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DEVELOPMENT OF IMPACT ASSESSMENT INSTRUMENTS FOR RENEWABLE ENERGY INVESTMENTS IN ORANG ASLI COMMUNITIES

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ABSTRACT

Background and Purpose: The transition to renewable energy is crucial for sustainability, but its impact on marginalized communities, such as the Orang Asli in Malaysia, is insufficiently explored. This study aims to develop culturally sensitive impact assessment tools to evaluate renewable energy projects' effects on the Orang Asli. The purpose is to create a comprehensive framework that ensures these projects are socially, economically, and environmentally inclusive.

Methodology: This study used the Fuzzy Delphi Method (FDM) and Analytic Hierarchy Process (AHP) to identify and prioritize key impact indicators. A panel of 12 experts from diverse fields provided input through surveys in multiple rounds. The FDM identified seven main indicators and 25 sub-indicators related to health, living standards, education, service delivery, cultural preservation, skills development, and safety. AHP was then used to rank the importance of these indicators.

Findings: The study identified seven critical impact indicators: health quality, economic diversification, education, cultural preservation, service delivery, skills development, and safety. Health quality was the most important, emphasizing the need for improved healthcare access and disease prevention. Economic diversification, education, and stakeholder engagement were also prioritized as essential for long-term sustainability and resilience.

Contributions: This study offers a culturally sensitive framework for assessing renewable energy impacts on marginalized communities. It provides valuable insights for policymakers and energy developers to ensure that renewable energy transitions are inclusive, equitable, and aligned with the needs of indigenous communities, with broader global applicability.

Keywords: Renewable energy, Orang Asli, impact assessment, Fuzzy Delphi method, Analytic Hierarchy process.

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1.0 INTRODUCTION

Transitioning to renewable energy is crucial for achieving global sustainability goals, reducing reliance on fossil fuels, and mitigating climate change. In Malaysia, this shift is a national priority, supported by policy frameworks aimed at promoting sustainable development and energy security (Gan et al., 2023; Kumar & Rathore, 2023). However, the impacts of these investments on indigenous communities, such as the Orang Asli, have not been extensively studied. Renewable energy sources like hydropower, wind, and solar are growing significantly, offering low environmental impact and economic benefits (Kazeem Alasinrin et al., 2023; Mohamed Yusoff et al., 2023). Policies promoting renewable energy aim to reduce carbon emissions and enhance energy security, though challenges such as public opposition and storage issues persist. To ensure balanced development of sustainable energy systems, it is essential to consider the specific needs and impacts on indigenous communities like the Orang Asli.

Renewable energy investments present a promising solution to address the challenges faced by the Orang Asli community in Malaysia. Despite being recognized as indigenous peoples, the Orang Asli continue to encounter marginalization in various aspects such as education, healthcare, and socioeconomics (Diansyah et al., 2022; Razak, 2022; Selvaratnam et al., 2023; Yh Loh & Idrus, 2023). Their traditional reliance on the natural environment for sustenance and livelihood underscores the importance of sustainable practices. Involving the Orang Asli in forest management has shown positive social and environmental outcomes, highlighting their potential as meaningful stakeholders in Malaysia's forest management initiatives (Mahmud et al., 2022b). By harnessing renewable energy sources, such as solar

panels for basic infrastructure needs like street lighting and healthcare facilities, the Orang Asli could improve their quality of life, enhance economic resilience, and reduce their dependency on traditional practices for healthcare, ultimately contributing to their overall well-being and development.

Assessing the impact of renewable energy investments on the Orang Asli community is crucial for ensuring the sustainability and benefits of such projects. Research indicates that renewable energy usage positively influences environmental quality and lowers CO2 emissions, emphasizing the importance of investing in renewable energy technologies (Mahmud et al., 2022). Additionally, the Orang Asli have traditionally demonstrated good stewardship in managing the environment, but socio-economic development indicators among them remain low, highlighting the need for sustainable development initiatives (Calderon-Tellez & Herrera, 2023). Furthermore, establishing an energy delivery services model that considers socio-cultural, environmental, and support service factors is essential for meeting the energy needs of the Orang Asli community and enhancing their overall well-being (Amin et al., 2022).

