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# Renewable Energy Policy and Its Impact on Fulfilling Electricity Needs and Community Welfare in the Small Islands Area, Semau Island, Kupang Regency, East Nusa Tenggara, Indonesia

**Frans J. Likadja**

frans.likadja@staf.undana.ac.id

University of Nusa Cendana

**Fredrik L. Benu**

University of Nusa Cendana

**Petrus Kase**

University of Nusa Cendana

**Petrus de Rozari**

University of Nusa Cendana

**Short Report**

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# Renewable Energy Policy and Its Impact on Fulfilling Electricity Needs and Community Welfare in the Small Islands Area, Semau Island, Kupang Regency, East Nusa Tenggara, Indonesia


## Abstract

This study examines renewable energy policy implementation in small island regions, focusing on Semau Island, Kupang Regency, East Nusa Tenggara. Using a mixed-methods approach with sequential explanatory design, the research integrates quantitative SEM analysis and qualitative thematic analysis. Findings demonstrate that energy diversification policy through Smart Grid Solar Power Plants significantly influences electricity needs fulfillment $\beta = 0.75, p < 0.001$ and directly strengthens electricity provision $\beta = 0.68, p < 0.001$. The policy substantially impacts community welfare $\beta = 0.72, p < 0.001$, with electricity fulfillment contributing significantly to welfare improvement $\beta = 0.55, p < 0.001$. Applying Matland's ambiguity-conflict theory, implementation occurs in the Experimental Quadrant, characterized by high ambiguity but low conflict. Key challenges include limited public understanding of smart grid concepts, minimal policy socialization, and technical issues. Despite these, strong community support (74%) for renewable energy transition and high participation expectations create favorable implementation conditions. The study demonstrates that while Smart Grid technology is crucial, success depends heavily on structural factors including regulatory support and policy effectiveness. This research provides empirical evidence for developing holistic renewable energy implementation strategies in small island regions that integrate technical, social, and policy dimensions for sustainable energy development and enhanced community welfare.



Keywords: Renewable Energy Policy, Smart Grid, Small Islands, Electricity Access, Community Welfare, Policy Implementation


## 1. Introduction

The global energy sector faces critical challenges, including excessive dependence on fossil fuels, which creates economic vulnerability through volatile prices and environmental degradation due to greenhouse gas emissions (Henderson & Sen, 2021). The International Energy Agency identifies clean energy transition and source diversification as primary solutions to mitigate GHG impacts and achieve carbon neutrality targets. Energy infrastructure development has a significant effect on economic performance and social welfare, with access to electricity being a fundamental necessity for sustainable regional development.

Indonesia has established comprehensive energy policies through key regulations that mandate sustainable energy management and prioritize the development of New and Renewable Energy to reduce fossil fuel dependence (PP No. 79, 2014). The government actively promotes Solar Power Plants and other clean energy sources to enhance energy security and mitigate environmental impacts. However, despite achieving an average electricity consumption of 1,285 kWh per capita in 2023, policy implementation faces complex challenges, particularly in remote regions where over 700 million people globally lack access to electricity (Mugisha et al., 2021) (Wassie & Adaramola, 2021) (Volkert & Klagge, 2022).

Small island regions present particularly complex implementation challenges compared to mainland areas. Policy implementation in archipelagic contexts often falls into categories characterized by high ambiguity and conflict, as noted by Matland (1995). Top-down policy models frequently fail in remote areas due to inadequate adaptation to local conditions. Matland's Ambiguity-Conflict Theory offers a relevant analytical framework, identifying four implementation types based on the levels of ambiguity and conflict: administrative, political, experimental, and symbolic (Matland, 1995a).

Case studies from various small islands demonstrate these implementation challenges. Research in the Moa Strait reveals that the tidal energy potential faces technological limitations despite its theoretical capacity (Rosyid et al., 2024). Nain Island's reliance on limited diesel power and Trinidad and Tobago's multidimensional barriers highlight common obstacles, including high costs, inadequate infrastructure, and limited technical knowledge (Straker, 2023).

Structural factors significantly contribute to the failures of implementing renewable energy policies. Van Meter and Van Horn (1975) identify inadequate resources, non-optimal implementing agencies, and poor inter-organizational communication as major obstacles (Van Meter & Van Horn, 1975). Technological limitations and unfavorable economic considerations further hinder optimal implementation despite substantial resource potential (Indah and Rarasati 2023), (De Laurentis & Pearson, 2021).

The research gap between national targets and local realization indicates ineffective implementation of energy diversification policies (Howlett, 2019). While Matland's theory provides valuable insights, critics note its flexibility lacks clear guidance for large-scale implementation, emphasizing the importance of street-level bureaucracy and policy network complexities (Lipsky, 1980) (M. and Rhodes, 1992),.

## 2. Literature Studies and Methodology

### 2.1 Literature Studies

#### 2.1.1 Conflict-Ambiguity-Theory

Matland's Ambiguity-Conflict Theory was developed by Richard E. Matland (1995) as an analytical framework for understanding the implementation of public policy. According to Matland, the success of policy implementation is greatly influenced by two main dimensions: the level of ambiguity and the level of conflict. The level of ambiguity refers to the clarity of the policy objectives and how to achieve those objectives, while the level of conflict relates to disputes or differences of interest between the parties involved in implementation (Matland, 1995a).

Based on the combination of these two dimensions, Matland identified four types of policy implementation, namely Administrative Implementation (low ambiguity, low conflict): Technical and predictable implementation, Political Implementation (low ambiguity, high conflict): Implementation influenced by political and negotiation forces, Experimental Implementation (high ambiguity, low conflict): Adaptive and exploratory implementation, Symbolic Implementation (ambiguity high, high conflict): Implementation that is more rhetorical than substantive

#### 2.1.2 Implementation of Renewable Energy Policy

The implementation of renewable energy policies in the archipelago presents complex challenges that involve technical, economic, social, and institutional aspects. (Volkert dan Klagge 2022) It states that energy diversification is happening very slowly in many developing countries, with key challenges including weak local government capabilities, overlapping responsibilities between agencies, and low transparency in project management.

A study by Mugisha et al. (2021) revealed that the COVID-19 pandemic has slowed efforts to achieve universal access to electricity, particularly in the Sub-Saharan African region, where approximately 592 million people lack access to electricity. This condition shows the importance of an implementation approach that is adaptive to changing external conditions.

