

Penta-Helix Collaboration in Renewable Energy Policy Governance: Evaluating the Role of Non-State Actors in Indonesia's Energy Self-Sufficient Village Program

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DOI: <https://doi.org/10.55299/jsh.v4i1.1533>

Article history: Received June 25, 2025; Revised July 25, 2025; Accepted August 20, 2025

Abstract

Indonesia's transition towards renewable energy requires comprehensive governance frameworks that engage multiple stakeholders beyond traditional government actors. This study examines the implementation of the penta-helix collaboration model in renewable energy policy governance, with specific focus on non-state actors' roles in the Energy Self-Sufficient Village (Desa Mandiri Energi/DME) program. Using a qualitative research methodology, this investigation analyzes the collaborative dynamics between government, academia, business sector, community, and media in advancing renewable energy initiatives at the village level. The research reveals that non-state actors play crucial roles as policy entrepreneurs, implementers, and sustainability champions within the DME framework. However, challenges persist in coordination mechanisms, resource allocation, and institutional capacity building. The findings demonstrate that effective penta-helix collaboration requires structured governance frameworks, clear role definitions, and sustained political commitment to achieve meaningful renewable energy transformation at the grassroots level. This research contributes to the understanding of multi-stakeholder governance models in energy transition contexts and provides insights for policymakers seeking to enhance collaborative approaches in renewable energy development.

Keywords: penta-helix collaboration, renewable energy governance, non-state actors, energy self-sufficient villages, Indonesia energy policy

INTRODUCTION

Indonesia faces significant challenges in achieving its renewable energy targets while ensuring equitable access to clean energy across its vast archipelagic territory. The Indonesian government has committed to increasing the renewable energy share in its energy mix to 23% by 2025 and achieving net-zero emissions by 2060. Central to this ambitious agenda is the Energy Self-Sufficient Village (Desa Mandiri Energi/DME) program, initiated in 2007, which aims to empower rural communities to meet at least 60% of their energy needs through local renewable energy resources (Nasir & Bengi, 2024).

The complexity of energy transition governance necessitates collaborative approaches that extend beyond traditional government-centric models. The penta-helix framework, encompassing government, academia, business sector, community, and media, has emerged as a promising governance model for addressing multifaceted development challenges. This collaborative approach recognizes the importance of diverse stakeholder participation in policy formulation, implementation, and evaluation processes.

Non-state actors have increasingly gained prominence in global energy governance, particularly in the context of climate change mitigation and sustainable development. These actors, including private sector entities, civil society organizations, academic institutions, and media organizations, possess unique capabilities, resources, and networks that complement government efforts in renewable energy development. Understanding their roles and contributions within collaborative governance frameworks is essential for designing effective energy transition strategies.

This research addresses a critical gap in the literature by examining how non-state actors operate within the penta-helix collaboration model in Indonesia's renewable energy policy governance. Specifically, it investigates the roles, challenges, and contributions of non-state actors in the implementation of the DME program, which represents a significant grassroots initiative in Indonesia's energy transition strategy (Simanjuntak et al., 2023).

The study's significance lies in its potential to inform policy design and implementation strategies for renewable energy development in developing countries with similar geographic and socio-economic characteristics. By analyzing the collaborative dynamics within the penta-helix framework, this research contributes to broader discussions on multi-stakeholder governance in

energy transition contexts and provides practical insights for enhancing collaborative approaches in sustainable development initiatives.

The penta-helix model represents an evolution of earlier collaboration frameworks, building upon the triple helix (government-industry-university) and quadruple helix (adding civil society) models by incorporating media as a fifth stakeholder category. This comprehensive framework recognizes the media's crucial role in information dissemination, public awareness creation, and policy advocacy within collaborative governance arrangements (Kunwar & Ulak, 2024).

Carayannis and Campbell's foundational work on multi-helix models emphasizes the importance of knowledge-based innovation systems in addressing complex societal challenges. The penta-helix model extends this concept by creating synergistic relationships between diverse stakeholders, each contributing unique resources and capabilities toward common objectives. In the context of renewable energy governance, this model facilitates integrated approaches that combine policy frameworks, technical expertise, financial resources, community participation, and communication strategies.

Recent scholarship on penta-helix collaboration in Indonesia demonstrates its application across various sectors, including disaster management, tourism development, and agricultural innovation. These studies highlight the model's potential for addressing multi-dimensional challenges while acknowledging implementation difficulties related to coordination, resource allocation, and institutional capacity building (Carayannis & Morawska, 2023).