However, existing impact assessment tools may not fully capture the unique context and needs of these communities. This study aims to develop tailored impact assessment instruments that are culturally sensitive and comprehensive, providing a more accurate evaluation of renewable energy projects' effects on the Orang Asli. By addressing this gap, the study seeks to contribute to both the practical implementation of renewable energy initiatives and the academic discourse on impact assessment and indigenous studies.

2.0 METHODOLOGY

2.1 Initial Workshop and Indicator Development

The initial workshop employed nominal group techniques to propose seven indicators and 25 sub-indicators for developing impact assessment instruments for renewable energy investments among the Orang Asli community in Malaysia. These indicators, presented in Table 1, were designed to capture various dimensions of impact, including economic, educational, social, health, safety, skills, and cultural aspects. Subsequently, the methodology incorporated the Fuzzy Delphi Method (FDM) and the Analytic Hierarchy Process (AHP) to refine and prioritize these indicators. The integration of these methodologies ensured a systematic and expert-driven approach to the development of robust and comprehensive assessment instruments.

Table 1 : Proposed indicators and sub-indicators

INDICATORS	SUB INDICATORS
Improving The Economic Level Of Orang Asli	1. Measurement of household income level. 2. Increasing the diversity of economic activities (such as online businesses, marketing, and eco-tourism). 3. Development of agricultural technology. 4. Attracting foreign investors.
Improving The Level Of Education Among Orang Asli	1. Increase in school attendance of Orang Asli students. 2. Improvement in academic performance of Orang Asli students. 3. Increase in the number of Orang Asli students attending higher education institutions. 4. Improvement in the literacy level of Orang Asli students. 5. Improvement in the literacy level of Orang Asli adults.
Improving The Social Value Of Orang Asli Communities	1. Improvement of community unity (e.g., attendance at places of worship, community involvement in mutual aid programs). 2. Increase in the number of community activities (e.g., social activities such as recreational activities, local community meetings). 3. Enhancement of communication skills among Orang Asli society. 4. Increase in the level of interaction among the community members.
Improving The Quality Of Health Among Orang Asli	1. Quality of healthcare services. 2. Orang Asli health level. 3. Improved disease control quality (e.g. dengue, polio, malaria). 4. Awareness of family planning.
Ensuring The Safety Of Residents	1. Reduction of the threat posed by wild animals. 2. Improvement in the safety of residents (e.g. fewer accidents, falling trees, and so on).
Improving The Skills Of Orang Asli	1. Improvement of IT literacy among Orang Asli. 2. Enhancing of the employability skills of Orang Asli. 3. Creation of job opportunities channels (e.g. job vacancies advertisements).
Preserving The Customs And Culture Of Orang Asli	1. The level of practice of Orang Asli customs and traditions. 2. Improvement of Orang Asli handicraft products. 3. Increased efforts to promote Orang Asli culture.

2.2 Fuzzy Delphi Method

Fuzzy Delphi Method (FDM) is a modified version of the method based on the traditional Delphi method. This method was introduced by Kaufmann and Gupta (1988). FDM is an analytical decision-making method that integrates fuzzy set theory into the traditional Delphi method,

which aims to overcome certain ambiguities arising from expert panel consensus (Lee et al., 2021). According to Mabrouk (2021), the traditional Delphi method has often encountered various challenges such as low convergence of expert opinions, high execution costs, and the potential risk of exclusion of distinct expert opinions from researchers. FDM is a more advanced version of the Delphi method because it applies triangulation statistics to measure the distance between levels of consensus within the expert panel (Ghazali et al., 2019). This means that applying this method to a group of experts can eliminate any ambiguity in the general understanding of their opinions (Lin et al., 2020). The selection of this method can also reduce the cost and time of analysing the results while increasing their completeness and consistency since it can address the ambiguity and subjectivity of experts' responses without affecting their initial opinion (Mohd Jamil et al., 2014).

