Community-Driven Solar Energy in Northern Thailand:
A Governance-Specific Framework for Energy Justice
in Marginalized Highland Communities

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Abstract

This study develops a governance-specific framework for energy justice to address persistent inequities in renewable energy adoption within marginalized remote communities in Thailand. Focusing on Nong Prue Subdistrict, Kanchanaburi Province, the research employs a mixed-methods participatory design—including People Scorecards, Focus Group Discussions, and in-depth interviews—to examine how structural barriers, financial burdens, and institutional fragmentation constrain solar energy access in Western Thailand. Findings reveal that reliance on diesel generators imposes unsustainable economic and environmental costs, whereas solar systems offer viable alternatives if supported by inclusive governance, tailored financial mechanisms, and capacity-building.

Integrating Diffusion of Innovations and Social Practice theories, the study advances energy justice scholarship beyond technocratic models by highlighting how constrained decentralization and fragmented authority mediate renewable energy transitions. The proposed model synthesizes distributive, procedural, and recognition justice with participatory planning, offering a context-specific pathway to alleviate energy poverty. This research underscores the role of community agencies in shaping just solar transitions, providing empirical evidence and theoretical innovation for policy and practice in the Global South.

Keywords: Energy Justice, Solar Adoption, Rural Thailand, Hybrid Governance, Participatory Policy, Energy Poverty, Community-Driven Governance, Diffusion of Innovations, Social Practice Theory

Introduction

Access to clean, affordable, and reliable energy is increasingly recognized as a cornerstone of sustainable development, poverty alleviation, and improved quality of life (International Energy Agency, 2022). However, substantial disparities persist in marginalized remote and mountainous regions across Southeast Asia. Within the Greater Mekong Subregion (GMS), rural communities continue to face multidimensional energy poverty shaped by geographic isolation, environmental vulnerability, the institutional fragmentation that hinders equitable resource distribution.

In Thailand, national energy policies such as the Alternative Energy Development Plan (AEDP 2018-2037) have emphasized renewable energy expansion, particularly solar photovoltaic (PV) deployment, as a strategy to achieve energy security and climate goals (Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2020a). However, these policies often rely on technocratic, top-down approaches that overlook the complex local governance nuances essential for effective implementation. This gap is particularly evident in marginalized remote areas, where communities—such as those in Nong Prue Subdistrict, Kanchanaburi Province—remain underserved. Despite being situated in a region with high solar potential, Nong Prue faces

persistent energy access barriers, making it an ideal setting to examine how institutional fragmentation and local power dynamics mediate energy justice in Western Thailand.

Nong Prue represents a microcosm of the broader structural and institutional constraints affecting Thailand's energy transition. The subdistrict is characterized by mountainous terrain, dispersed settlement patterns, and limited infrastructure, all of which make grid-based electrification technically challenging and economically unfeasible. In remote villages like Ban Tha Kradat and Ban Huay Nam Khun, over 80% of households rely on diesel generators, spending between 300–500 Thai Baht ($9–15 USD) per day on fuel. This economic burden exemplifies distributive injustice, as high energy costs directly jeopardize essential public services, including healthcare and education. For instance, clinics often experience power outages that jeopardize medical care, while schools struggle to integrate digital tools due to a lack of electricity.

Beyond infrastructure constraints, the challenges in Nong Prue are compounded by environmental degradation, including deforestation, soil erosion, and unsustainable farming practices, which have contributed to declining agricultural productivity and food insecurity (Anschell et al., 2021). However, the primary barrier to transitioning from these vulnerabilities lies in institutional fragmentation and a lack of localized technical expertise. Existing scholarship and pilot projects, such as solar-powered irrigation initiatives, frequently fail to scale because they prioritize technocratic fixes over participatory governance (Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2020b). These interventions often overlook the procedural justice required to ensure long-term maintenance and community ownership. Consequently, there remains a critical gap in understanding how integrated governance models can overcome the high upfront costs and coordination failures that currently stifle renewable energy adoption in such marginalized contexts.

To address these multifaceted barriers, this study adopts the Energy Plus approach, which posits that renewable energy access must be integrated with broader developmental goals—such as poverty reduction, gender equity, and environmental sustainability—to ensure tangible socio-economic benefits. By moving beyond mere electrification, this framework aligns with recognition justice by addressing the specific needs of marginalized groups. In the context of Nong Prue, the 'Energy Plus' model provides a lens to evaluate how solar interventions can simultaneously enhance food security through irrigation, improve public service delivery, and foster local entrepreneurship. Applying this integrated perspective is essential for developing a governance-specific framework that transitions from technocratic delivery to a justice-oriented, community-driven energy model.