#### 2.1.3 Sustainability of Renewable Energy Plant Operations

The sustainability of renewable energy plant operations is influenced by various technical and non-technical factors. According to Rao, Sahoo, and Yanine (2025), the implementation of solar power plants in Smart Grid Hybrid requires the integration of complex

technologies, including Internet of Things (IoT) systems, for monitoring and optimization of operations. However, implementation challenges include high investment costs, the need for skilled technical personnel, and the development of effective maintenance systems. Case studies in Trinidad and Tobago identified key barriers to renewable energy implementation, including high system installation costs, lack of public awareness, absence of supporting infrastructure, and lack of clear policies and regulations (Straker, 2023)

#### 2.1.4.1 Bottom-Up Implementation Theory (Lipsky)

Implementation theory, developed from the bottom up by Michael Lipsky (1980), offers an alternative perspective that is at odds with the top-down approach underlying Matland's theory. Lipsky argues that the actual implementation of the policy occurs at the level of "*Street-level bureaucracy,* "Where the field implementers have significant discretion in interpreting and implementing policies (Lipsky 1980). According to Lipsky, the "*street-level bureaucrats,* "Such as field officers, technicians, and plant operators, can shape policy through their day-to-day decisions. In the context of renewable energy implementation, this theory explains why the same policy can yield different outcomes in different locations, depending on the interpretation and implementation capacity at the local level.

#### 2.1.4.2 Van Meter and Van Horn Implementation Model

Van Meter and Van Horn (1975) developed a more comprehensive implementation model by emphasizing six key variables that influence policy implementation, namely Resources: Funds, labor, facilities, and technology, Characteristics of Implementing Agents: Formal and informal organizations involved, Implementing Attitudes: Motivation and commitment to policies, Interorganizational Communication: Inter-agency coordination, Economic, Social, and Political Environment and external conditions, Implementing Dispositions: Perceptions and responses to policies.

This model criticizes Matland's simplification by arguing that policy implementation is influenced by factors that are more complex and multidimensional than simply ambiguity and conflict. (Van Meter & Van Horn, 1975).

#### 2.1.4.3 *Policy Network Theory*

Policy network theory provides an alternative perspective, emphasizing the importance of relationships and interactions among diverse actors in policy implementation. (Rhodes and

Marsh 1992) said that policy implementation occurs in a network of interdependent actors, where power and resources are distributed among various stakeholders.

In the context of renewable energy, this theory explains why implementation often involves the complexity of coordination between governments, the private sector, communities, and international institutions. Criticism of Matland from this perspective is that the ambiguity-conflict model ignores the network dynamics and power relations that influence implementation.

2.1.4.4 Coalition Advocacy Theory (Sabatier and Jenkins-Smith)

Paul Sabatier and Hank Jenkins-Smith (1993) developed a coalition advocacy theory that emphasizes the role of belief systems and policy learning in the implementation process. According to this theory, policy implementation is influenced by a coalition of actors who share the same belief system and compete to influence policy (Cairney, 2016). This theory criticizes Matland for ignoring the role of belief systems and learning processes in policy implementation. In the context of renewable energy, the difference in trust systems between proponents of fossil energy and renewable energy may explain a deeper implementation conflict than just a conflict of interest.

2.1.5 Academic Debates Regarding the Matland Model

2.1.5.1 Criticism of Two-Dimensional Simplification

Many critics argue that Matland's two-dimensional model oversimplifies the complexity of policy implementation. (O'Toole Jr. 2000)

Criticizes that by focusing only on ambiguity and conflict, Matland's model overlooks other essential factors, such as institutional capacity, resources, and historical context.

In the context of renewable energy implementation, this critique is relevant because it demonstrates that successful implementation depends not only on policy clarity and conflict management but also on technical capacity, funding availability, and historical experience with similar projects.

2.1.5.2 Criticism of the Neglect of the Institutional Context

(Michael Hill and Peter Hupe, 2002) argues that the Matland model ignores the importance of the institutional context in policy implementation. They emphasize that

institutional structures, organizational norms, and formal power relations affect implementation in ways that are not fully captured by the dimensions of ambiguity and conflict.

In the implementation of renewable energy in small islands, institutional contexts such as local government capacity, central-regional relations, and local regulatory frameworks play a critical role that is often more important than the level of ambiguity or policy conflict.

2.1.5.3 Criticism from a Post-Positivist Perspective

From a post-positivist perspective, Yanow (2000) criticizes Matland's model for assuming that ambiguity and conflict can be measured objectively. Yanow argues that the meanings of policy, ambiguity, and conflict are socially constructed through the process of interpretation and therefore cannot be understood through fixed and objective categories.

In the context of renewable energy, this critique is relevant because it suggests that what one group of stakeholders perceives as "ambiguity" may be perceived as "flexibility" by another, and what is perceived as "conflict" may actually reflect differences in perceptions of problems and solutions.

2.1.5.5 Defense and Development of the Matland Model

Despite various criticisms, the Matland model continued to be maintained and developed by its supporters. Matland himself (1995) argues that the model is not intended as a comprehensive theory, but rather as a practical heuristic framework for organizing and synthesizing the diverse literature on implementation.

Recent developments of the Matland model include its application in more specific policy contexts, as demonstrated by Al-Worafi et al. (2021) in pharmacovigilance studies. These studies indicate that the model remains applicable for analyzing policy implementation in diverse contexts and countries.

## 2.2 Research Methodology

1. Types and Approaches to Research

This study employs a mixed-methods approach that combines quantitative and qualitative methods with a sequential explanatory design. The research begins with the collection of quantitative data, followed by quantitative data analysis, then qualitative data collection, and finally, qualitative data analysis.

2. Research Location and Time

The research location is situated on Semau Island, Kupang Regency, NTT Province, comprising two sub-districts: Semau District and South Semau District. The research period lasted from May to August 2025.

3. Population and Sample

The study population is 3,542 household electricity customers on Semau Island. The sampling technique employs cluster random sampling, with clusters defined as villages on Semau Island. The minimum sample size for the SEM-AMOS analysis was 123 respondents (Hair et al., 2010).