The role of non-state actors in global energy governance has expanded significantly over the past two decades, driven by recognition of their unique capabilities in addressing climate change and sustainable development challenges. These actors operate across multiple scales, from local community organizations to multinational corporations and international networks, contributing diverse resources, expertise, and perspectives to energy transition processes.

Private sector actors bring technological innovation, financial resources, and operational efficiency to renewable energy development. Academic institutions contribute research capabilities, technical expertise, and human resource development functions. Civil society organizations provide community mobilization, advocacy, and monitoring capabilities. Media organizations facilitate information dissemination, public awareness campaigns, and democratic accountability processes.

The literature on non-state actors in energy governance emphasizes their roles as policy entrepreneurs, implementers, and advocates within multi-level governance arrangements. However, challenges persist regarding coordination mechanisms, accountability frameworks, and power imbalances between different actor categories. Understanding these dynamics is crucial for designing effective collaborative governance models in energy transition contexts (Islam & Jahan, 2025).

The DME program represents Indonesia's commitment to decentralized renewable energy development and rural empowerment. Launched in 2007, the program aims to establish self-sufficient energy communities that can meet at least 60% of their energy needs through local renewable energy resources, including solar, biomass, microhydro, wind, and biogas technologies.

The program's conceptual framework emphasizes participatory approaches that involve all stakeholders in planning, implementation, and maintenance processes. This approach recognizes the importance of community ownership and local capacity building in ensuring project sustainability. The DME initiative aligns with Indonesia's broader energy transition strategy and contributes to multiple Sustainable Development Goals, including affordable and clean energy (SDG 7), sustainable communities (SDG 11), and climate action (SDG 13).

Recent evaluations of the DME program highlight both successes and challenges in implementation. Successful cases demonstrate the program's potential for improving energy access, reducing dependence on fossil fuels, and stimulating local economic development. However, challenges persist regarding technical capacity, financial sustainability, maintenance systems, and coordination between different levels of government and stakeholders (Khan, 2025).

Collaborative governance has emerged as a prominent approach for addressing complex policy challenges that require coordination between multiple stakeholders with diverse interests and capabilities. In energy transition contexts, collaborative governance frameworks facilitate integration of technical, economic, social, and political considerations in policy design and implementation processes.

The literature on collaborative governance emphasizes the importance of institutional design, leadership, and process management in achieving effective collaboration. Key factors include clear goal setting, shared understanding of roles and responsibilities, effective communication mechanisms, and sustained commitment from all stakeholders. However, collaborative governance also faces challenges related to power imbalances, conflicting interests, and coordination costs.

Recent studies on energy transition governance highlight the importance of multi-level and multi-stakeholder approaches that integrate national policy frameworks with local implementation strategies. These approaches recognize the complexity of energy systems and the need for coordinated action across different scales and sectors to achieve meaningful transformation

METHODS

This study employs a qualitative research methodology to examine the complex dynamics of penta-helix collaboration in renewable energy policy governance. The qualitative approach is particularly suitable for exploring stakeholder interactions, institutional processes, and governance mechanisms within the DME program context. This methodology allows for in-depth analysis of collaborative relationships, identification of implementation challenges, and understanding of contextual factors that influence policy outcomes.



Figure 1. Qualitative Research

The research adopts an interpretive paradigm that recognizes the socially constructed nature of governance processes and the importance of stakeholder perspectives in understanding collaborative dynamics. This approach emphasizes the need to understand how different actors perceive their roles, interpret policy objectives, and navigate institutional arrangements within the penta-helix framework.

The study utilizes a multiple case study design to examine penta-helix collaboration in DME implementation across different regional contexts. This design allows for comparative analysis of collaborative dynamics under varying conditions while maintaining focus on the specific phenomenon of non-state actor participation in renewable energy governance.

Case selection criteria include: (1) active DME program implementation, (2) evidence of multi-stakeholder collaboration, (3) presence of diverse renewable energy technologies, (4) availability of relevant documentation and stakeholders for interviews, and (5) geographic diversity to capture different regional contexts within Indonesia.

Data Collection Methods

Primary data collection involves semi-structured interviews with key stakeholders representing each element of the penta-helix framework:

Government actors: National and regional energy officials, local government representatives, and program coordinators involved in DME implementation.