While the Energy Plus approach provides a useful development lens, the success of energy interventions ultimately hinges on the local governance landscape in which they operate. In Thailand, although decentralization has been formally endorsed, practical authority and fiscal resources remain largely centralized. This phenomenon, described as "constrained decentralization", limits the ability of local governments and communities to initiate and sustain renewable energy projects (Resurrección & Elmhirst, 2020). Existing studies often fail to reconcile this tension between local agencies and centralized control. In Nong Prue, for instance, although farmer cooperatives and local leaders demonstrate high capacity for participatory action—such as lobbying for solar subsidies and organizing energy workshops—their efforts remain peripheral to formal planning (Gabay & Ilcan, 2018). This research, therefore, addresses the critical need for a governance-specific model that bridges the gap between bottom-up initiatives and fragmented top-down authority.

Against this backdrop, this study argues that a governance-specific model of energy justice is urgently needed— one that recognizes the political, institutional, and participatory dimensions of renewable energy transitions.

Building on recent scholarship that critiques Western-centric assumptions of functional decentralization, this research develops a contextualized framework grounded in the hybrid governance regimes of Southeast Asia, where centralized bureaucracy coexists with nominal local autonomy (Hall et al., 2011). The case of Nong Prue, Kanchanaburi, provides an ideal setting to empirically explore this framework, as it captures the friction between top-down energy mandates and the lived realities of marginalized communities. By synthesizing these elements, the study offers a scalable pathway for navigating justice in contexts where institutional authority remains fragmented and constrained.

The case of Nong Prue provides an ideal setting to explore how community-driven solar initiatives can dismantle structural inequalities through inclusive governance. By integrating household surveys with participatory tools—including focus group discussions, in-depth interviews, and People Scorecards—this study systematically examines energy outcomes across three thematic levels:

- At the community level, it captures the lived experiences and socio-economic burdens of energy poverty.

- At the governance level, it identifies the institutional barriers and fragmented authority that stifle local initiatives.

- At the policy level, it evaluates how local agency can be harnessed to drive theoretical innovation in energy justice.

In doing so, the research provides both empirical depth and actionable recommendations for policy reform and community empowerment in marginalized contexts.

The objectives of this study are as follows:

1. To examine the structural, environmental, and institutional factors that contribute to energy poverty in Nong Prue Subdistrict.

2. To analyze the roles of local stakeholders, including community leaders, farmer cooperatives, NGOs, and government agencies—in shaping solar energy adoption and sustainability.

3. To assess the applicability of the Energy Plus approach in enhancing the socio-economic and environmental benefits of solar energy initiatives in marginalized highland communities.

4. To develop a governance-specific framework for inclusive solar energy transitions, grounded in local participation and adaptable to the governance contexts of other regions in the Greater Mekong Subregion.

Methods and Materials

This study employs a mixed-methods participatory research design, integrating qualitative techniques with community engagement tools to uncover structural, financial, and governance barriers to solar energy adoption in marginalized remote and mountainous communities. The design is guided by energy justice principles and the Energy Plus approach, prioritizing the co-creation of solutions grounded in the lived experiences of local stakeholders (Sovacool & Dworkin, 2015). Informed by best practices in participatory energy research within Global South contexts (Jenkins et al., 2016), this methodology ensures data triangulation by cross-referencing participatory outcomes with institutional analysis. To minimize researcher bias, the fieldwork—conducted in Nong Prue Subdistrict, Kanchanaburi Province, between March and June 2024—was facilitated through a reflexive approach, where the researcher acted as a neutral moderator to empower community-led discourse.

1. **Research Design Overview**

The research process was structured into three interlinked phases designed to ensure methodological rigor and data triangulation:

- **Phase 1.1:** Issue identification and prioritization using People Scorecards.
- **Phase 1.2:** Collaborative problem-solving and cross-verification of data via Focus Group Discussions (FGDs).
- **Phase 1.3:** In-depth exploration of stakeholder experiences and institutional dynamics through semi-structured interviews and documentary review.

This multi-phase approach allows for iterative validation, where findings from the participatory sessions are cross-referenced with institutional data to enhance the study's internal validity.

2. **People Scorecards: Participatory Problem Prioritization**

People Scorecards are a participatory assessment tool that enables communities to identify and prioritize development challenges in a transparent and democratic manner. This method is crucial in settings where conventional top-down planning fails to capture marginal voices (Gaventa & Barrett, 2010).