4. Research Variables and Indicators

The study used four main latent variables:

Smart Grid Solar Power Plants (X1-X4): Perception of use, environmental contribution, energy efficiency

1) Energy Diversification Policy (X6-X10): Government policy perceptions, incentives, infrastructure
2) Electrification Ratio (X11-X15): Availability of power grid and distribution substation
3) Electricity Demand Fulfillment (X16-X20): Availability, quality, and satisfaction of electricity supply
4) Improving Community Welfare (Y1-Y4): Economic, educational, and health impacts

5. Data Collection Techniques

Data collection was carried out using a quantitative questionnaire with a Likert scale of 1-5, and conducted in-depth interviews with selected respondents, direct observations in the field, and documented the implementation of energy policies and the collection of technical data *of Smart Grid Solar Power Plants*

6. Quantitative Data Analysis

Using Structural Equation Modeling (SEM) with the AMOS software Analysis version includes:

- Evaluation of the measurement model: Convergent validity (AVE > 0.5) and reliability (CR > 0.7) test

- Evaluation of structural models: Path coefficients and significance
- Fit Test Suitability: Chi-square, GFI, CFI, RMSEA.

7. Qualitative Data Analysis

Qualitative data analysis using thematic analysis (Braun & Clarke, 2006) through:

- Data transcription and organization
- Theme-based data coding
- Interpretation of results with local context
- Triangulation for data validation

8. Validity and Reliability

Validity and reliability are seen from:

- Convergent validity: Loading factor > 0.7 and AVE > 0.5
- Build reliability: Composite Reliability (CR) > 0.7 and Cronbach's Alpha > 0.7

## 3. Result

### 3.1 Research Site Profile

The research location is situated on Semau Island, a small island located southwest of Timor Island, which is part of the Kupang Regency administrative area in East Nusa Tenggara Province. Semau Island is divided into two sub-districts: South Semau District and Semau District (Badan Pusat Statistik Kabupaten Kupang. In general, Semau Island has a varied topography, dominated by coastal lowlands and limestone hills in the central part. Semau District generally has a relatively flat to light undulating landscape, especially in coastal areas, while South Semau District tends to have more hilly and steep contours in some parts.

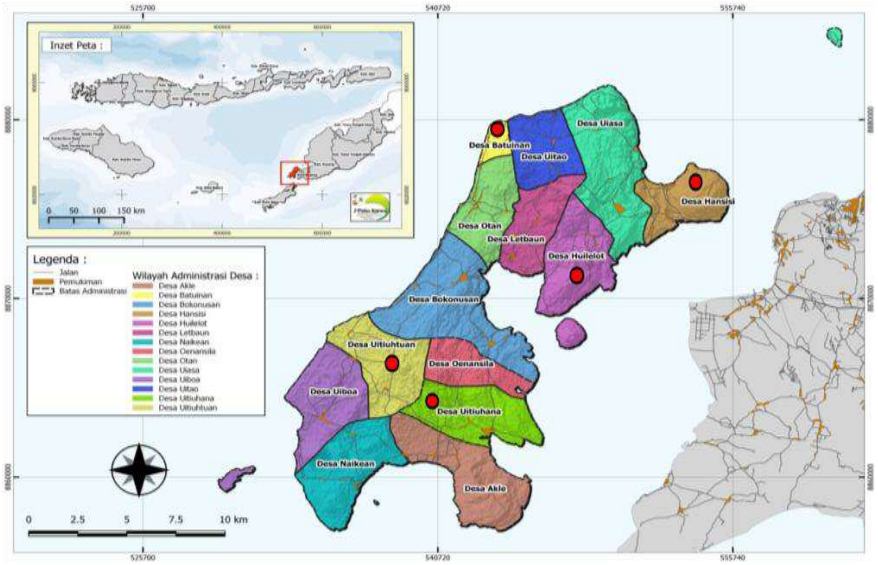



Figure 1. Map of Semau Island Research Location, Kupang Regency, East Nusa Tenggara Province (NTT)

Environmental conditions in both sub-districts are characterized by a dry tropical environment with relatively low rainfall and a long dry season. The vegetation is dominated by savannas, shrubs, and trees that are adaptive to dry climates, such as palm trees and acids. Freshwater resources are often a crucial issue, where communities are heavily dependent on dug wells or limited sources of spring water.

3.2 Semau Island Electricity System

The Electricity System on Semau Island is radial. Electricity for community needs is supplied by a Hybrid System Power Plant, namely the Smart Grid Hybrid Solar Power Plant (PLTS), precisely in Huilelot Village, Semau District, with a capacity of 450 kWP, operating since 2020 and working in parallel with 5 (five) units of Diesel Power Plants (PLTD) with a total installed capacity of 1600 kW. The Semau system power plant supplies an electrical load of 405 kW, corresponding to its installed power PV can work both during the day and night, and electricity is provided using batteries, as seen in the following Figure. 2

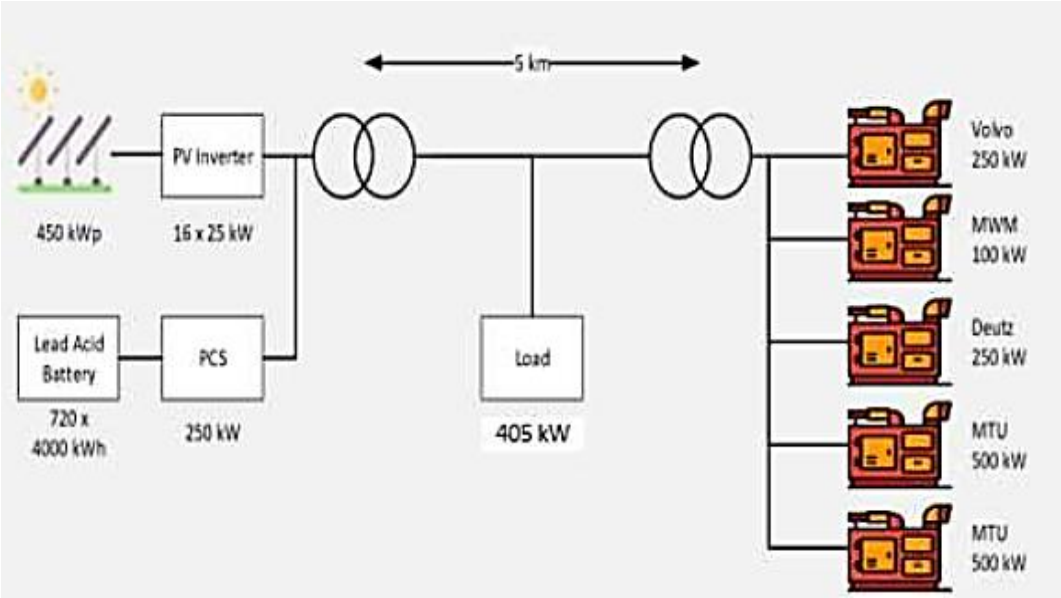



Figure 2. Semau Island Electricity System

The operation of the Semau Island Electricity System is entirely carried out by the Oesao Customer Service Unit (ULP), under the supervision of PT. PLN (Persero) Regional Main Unit (UIW) NTT.