2.2.1 Participant

The participants for this study were selected through purposive sampling from a panel of 12 experts. According to Adler and Ziglio (1996), a sample size of 10 to 15 experts is appropriate for the Delphi technique, which is used to gather expert opinions. The experts were categorized into three groups: policymakers, academicians, and non-governmental organization (NGO) representatives. Among the 12 participants, five were policymakers (41.7%), two were academicians (16.7%), and five represented NGOs (41.7%). Regarding academic qualifications, six participants (50%) held a bachelor's degree, three participants (25%) held a master's degree, and three participants (25%) held a PhD. In terms of professional experience, four participants (33.3%) had between 11 to 20 years of working experience, while eight participants (66.7%) had 21 or more years of experience. These participants' diverse backgrounds and expertise provided a broad perspective for the study's objectives.

2.2.2 Instrument of Study

In this study, the survey questionnaire is employed to elicit experts' opinions on the list of indicators of the instrument. The questionnaire is constructed based on previous literature and small group discussions among participants using the nominal group technique (NGT) to obtain feedback on the list of indicators. The questionnaire is divided into two main sections: (1) Section A: Profile of the experts and (2) Section B: Experts' opinion on indicators for the instrument.

2.2.3 Procedure and Data Analysis

The procedure for the Fuzzy Delphi Method is as follows:

1) Selection of Participants (Experts): In the Delphi method, the selection of experts is crucial because it can influence the quality of the study results (Jacobs, 1996). In this study, the panel of experts consisted of policymakers, policy executors, academics, and non-governmental organisations (NGOs). The selection of the panel of experts for this study was based on the following criteria: (i) The expert must have knowledge of renewable energy and Orang Asli; (ii) The expert must have at least five years of experience in their respective field; (iii) The experts must have at least a bachelor's degree and a doctorate for academics; (iv) The experts who agree to participate must fully commit to the duration of the study; and (v) The expert must have excellent communication skills.
2) Determination of Linguistic Scale: The linguistic scales are similar to Likert scales with the addition of fuzzy numbers incorporated into response scales based on a triangular fuzzy number (Ghazali et al., 2019), as shown in Figure 1. Determining the linguistic scale is essential to resolve the problem of fuzziness between experts' opinions. Hence, in order to take into account the fuzziness of the experts' opinions, three levels of fuzzy values were assigned to each response: minimum value (m_1), most plausible value (m_2), and maximum value (m_3) (Abdullah et al., 2021). In this study, a seven-point linguistic scale (ranging from 1 = extremely not important to 7 = extremely important) was used to collect feedback from participants (experts).

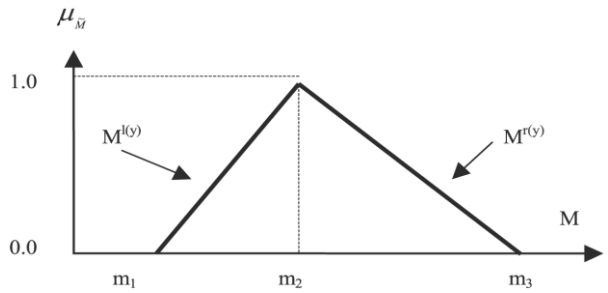

Figure 1: Triangular fuzzy number

3) Calculation of the Threshold Value (d): The threshold values (d) are critical in determining the level of consensus among experts. The expert consensus is considered reached if the threshold value is less than or equal to 0.20 (Cheng & Lin, 2002). The threshold value (d) is calculated according to the following formula:

$$d(\bar{m},\bar{n}) = \sqrt{\frac{1}{3}\left[(m1-n1)^2 + (m2-n2)^2 + (m3-n3)^2\right]}$$

4) Determination of the Agreement of Each Item and the Overall Items: In FDM, determining expert consensus on the items is important to ensure that the items can be adopted for the study under investigation. The overall expert consensus must be greater than 75%. If the expert consensus percentage for each item exceeds 75%, then it is considered to have reached consensus (Rahman et al., 2021). However, if the expert consensus is less than 75%, a second round of fuzzy Delphi should be conducted (Abdullah et al., 2016).
5) Calculation of the Defuzzification Value: The defuzzification process is to determine the ranking (A_{max} score) of each item which reflects the level of expert consensus. A higher A_{max} score implies a higher ranking of the items compared to others. In this study, a defuzzification value (A_{max} score) ≥ 0.5 (Abdullah et al., 2021) is applied to select the list of indicators for the index instrument. Indicators with a score ≥ 0.5 will be accepted, while those below 0.5 will be rejected. Indicators with the highest defuzzification values are prioritized to be considered as outcome items (indicators) for the development of the instrument. The calculation of the defuzzification value is based on the following formula:

$$A_{max} = 1/4 \times (a_1 + 2a_m + a_2)$$

2.3 Analytic Hierarchy Process

Following the Fuzzy Delphi Method (FDM), the Analytic Hierarchy Process (AHP) was used to analyze, rank, and prioritize the identified indicators and sub-indicators. Developed by Saaty (1980), AHP is a multi-criteria decision-making (MCDM) tool widely applied across fields such as politics, economics, and engineering (Leal, 2020). It helps decision-makers address complex problems involving subjective and objective criteria (Ameri, 2013; Ishizaka & Labib,

2009). AHP was chosen for this study due to its ability to systematically capture expert input and determine the weights of indicators and sub-indicators. This ensured the prioritization of elements most aligned with the study's objectives and the needs of the community.

2.3.1 Instrument of the Study for AHP

The survey questionnaire for this study was constructed based on the previous literature and small group discussions among participants using the nominal group technique (NGT). Thus, the survey questionnaire is divided into three sections:

1. Section A: Indicator of corporate investment impact assessment instrument. These items was measured using a Saaty scale ranging from 1= Equal Importance to 9 = Extreme Importance (Saaty, 2008).
2. Section B: Sub-Indicator of corporate investment impact assessment instruments. These items was measured using a Saaty scale ranging from 1= Equal Importance to 9 = Extreme Importance (Saaty, 2008), as shown in Table 1.

Table 2: The fundamental scale of absolute numbers

Intensity of Importance	Definition
1	Equal Importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

2.3.2 Procedure and Data Analysis for AHP

The AHP process involved six key steps. Step 1: Defining the Goal entailed clarifying the objective of the study, which was to develop a renewable energy impact assessment instrument for the Orang Asli (Leal, 2020). Step 2: Hierarchy Construction required building a hierarchical structure where the top level represented the study's goal, the second level included the

indicators, and the third level comprised the sub-indicators (Darko et al., 2018). This hierarchical breakdown facilitated a structured analysis of the problem.

In Step 3: Pairwise Comparison, the relative importance of indicators and sub-indicators was established by comparing them in pairs. Experts rated these comparisons on a nine-point scale, ensuring the systematic evaluation of each element. Step 4: Calculating Relative Weights involved determining the relative significance of each element using eigenvector calculations, which provided weighted scores for the indicators and sub-indicators (Khamkanya et al., 2012).

Step 5: Determining Consistency Ratio (CR) ensured the reliability of expert judgments by verifying that the CR was ≤ 0.1. If the CR exceeded this threshold, the comparisons were revised (Ahmad & Pirzada, 2014; Awad & Jung, 2022). Finally, Step 6: Producing the Results synthesized local and global weights, with local weights representing relative significance within groups and global weights reflecting overall importance across all sub-indicators (Kil et al., 2016).

This structured approach ensured a comprehensive prioritization of indicators and sub-indicators for the assessment instrument.

4.0 RESULTS AND DISCUSSION

This study aimed to develop a comprehensive instrument for measuring the impact of renewable energy investments on the Orang Asli community, employing the Fuzzy Delphi Method (FDM) and the Analytic Hierarchy Process (AHP). The FDM revealed significant consensus among experts, highlighting the critical factors affecting the community. However, the rejection of the "Literacy of adult Orang Asli individuals" sub-indicator indicates differing views, suggesting the need for further exploration. The final list of seven indicators and 25 sub-indicators covers various impact areas, ensuring a holistic approach to assessment (Refer Table 2). Subsequently, the Analytic Hierarchy Process (AHP) was utilized to determine the relative weights of each indicator and sub-indicator. This quantitative assessment provides a structured framework to rank these factors based on their importance, tailored to the context of renewable energy investment among the Orang Asli community. The precise weights obtained through AHP offer a robust foundation for assessing the impacts of renewable energy projects, considering the community's unique characteristics.