Purpose and Rationale The objective of employing Scorecards was twofold: 1) to ensure that research questions reflect the community's lived priorities, and 2) to cultivate ownership among participants. To minimize researcher bias and power asymmetries during the scoring process, sessions were moderated by trained local facilitators who ensured that all demographic subgroups—including women and the elderly—could express their priorities without institutional pressure. This approach aligns with the study's focus on community-driven governance.

Implementation in Nong Prue

A community workshop was convened with 50 participants, a sample size determined to be the optimal balance between ensuring robust demographic representation and maintaining logistical feasibility for an interactive participatory session. Participants were purposively selected to reflect the subdistrict's diversity, comprising farmers (40%), local officials (20%), community enterprise members (20%), and students (20%).

To minimize research bias and prevent the dominance of specific individuals, the workshop employed a structured facilitation technique:

1. **Open-ended Inquiry:** Facilitators introduced neutral prompts regarding daily energy challenges, allowing issues to emerge organically from the participants.

2. **Visual Brainstorming:** Key issues—including unreliable electricity, high diesel costs, and water scarcity—were documented on large visual boards to ensure transparency.

3. **Anonymized Prioritization:** Using sticker voting, each participant independently selected the top three issues affecting their livelihood. This method was chosen to mitigate power asymmetries, ensuring that marginalized voices (such as students and small-scale farmers) carried equal weight to local officials in the final prioritization.

Reflexivity and Bias Mitigation

During the participatory sessions, certain power asymmetries were observed; for instance, marginalized participants, including women and elders, were initially hesitant to share perspectives in the presence of local authorities. To mitigate facilitation bias and ensure inclusive representation, the research team adopted a reflexive role, acting as neutral moderators rather than directors of the conversation.

Culturally appropriate engagement techniques—such as small-group breakouts conducted in local dialects—were employed to create a "safe space" for expression. Facilitators emphasized the link between the scorecard process

and tangible community outcomes to build trust and counteract research skepticism. To ensure data integrity, the researcher maintained a reflexivity journal to document and cross-check personal observations against participant responses, thereby minimizing subjective over-interpretation of the findings. This transparent approach ensured that the prioritized issues reflected authentic community lived experiences rather than researcher-led assumptions.

Outcomes

The scorecard process yielded a clear ranking of community concerns. Energy poverty and water scarcity emerged as the two most urgent issues, providing a focused foundation for deeper inquiry through subsequent FGDs. This method demonstrated that participatory tools not only improve data accuracy but also reinforce democratic inclusion in development research.

3. Focus Group Discussions (FGDs): Deepening Community-Driven Insight

FGDs were conducted to expand upon the issues prioritized through the People Scorecards and to explore causal linkages, lived consequences, and community-driven solution pathways. FGDs were designed to allow for open-ended, context-sensitive discussion while maintaining thematic focus.

Purpose and Justification

FGDs are a well-established method for eliciting nuanced insights from demographically or experientially similar groups. In this study, they served as a bridge between problem identification and policy-relevant solution development. Crucially, the use of FGDs facilitated data triangulation, as it allowed the research team to cross-verify the individual priorities identified in the Scorecard phase with collective group deliberations. (Morgan, 1997).

Implementation in Nong Prue

To ensure a "safe space" for expression and to minimize dominance bias, participants were organized into three homogeneous groups based on their functional roles:

- **FGD 1:** Local farmers, focusing on agricultural energy use and irrigation.

- **FGD 2:** Community leaders and elected officials, addressing governance bottlenecks and institutional constraints.

- **FGD 3:** Entrepreneurs and cooperative members, discussing financing and renewable energy adoption for productive uses.

Each 90-minute session was facilitated by trained moderators using a semi-structured guide. To ensure data verification (Member Checking), the facilitators provided a summary of key takeaways at the end of each session, allowing participants to confirm, clarify, or correct the recorded insights in real-time. This process ensured that the findings were a true reflection of the community's consensus.

Challenges and Mitigation

To address power asymmetries and facilitator bias, moderators adopted a reflexive role, acting as neutral facilitators rather than experts. Balanced participation was ensured through equal turn-taking prompts and breakout pairs. Furthermore, a member-checking process was integrated into each session; facilitators synthesized discussion points in real time and presented them back to the group for validation, ensuring the recorded insights accurately reflected the participants' consensus without researcher over-interpretation.

Outcomes

The FGDs produced grounded insights into the social and institutional dynamics of energy poverty, with notable outcomes including: 1) broad support for solar-powered irrigation systems, particularly among farmers affected by diesel price volatility, 2) an identified need for capacity-building programs, such as solar panel

maintenance training, and 3) a recognition that local administrative bodies lack discretionary budgets and technical mandates for energy projects, despite formal decentralization policies. These insights directly informed the design of the governance-specific energy justice framework proposed by the study and reaffirmed the need for localized participatory energy planning.