3.3 Demographic Profile of Respondents

This study involved a total of 123 respondents with diverse demographic characteristics. The majority of respondents were men, comprising 67.48% (83 people), while female respondents accounted for 32.52% (40 people). In terms of age, the average age of the respondents was 42.08 years, with a standard deviation of 13.40 years, indicating a diverse age range from 20 to 79 years.

The age distribution of respondents revealed that the majority fell within the productive age group. The age group of 25-45 years dominated at 50.41% (62 people), followed by the age group over 45 years old at 40.65% (50 people), and the age group under 25 years old at 8.94% (11 people). The respondents are predominantly comprised of the productive age and adult populations.

Respondents were spread across several villages in Semau District, with the highest concentration in Huilelot Village (30.08%), followed by Uitiuthtuan (26.02%) and Akle (13.01%). In terms of the primary source of electricity, all respondents (123 respondents, 100%) used PLN Electricity (PLTS Hybrid PLTD), with four respondents (3.25%) also adding other sources of electricity, namely solar home systems (SHS).

The distribution of electric power contracts shows that the majority of respondents have a 900 VA power contract of 53.66% (66 people), followed by 450 VA (22.76%) and 1300 VA and above (13.82%). Of the respondents, 22.76% were subsidized PLN electricity customers. Regarding access to electricity, most respondents (91.87%) use electricity for household needs, while almost all respondents (99.19%) use the Prepaid payment system. The distribution of electricity access in rural Semau Island, along with its use, is illustrated in Figure 3, below.

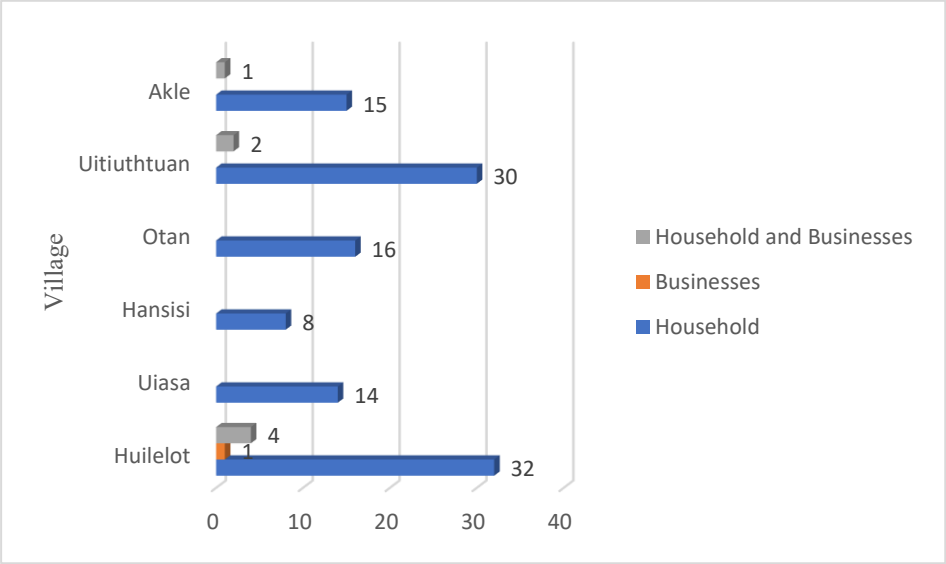



Figure 3. Distribution of electricity access in rural Semau Island and its use

Result of SEM Amos

Dari hasil analisis kualittatif menggunukan Sem – Amos dapat dilihat sebagai berikut.

### 3.4 Test the Goodness of Fit Model in SEM Amos

The Goodness of Fit test in Structural Equation Modelling (SEM) is a series of statistical indicators used to evaluate the extent to which the proposed theoretical model fits the empirical data collected. The goal is to determine whether the hypothetical model can adequately explain the relationships between variables in the data.

This section presents the results of the model fit test (Goodness of Fit) from the structural equation modeling (SEM) that was formed using AMOS software version 26. This test aims to evaluate the extent to which the hypothesized theoretical model aligns with the empirical data collected on the concept of improving people's welfare through the use of Electrical energy sources.

The model fit test involves two main analytical tools: Absolute Fit Measure (AFM) and Incremental Fit Measure (IFM). Some of the AFM indicators examined include the Chi-square coefficient ($\chi 2$), Goodness-of-Fit Index (GFI), and Root Mean Square Residual (RMR). Meanwhile, some IFM indicators to check model fit are the Normed Fit Index (NFI), Incremental Fit Index (IFI), and Comparative Fit Index (CFI). The results of the model goodness-of-fit test are presented in the following Table 1:

Table 1. Test Results Goodness of Fit from Research Models

| Goodness of Fit Indicator | Value | Rules of Thumb | Interpretation Based on Criteria |
|---|---|---|---|
| Chi-square ($X^2$) | 0,002 | Less than the critical value (depending on DF and P-value) | **Good** |
| Probability Level (P) | 0.078 | ≤0.05 (Fit) | Fit |
| CMIN/DF | 1.613 | ≤5 (Good), ≤3 (Excellent) | Excellent |
| GFI | 0.912 | ≥0.90 (Fit) | Fit |
| RMR | 0.037 | ≤0.05 (Fit) | Fit |
| NFI | 0.904 | ≥0.90 (Fit) | Fit |
| IFI | 0.913 | ≥0.90 (Fit) | Fit |
| CFI | 0.971 | ≥0.95 (Excellent) | Excellent |

Source: Primary data analysis generated by Amos Software

From Table 1 above, the analysis criteria for the Chi-square test on the model indicate that it is a suitable model due to the degree of probability (Chi-square ≤ 0.05). The results of the analysis show that the value of $\chi 2$ is 0.002 with a probability level (p-value) of 0.000. Therefore, the model covariance matrix is not different from the sample covariance matrix, and thus, this model is suitable. The results of the analysis show that the GFI indicator for the model is 0.912. According to the guidelines, a model is categorized as ideal if the GFI value is 0.90 or greater. The GFI value of the model is 0.912, indicating that the model for improving community welfare through the use of electrical energy sources is a suitable one.

