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Impact of Energy Transformation on Economic Productivity and Environmental Sustainability in Toba-Asahan, Indonesia

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ABSTRACT

This study explores the influence of energy transformation on economic productivity and environmental sustainability in the Toba-Asahan region. The focus is on how renewable energy impacts community productivity, addressing a critical research gap in the literature. While energy transitions have been widely studied in other regions, specific research on their effects in Toba-Asahan remains limited. This study uniquely explores how human resources mediate the impact of renewable energy on community productivity in Toba-Asahan, shifting focus from environmental effects to economic productivity in a region previously under-researched in energy transformation studies. Using Structural Equation Modeling (SEM) based on data collected from 230 respondents, this research analyses the relationship between human resources, energy utilization, and productivity. The findings reveal that human resources have a significant positive impact on both energy utilization and productivity. However, the direct effect of energy on productivity is found to be statistically insignificant. The study concludes that enhancing human capital and increasing community awareness of renewable energy's benefits are essential for maximizing productivity and achieving sustainable economic growth in the Toba-Asahan region.

Keywords: Energy, Human Resources, Productivity, Toba Asahan River
JEL Classifications: Q01, Q42, O13

1. INTRODUCTION

Various factors, including regional development planning, tourism strategies, socio-economic conditions, and environmental conservation efforts, shape the productivity of the community in the Toba Asahan region. Continuous effort is essential to ensure that tourism destinations like Lake Toba remain competitive and attractive to both domestic and international tourists (Kennedy, 2023). Geotourism has been proven to be an effective strategy for increasing tourist numbers while preserving the environment, especially in areas such as the Lake Toba Geopark (Ginting et al., 2020). The development of tourism, along with regional planning, socio-economic, and environmental considerations, plays a key role in shaping the productivity of the Toba Asahan community. By implementing evidence-based strategies and engaging stakeholders, sustainable development and growth can be achieved in this region. The influence of energy on community productivity in the Toba Asahan region is complex, involving renewable energy use, community empowerment, and sustainable development. Research shows that renewable energy, combined with community empowerment, can positively affect economic activities, improve environmental quality, and support sustainable settlement management (Surya et al., 2021).

Additionally, the adoption of renewable energy is crucial in reducing carbon emissions, decarbonizing the electricity sector, and supporting climate change mitigation efforts (Osman et al., 2022). Community-owned renewable energy projects have demonstrated significant environmental and socio-economic benefits, revitalizing local economies and empowering communities through revenue generation and renewable energy programs (Berka and Creamer, 2018; Callaghan and Williams, 2014). The implementation of alternative energy management strategies has also been identified as an effective way to improve energy productivity and address increasing energy demand (Phoochinda and Khoasitthiwong, 2015; Yılmaz, 2023). Studies suggest that advancements in sustainable technologies can enable communities to achieve energy self-sufficiency (Nava, 2023; Marique and Reiter, 2014). In summary, the adoption of renewable energy and the empowerment of communities through sustainable energy initiatives are crucial for enhancing productivity and supporting sustainable development in regions like Toba Asahan. By integrating renewable energy technologies, encouraging community participation, and implementing effective energy management strategies, communities can achieve higher productivity, economic growth, and environmental sustainability.

However, there is still a significant research gap regarding the specific impact of energy on community productivity in the Toba Asahan region. While several studies have explored energy transitions (Gazzani, 2024), the potential of the circular economy and bioeconomy for sustainable development (Ferraz, 2023), and regional contributions to climate change mitigation (Hong-Jie et al., 2019), specific research on how energy influences productivity in this region is limited. Drawing insights from the broader regional dynamics of energy transitions and climate change mitigation can provide valuable lessons to improve community productivity in Toba Asahan (Hong-Jie et al., 2019). Additionally, incorporating the principles of the circular economy and bioeconomy offers innovative solutions to boost productivity while minimizing environmental impact (Ferraz, 2023). Addressing this research gap is critical for policymakers, researchers, and local communities in the Toba Asahan region to make informed decisions about energy policies, resource management, and community development strategies. This knowledge will help ensure the efficient use of energy resources to enhance community productivity while preserving the local environment.