Table 3: Findings of Fuzzy Delphi analysis

Indicator & Sub-Indicator	Defuzzification Value	Agreement (%)	Treshold Value, D	Status
Level of Household Living Standard				
Measurement of household income level	0.806	0.8	0.230	Accepted
Development of economic activity diversity	0.881	0.8	0.118	Accepted
Transformation of agricultural technology	0.850	1	0.100	Accepted
Attraction of foreign/external investors	0.753	0.9	0.156	Accepted
Educational Level of Orang Asli				
Attendance of students in schools	0.886	0.9	0.076	Accepted
Academic performance of Orang Asli students	0.858	1	0.118	Accepted
Number of students in higher education institutions	0.844	1	0.153	Accepted
Literacy of Orang Asli students	0.872	0.8	0.152	Accepted
Literacy of adult Orang Asli individuals	0.797	0.7	0.184	Rejected*
Early childhood education	0.883	0.7	0.151	Accepted
Social Values of The Orang Asli Community				
Unity and social harmony	0.842	1	0.093	Accepted
Sustainability of community activities	0.881	0.8	0.118	Accepted
Interactions and communication skills with the community	0.864	0.9	0.083	Accepted
Level of interconnectedness and harmony networks within the community	0.836	1	0.141	Accepted
Health Quality of The Orang Asli				
Quality of healthcare services	0.911	0.9	0.102	Accepted
Health status of the Orang Asli community	0.900	1	0.066	Accepted
Improvement of disease control measures	0.850	1	0.119	Accepted
Awareness and practice of social health	0.911	0.9	0.101	Accepted

Population Safety Assurance				
Control of wild animal threats	0.844	1	0.137	Accepted
Safety of residential environments	0.872	0.8	0.117	Accepted
Crime control measures	0.819	1	0.119	Accepted
Skills of the Orang Asli				
Digital literacy among the Orang Asli	0.864	0.8	0.105	Accepted
Practical (technical) skills of the Orang Asli	0.853	1	0.147	Accepted
Preserving Orang Asli Culture and Language				
Practicing Orang Asli customs and language	0.886	0.9	0.084	Accepted
Preserving the heritage of Orang Asli traditions	0.872	0.8	0.106	Accepted
Promoting and documenting Orang Asli customs and traditions	0.881	0.8	0.118	Accepted
Service Delivery to The Orang Asli				
Efficiency in agency administration with traditional leadership	0.894	0.9	0.101	Accepted
Readiness for in-situ service delivery	0.878	0.9	0.080	Accepted
Responsibility and engagement of stakeholders in service delivery	0.911	0.9	0.102	Accepted

*. Indicator was rejected.

Table 4: Global and local weightages assigned to each indicator and sub-indicator

Indicators & Sub-Indicators	**Global Weightage**	**Local Weightage**
Health Quality of The Orang Asli	0.21	
Awareness and practice of social health		0.364
Quality of healthcare services		0.354
Health status of the Orang Asli community		0.177
Improvement of disease control measures		0.105
Level of Household Living Standard	**0.184**	
Development of economic activity diversity		0.507
Transformation of agricultural technology		0.232
Measurement of household income level		0.176
Attraction of foreign/external investors		0.084
Educational Level of Orang Asli	**0.178**	
Early childhood education		0.348
Attendance of students in schools		0.229
Literacy of Orang Asli students		0.172
Academic performance of Orang Asli students		0.143
Number of students in higher education institutions		0.108
Service Delivery to The Orang Asli	**0.157**	
Efficiency in agency administration with traditional leadership		0.451
Responsibility and engagement of stakeholders in service delivery		0.331
Readiness for in-situ service delivery		0.218
Social Values of The Orang Asli Community	**0.079**	
Interactions and communication skills with the community		0.371
Level of interconnectedness and harmony networks within the community		0.233
Unity and social harmony		0.241
Sustainability of community activities		0.156
Preserving Orang Asli Culture and Language	**0.073**	
Practicing Orang Asli customs and language		0.432
Promoting and documenting Orang Asli customs and traditions		0.328
Preserving the heritage of Orang Asli traditions		0.24
Skills Of the Orang Asli	**0.071**	
Practical (technical) skills of the Orang Asli		0.752
Digital literacy among the Orang Asli		0.248
Population Safety Assurance	**0.048**	
Safety of residential environments		0.551
Control of wild animal threats		0.3
Crime control measures		0.15