The results of the analysis also showed that the RMR value of the model was 0.037. The model can be considered suitable if the RMR value is ≤0.05, as the result of 0.037 is an appropriate outcome. The NFI value of the model is 0.904, which is above the rule of thumb for an NFI value of ≥0.90, indicating a good model fit. The results of the analysis also showed that the IFI value for the model was 0.913. where, if the IFI value is also ≥ 0.90, then the model is suitable. If the CFI value is greater than or equal to 0.95, it is often considered excellent. The results of the analysis showed that the CFI value was 0.971, indicating an exceptional result for CFI.

### 3.5 Confirmatory Factor Analysis

Before analyzing structural equations, the reliability of the construct variable indicators needs to be tested. The reliability test will measure the level of significance of the indicator in constructing construct variables. Two formulas can be used to analyze the reliability of indicators, namely Construct Reliability (CR) and Variance Extracted (AVE). The reasonable threshold of construct reliability is greater than 0.60. The rule of thumb for extracted variances greater than 0.50. Table 2 shows the output of the standardized loading factor (standardized regression weight) generated by the Amos software, version 26:

Table 2. Standardized Regression Weights: (Group number 1- Default Model)

| | | | **Estimate** |
|---|---|---|---|
| Energy Diversification Policy | <--- | Smart Grid Solar Power Plant | ,700 |
| Electrification Ratio | <--- | Smart Grid Solar Power Plant | ,351 |
| Electrification Ratio | <--- | Energy Diversification Policy | ,667 |
| Electricity Needs Fulfillment | <--- | Smart Grid Solar Power Plant | ,681 |
| Electricity Needs Fulfillment | <--- | Electrification Ratio | ,956 |
| Electricity Needs Fulfillment | <--- | Energy Diversification Policy | ,748 |
| Welfare Improvement | <--- | Smart Grid Solar Power Plant | ,524 |
| Welfare Improvement | <--- | Energy Diversification Policy | ,718 |
| Welfare Improvement | <--- | Electrification Ratio | ,676 |
| Welfare Improvement | <--- | Electricity Needs Fulfillment | ,547 |
| X1 | <--- | Smart Grid Solar Power Plant | ,685 |

| | | | Estimate |
|---|---|---|---|
| X2 | <--- | Smart Grid Solar Power Plant | ,802 |
| X3 | <--- | Smart Grid Solar Power Plant | ,790 |
| X4 | <--- | Smart Grid Solar Power Plant | ,756 |
| X5 | <--- | Smart Grid Solar Power Plant | ,594 |
| X6 | <--- | Energy Diversification Policy | ,703 |
| X7 | <--- | Energy Diversification Policy | ,576 |
| X8 | <--- | Energy Diversification Policy | ,641 |
| X9 | <--- | Energy Diversification Policy | ,712 |
| X10 | <--- | Energy Diversification Policy | ,680 |
| X11 | <--- | Electrification Ratio | ,602 |
| X12 | <--- | Electrification Ratio | ,696 |
| X13 | <--- | Electrification Ratio | ,798 |
| X14 | <--- | Electrification Ratio | ,538 |
| X15 | <--- | Electrification Ratio | ,877 |
| X16 | <--- | Electricity Needs Fulfillment | ,600 |
| X17 | <--- | Electricity Needs Fulfillment | ,615 |
| X18 | <--- | Electricity Needs Fulfillment | ,433 |
| X19 | <--- | Electricity Needs Fulfillment | ,627 |
| X20 | <--- | Electricity Needs Fulfillment | ,745 |
| Y1 | <--- | Welfare Improvement | ,737 |
| Y2 | <--- | Welfare Improvement | ,838 |
| Y3 | <--- | Welfare Improvement | ,883 |
| Y4 | <--- | Welfare Improvement | ,787 |
| Y5 | <--- | Welfare Improvement | ,535 |

Intercepts: (Group number 1 - Default model)

### 3.6 Reliability Test

Reliability is a measure of the internal consistency of the indicators of a formed variable that shows to what degree each indicator indicates a standard formed variable. Construct (composite) Reliability (CR): (Hair et al., 2010) state that an acceptable Composite Reliability value is 0.70 or higher. However, in exploratory research, values between 0.60 and 0.70 are still adequate. A value below 0.60 indicates a lack of internal consistency.

In evaluating the measurement model, the Average Variance Extracted (AVE) is a key indicator for assessing the convergent validity of a construct. Based on the established criteria, the minimum acceptable AVE value is 0.50 (Siswoyo Haryono, 2020) (Fornell & Larcker, 1981). The interpretation of this value is crucial: if the AVE reaches or exceeds 0.50, it indicates that the latent construct under study can explain at least 50% of the total variance of its constituent indicators. Conversely, if the AVE value is less than 0.50, it indicates that most of the variance in the indicator is explained more by measurement error. Compared to the construct itself (Hair et al., 2010).

## 4. Discussion

### 4.1. Context Analysis Parameters

The context of the Small Island Region refers to the unique geographical, social, economic, and environmental characteristics of the archipelago, including geographical isolation, limited infrastructure, vulnerability to climate change, and dependence on energy imports (Michael Hill and Peter Hupe, 2002). The identification of Island Characteristics includes an analysis of factors such as population size, level of economic development, availability of local energy resources, institutional capacity, and existing infrastructure conditions. Stakeholder & Network Mapping is the process of identifying all actors involved in policy implementation, including central and local governments, local communities, the private sector, NGOs, and international organizations, as well as the relationships between them. The *Ambiguity & Conflict* Assessment utilizes the Matland model to evaluate the level of ambiguity and conflict among stakeholders, which determines the appropriate implementation strategy (Matland, 1995a) (Studies, 2024).