4. In-depth Interviews: Institutional Perspectives and Governance Insights

To complement the community-based participatory tools, this study employed semi-structured in-depth interviews with key informants at the institutional level. These interviews provided a deeper understanding of the governance, policy implementation, and institutional coordination challenges that influence solar energy access in marginalized areas.

Purpose

The interviews were designed to uncover mismatches between national policy design and local implementation, examine the institutional constraints facing decentralized energy planning, and explore perceptions of participatory governance among public and non-state actors.

Sampling and Participants

A total of 12 key informants were selected using purposive and snowball sampling. Snowball sampling was particularly necessary to identify and access gatekeepers and individuals with highly specific knowledge of inter-agency coordination and informal power dynamics, which are often not reflected in formal organizational charts. The participants included: 1) officials from the Department of Alternative Energy Development and Efficiency (DEDE) and the Provincial Electricity Authority (PEA) (n = 4), 2) elected local administrators and subdistrict officials (n = 3), 3) representatives from NGOs working in rural electrification and sustainable development (n = 3), and 4) energy researchers and policy analysts from local universities (n = 2).

Data Collection and Analysis

Interviews (45-60 minutes) followed a semi-structured guide. All sessions were audio-recorded with consent and transcribed verbatim. Data were analyzed using NVivo software (Version 12), employing a multi-stage thematic coding process. This involved: 1) Initial open coding to identify emergent concepts, 2) Axial coding to organize codes into parent and child nodes, and 3) Selective coding to synthesize core domains—policy coherence, local autonomy, and stakeholder engagement. To ensure coding consistency, the researcher cross-checked themes against interview transcripts periodically during the analysis phase.

Key Findings

The interviews revealed that national frameworks are often hindered by fragmented implementation. Local governments reported insufficient budgets and a lack of technical mandates. These institutional insights were then triangulated with the community-level findings from FGDs and Scorecards to identify the implementation gap between top-down policy and bottom-up reality. This confirmed the state of constrained decentralization in the region.

5. Documentary Analysis: Policy Context and Institutional Constraints

To triangulate primary data and contextualize governance dynamics, the study also undertook documentary analysis of relevant national and subnational policy documents, including laws, strategic plans, and development reports that shape renewable energy implementation in rural Thailand. This step was crucial for cross-verifying the institutional barriers reported by interviewees with formal legal frameworks. The documents reviewed specifically included: 1) Thailand's Alternative Energy Development Plan (AEDP 2018-2037), 2) Energy for

All Program Guidelines (International Energy Agency, 2022), 3) the Local Administration Act (No. 6), B.E. 2562 (Government Gazette Division, Secretariat of the Cabinet, 2019), 4) the annual development plans and budgets of Nong Prue Subdistrict (2020−2023), and 5) National Economic and Social Development Council (NESDC) reports on rural poverty and infrastructure gaps.

Analytical Approach

A directed content analysis approach was applied, where documents were coded using NVivo to identify thematic overlaps and contradictions. This enabled the identification of: 1) gaps between policy rhetoric and resource allocation, 2) overlapping mandates between central and local agencies, and 3) ambiguities in local authority for initiating solar projects. The documentary analysis confirmed the systemic challenges reported in interviews and FGDs, reinforcing the need for multi-level governance reform to support inclusive energy transitions.

6. Conceptual Framework: Governance-Specific Energy Justice in Highland Communities

To integrate empirical findings and guide analysis, this study develops a governance-specific energy justice framework that contextualizes the principles of distributive, procedural, and recognition justice within Thailand's hybrid governance environment. The framework is built upon several core assumptions, namely: 1) distributive justice focuses on equitable access to energy resources, 2) procedural justice emphasizes inclusion in decision-making processes, 3) recognition justice highlights the need to acknowledge marginalized groups' perspectives and knowledge systems, and 4) governance outcomes are shaped by the interaction of centralized institutional mandates and local community agencies.

Methodological Integration and Quantitative Rigor

The multi-method approach—combining participatory tools, institutional interviews, and documentary review—ensures both bottom-up and top-down perspectives are captured. To support the qualitative insights, quantitative data on household energy expenditures and localized solar potential were integrated. Solar radiation data were sourced from the Department of Alternative Energy Development and Efficiency (DEDE) database, and energy-cost burdens were calculated based on primary household survey data (n = 50) to quantify the financial pressure on the community.

Synthesis and Validation: The use of People Scorecards and FGDs allowed for the co-creation of solutions, while interviews and policy analysis illuminated governance bottlenecks. The conceptual framework serves as a tool for "analytical triangulation", synthesizing these diverse data streams into a model that advances both theory and practice in energy justice for marginalized regions. By reconciling centralized mandates with local agency, the framework offers a scalable pathway for inclusive energy transitions.