4.1 Health Quality of the Orang Asli

The health quality of the Orang Asli emerged as the most critical indicator, with a global weightage of 0.21. This underscores the paramount importance of health in the overall well-being of the community. Within this category, awareness and practice of social health (local weightage: 0.364) and the quality of healthcare services (local weightage: 0.354) were the most significant sub-indicators. These findings highlight the necessity of improving healthcare awareness and access, which can be facilitated through targeted renewable energy projects that support health infrastructure and outreach programs. The health status of the community and disease control measures, although weighted lower, are still crucial components that should not be overlooked.

The Health Quality indicator, encompassing sub-indicators such as the quality of healthcare services and health status of the Orang Asli community, is essential for developing impact assessment instruments for renewable energy investments among the Orang Asli. This is due to the marginalized community's poor health outcomes and limited access to healthcare services (Belicza et al., 2004). The Orang Asli community in Malaysia faces significant challenges, including high prevalence rates of non-communicable diseases, low socioeconomic status, and reliance on traditional medicine for healthcare needs (Darwina et al., 2012; Zulkipli et al., 2021). By incorporating indicators related to healthcare quality and health status, impact assessment instruments can more effectively evaluate the success of renewable energy investments in enhancing the overall well-being and health outcomes of the Orang Asli community. This approach ensures that such initiatives are responsive to the specific needs and vulnerabilities of this marginalized population (Selvaratnam et al., 2023).

4.2 Level of Household Living Standard

The level of household living standard was the second most important indicator, with a global weightage of 0.184. The development of economic activity diversity (local weightage: 0.507) was identified as the most crucial sub-indicator within this category. This suggests that diversifying economic activities can significantly enhance living standards, possibly through renewable energy projects that create new employment opportunities and stimulate local economies. The transformation of agricultural technology (local weightage: 0.232) and measurement of household income level (local weightage: 0.176) also play substantial roles, indicating that technological advancements and income tracking are essential for assessing and improving economic conditions.

Economic diversification, as emphasized in various studies, plays a vital role in the development of rural communities like the Orang Asli Asli (Kimkong et al., 2023; Tamrazov & Abdullaeva, 2022; Vanchikova et al., 2022). These studies highlight the significance of income diversification, particularly through agriculture, in improving living standards and overall well-being. Technological advancements in agriculture are also crucial for enhancing productivity and sustainability in rural areas (Waseem et al., 2023). By promoting crop diversification, sustainable farming practices, and modern agricultural techniques, communities can achieve economic stability, food security, and an improved quality of life. The integration of diverse economic activities and innovative agricultural practices is essential for the sustainable development of rural regions, ensuring long-term prosperity and resilience (Denysiuk et al., 2022). These studies support the current findings, emphasizing the necessity of diverse economic activities and modern agricultural practices in sustainable development.

4.3 Educational Level of Orang Asli

Education is another vital indicator, with a global weightage of 0.178. Early childhood education (local weightage: 0.348) and attendance of students in schools (local weightage: 0.229) are the most important sub-indicators, reflecting the need for foundational educational support and consistent school attendance. Literacy and academic performance of students, along with the number of students in higher education, are also significant, suggesting that renewable energy investments should incorporate educational components to foster long-term socio-economic development. Educational level plays a crucial role in the impact assessment of renewable energy investment in the Orang Asli community.

Research demonstrates that educational attainment significantly influences renewable energy use in both the short and long term, with policies promoting education being essential for increasing the adoption of renewable energy sources. Studies emphasize sustainable education practices to ensure readiness for sustainable initiatives, highlighting the need for interventions to translate beliefs into performance for societal and national development (Haron et al., 2015). Additionally, educational level is vital in addressing dropout rates and improving educational outcomes, directly impacting community development and well-being. Higher levels of education positively influence renewable energy utilization, reducing CO2 emissions (Özbay & Duyar, 2022; Sart et al., 2022).