2. LITERATURE REVIEW

2.1. Community Empowerment

Community empowerment theory is a concept that focuses on increasing the capacity and independence of communities to deal with problems and improve their quality of life. The goal is to make communities capable and self-reliant in addressing various issues, including health and environment, as well as increasing their awareness, ability, and active participation in development. The empowerment approach, according to Dhamotharan, includes seven steps: Relationship building, capacity discovery, building community ideals, defining a course of action, designing actions, implementing activities, and documentation and learning. The implementation of community empowerment theory can be applied in various contexts, such as MSME development, environmental management, and post-pandemic economic recovery. The success of community empowerment depends on the active participation of the community, support from the government and stakeholders, training and capacity building, utilization of local potential, and continuous monitoring and evaluation.

Community empowerment is a multifaceted concept that involves enabling individuals, organizations, and communities to have control over their lives, resources, and decision-making processes (Israel et al., 1994). This empowerment aims to enhance people's participation in development activities, improve human and institutional resources, and promote a people-centered approach to development (Istikhoroh et al., 2018). Elements of community empowerment include enhancing participation, developing leadership, building empowering organizational structures, and increasing problem-solving capacities (Hong, 2022).

Moreover, community empowerment is seen as a process through which individuals gain greater access to and control over valued resources, leading to democratic participation in community life and a critical understanding of their environment (Perkins and Zimmerman, 1995). It involves facilitating communities to play an active role in social activities and empowering them by enhancing their potential capabilities (Rachmawatie et al., 2020). Empowerment also entails individuals achieving increasing control over various aspects of their lives and participating in the community with dignity (Freina et al., 2015).

Furthermore, community empowerment shifts the focus from individual and behavioral approaches to more collective, community-based actions (Whitehead, 2004). It involves moving towards a model where communities gain greater control over resources and decision-making processes, promoting local capacity and positive outcomes (Brodsky and Cattaneo, 2013). Empowerment is also about having control over the determinants of one's quality of life and creating professional relationships where clients or communities take charge of the change process (Tengland, 2007).

In summary, community empowerment is a complex and multi-dimensional concept that involves enabling individuals, organizations, and communities to have control over their lives, resources, and decision-making processes. It encompasses enhancing participation, developing leadership, and promoting a people-centered approach to development. Empowerment also involves shifting towards collective, community-based actions and promoting local capacity and positive outcomes.

2.2. Sustainability Theory

Sustainability theory provides a comprehensive framework for understanding the interaction between renewable energy and community productivity. It emphasizes the balance between economic, social, and environmental aspects of long-term development, which is particularly relevant to the implementation of renewable energy and its impact on community productivity.

In the context of renewable energy, the economic dimension of Sustainability Theory reflects how the utilization of clean energy sources can encourage efficient and sustainable economic growth. The use of renewable energy has the potential to increase community productivity through the creation of new jobs, the development of local industries, and increased operational efficiency in various sectors. For example, the implementation of solar panels in public facilities such as fish auctions can increase trade activities and promote local economic development.

Sustainability Theory also emphasizes the importance of integrating sustainability concepts into organizational and business strategies. In the context of renewable energy, companies, and institutions can integrate the use of clean energy into their operations to achieve long-term competitive advantage. This approach not only improves efficiency and reduces operational costs but also enhances corporate image and attracts increasingly environmentally conscious consumers.

By using Sustainability Theory as a lens to understand the impact of renewable energy on societal productivity, we can identify and maximize the long-term benefits of the energy transition. This theory helps us understand that increasing societal productivity through renewable energy is not just about economic efficiency but also about creating a sustainable and equitable system that supports overall societal well-being.

Sustainability theory encompasses a broad and multidisciplinary field that seeks to address the long-term viability of systems and practices in various domains. While there is no universally agreed-upon definition of sustainability due to its complex and multifaceted nature, scholars have proposed several frameworks and models to conceptualize sustainability (Chang, 2016; Starik and Kanashiro, 2013; Trigo et al., 2021; Vos et al., 2020). These frameworks often consider factors such as environmental impacts, social considerations, governance structures, and economic dimensions to assess sustainability (Chan and Hsieh, 2022; Koh et al., 2017; Geldres-Weiss et al., 2021). The concept of sustainability extends beyond mere environmental concerns to include social, economic, and governance aspects, emphasizing the need for a holistic approach to sustainability management (Geldres-Weiss et al., 2021; Anderies et al., 2013).

Moreover, sustainability theory is closely linked to concepts such as resilience and robustness, which together provide a comprehensive understanding of how systems can adapt and persist in the face of challenges and changes (Flynn et al., 2018). The integration of sustainability principles into various fields, such as healthcare, critical care practice, and business operations, highlights the importance of ensuring the continuity and effectiveness of practices over time (Baid et al., 2019; Penno et al., 2019; Moore et al., 2022).