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Results

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The findings of this study, derived from integrated mixed-methods research, offer a comprehensive understanding of the multifaceted energy and development challenges in Nong Prue Subdistrict. To ensure methodological transparency, the results are synthesized from three primary data streams: qualitative insights from participatory tools (People Scorecards and FGDs), institutional perspectives from in-depth interviews, and quantitative evidence from household surveys and technical solar radiation modeling.

Energy Poverty and Socio-Economic Burdens (Addressing Objective 1)

Energy poverty emerged as a critical challenge, with findings cross-validated through both quantitative surveys and participatory assessments. Quantitative data from the household surveys (n = 50) indicated that approximately

85% of households in Nong Prue rely on diesel generators as their primary electricity source—a solution that is both costly and unsustainable (IEA et al., 2020).

Complementing this, the People Scorecard exercises allowed community members to rate the reliability of local infrastructure; these participatory ratings highlighted that 90% of schools, 75% of healthcare centers, and 80% of small businesses suffer from intermittent or insufficient power.

In-depth interviews provided further context to these figures, revealing that diesel fuel expenses account for 30-40% of monthly household income. The technical difficulty of grid expansion in mountainous terrain was a recurring institutional barrier. Participants identified solar power as a transformative alternative with the potential to reduce electricity costs by up to 70%, a finding that aligns with rural electrification trends in Laos and Nepal (Sovacool & Dworkin, 2014). However, as identified in both FGDs and interviews, this transition is currently stifled by low technical literacy and a lack of localized financing mechanisms.

Environmental Degradation and Technical Feasibility (Addressing Objective 3)

Focus Group Discussions (FGDs) emphasized the region's growing vulnerability to environmental degradation. Participants identified deforestation, slash-and-burn agriculture, and illegal logging as primary drivers of soil erosion. Based on regional environmental assessments, over 60% of forest cover in the Western Forest Complex has been degraded or lost in the last two decades, contributing to a 30% decline in water retention and agricultural output (Royal Forest Department, Ministry of Natural Resources and Environment, 2022; Global Forest Watch, n.d.). In response, participants advocated solar irrigation systems to enhance agricultural resilience. Technical analysis conducted for this study reveals that transitioning to solar could result in a potential annual reduction of 1.5-2 tons of CO_2 emissions per household. However, the environmental impact of solar energy must be viewed through a life-cycle lens. While solar deployment reduces carbon footprints, the system's end-of-life phase—specifically the decommissioning of lead-acid batteries and photovoltaic (PV) modules—poses significant risks if not managed through specialized e-waste recycling programs. Without a formal disposal framework, heavy metals could leach into the mountainous watershed, potentially offsetting the initial environmental gains.

Socio-Economic Development and Governance Agency (Addressing Objectives 2 and 4)

In-depth interviews with local leaders and residents highlighted the centrality of energy access to broader socio-economic aspirations. Stakeholders expressed a strong demand for capacity-building in solar technology, agricultural processing, and small enterprise development. To address the need for clearer policy implications, these findings suggest that local government units (SAOs) and NGOs should pivot from mere equipment provision to funding long-term vocational training programs. Interviewees estimated that solar-based initiatives could create between 50 and 100 new local jobs, particularly in the installation, repair, and maintenance sectors. This participatory data emphasizes the historical failure of top-down approaches and stresses the importance of aligning future development projects with localized knowledge and governance structures. By integrating these socio-economic targets into the proposed energy justice framework, the study provides a roadmap for local leaders to advocate for decentralized energy budgets that prioritize community-led employment.

Technical Feasibility and Life-Cycle Cost Analysis (Addressing Objective 3)

Technical analysis based on the Solar Potential Map of Thailand (Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2020b) revealed that Nong Prue receives solar radiation levels averaging 5.0-5.5 kWh/m²/day. According to global and national standards, these levels are classified as excellent for photovoltaic (PV) deployment, exceeding the minimum threshold of 4.0 kWh/m²/day required

for high-efficiency energy production (International Renewable Energy Agency & International Labour Organization, 2022).

Energy consumption profiles from household surveys showed a daily demand of 5-10 kWh for residences and 20-30 kWh for community institutions. Comparative simulations between PV systems and diesel generators indicated that while solar systems require a higher initial investment (100,000-150,000 THB), they result in 40-50% lower Levelized Cost of Electricity (LCOE) over a 20-year lifecycle (International Renewable Energy Agency & International Labour Organization, 2022). To ensure long-term environmental sustainability, this technical feasibility assumes the integration of a circular management plan for system decommissioning, as suggested in previous sections, to mitigate the impact of solar e-waste at the end of the 20-year period.

