTION ANALYSIS OF THE DIENG GEOTHERMAL POWER PLANT WITH THE SUSTAINABLE DEVELOPMENT GOALS (SDGs) USIANG NILSSON SCALE

DIMENSI	TEMUAN	SDGS							
		1	3	6	8	9	13	15	16
SOSIAL	Penolakan tertutup akibat erosi kepercayaan	0	0	0	-1	-1	-1	-1	-2
	Partisipasi masyarakat yang terfragmentasi	-1	-1	0	-1	-1	-1	-1	-3
	Ketidakadilan Distribusi Manfaat Dan Beban Sosial	-2	-2	-1	-2	-1	-1	-1	-3
	Memburuknya relasi perusahaan – masyarakat	-2	-1	0	-2	-1	-1	-1	-2
EKONOMI	Meningkatnya Pengeluaran Rumah Tangga	-3	-3	-2	-1	0	-1	-2	-2
	Peluang Ekonomi Yang Muncul Ada Namun Bersifat Terbatas	-1	+1	0	+1	0	+1	0	-1
	Hambatan Diversifikasi Mata Pencaahan	-2	0	0	-2	-1	0	0	-1
	Kenaikan Nilai Lahan Sebagai Manfaat Ganda	+1	+1	0	+1	+1	0	-1	0
LINGKUNGAN	Penurunan Kualitas Air Tanah	-1	-2	-3	-1	-1	-2	-2	-1
	Penurunan Produktivitas Tanah Dan Ketidakpasian Pertanian	-2	-2	0	-2	-1	-1	-2	-1
	Gangguan Bau Dan Korosi Material	0	-1	0	0	0	-1	-1	-2
	Rasa Tidak Aman Terhadap Lingkungan	-1	-1	-2	-1	0	-1	+1	-2

NILSSON SCALE LEGEND

3 (INDIVISIBLE)	2 (REINFORCING)	1 (ENABLING)	0 (CONSISTENT)	-1 (CONSTRAINING)	-2 (COUNTERACTING)	-3 (CANCELLING)
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Figure 3. Sustainability Analysis Using the Nilsson Scale

Figure 3 summarizes the interactions between eight Sustainable Development Goals and 13 research findings across the social, economic, and environmental dimensions associated with the operation of the Dieng Geothermal Power Plant as part of Indonesia's effort to achieve SDG 7. These interactions were evaluated using the Nilsson Scale, which ranges from +3 (reinforcing) to -3 (counteracting) (Nilsson et al., 2018). The analysis shows that the 13 research findings and the eight relevant SDGs do not all move in the same direction. Positive interactions are visible in the economic dimension through new employment opportunities and increased land values, although these outcomes also interact negatively with declining quality of the natural resources on which primary livelihoods depend. Negative, constraining, or conflicting interactions are more dominant in the social and environmental dimensions, particularly in relation to economic and social welfare, health, clean water, infrastructure development, environmental sustainability, and institutional governance.

Experiences of changes in water, soil, and air, together with environmental uncertainty, have encouraged residents to undertake various forms of adaptation that create additional expenditure, from seeking alternative water sources and increasing agricultural inputs to repairing household materials. The accumulation of these costs subsequently affects household economic resilience. When economic pressure occurs alongside perceptions of unequal benefit distribution and limited opportunities for participation, the consequences extend to public dissatisfaction, declining trust, increasingly fragmented participation, and a widening social distance between communities and the operator of the Dieng Geothermal Power Plant, PT Geo Dipa Energi. These conditions may in turn intensify resistance or reduce the project's social legitimacy.