#### 4.1.1. Policy Implementation Quadrant Parameters

The Administrative Quadrant (Low Ambiguity-Low Conflict) occurs when the policy objectives are clear and accepted by all stakeholders, allowing implementation through structured administrative procedures. The Political Quadrant (Low *Ambiguity-High Conflict)* is characterized by clear goals, but the presence of substantial differences of interest among stakeholders requires negotiation strategies and political compromises. The Experimental Quadrant (High *Ambiguity-Low Conflict*) occurs when policy objectives are unclear, but there are no significant conflicts, allowing for a trial-and-error approach and adaptive learning. The Symbolic Quadrant (High *Ambiguity-High Conflict*) is the most complex situation where goals are unclear and conflict is high, requiring a consensus approach and legitimacy building (Matland, 1995b).

Experimental Quadrant (High Ambiguity-Low Conflict) occurs when policy objectives are unclear. Still, there are no significant conflicts, in this study it can be seen that the people of Semau do not understand the concept *of smart grid* and the technology used in Semau solar PV, Socialization of energy diversification policies is still minimal and uneven, Smart *grid* systemdoes not function optimally due to damage to computer components, the installed power capacity of solar power plants is reduced due to damage to battery storage, new technologies that are not fully understood by operators and the public.

Low conflict is evident in the Semau community's strong support for replacing PLTD with solar power plants (74% support), with minimal resistance to energy diversification policies. Community participation reaches 74%, with a majority expecting to be involved in development programs. While Smart Grid solar technology is important, its success depends heavily on structural factors, including adequate regulatory and policy support, which is a key takeaway from this experimental approach.

### 4.1.2. Network Strategy Parameters

Structured Network strategies are implemented in administrative quadrants, involving hierarchical coordination and clear division of roles among actors. The Negotiation Network strategy is used in the political quadrant, focusing on conflict mediation, coalition building, and finding win-win solutions. The Exploratory Network Strategy is applied to the experimental quadrant, emphasizing experimentation, innovation, and collective learning. Consensus Network strategies are needed in symbolic quadrants, aiming to build agreement through dialogue, trust-building, and inclusive participation (Voets & Governance, 2021) (Studies, 2024).

In this study, the Structured Network Strategy is implemented through precise hierarchical coordination between the central government, the regions, and PT. PLN is the leading operator. The implementation of Smart Grid Solar Power Plants on Semau Island shows strong administrative characteristics with a structured division of roles. The central government established an energy diversification policy through Presidential Regulation No. 112 of 2022, the local government of Kupang Regency as a facilitator, and PT. PLN as a technical implementer. However, the study's results revealed that, although an administrative structure has been formed, coordination between organizations remains a significant challenge. There is often a mutual exchange of responsibilities or a struggle for authority due to unclear boundaries of authority and coordination, which hinders the optimization of policy implementation.

The dominant top-down approach to implementing energy diversification policies has proven effective in strengthening administrative structures. The results of SEM Amos' analysis indicate that the energy diversification policy has a significant influence on increasing the electrification ratio (estimate = 0.67; $p < 0.001$) and meeting electricity needs (estimate = 0.75; $p < 0.001$). However, this approach faces limitations in local adaptation, where policy socialization is still minimal, and people in the South Semau sub-district generally do not understand the concept of a smart grid, indicating the need to strengthen structured network strategies by enhancing vertical and horizontal communication among actors.

4.1.3. Polycentric Parameter Governance

Ostrom's Polycentric Governance refers to a management system that involves multiple centers of decision-making, which are coordinated with each other and relevant to the archipelago, characterized by distributed authority (Ostrom, 2010). *Polycentric governance* is suitable for the archipelago because it can accommodate the diversity of local conditions and specific needs in the small archipelago of Semau Island. This system enables policy adaptation tailored to the unique characteristics of Semau Island, which features varied topography, dry tropical environmental conditions, and a community with strong communal traditions.

This approach aligns with research findings that structured policies (top-down paths) are dominant in influencing outcomes in the field, but need to be balanced with community participation (bottom-up).

In the implementation of Smart Grid Solar Power Plants on Semau Island, *polycentric governance* enables collective learning through a process that incorporates various stakeholder perspectives, including community and customer perspectives, solar PV/PLN operators, and

social/educational actors, to create feedback mechanisms that enrich the understanding of policy implementation and aligns with the Ostrom principle, which states that the success of resource management is highly dependent on community empowerment and adaptation to local conditions. *The polycentric governance* system offers an ideal framework for addressing the challenges of implementing renewable energy policies in archipelagos with complex geographical and social characteristics, such as those found on Semau Island.

#### 4.1.4. Parameters of the Hybrid Approach

The hybrid approach, as described by Howlett (2019), is a policy implementation strategy that combines the strengths of traditional and contemporary public administration paradigms. In the context of this study, a hybrid approach is employed by combining a top-down model (from the central government) with a bottom-up model (involving local community participation). This approach is particularly relevant for implementing energy diversification policies in small archipelago areas, such as Semau Island, which have complex geographical and social characteristics. Howlett emphasized that effective public policy must combine technical, political, and social aspects. In the implementation of *Smart Grid Hybrid* Solar Power Plants on Semau Island, the hybrid approach enables the adaptation of national policies to local conditions while maintaining consistency in policy objective, is reflected in the coordination between the central government, as stipulated in Presidential Regulation No. 112 of 2022 concerning the Acceleration of Renewable Energy Development, and the participation of local communities in development programs. The hybrid approach is also reflected in the policy implementation model, which integrates top-down structural aspects through central government regulations and the role of PT. PLN as an operator, bottom-up adaptive aspects through community participation in development programs and technology adaptation according to local conditions

#### 4.1.5 Contextual Adaptation

Contextual adaptation, as defined by Hill and Hupe (2002), refers to the ability of policy implementation to adapt to local conditions, community characteristics, and the specific environment in which the policy is being implemented. This concept emphasizes that the success of policy implementation depends not only on good planning from the central level but also on adaptability to unique local contexts. Hill and Hupe argue that policy implementation can fail if there is a mismatch or lack of cooperation in the implementation chain that connects the various levels of the organization.

In policy implementation theory, Hill and Hupe identify that effective policies must be responsive to local characteristics and involve a variety of actors in the implementation process. They emphasized the importance of effective coordination between the various actors and levels of the organizations involved. This approach rejects the one-size-fits-all model and recognizes that each region has unique characteristics that necessitate tailored policy implementations.

The operation of the Smart Grid Solar Power Plant on Semau Island highlights an urgent need for contextual adaptation due to its unique geographical and social characteristics. Semau Island, as a small archipelago, faces specific challenges, including limited infrastructure, varied topographic conditions, and a community with strong communal traditions. The study's results revealed that, although the energy diversification policy has been established nationally through Presidential Regulation No. 112 of 2022, its implementation at the local level faces challenges in adaptation.