Furthermore, the development of sustainable careers and sustainable business models underscores the need to consider sustainability across different dimensions, including individual well-being, organizational practices, and stakeholder relationships (Vos et al., 2020; Geldres-Weiss et al., 2021). The shift towards sustainable development paradigms has influenced management theories and research, emphasizing the interconnectedness between sustainability, community well-being, and organizational success (Gladwin et al., 1995). Additionally, the evolving landscape of sustainability reporting and impact assessment reflects a growing emphasis on forward-looking strategies that aim to secure resources for future generations and enhance the overall quality of life (Asogwa et al., 2021; Pope et al., 2013).

In conclusion, sustainability theory encompasses a diverse range of concepts, frameworks, and models that aim to promote long-term viability, resilience, and positive impacts across various sectors. By integrating environmental, social, economic, and governance considerations, sustainability theory provides a robust foundation for addressing current challenges and fostering sustainable practices for the future.

3. METHODOLOGY

3.1. Hypotheses Development

To substantiate this hypothesis, it is imperative to delve into the intricate dynamics of energy utilization and its intersection with human resources in river basins. Numerous studies have established a strong correlation between energy production and economic development, particularly in river basin regions where resource management plays a pivotal role in achieving sustainability (Lu et al., 2023). For instance, the transformation of energy structures in the Yellow River Basin underscores the necessity of inclusive development, which is closely tied to the competencies and skills of the workforce engaged in energy production and management (Liang et al., 2023). This suggests that enhancing human capital can optimize energy utilization and, by extension, improve overall productivity.

Climate change further complicates the energy transformation process by impacting water resources. In the Pungwe River Basin, for example, changes in climate patterns have been shown to affect water availability, subsequently influencing energy production (Andersson et al., 2011). This underscores the importance of cultivating a skilled workforce capable of adapting to these environmental challenges and implementing innovative energy management solutions. By prioritizing human capital development, the Toba-Asahan River Basin can bolster its resilience to climate change and ensure sustainable energy production and productivity. The socio-economic landscape of the Toba-Asahan River Basin also plays a critical role in shaping human resource capabilities. Economic activities, particularly those linked to energy production, are deeply influenced by the availability of skilled labor and the efficacy of management practices (Ma and Wang, 2022). Aligning workforce development initiatives with the region's energy objectives can create a more productive environment that supports sustainable economic growth.

Moreover, regulatory frameworks and policies governing energy production and human resource development are essential for fostering alignment between human resource strategies and energy transformation goals. Effective governance can facilitate this alignment, ensuring that the workforce is adequately equipped to navigate the demands of a rapidly evolving energy landscape (Wang et al., 2022). This alignment is critical to fostering a culture of innovation and sustainability within the energy sector. Based on the discussion surrounding the benefits of human resources and renewable energy on societal productivity, the following hypothesis is proposed:

H_1: Human resource development significantly influences the Energy Transformation of the Toba-Asahan community.

The development of human resources in Indonesia's renewable energy sector is a critical element in achieving the nation's energy goals by 2045, as highlighted by Udin (2020). The availability of skilled labor is crucial for the successful implementation of energy transformation projects, particularly in river basins where sustainable development hinges on local expertise and community engagement. This supports the hypothesis that investing in human capital is paramount for the successful deployment of energy initiatives. Furthermore, challenges and opportunities identified in the literature suggest the necessity for comprehensive training programs to build the capacities of local communities, enabling them to participate actively in renewable energy projects.

The concept of integrated river basin management further reinforces this hypothesis. Pradhan et al. (2021) advocate for a holistic management approach that encompasses both ecological and socio-economic factors. This comprehensive perspective ensures that energy transformation projects are not only technically feasible but also socially and economically sustainable. By enhancing local human resources, stakeholders can foster broader community participation, which is vital for the effective and long-term management of river basins. The application of systems thinking, as discussed by Chen et al. (2011), highlights the importance of incorporating human resource dynamics into river basin management strategies. Their work emphasizes the critical role that local knowledge and practices play in ensuring sustainable energy transformations. This aligns with the hypothesis that human resources are central to achieving successful and sustainable outcomes in energy initiatives within river basins.