Within the Triple Bottom Line framework, these patterns indicate that local sustainability surrounding the Dieng Geothermal Power Plant has not yet fully achieved a balance among social, economic, and

environmental dimensions. The plant's contribution to low-carbon energy remains significant, and a smaller segment of the community has obtained economic benefits. However, these positive benefits are not always distributed equitably, while environmental, economic, and social burdens are borne more heavily by residents living closest to the operational area. The Nilsson Scale analysis therefore indicates that sustainability dynamics in Pawuhan are still dominated by trade-offs rather than reinforcing synergies. These findings underscore that the success of renewable-energy projects should not be determined solely by their capacity to generate low-carbon energy, but also by how energy production contributes to protecting living spaces and the environment, strengthening local livelihoods, distributing benefits more fairly, ensuring information transparency, and enabling meaningful community participation.

CONCLUSION

This study finds that the lived experience of residing alongside the operation of the Dieng Geothermal Power Plant in Pawuhan Hamlet, Banjarnegara, is shaped by interconnected social, economic, and environmental dynamics. The findings show that geothermal development has created both opportunities and challenges for communities living closest to the geothermal industry. Although the plant has generated employment opportunities and increased the market value of land for certain groups, these benefits are not experienced by most residents. At the same time, many residents face additional economic pressures through increased household expenditure, particularly the cost of accessing alternative clean-water sources after perceived groundwater contamination, repairing damaged household materials, and increasing agricultural production inputs that are perceived to be associated with the activities of the Dieng Geothermal Power Plant.

From the social perspective, the study shows that the sustainability of renewable-energy development is strongly influenced by the quality of relations between the geothermal operator and surrounding communities. The emergence of passive resistance, limited participation, declining trust, and weakening social legitimacy indicates that physical proximity to the geothermal industry does not automatically generate social acceptance. Instead, acceptance is built through meaningful participation, information transparency, and fair distribution of both benefits and burdens. Environmental experiences were characterized by perceived changes in water quality, agricultural-soil productivity, and air conditions.

The conceptual contribution of this study is to demonstrate that the sustainability of geothermal power-plant operations as a low-carbon energy source cannot be evaluated solely through technical performance, energy production, or contribution to the energy transition. Through a phenomenological perspective combined with the Nilsson Scale and Triple Bottom Line frameworks, the study highlights that the Dieng Geothermal Power Plant may simultaneously function as a climate-mitigation solution and as a source of new social, economic, and environmental inequalities. The findings show that relationships between the research findings and the three sustainability dimensions – manifested through eight relevant Sustainable Development Goals – are dominated by trade-offs rather than synergies. This indicates the need for a more inclusive and justice-oriented approach to the governance of future renewable-energy projects. Future New and Renewable Energy initiatives should strengthen community participation, ensure equitable access to economic opportunities, establish transparent and sustained compensation systems, and prioritize environmental protection. In this way, the renewable energy industry can advance genuine sustainable development in which social welfare, economic improvement, and environmental protection are achieved simultaneously.

Based on the findings and limitations of this study, future research should broaden the examination of geothermal-development sustainability by not only investigating community experience and meaning through phenomenological approaches, but also complementing such work with more multidisciplinary studies, including comprehensive economic and environmental analyses based on scientific testing and measurement.

For communities, the findings may serve as a basis for strengthening participation in the planning, monitoring, and evaluation of geothermal-development activities, particularly in articulating community experiences and needs across social, economic, and environmental dimensions. For geothermal operators, the findings may inform efforts to strengthen community-communication and participation mechanisms, improve transparency regarding operational activities and potential impacts, ensure more inclusive distribution of economic benefits, and establish complaint-handling and compensation mechanisms that are transparent, responsive, and sustainable. For government, the findings may support stronger oversight and governance of geothermal development, particularly through mechanisms for monitoring social, economic, and environmental impacts, careful implementation of sustainable-development principles, and integration of justice and community-participation principles into renewable-energy planning and evaluation. Through the joint use of these findings by communities, operators, and government, geothermal-energy development can be directed not only toward meeting energy demand through low-carbon sources, but also toward ensuring that development benefits are more equitably distributed without compromising environmental sustainability and the welfare of communities surrounding geothermal-industry operations.

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CRedit Contribution. AFM: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft; AK: Supervision, Validation, Review & Editing; SYH: Supervision, Validation, Review & Editing.

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