Academic institutions: Researchers, faculty members, and students engaged in renewable energy research, technology development, and community outreach programs.

Business sector: Private companies, cooperatives, and social enterprises involved in renewable energy technology provision, financing, and maintenance services.

Community representatives: Village leaders, community organizations, and local residents participating in DME initiatives.

Media representatives: Journalists, communication specialists, and media organizations covering renewable energy and rural development issues.

Secondary data sources include policy documents, program reports, academic publications, media coverage, and online resources related to DME implementation and renewable energy policy in Indonesia.

Data Analysis Approach

The research employs thematic analysis to identify patterns, themes, and relationships within the collected data. The analysis process involves:

1. Data familiarization: Comprehensive review of all collected materials to gain overall understanding of the research context and stakeholder perspectives.
2. Initial coding: Systematic identification of relevant concepts, ideas, and patterns within the data, with particular attention to roles, relationships, and challenges within the penta-helix framework.

3. Theme development: Organization of codes into broader thematic categories that capture key aspects of penta-helix collaboration in DME implementation.
4. Theme refinement: Review and refinement of themes to ensure they accurately represent the data and address the research questions.
5. Interpretation and reporting: Analysis of themes in relation to existing literature and development of conclusions and recommendations.

The analysis is guided by the conceptual framework of penta-helix collaboration and focuses on understanding the roles, contributions, challenges, and interactions of non-state actors within the DME program context.

RESULTS AND DISCUSSION

A. Research Result

Academic Institutions emerged as pivotal knowledge brokers and technical experts. Universities like Diponegoro University engage actively in applied research, technical feasibility studies, and capacity-building programs for renewable technology systems such as solar panels, biomass digesters, and micro-hydropower units. Through community service programs (KKN) and partnerships with corporate social responsibility initiatives, academic actors deliver tailored solutions adapted to local contexts and disseminate knowledge for sustainability. Their contributions extend beyond technology to encompass training village technicians and community members, empowering local ownership and problem-solving capacity. Such continuous academic engagement supports innovation and adaptive management of energy projects.

Business Sector actors, including renewable energy equipment suppliers, entrepreneurs, cooperatives, and financing institutions, provide vital resources such as capital investment, technology procurement, operational expertise, and maintenance services. Private companies facilitate scaling and replication by introducing market-driven mechanisms that complement government subsidy programs. However, research reveals tensions between profit-oriented business objectives and community welfare goals, necessitating transparent public-private partnership frameworks. The private sector's involvement is critical in bridging supply chain gaps and ensuring the availability of high-quality renewable energy systems that are economically viable and sustainable.

Community Organizations and village leaders perform crucial roles as implementers, beneficiaries, and stewards of renewable energy solutions. Local cooperatives, farmer groups, and traditional customary institutions leverage intimate knowledge of local environmental and social conditions to drive project relevance and appropriateness. Communities exhibit ownership through participatory planning, managing microgrid operations, and maintaining equipment, which significantly enhances project sustainability. The empowerment of marginalized groups, including women's groups, further reflects the inclusive potential of the DME program under the penta-helix framework.

Media Actors play a vital role in information dissemination, public awareness building, and accountability enforcement. Local and national media outlets report on success stories, technology adoption, and policy advances, generating public and political support. Media participation also surfaces challenges and grievances which help in reflexive governance and adaptive policy improvements. The dynamic communication networks foster stakeholder alignment, transparency, and wider societal engagement with renewable energy initiatives.

Government Actors, while not the focus of non-state roles, remain indispensable in providing regulatory frameworks, direct financial support, monitoring mechanisms, and facilitation of coordination platforms. Their stewardship ensures alignment with national energy goals and integration with broader development plans.

Collaboration Dynamics and Governance Mechanisms

The interplay between these five actors is enabled and constrained by various governance mechanisms. Multi-stakeholder forums and coordination committees serve as formalized platforms for dialogue, policy design, and problem-solving at district and provincial levels. These spaces facilitate the negotiation of roles, responsibilities, and resource allocation but face challenges including irregular attendance, communication gaps, and power asymmetries favoring government officials.

Partnership agreements and Memoranda of Understanding (MoUs) delineate formal collaboration terms, but enforcement and flexibility to adapt to evolving needs remain concerns. Capacity building is emphasized as an ongoing necessity, particularly to strengthen community actors' competences in technical maintenance, financial management, and organizational governance. Information sharing systems—ranging from digital reporting platforms to community notice boards—are critical to ensuring transparency and timely response to operational issues.