The study's findings reveal a gap between national policies and local implementation, highlighting the need for an adaptive approach. For example, a smart grid system, designed as sophisticated technology, does not function optimally due to damage to computer components and a decrease in installed capacity resulting from battery damage. Meanwhile, people in South Semau lack an understanding of the smart grid concept due to a lack of socialization, which confirms Hill and Hupe's argument that implementation requires adjustments to the technical capacity and level of understanding of local communities.

Contextual adaptation is also reflected in the need for a participatory approach that involves communities in development programs. The results showed that 74% of people expect involvement in development programs, which aligns with Hill and Hupe's principles emphasizing the importance of involving various actors in policy implementation. The data triangulation process in this study, involving the perspectives of the community, PLTS/PLN operators, and social/educational actors, is a practical example of an adaptive approach that pays attention to the local context.

Thus, this study provides empirical evidence on the importance of contextual adaptation in implementing renewable energy policies in minor archipelagos, such as Semau Island, which aligns with Hill and Hupe's policy implementation theory.

4.2. Output and *Yield Parameters*

The Energy Diversification Policy, as a key output, includes policy drafts that promote the use of various renewable energy sources, energy efficiency, and energy security. Community welfare as a social outcome encompasses increasing access to energy, job creation, reducing energy poverty, and enhancing the quality of life. Energy Security, as a technical-economic outcome, encompasses energy supply reliability, resource diversification, and a reduction in import dependence. Environmental sustainability, as an ecological outcome, encompasses reducing greenhouse gas emissions, conserving natural resources, and adapting to climate change.

4.3 Enabling Parameter Factors

Local Technical Capacity refers to the knowledge, skills, and capabilities of local communities and institutions in managing renewable energy systems. Supporting infrastructure includes transmission and distribution systems, energy storage facilities, and necessary communication networks. Regulations & Incentives include legal frameworks, funding schemes, feed-in rates, and fiscal incentives that support renewable energy investments. Community participation emphasizes the active involvement of local communities in the planning, implementation, and management of energy systems, ensuring *ownership* and sustainability (Ostrom, 2010). Figure 4.7 below illustrates the Energy Diversification Policy Modeling applied in the Small Islands Region, specifically on Semau Island, Kupang Regency.

The analysis of administrative quadrants in this study is reflected in the implementation of energy diversification policies through a structured top-down approach. Hierarchical coordination between the central government (stipulating Presidential Regulation No. 112 of 2022), the local government of Kupang Regency as a facilitator, and PT. PLN, as a technical operator, establishes an effective administrative structure for implementing Smart Grid Solar Power Plants on Semau Island.

The exploratory network strategy revealed critical information gaps, as the public was unaware of the concept of smart grids, while operators confirmed that the smart technology was not functioning correctly.

Ostrom's Polycentric Governance is highly relevant to the characteristics of the small archipelago of Semau Island. Energy diversification policies enable coordination among multiple centers of decision-making, including central, regional, and local governments. However, the study's results revealed that, although a polycentric structure has been formed,

coordination between organizations remains a significant challenge, with frequent shifting of responsibilities due to unclear boundaries of authority.

Howlett's hybrid approach is translated through a combination of implementation models that blend traditional and contemporary public administration paradigms. The research adopts an approach that combines the strengths of top-down (efficiency and consistency) and bottom-up (local adaptation and participation). The results show that while Smart Grid solar technology is important, its success is highly dependent on structural factors, including adequate regulatory and policy support.

Hill and Hupe's contextual adaptation is reflected in the policy implementation's ability to adapt to the local conditions of Semau Island. Unique geographical and social characteristics necessitate a responsive approach to the community's needs.

The research outputs show that the Smart Grid PLTS directly strengthens the fulfillment of electricity needs. *Outputs* included improved access to electricity and enhanced service quality. However, they faced technical challenges, such as smart grid systems that did not function optimally due to computer component damage.

The research outcomes are reflected in the positive impact on community welfare, as evidenced by the fulfillment of electricity needs. The implementation of energy diversification policies has a significant and direct impact on welfare, as stable access to electricity is a crucial prerequisite for socio-economic development in small island areas.

The integration of this theoretical framework yields a comprehensive understanding that the successful implementation of renewable energy policies in the archipelago necessitates a holistic approach that combines structural, participatory, and contextual aspects to achieve tangible outcomes.