The compounded challenges posed by climate change and resource scarcity in river basins necessitate innovative, human-centered solutions. Ray et al. (2015) address the hydroclimatic obstacles faced in the Brahmaputra River Basin, asserting that these challenges can only be mitigated through efforts to enhance human capacities. This reinforces the hypothesis that human resources are integral to addressing the complex demands of energy transformation in river basins. Based on this discussion, another hypothesis emerges:

H_2: Human Resource development significantly affects the productivity of the Toba-Asahan River Basin.

Exploring the interconnections between energy transformation, productivity, and the unique ecological and socio-economic characteristics of the Toba-Asahan River Basin is essential. The water-energy-food (WEF) nexus is particularly relevant here, as it emphasizes the interdependence of these vital resources and their collective impact on productivity and sustainability (Chen and Chen, 2021; Yang et al., 2018). The Toba-Asahan region, known for its rich natural resources, faces critical challenges in energy supply, environmental degradation, and the need for sustainable development. Understanding the dynamics of energy transformation within this nexus is crucial for enhancing productivity.

Research from the Yangtze River Basin highlights the importance of symbiotic coordination among water, energy, and food systems, a model that can be applied to the Toba-Asahan context (Chen and Chen, 2021). Adopting such an approach allows stakeholders to identify key factors that enhance resource use efficiency and promote sustainable practices. For instance, optimizing hydropower generation while safeguarding ecological integrity can boost productivity in both agricultural and industrial sectors. Similarly, the Penobscot River case illustrates how a basin-scale approach can balance power generation with ecosystem restoration, a strategy that could be beneficial for Toba-Asahan (Opperman et al., 2011). Therefore, the hypothesis proposed is:

H_3: Energy transformation can significantly enhance the productivity of the Toba-Asahan community.

The relationship between water and energy is particularly evident in agricultural contexts, where irrigation practices heavily influence both energy consumption and crop yields. Unregulated irrigation, for example, can limit energy generation potential, as excessive water use for agriculture reduces the water available for hydropower generation (Geressu et al., 2020). This highlights the need for better management practices that align agricultural water use with energy production goals.

The integration of sustainable energy practices and efficient water management in the Toba-Asahan River Basin has the potential to significantly boost agricultural productivity, stimulate economic growth, and ensure ecological balance. The multi-dimensional approach supported by various studies underscores the importance of coordinated resource management in achieving these goals. Future research should focus on empirical data collection to further substantiate these hypotheses and guide policy-making in the region. Based on the broader discussion, the final hypothesis is:

H_4: Human resource development can significantly influence the productivity of the Toba-Asahan community through energy transformation.

3.2. Conceptual Framework

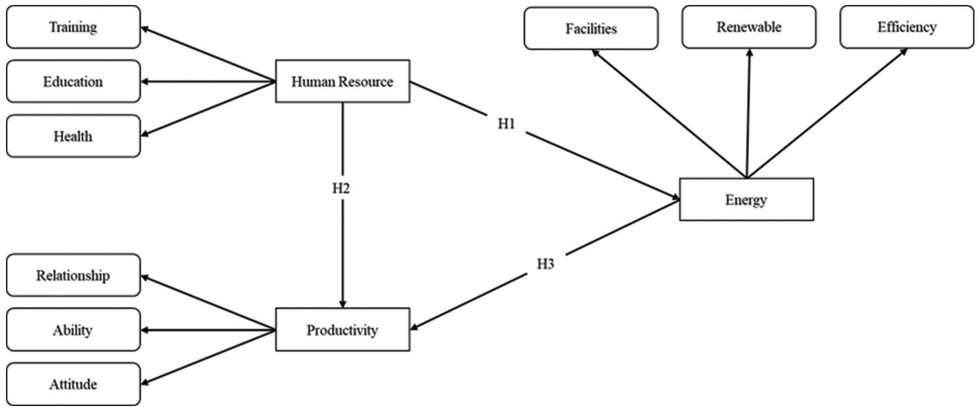
The conceptual framework of this study, as depicted in Figure 1, outlines the relationships among the key constructs.

3.3. Research Methodology

This research employs AMOS software to analyze the proposed pathways using the Structural Equation Modeling (SEM) approach. AMOS was selected for its robust capabilities in managing intricate relationships between variables and accommodating data that may not adhere strictly to normal distribution patterns. The analysis begins with the development of a theoretical model based on an extensive review of the literature, which helps identify the independent, dependent, and mediating variables, followed by the formulation of research hypotheses. This theoretical model serves as the foundation for subsequent analytical processes.