Educational attainment also enhances renewable energy consumption in selected South Asian countries, underscoring its importance in promoting renewable energy use (Jamshid et al., 2022). Furthermore, household energy profiles and willingness to adopt renewable energy

sources are influenced by income, education level, and cultural aspects, necessitating the consideration of educational backgrounds in renewable energy investment assessments (Szumilas-Kowalczyk, 2020). These findings underscore the critical role of educational levels in shaping attitudes towards and the adoption of renewable energy sources, emphasizing the need to incorporate educational factors in impact assessments for renewable energy investments.

4.4 Service Delivery to the Orang Asli

Service delivery holds a global weightage of 0.157, highlighting the importance of efficient and effective administrative functions and stakeholder engagement. Efficiency in agency administration with traditional leadership (local weightage: 0.451) and stakeholder responsibility and engagement in service delivery (local weightage: 0.331) are pivotal. This indicates that projects must ensure robust administrative practices and active stakeholder participation to be successful. Readiness for in-situ service delivery also remains a key factor, ensuring that services are accessible and responsive to the community's needs. These factors play significant roles in ensuring effective project implementation and community involvement (Tarmuji & Dhanurendra, 2022; Zulkipli et al., 2021).

Efficient agency administration contributes to the smooth operation and management of renewable energy projects, thereby enhancing overall project efficiency and success rates. Additionally, stakeholder engagement fosters community participation and support, leading to increased project acceptance and sustainability. These elements are vital for the success of renewable energy investments within marginalized communities like the Orang Asli (Taisch et al., 2014). By focusing on these indicators, impact assessment instruments can better evaluate the effectiveness and long-term benefits of renewable energy initiatives among the Orang Asli community. This approach ultimately promotes sustainable development and improved living conditions (Papapostolou et al., 2023).

4.5 Social Values

Social values (global weightage: 0.079) and preserving Orang Asli culture and language (global weightage: 0.073) are crucial for maintaining community cohesion and cultural identity. The sub-indicators within these categories emphasize the importance of interactions and communication skills, unity, and the practice and documentation of customs and traditions. These aspects are essential for sustaining the social fabric and cultural heritage of the Orang Asli, and renewable energy projects should integrate cultural preservation initiatives to ensure community support and engagement. Social values such as unity and social harmony are crucial

in assessing the impact of renewable energy investments in the Orang Asli community (Abdullah et al., 2021; Mahmud et al., 2022).

These values are essential for ensuring the sustainability of community activities and the successful implementation of renewable energy projects. Incorporating social values into the development and evaluation of renewable energy initiatives addresses the unique needs of the Orang Asli community while preserving their cultural heritage and promoting socio-economic development development (Leal Filho et al., 2022; Zulkipli et al., 2021). Additionally, social entrepreneurship in the renewable energy sector can significantly contribute to sustainable development by fostering community awareness, promoting energy savings, and creating positive social externalities in rural and developing areas (Bataineh et al., 2023). Emphasizing social values in renewable energy investments not only enhances the effectiveness of these projects but also promotes long-term benefits for the Orang Asli community.

4.6 Skills and Cultural Preservation of the Orang Asli

Skills development, particularly practical (technical) skills (local weightage: 0.752) and digital literacy (local weightage: 0.248), is critical for empowering the Orang Asli community. Although this indicator has a lower global weightage of 0.071, the high local weightage of practical skills underscores the necessity of skill-building programs within renewable energy projects to enhance employability and technical competence. This importance is underscored by research emphasizing community involvement and empowerment (Zulkipli et al., 2021), the need to document local knowledge and culture using digital media technology technology (Angelina et al., 2021), and the significance of aligning community needs and opportunities for sustainable livelihoods, including socio-cultural aspects (Mahmud et al., 2022). By focusing on these indicators and sub-indicators, impact assessment instruments can effectively evaluate the socio-economic, technological, cultural, and heritage contexts within the Orang Asli community. This ensures that renewable energy investments align with their skills, cultural preservation, and overall well-being, thereby promoting sustainable development tailored to the community's unique needs and strengths.