Challenges to Effective Penta-Helix Collaboration

Despite the model's promise, several challenges hamper effective collaboration. Coordination complexity arises from balancing different institutional cultures, decision-making processes, and timelines among diverse actors. Power imbalances often privilege government stakeholders due to regulatory control and resource dominance, limiting community influence despite their central role in implementation.

Resource constraints, especially financial and human capital shortages at the village level, constrain meaningful engagement and sustainability. Smaller communities without strong organizational structures struggle to capitalize on technical and financial

opportunities. Institutional gaps, including unclear role definitions and fragmented policies, further complicate collaboration and dilute accountability.

Success Factors and Best Practices

Strong, visionary leadership from all stakeholder categories acts as a key catalyst in overcoming barriers and sustaining collaboration momentum. Local champions with both technical acumen and community trust effectively mediate between stakeholders.

Developing a shared vision and clear common objectives helps to align agendas and build mutual trust. Projects showing adaptive governance—incorporating feedback loops, iterative learning, and flexibility—report higher success and longer-term impact. Lastly, promoting local ownership through participatory planning and capacity enhancement ensures that communities remain engaged and capable of maintaining renewable energy systems beyond initial external support phases.

Table 1. Non-State Actor Roles and Collaboration Features

Penta-Helix Actor	Roles and Responsibilities	Contributions to DME Program	Collaboration Challenges	Best Practices / Enablers
Academia	Technical research, capacity building, knowledge dissemination	Provide renewable tech expertise, training, adaptive solutions	Limited funding continuity, coordination delays	University-community partnerships, applied research integration
Business Sector	Technology supply, financing, operations, maintenance	Capital investment, market mechanisms, tech deployment	Balancing profit objectives with community needs	Transparent partnership frameworks, CSR collaborations
Community	Project ownership, local knowledge, implementation	Operation/maintenance of systems, social mobilization	Limited technical skills, financial constraints	Participatory planning, leadership empowerment
Media	Information dissemination, public awareness, accountability	Promote successes, highlight challenges, increase visibility	Media access in remote areas, message framing	Multiplatform engagement, community media involvement
Government	Regulation, financing, facilitation, monitoring	Policy support, resource allocation, coordination	Bureaucracy, power imbalances	Dedicated coordination units, clear mandates

B. Discussion

The penta-helix framework theorizes that sustainable development challenges—such as energy transitions—require integrated efforts from government, academia, business, community, and media actors. This study’s empirical findings affirm this premise by highlighting the indispensable roles each stakeholder group plays, demonstrating complementarities of expertise, resources, and legitimacy. These outcomes are consistent with findings from other sectors in Indonesia and Southeast Asia, where penta-helix collaboration enhanced policy coherence, innovation diffusion, and social inclusion (Putri, 2025).

However, the bureaucratic structure and institutional legacies in Indonesia complicate such collaboration dynamics. Government agencies typically wield dominant regulatory and financial power, which can unintentionally suppress grassroots voices, particularly community groups that are central to the sustainability of decentralized renewable energy projects. This power imbalance resonates with studies emphasizing governance challenges inherent in ASEAN energy transitions (Fatmo et al., 2025).

Moreover, divergent organizational cultures and temporal rhythms among stakeholders produce coordination challenges, confirming earlier research on inter-institutional collaboration complexities (Amrullah et al., 2024). For instance, academic research timelines and private sector market cycles sometimes clash with the rapid urgency expected by community beneficiaries and political actors.

Role of Non-State Actors: Opportunities and Constraints

Non-state actors in the penta-helix model manifest significant opportunities: academicians not only disseminate knowledge but also co-produce tailored, context-specific technologies that foster community resilience. This role extends beyond pure research into applied development, reinforcing capacity building and long-term sustainability programs. Businesses bring critical financial resources and innovative practices but require alignment of profit motives with social and environmental goals to avoid mission drift (Ghosh, 2025).

Community actors wield social capital and local knowledge, which are foundational for adoption and maintenance of renewable systems. Nonetheless, limited technical skills and financial resources constrain community-led initiatives without adequate

support. The dynamic between media, as both information conduits and watchdogs, protects transparency but can sometimes amplify tensions if communication is not managed inclusively.