The questionnaire design was meticulously crafted to ensure both the validity and reliability of the instruments, ensuring they

Figure 1: Conceptual framework



accurately measure the intended constructs. Out of 400 distributed questionnaires, 300 were returned, with 230 being fully completed and 70 partially filled. The educational background of the respondents reveals that 140 were high school graduates, 90 held university degrees, 40 had completed elementary school, 20 had finished middle school, and 10 respondents did not specify their educational background. Additionally, the majority of respondents fall within the productive working age range of 25–60 years, ensuring the relevance of the data to the research objectives. Table 1 represents the items used.

The research area focuses on the Toba Asahan River Basin, which encompasses six sub-districts. These sub-districts provide a comprehensive overview of the socio-economic conditions in the research area, aligning with the study's objectives. The main constructs in this study include renewable energy awareness, perceived impact on productivity, sustainability practices, and challenges and barriers to renewable energy adoption. These constructs will be measured using a Likert scale, which covers a range of attitudes and perceptions. The study will use structured questionnaires to collect data from respondents, complemented by interviews with key informants such as river users, hamlet heads, village heads, and the sub-district head. This mixed-method approach allows for a comprehensive understanding of individual and institutional perspectives on renewable energy.

Upon data collection, the analysis will proceed using AMOS, beginning with the validation of the measurement model to confirm the reliability and validity of the instruments. This is a critical step to ensure that the observed data accurately represent the constructs. Next, the structural model analysis will be conducted to test the formulated hypotheses rigorously. The results will then be interpreted within the context of the research questions and aligned with both theoretical insights and practical implications.

Ultimately, this research aims to provide a comprehensive strategy for optimizing natural resources through renewable energy in the Toba Region. By synthesizing theoretical insights with empirical data, this research will offer actionable recommendations for stakeholders at various levels, ensuring that the transition to renewable energy not only supports community productivity but also aligns with the broader goals of environmental management and sustainable development.

Table 1: Research instrument

Constructs	Instruments
Human resource	Training improves human resources knowledge
	Education supports human resource management
	Health facilities support human resource management
Energy	Energy access is adequate for productivity
	Renewable energy is well established
	Energy Use is Efficient
Productivity	Community relations well established for productivity
	Community capability is good enough to improve energy management
	Community attitude supports energy for increased productivity

4. RESULTS

A measurement model in Structural Equation Modeling (SEM) focuses on the relationship between latent variables (unobservable concepts like satisfaction or motivation) and their measured indicators (observable variables obtained from surveys or tests). It is also known as Confirmatory Factor Analysis (CFA). It is used to verify the validity and reliability of the latent variables by assessing how well the indicators represent the underlying constructs. The model ensures that the indicators properly measure the intended latent variables (construct validity) and consistently do so (reliability). Measurement models are confirmatory, meaning they test pre-specified relationships based on theory or previous research. Each indicator has a factor loading, showing how strongly it reflects the latent variable. The model's fit is evaluated to ensure that the data aligns with the hypothesized measurement structure before proceeding to the structural part of SEM.

Furthermore, the details of the Measurement Model are elaborated in Figure 2, as illustrated below:

Based on the literature referenced by Curran et al. (1996), West et al. (1995), normality can be assessed through the values of skewness and kurtosis. Specifically, data is considered to meet the normality criteria when the skewness values fall within the range of −2-2 and kurtosis values range from −7 to 7. Referring to the results presented in Table 2, it is evident that the data in this study adheres to the normality criteria established by these scholars. This

Table 2: Descriptive statistics and normality

Variable	Item Code	min	Max	Mean	Standar deviation	skew	kurtosis
Productivity	P3	2.000	8.000	4,93	1,233	−0.450	−0.480
	P2	2.000	8.000	4,84	1,211	−0.544	−0.499
	P1	2.000	10.000	4,87	1,212	−0.407	0.028
Energy	E1	2.000	8.000	4,93	1,308	−0.573	−0.321
	E2	2.000	8.000	4,96	1,237	−0.603	−0.253
	E3	2.000	8.000	4,76	1,254	−0.442	−0.647
Human Resource	HR1	2.000	8.000	4,99	1,260	−0.578	−0.271
	HR2	2.000	9.000	5,04	1,208	−0.578	0.058
	HR3	2.000	8.000	4,95	1,213	−0.571	−0.302

Source: AMOS 22

indicates that the data approximates a normal distribution, making it suitable for further statistical analyses that assume normality.