Comparative Analysis: Solar Energy vs. Diesel Generators

A comparative analysis was conducted to evaluate the feasibility of transitioning from diesel generators to solar energy systems. The results highlight the technical, economic, and environmental advantages of solar energy over diesel generators. (see Table1)

Table 1 Comparative analysis: Solar energy vs. Diesel generators

Parameter	Diesel Generators	Solar Energy Systems
Daily Operating Cost	300-500 THB ($9-15 USD)	0 THB (after initial investment)
Initial Investment	Low (10,000-20,000 THB)	High (100,000-150,000 THB)
Environmental Impact	High (CO_2 emissions, noise)	Low (zero emissions, silent)
Reliability	Moderate (requires fuel supply)	High (dependent on sunlight)
Lifespan	5-10 years	20-25 years

This analysis confirms the long-term economic and environmental viability of solar systems in off-grid settings. These findings directly support Objective 3 by proving technical viability and suggest a clear policy implication for Objective 4: the need for financial mechanisms, such as low-interest loans or subsidies, to bridge the initial investment gap for marginalized households.

Interconnected Challenges and Opportunities

The synthesis of participatory data and technical analysis underscores a critical convergence of energy, environmental, and livelihood concerns. The lack of reliable electricity in Nong Prue does not merely represent a service gap; it deepens socio-economic vulnerabilities and exacerbates environmental harm through a reliance on fossil fuels and forest-dependent livelihoods. By integrating findings from People Scorecards (local priorities) with In-depth Interviews (institutional barriers), this study confirms frameworks like Social Practice Theory, which highlight that energy behavior is inseparable from material and governance conditions (Shove et al., 2012).

Techno-economic modeling based on the 5.0-5.5 kWh/m²/day radiation levels estimates that localized, decentralized solar systems across the subdistrict could generate a cumulative capacity of 1.5-2 MW. This output is sufficient to meet the essential energy needs of over 1,000 households while significantly reducing deforestation pressure—as households pivot away from charcoal and diesel—and mitigating carbon emissions. However, as noted in the environmental impact assessment, the realization of these opportunities is contingent upon a robust governance framework that manages the full life cycle of solar technology, including end-of-life recycling.

Synthesis of Community Engagement and Actionable Pathways (Addressing All Objectives)

The participatory design of this research proved essential for contextualizing technological solutions within the specific socio-political landscape of Nong Prue. By integrating People Scorecards, FGDs, and quantitative

modeling, this study has successfully addressed its four core objectives: identifying socio-economic burdens (**Objective 1**), uncovering governance bottlenecks (**Objective 2**), validating technical and environmental feasibility (**Objective 3**), and co-designing a community-led framework (**Objective 4**). These tools fostered trust, enhanced local ownership, and facilitated co-design of realistic solutions—a process consistent with literature on community-based energy governance (Resurrección & Elmhirst, 2020).

To translate these findings into practice, the study identifies specific policy implications for three key groups:

- **For Local Government (SAOs):** Shift from centralized procurement to decentralized "Energy Service Units" that can manage local solar maintenance budgets and technical training.

- **For NGOs and Development Agencies:** Focus on "Energy Plus" interventions—coupling solar installations with productive uses like agricultural processing to ensure long-term financial sustainability.

- **For Community Leaders:** Establish "Community Energy Committees" to oversee the fair distribution of resources and manage the end-of-life recycling programs (solar e-waste) identified as a critical environmental risk.

In conclusion, the findings underscore that solar energy is a viable and cost-effective solution for Nong Prue District, provided it is supported by decentralized governance. By leveraging participatory tools, the study has identified solutions that are not only technically sound but also socially legitimate, laying the foundation for long-term resilience and self-reliance. Refer to **Table 2** for a summarized alignment of Research Methods, Key Findings, and Proposed Solutions.