4.7 Population Safety Assurance

Population safety assurance, with a global weightage of 0.048, although the least weighted, remains important. The safety of residential environments (local weightage: 0.551) and control of wild animal threats (local weightage: 0.3) are the primary concerns. Ensuring safe living conditions is essential for the community's well-being and should be addressed by renewable

energy initiatives through environmental and infrastructural improvements. This is due to the community's vulnerability and the need to address risks comprehensively (Zulkipli et al., 2021). The Orang Asli community faces significant challenges in terms of safety and environmental risks, making it essential to evaluate and mitigate these threats to ensure the well-being of the population. Additionally, the Social Impact Assessment (SIA) method, which combines environmental and social indicators, underscores the importance of assessing safety guarantees and social resources. This highlights the significance of considering safety aspects in renewable energy projects (Mahmud et al., 2022). By focusing on these safety indicators, impact assessment instruments can effectively address the specific needs and concerns of the Orang Asli community, contributing to sustainable development and improved living conditions (Zuluaga et al., 2022).

The comprehensive instrument developed through this study provides a robust framework for assessing the impact of renewable energy investments on the Orang Asli community. By prioritizing health quality, household living standards, education, service delivery, social values, cultural preservation, skills development, and population safety, stakeholders can design and implement renewable energy projects that are aligned with the specific needs and strengths of the Orang Asli. This approach promotes sustainable development and improved living conditions, ensuring that renewable energy investments deliver tangible and lasting benefits to this marginalized community.

4.8 Limitation

While this study has provided valuable insights into the development of assessment instruments for evaluating the impact of renewable energy investments on the Orang Asli community, several limitations need to be acknowledged. Firstly, the rejection of the "Literacy of adult Orang Asli individuals" sub-indicator suggests differing views among experts, indicating the need for further exploration and discussion among stakeholders to achieve a more nuanced understanding. Secondly, although the study involved focus group discussions, workshops, and surveys with various segments of the Orang Asli population in the initial phase, the direct incorporation of all community members' views was not feasible due to logistical constraints and resource limitations. Thirdly, the number of participants, while representing a diverse range of stakeholders, including Orang Asli representatives, may not fully capture all perspectives within the community, potentially affecting the comprehensiveness and inclusivity of the assessment process. Lastly, the subjective judgment of experts in prioritizing indicators and sub-indicators could introduce biases or inconsistencies.

4.9 Recommendation

To address these limitations and enhance the development of assessment instruments for renewable energy investments among the Orang Asli community, the following recommendations are proposed. Firstly, field testing and piloting the instruments in real-world settings will provide essential feedback on their effectiveness and relevance to the community's context. Thirdly, implement longitudinal studies to monitor and assess the long-term impacts of renewable energy projects on the Orang Asli community, providing valuable insights into the sustainability and socio-economic development of these initiatives. Finally, directly incorporate the views of all segments of the Orang Asli community through focus group discussions, workshops, or surveys in the initial phases of future studies, ensuring that the perspectives and priorities of all community members are adequately considered in the assessment process. By implementing these recommendations, future research can overcome the limitations of this study and contribute to the development of more inclusive, effective, and sustainable assessment instruments tailored to the specific needs and contexts of the Orang Asli community.

5.0 CONCLUSION

This study has developed a culturally sensitive framework for assessing the impact of renewable energy investments on the Orang Asli community in Malaysia. Using the Fuzzy Delphi Method (FDM) and Analytic Hierarchy Process (AHP), it identified seven key impact indicators: health quality, household living standards, education, service delivery, social values, cultural preservation, skills development, and safety. Health quality emerged as the most critical factor, highlighting the need for improved healthcare infrastructure. While the study provides valuable insights for inclusive renewable energy projects, it acknowledges limitations, such as the exclusion of some community perspectives and expert bias. Future research should incorporate more inclusive approaches, piloting the framework, and conducting long-term studies to assess the impacts over time. Overall, this framework offers policymakers and energy developers valuable tools to design sustainable, equitable renewable energy projects that align with the needs of the Orang Asli, promoting community resilience and socio-economic development.

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