Table 3 shows that the loading factor value of each variable is greater than the cross-loading value. Therefore, this shows that all indicators of all variables used in this study are declared valid. Discriminant validity can also be seen from the Average Variance Extracted (AVE) value. The criteria for a good AVE Fornel-Larcker criterion is above 0.5.

The calculation process of the Fornel-Larcker criterion is carried out by comparing the AVE root of each construct to the correlation between one construct and another in the research hypothesis model. Suppose the calculation results of the Fornel-Larcker Criterion show that the AVE root value of each construct is greater than the correlation value between one construct and another construct. In that case, the discriminant validity is declared good. The discriminant validity value based on the Fornel-Larcker Criterion in this research model can be seen in Table 3 below:

Based on Table 4, the results of the discriminant validity assessment using the calculation method of the Fornell-Larcker Criterion show that the root value of the AVE Fornell-Larcker Criterion on each construct has a greater value when compared to the correlation between constructs. Thus, the discriminant validity of the Fornell-Larcker Criterion shows that the model and indicators of the construct are valid.

In Table 5, the results of the measurement model's results, the constructs have met the criteria for validity and reliability as established in academic research. The achieved validity indicates that the indicators used accurately represent the constructs being measured, while reliability reflects the internal consistency of these constructs. With both criteria fulfilled, the measurement model is deemed appropriate and valid, allowing for the continuation of hypothesis testing using Structural Equation Modeling (SEM) in accordance with recognized analytical procedures in the academic literature. Upon completion of the goodness-of-fit, the structural equation model is then perform, which is depicted in Figure 3.

Based on the results in Table 6, the results of the direct effect of Human Resources with (P = 3 stars), the first hypothesis is accepted, meaning that there is a significant positive effect

Table 3: Factor loading, variance extracted, and construct reliability

Variable	Item code	Item	Factor LOADING	AVE	CR
Productivity	P3		0.884	0,79	0,912
	P2		0.853		
	P1		0.882		
Energy	E1		0.898	0,80	0,922
	E2		0.912		
	E3		0.870		
Human resource	HR1		0.865	0,76	0,910
	HR2		0.872		
	HR3		0.926		

Source: AMOS 22

Table 4: Discriminant variance (fornell and larcker criterion)

Variable	PM	ENERGI	SDM
Productivity	0,912		
Energy	0,354	0,959	
Human resource	0,895	0,364	0,957

Source: AMOS 22

Note: Diagonal values (bolded) are the square root of AVE, whereas off-diagonals are correlation coefficients

between Human Resources and Energy in the Toba Asahan area.

The results of the direct effect of Human Resources on energy with (P = 3 stars), the second hypothesis is accepted, meaning that there is a significant positive effect between Human Resources and Productivity in the Toba Aasahan area. The results of the direct effect of Energy on Productivity with ($P = 0.349 > 0.05$) then the third hypothesis is rejected, meaning that there is an insignificant positive effect between Energy and Productivity in the Toba Asahan area.

Based on the results in Table 7, the indirect effect of Human Resources with ($P = 0.356 > 0.05$), the fourth hypothesis is rejected, meaning that there is a positive but insignificant influence between Human Resources on Productivity through Energy in the Toba Asahan region.

Based on the results of Table 8, it is known that the R-square for the energy variable value of 0.133 means that the human resources and productivity variables succeeded in explaining 13.3% of

Table 5: Goodness of fit indices of overall measurement model

Criterion	Index value	Level of acceptance	Literature
Absolute fit indices			
Goodness of fit index (GFI)	0,947	≥0,90	Joreskog and Sorbom (1984)
Incremental fit indices			
Normed fit index (NFI)	0,966	≥0,90	Bollen (1989)
Tucker lewis index (TLI)	0,961	≥0,90	Bagozzi and Yi (1988)
Comparative fit index (CFI)	0,947	≥0,90	Bentler and Bonett (1980)
Parsimonious fit index			
Adjusted goodness of fit index (AGFI)	0,900	> 0,80	Chau and Hu (2001)

Source: AMOS 22

Table 6: Hypothesis test of direct effect

Hipotesis	Jalur	Standard beta	Standard error	Critical ratio	P-value
H1	HR→Energy	0.383	0.057	6.716	***
H2	HR→Productivity	0.878	0.049	17.945	***
H3	Energy→productivity	0.031	0.033	0.937	0.349