Table 2 Research methods, key findings, and proposed solutions in nong prue district

Research Method	Purpose	Key Findings	Proposed Solutions
People Scorecards	Empowering communities by identifying and prioritizing key issues	Limited access to electricity is identified as a major issue, with reliance on expensive and environmentally harmful diesel generators.	**Community-Driven Solar Energy Projects:** Implement solar-powered irrigation systems and microgrids to provide reliable, affordable electricity.
		High costs of diesel fuel and technical challenges in expanding the electrical grid due to rugged terrain.	**Training Programs:** Provide hands-on training in solar technology installation and maintenance to build local capacity and create job opportunities.
		Strong community interest in solar energy but barriers include lack of technical knowledge, financial resources, and institutional support.	**Financial Mechanisms:** Develop accessible financing options to support the adoption of solar energy systems.
Focus Group Discussions	Facilitate in-depth discussions to uncover challenges and co-create solutions	Deforestation, illegal logging, and unsustainable farming practices have led to soil erosion, loss of biodiversity, and water source degradation.	**Integrated Resource Management:** Promote reforestation, sustainable land use practices (e.g., agroforestry), and solar-powered water pumping systems to improve water access and reduce reliance on diesel pumps.
		Environmental degradation exacerbates water scarcity and reduces agricultural productivity.	**Community Awareness Programs:** Educate communities on sustainable practices and the benefits of renewable energy for environmental conservation.

Table 2 (Cont.)

Research Method	Purpose	Key Findings	Proposed Solutions
In-Depth Interviews	Gain deeper insights into community needs through one-on-one interactions	High demand for capacity-building programs in renewable energy, agricultural processing, and marketing to empower local stakeholders.	**Capacity Building:** Organize workshops on renewable energy technologies, agricultural processing, and marketing to enhance skills and create sustainable livelihoods.
		Top-down approaches often fail to address local needs; community-driven initiatives are preferred.	**Community-Led Initiatives:** Encourage local involvement in planning and implementing projects to ensure relevance and sustainability.
		Solar energy projects can create economic opportunities and improve access to education and healthcare.	**Partnerships:** Collaborate with educational institutions, private sector actors, and NGOs to provide expertise, resources, and funding for scaling up initiatives.
Proposal Development	Develop actionable solutions collaboratively with stakeholders	Energy poverty, environmental degradation, and socio-economic underdevelopment are deeply interconnected.	**Holistic Approach:** Integrate renewable energy technologies with participatory approaches to address multiple challenges simultaneously.
		Solar energy can serve as a common solution, reducing reliance on fossil fuels, promoting sustainable practices, and creating economic opportunities.	**Multi-Stakeholder Collaboration:** Foster partnerships between governments, private companies, NGOs, and academic institutions to ensure the success and scalability of initiatives.
		The proposed solutions align with the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 15 (Life on Land).	**Scalability:** The framework developed for Nong Prue District can serve as a model for other marginalized regions facing similar challenges.
			Knowledge Sharing: Share lessons learned and best practices with other communities and stakeholders to promote wider adoption of sustainable development strategies.

Limitations

While the study provides valuable insights, several limitations must be acknowledged. First, the participatory tools, though inclusive—may still reflect the views of more vocal or influential community members, potentially sidelining more marginalized voices. Second, technical feasibility assessments were based on average solar radiation and modeled energy use, not longitudinal performance data. Third, the findings are context-specific and may not be fully generalizable to other highland regions in Thailand or the GMS. Nonetheless, the mixed-methods approach and triangulation of data sources lend strong credibility to the findings.

Discussion and Theoretical Implications

This section synthesizes empirical findings to broaden theoretical and policy implications. The results in Nong Prue reflect a dynamic interaction between community agencies and institutional frameworks, which can be analyzed through several theoretical lenses.

Energy Justice and the Hybrid Governance Challenge: The findings from Nong Prue map directly onto the three pillars of **Energy Justice,** revealing how marginalized communities navigate hybrid governance:

- **Distributive Justice:** The high diesel costs (30–40% of income) and intermittent power in schools (90%) and clinics (75%) highlight a profound distributive inequity. Solar energy serves as a tool for justice by redistributing economic resources back to households through 40–50% lower lifecycle costs, as shown in the comparative analysis.

- **Procedural Justice:** The exclusion of cooperatives and local leaders from central energy planning reflects a procedural gap. This study's use of People Scorecards and FGDs addressed this by ensuring community voices were central to the co-design of solutions, moving beyond top-down mandates.

- **Recognition Justice:** By identifying the unique needs of local farmers and small entrepreneurs, this research recognizes the "lived experience" of energy poverty. It acknowledges that marginalized groups are not just passive consumers but active agents with localized knowledge (Shove et al., 2012).

Innovation Diffusion and Social Practice: The findings align with Diffusion of Innovations Theory (Rogers, 2003). In Nong Prue, solar adoption is driven by its "relative advantage"—specifically cost savings and reliability. The participatory nature of the Scorecards and FGDs facilitated "observability" and reduced uncertainty among residents, which Rogers identifies as critical for technology adoption.

Furthermore, consistent with Social Practice Theory (Shove et al., 2012), energy use here is a routine embedded in survival. Solar energy does not just provide "power"; it reconfigures social practices such as irrigation and education. By reducing the reliance on deforestation for fuel, solar adoption creates a transition in social norms toward environmental resilience.