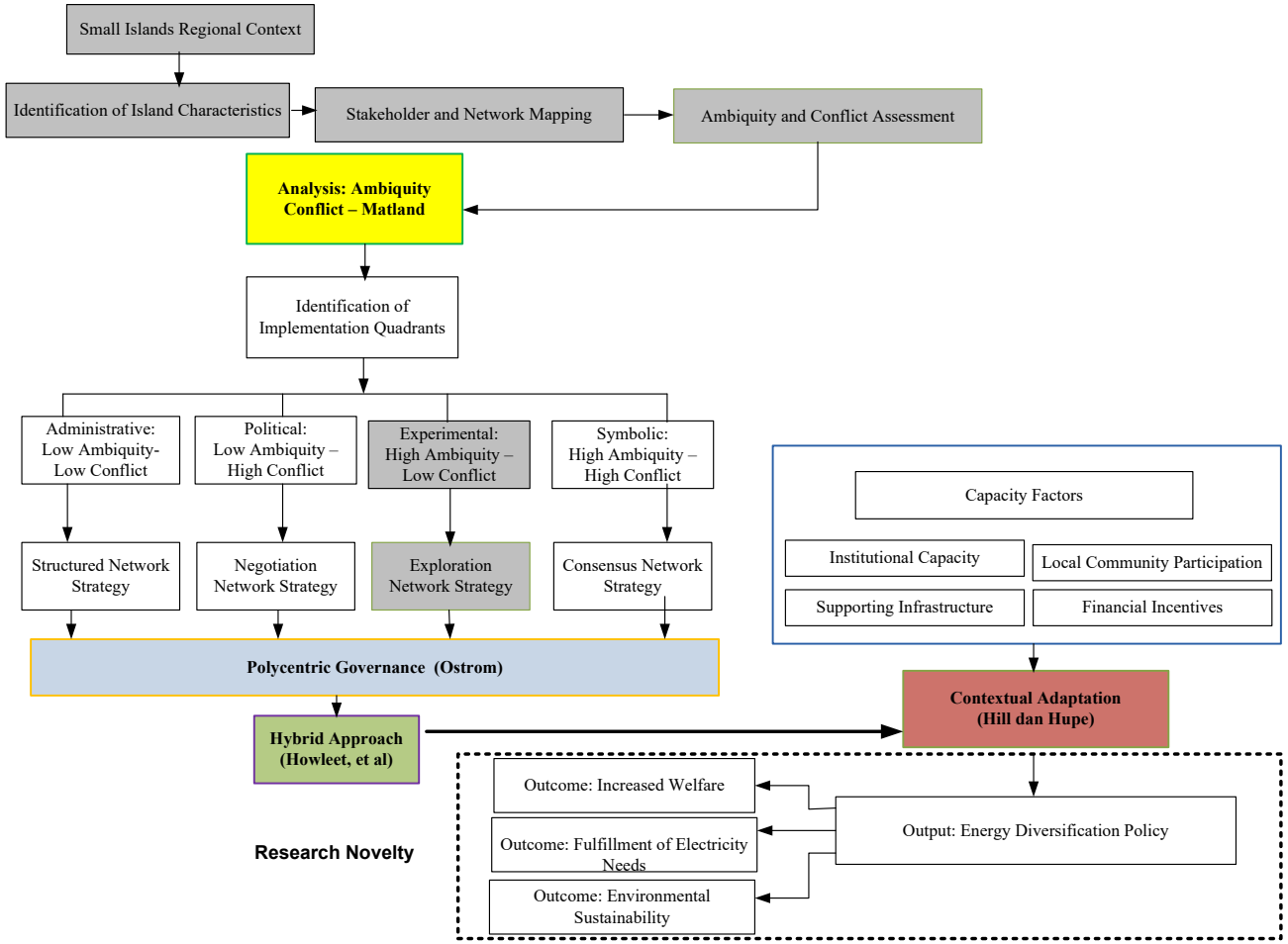



Figure 4. Modeling of Energy Diversification Policy in Small Island Regions

From Figure 4. above**,** it is evident that modeling Energy Diversification Policy in the Small Islands Area, specifically on Semau Island, Kupang Regency, requires an administrative quadrant analysis, which is reflected in the implementation of energy diversification policies through a structured top-down approach. Hierarchical coordination between the central government (stipulating Presidential Regulation No. 112 of 2022), the local government of Kupang Regency as a facilitator, and PT. PLN, as a technical operator, establishes an effective administrative structure in the implementation of *Smart Grid Solar Power Plants* on Semau Island.

The exploratory network strategy revealed critical information gaps, as the public was unaware of the concept of smart grids, while operators confirmed that the smart technology was not functioning correctly.

*Ostrom's polycentric governance is highl*y relevant to the characteristics of the small archipelago, Semau Island. Energy diversification policies enable coordination among *multiple centers of decision-making*, including central, regional, and local governments. However, the study's results revealed that, although a polycentric structure has been formed, coordination between organizations remains a significant challenge, with frequent responsibilities being passed back and forth due to unclear authority boundaries.

Howlett's hybrid approach is translated through a combination of implementation models that blend traditional and contemporary public administration paradigms. The research adopts an approach that combines the strengths of top-down (efficiency and consistency) and bottom-up (local adaptation and participation). The results show that while Smart Grid solar technology *is important, its success is highly dependent on structural factors, including* adequate regulatory and policy support.

Hill and Hupe's contextual adaptation is reflected in the policy implementation's ability to adapt to the local conditions of Semau Island. Unique geographical and social characteristics necessitate a responsive approach to the community's needs.

The research outputs demonstrate that the Smart Grid Solar Power Plant directly enhances the fulfillment of electricity needs. *Outputs* in the form of increased access to electricity and service quality were achieved, although facing technical challenges such as *smart grid systems* that did not function optimally due to damage to computer components, and the capacity of installed power plants was reduced due to battery damage.

The research outcomes are reflected in the positive impact on community welfare, as evidenced by the fulfillment of electricity needs. The implementation of energy diversification policies has a significant and direct impact on welfare, as stable access to electricity is a crucial prerequisite for socio-economic development in small island areas.

The integration of this theoretical framework yields a comprehensive understanding that the successful implementation of renewable energy policies in the archipelago necessitates a holistic approach that combines structural, participatory, and contextual aspects to achieve tangible outcomes.

## 5. Conclusion and Recommendation

### 5.1 Conclusion

The Research on Energy Diversification Policy Analysis in the Small Islands Region, specifically on Semau Island, Kupang Regency, made an original contribution through the integration of multiple models, which has not been done in previous research. This study also adopts a more comprehensive Hybrid Methodological approach, focusing on Smart Grids in the context of small islands. Conduct Holistic Impact Measurement (technical, social, economic, environmental), and provide *contextually specific* Evidence-Based policy recommendations.

Thus, this study not only confirms the findings of previous studies but also develops a new paradigm for implementing renewable energy policies in the archipelago through a more integrated and comprehensive approach.

### 5. 2 Recommendations

#### 5.2.1 For sustainability

Based on the analysis's findings, a comprehensive strategic approach is necessary to optimize the implementation of renewable energy policies. Key recommendations include increasing community participation in decision-making, strengthening equitable energy infrastructure, and implementing more intensive socialization programs on the benefits and workings of Smart Grid PV. By actively engaging the community and enhancing infrastructure capacity, a more efficient and sustainable electricity system can be established on Semau Island, ultimately strengthening its positive impact on the community's overall well-being.

### 5.2.2. Policy Implications and Long-Term Sustainability

The implementation of energy policies on Semau Island through the Smart Grid Solar Power Plant has important implications for sustainable energy planning in other archipelago regions. Despite facing various challenges, the evaluation results reveal a significant correlation between meeting electricity needs and enhancing people's welfare. Long-term success requires a sustained commitment to system management, investment in local capacity building, and policy adaptation that is responsive to the specific conditions of the archipelago. This holistic approach will ensure that the benefits of renewable energy can be enjoyed equally and sustainably by all people of Semau Island.

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The study protocol was approved by the Research Ethics Committee of [University of Nusa Cendana, Faculty of Social and Political Sciences, Indonesia] (Approval by the head of the doctoral program study in administrative science studies) on 26 November 2025. Informed consent was obtained from all participants.

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