Source: AMOS 22

Table 7: Hypothesis test of indirect influence

Hipotesis	Jalur	Std.Beta	Std.Error	Critical Ratio	P-Value
H4	HR→Energy→Productivity	0.012	0.013	1.773	0.356

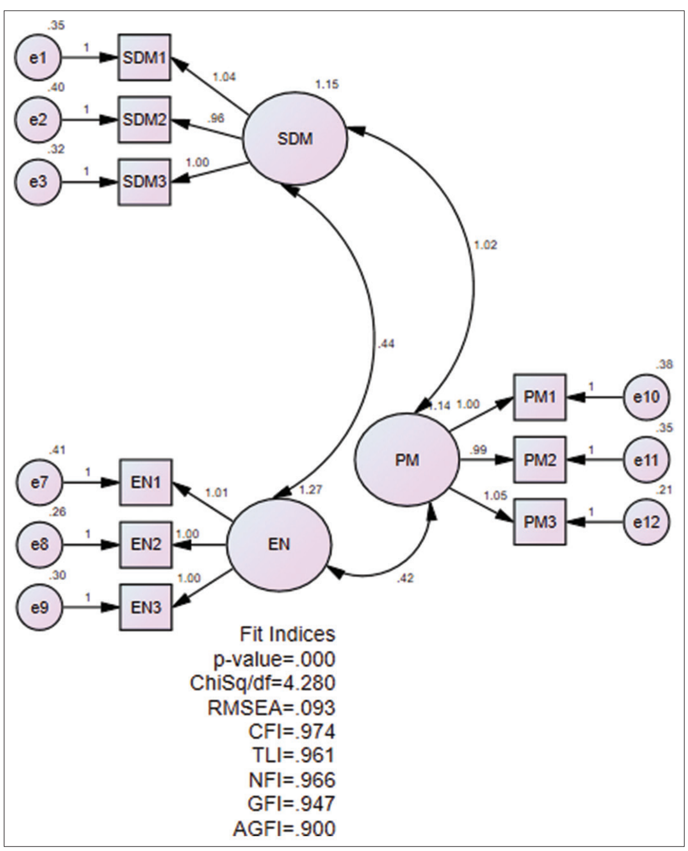
Source: AMOS 22

Table 8: R^2 result

R^2	Nilai	Ket
ENERGI	0.133	Moderate (Cohen, 1988)
PM	0.802	Substantial (Cohen, 1988)

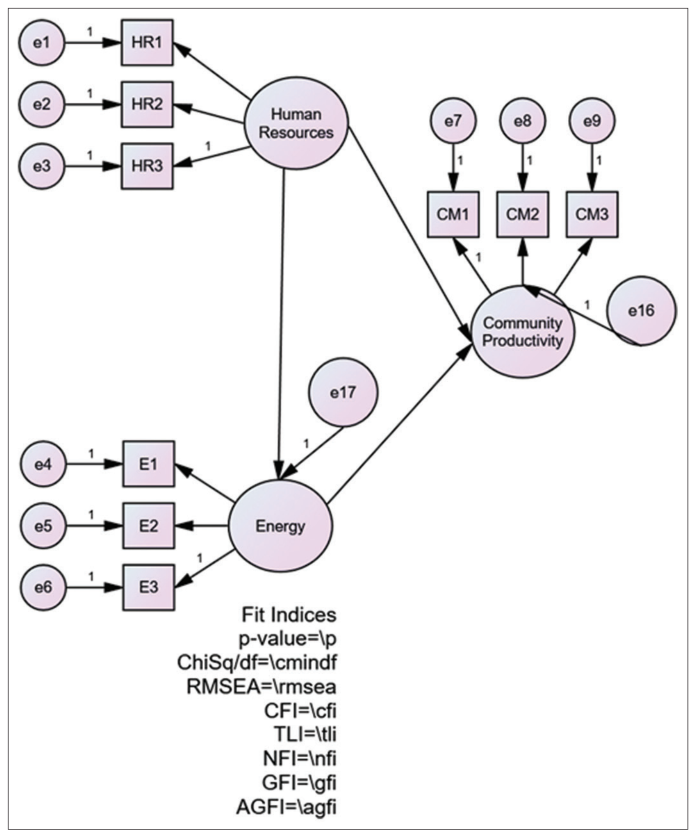
Source: AMOS 22

Figure 2: Measurement model



Source: AMOS 22

Figure 3: Structural equation model



Source: AMOS 22

the energy, and the remaining 86.7% was obtained from outside variables or methods not used in this study. This means that this R-square value is at a moderate level, according to the words (Cohen, 1988).