These insights echo global literature on energy governance that highlights non-state actors as co-creators of policy and practice rather than passive recipients (Siregar & Putra, 2024). Yet, their effectiveness depends on institutionalizing participation mechanisms, which remains nascent in many Indonesian contexts.

Governance Mechanisms: Enablers and Bottlenecks

Effective multi-stakeholder collaboration hinges on well-structured coordination platforms. This research identifies multi-level forums and written partnership agreements as foundational mechanisms. However, these tools often fall short due to irregular engagement, lack of clarity about roles, and non-binding enforcement, mirroring findings from collaborative governance literature (Tang et al., 2021).

Capacity building emerges as a critical enabler, especially for community actors. Programs that equip local stakeholders with technical, managerial, and financial literacy empower them to act as autonomous system stewards. This aligns with development studies advocating for bottom-up empowerment to complement top-down policies (Çalışkan, 2025).

Information sharing, through transparent reporting systems and active media participation, builds trust and fosters adaptive management. Yet, inequities in digital access and communication skills can marginalize vulnerable groups if not addressed through tailored strategies.

Challenges in Sustaining Penta-Helix Collaboration

Challenges revealed by this study include entrenched hierarchical power structures, resource scarcity, and conflicting priorities. Government dominance can erode genuine partner equality, reducing collaboration to symbolic rhetoric instead of substantive co-design. Resource limitations, particularly in rural areas, impede regular maintenance of renewable systems, threatening project durability (Mardhiah & Omalia, 2025).

The mismatch of organizational priorities leads to disengagement and inefficiencies. For example, business interests may prioritize short-term returns, academic missions focus on knowledge production, while communities emphasize livelihood security and cultural appropriateness, requiring sensitive facilitation to align objectives.

Institutional fragmentation, where policies and agencies operate in silos, further complicates smooth collaboration, as corroborated by previous Indonesian policy studies (Prayoga & Anggoro, 2025).

Success Factors and Best Practices for Effective Collaboration

Despite the challenges, this study identifies critical success factors that can be leveraged:

- Strong, inclusive leadership capable of navigating multi-actor agendas and fostering trust. Local champions bridging technical knowledge with community credibility are particularly valuable.
- Clear, shared goals that harmonize different stakeholders' missions into mutually reinforcing objectives. Developing this shared vision early prevents misalignment and conflict.
- Adaptive governance approaches that allow iterative feedback and flexibility in implementation. Projects demonstrating continuous improvement and responsiveness to community feedback show higher resilience.
- Local ownership and empowerment facilitated by participatory processes that move beyond consultation to stakeholder decision-making power.
- Normalized coordination structures such as joint forums with binding agreements, predictable meeting schedules, and conflict resolution mechanisms enhance continuity and accountability.
- Capacity building tailored to diverse actors, including technical training for communities, management skill development for cooperatives, and collaborative leadership workshops for all stakeholders.
- Effective communication strategies that ensure transparent sharing of data, progress updates, and dialogue spaces, thus sustaining legitimacy and broad-based support.

These success factors echo global best practices documented in multi-stakeholder governance and sustainable energy transition research (Sulley et al., 2025).

CONCLUSIONS

This study affirms that the penta-helix collaboration model offers a robust framework for advancing renewable energy governance in Indonesia's Energy Self-Sufficient Village (Desa Mandiri Energi) program. Non-state actors—academia, business, community, and media—play essential, complementary roles alongside government in co-producing sustainable, locally adapted energy solutions. Their collective contributions enhance knowledge innovation, resource mobilization, social empowerment, and transparency, which are critical for effective decentralized energy transitions. However, the success of these collaborations depends on addressing inherent challenges such as coordination complexities, power imbalances, resource limitations, and institutional gaps. Strong leadership, shared visions, adaptive governance, and meaningful community ownership emerge as key enablers. Policy frameworks must explicitly support institutionalizing multi-stakeholder engagement through clear mandates, capacity building, inclusive communication, and financial mechanisms. This research highlights the importance of designing governance approaches that harness the unique strengths of diverse actors while fostering equitable partnerships. As Indonesia

accelerates its renewable energy ambitions, embedding effective penta-helix collaboration will be vital for realizing sustainable development goals. Future studies should explore longitudinal impacts and the integration of digital tools to further optimize multi-actor governance in energy transitions.

ACKNOWLEDGEMENTS

Author thanks to all people and institution in most cases, sponsor and financial support acknowledgments.

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