Contradictions and Divergences: While this study aligns with global trends on solar viability, it diverges from some previous optimistic accounts of decentralization in Thailand. Despite the Local Administration Act (Government Gazette Division, Secretariat of the Cabinet, 2019), our data reveals that local bodies still lack the "discretionary budget" and "technical mandate" to initiate projects. Unlike studies that suggest decentralization is progressing well, our findings point to a **"stalled decentralization"** where legal authority exists on paper but is absent in practice due to central-local coordination bottlenecks.

Policy Implications and Future Research: Successful initiatives in marginalized regions require inclusive governance that facilitates capacity-building. However, this study has limitations that offer pathways for future research:

- **Longitudinal Data:** Future studies should track the 20-year lifecycle of these solar systems to assess long-term technical performance and e-waste management.

- **Sample Diversity:** Expanding the sample to include different ethnic groups or more remote "highland" clusters beyond Nong Prue would enhance the framework's generalizability across Thailand's diverse socio-technical landscapes.

Conclusion and Suggestions

This study provides a robust demonstration of how community-driven solar energy initiatives offer transformative pathways to overcome the interconnected challenges of energy poverty, environmental degradation, and socio-economic underdevelopment. The core theoretical contribution of this research is the development of a governance-specific Energy Justice framework, which addresses the reality of "constrained decentralization" within Thailand's hybrid governance landscape. By integrating renewable energy technologies with participatory tools, this research moves beyond technocratic solutions toward a model that is both socially legitimate and institutionally grounded.

From a Theoretical Perspective

– **Diffusion of Innovations** (Rogers, 2003): Shaped the interpretation of how "relative advantage" (cost savings) and "observability" (through community workshops) accelerate solar adoption.

– **Social Practice Theory** (Shove et al., 2012): Highlighted that energy transitions are only sustainable when solar technology is embedded into daily routines, such as irrigation and schooling, rather than treated as an isolated hardware installation.

Policy Implications and Concrete Recommendations: To bridge the gap between high-level energy strategies and ground-level implementation, this study offers two concrete recommendations:

1. **Institutional Reform:** The Ministry of Interior and Ministry of Energy should formalize Subdistrict Energy Planning Units with discretionary budgets, allowing local authorities to move beyond their current "constrained" status to achieve true procedural justice.

2. **Cross-Sectoral Partnership:** Establish a National Solar E-waste Framework that mandates NGOs and private contractors to include decommissioning and recycling plans in all rural electrification projects, ensuring that SDG 7 (Clean Energy) does not compromise SDG 15 (Life on Land).

Ultimately, by demonstrating the power of community agency within a hybrid governance model, this study calls for a fundamental shift toward demand-responsive energy governance. This approach not only addresses immediate needs but also lays the foundation for long-term equity, self-reliance, and the global advancement of the Sustainable Development Goals (SDG 7, 10, 13).

Suggestions for Future Investigations and Policymaking

Building upon the insights and findings of this study, future research should expand the empirical scope to include comparative studies across other marginalized or highland regions within Thailand and the Greater Mekong Subregion (GMS). Such cross-regional investigations would enhance the generalizability of the governance-sensitive energy justice framework and validate the applicability of participatory tools—such as People Scorecards, Focus Group Discussions (FGDs), and In-Depth Interviews—in different socio-cultural and ecological settings.

Moreover, quantitative studies using longitudinal data could complement the current qualitative findings by measuring the long-term impacts of community-driven solar energy projects on household income, health outcomes, education, and environmental indicators. Integrating geospatial and technological data (e.g., solar irradiance mapping and off-grid expansion models) could also provide policymakers with more robust planning tools.

On the policy front, the research underscores the need for institutional reforms that genuinely empower local governments and community organizations. Policymakers should prioritize decentralizing budgetary authority, establish localized energy planning units, and embed participatory mechanisms into official development planning frameworks. Capacity-building programs in renewable energy technology, financial literacy, and project management should be institutionalized to ensure sustainability and ownership of clean energy initiatives.

Additionally, future policy design should incorporate intersectional considerations—including ethnicity, gender, and socio-economic status—to address structural inequalities in energy access and ensure inclusivity. Multi-stakeholder collaboration between government agencies, academic institutions, NGOs, and the private sector must be formalized to facilitate knowledge exchange, financing mechanisms, and innovation transfer.

By addressing these future directions, both academic and policy communities can more effectively scale up equitable renewable energy solutions and contribute meaningfully to achieving the Sustainable Development Goals

(SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 10 (Reduced Inequalities).

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