The R-square result for the productivity variable value of 0.802

means that the human resources and energy variables succeeded in explaining 80.2% of productivity, and the remaining 19.8% was obtained from outside variables or methods not used in this study. This means that this R-square value is at the subtantial level (Cohen, 1988).

5. DISCUSSION

5.1. Effect of Human Resources on Energy

Based on the results of the direct effect analysis, it is found that Human Resources (HR) has a positive and significant influence on energy, with a path coefficient value of 0.335 and a significance value of 0.000, which is below the 0.05 threshold. This indicates that HR has a positive significant influence on energy in the Toba Asahan region. Thus, the second hypothesis is accepted, which states that the better the quality of human resources, the better the energy utilized by people in the Toba Asahan region.

Therefore, people in the Toba Asahan region need to maintain and protect resources that have a direct impact on renewable energy. One example is preserving the environment so that the flow of the Asahan River can be maintained, which is important for maintaining sustainable renewable energy production. Through nature conservation efforts, the steady flow of the Asahan River can support renewable energy productivity, ultimately contributing to environmental sustainability and improving the welfare of local communities.

5.2. Effect of Human Resources on Productivity

Based on the results of the direct effect analysis, it is found that Human Resources (HR) has a positive and significant influence on productivity, with a path coefficient value of 0.791 and a significance value of 0.000, which is below the 0.05 threshold. This indicates that HR has a positive significant influence on community productivity in the Toba Asahan region. Thus, the first hypothesis is accepted, which states that the better the quality of human resources, the higher the level of community productivity in the Toba Asahan region. Therefore, people in the Toba Asahan region need to improve their mindset so that they do not only depend on the natural resources available. If natural resources are not optimally utilized, they will be depleted over time, and the productivity of people in the Toba Asahan region may decline. There need to be strategic efforts in the management and utilization of human resources and natural resources to ensure the sustainability and increased productivity of communities in the region.

5.3. Effect of Energy on Productivity

Based on the results of the direct effect analysis, it is found that energy has a positive and insignificant effect on productivity, with a path coefficient value of 0.062 and a significance value of 0.068, which is above the 0.05 threshold. This indicates that energy has an insignificant positive influence on productivity in the Toba Asahan region. Thus, the third hypothesis is rejected, which states that the better the quality of energy, the better the productivity obtained by people in the Toba Asahan region. Therefore, it is expected that people in the Toba Asahan region understand the impact and benefits of renewable energy. With adequate knowledge about renewable energy, people in the Toba Asahan region can optimize their productivity. This understanding is important so that people can not only utilize the potential of renewable energy to the fullest but can also contribute to environmental sustainability and improved socio-economic welfare in the region.

5.4. Effect of Human Resource on Productivity through Energy

Based on the results of the indirect effect analysis, it is found that Human Resources has a positive and insignificant effect on Productivity through Energy, with a path coefficient value of 0.021 and a significance value of 0.090, which is above the 0.05 threshold. This indicates that although good energy can increase productivity, the effect of human resources on productivity through energy is not too large. One of the factors underlying this condition is the lack of understanding of the people in the Toba Asahan region on how to maximize the use of energy to increase productivity. Many of them are still not familiar with the concept of renewable energy, and most people there are not fully aware of the importance of preserving the environment. They tend only to know how to utilize natural resources for their daily needs without considering the long-term impact or potential for more efficient and productive use of renewable energy.

6. CONCLUSION AND SUGGESTION

The conclusions that can be drawn from this research are as follows: Human Resources has a positive and significant effect on community productivity in the Toba Asahan region. Human resources have a positive and significant impact on energy production in the Toba Asahan region. Energy has a positive and insignificant effect on community productivity in the Toba Asahan region. Human resources have a positive and insignificant impact on productivity through energy in the Toba Asahan region.

Researchers have also given some suggestions: It is expected that the community, especially in the Asahan River area, will play an active role in maintaining existing renewable energy sources. This effort will not only help increase the productivity of the local community. Still, it will also preserve the beauty of the environment and maintain the stability of the Asahan River water discharge, which is a vital component for the sustainability of renewable energy in the region. It is also expected that relevant agencies involved in renewable energy management should provide comprehensive training to communities in the Asahan River region. This training is important to improve the community's understanding and skills in utilizing renewable energy optimally so that they can contribute more effectively to sustainable resource management and increased local productivity.

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