Community Development on Renewable Energy Literacy by Symbiosis Bioenergy Model. Case Study: Manado City, Indonesia

Alicia A.E. Sinsuw, Sangkertadi, Hendrik Suryo Suriandjo, Liny Anna Maria Tambajong, Ivana Marcia Florence, Oktovian B.A. Sompie

Abstract

Indonesia, an expansive archipelago of 17,000 islands spanning 1.9 million km², faces a population of 267 million people spread across its diverse regions. As per Government Regulation No. 79 of 2014, Indonesia aims for a renewable energy mix of 23% by 2025 and 31% by 2050. Despite abundant renewable energy potential, such as biogas, there's a need for innovative approaches to meet these targets. The Symnery model, introduced in Manado City in 2018, involves a two-stage biogas production pilot plant utilizing slaughterhouse wastewater and agricultural waste. This model brings social, economic, and environmental benefits to rural communities, offering employment, training, and additional income. Energy literacy, crucial for understanding and managing energy complexities, is enhanced through the model. The government, adopting the two-stage symbiosis bioenergy model, simplified it for small islands around Manado city, distributing 18 units with local materials. Local training programs focus on knowledge transfer, monitoring, and demonstrating biogas advantages, aiming to improve living standards, promote cleaner environments, and reduce greenhouse gas emissions in Manado City by 6.29% in 2022-2023.

L'Indonesia, un vasto arcipelago di 17.000 isole che si estende per 1,9 milioni di km², ha una popolazione di 267 milioni di persone distribuite nelle sue diverse regioni. Secondo il Regolamento Governativo n. 79 del 2014, l'Indonesia mira a sviluppare un mix di energie rinnovabili del 23% entro il 2025 e del 31% entro il 2050. Nonostante il Paese presenti un abbondante potenziale di energia rinnovabile come il biogas, c'è bisogno di approcci innovativi per raggiungere questi obiettivi. Il modello Symnery, introdotto nella città di Manado nel 2018, prevede un impianto pilota di produzione di biogas in due fasi che utilizza le acque reflue dei macelli e i rifiuti agricoli. Questo modello porta benefici sociali, economici e ambientali alle comunità rurali, offrendo occupazione, formazione e reddito aggiuntivo. L'alfabetizzazione energetica, fondamentale per la comprensione e la gestione delle complessità energetiche, viene incentivata attraverso questo modello. Il Governo, adottando il modello di bioenergia simbiotica a due fasi, lo ha semplificato per le piccole isole intorno alla città di Manado, distribuendo 18 impianti con materiali locali. I programmi di formazione locali si concentrano sul trasferimento delle conoscenze, sul monitoraggio e sulla dimostrazione dei vantaggi del biogas, con l'obiettivo di migliorare gli standard di vita, promuovere ambienti più puliti e ridurre le emissioni di gas serra nella città di Manado del 6,29% nel 2022-2023.

SAPIENZA Università Editrice

Tracce Urbane, 14
12/2023, pp. 214-239
DOI: 10.13133/2532-6562/18494

ISSN 2532-6562

Parole Chiave: simbiosi bioenergetica; alfabetizzazione energetica ed empowerment comunitario; Isole minori.
Keywords: symbiosis bioenergy; energy literacy & community empowerment; Small Islands.

Introduction

Indonesia is a beautiful archipelago that comprises approximately 17.000 islands stretching from the western to the eastern part, each with its unique culture and community. In the small islands of Indonesia, community plays a vital role in the inhabitants' daily lives. These close-knit communities foster a sense of togetherness and mutual support. They rely on each other for various activities, such as fishing, farming, and trade. The community members work hand in hand, sharing resources and knowledge to ensure the well-being of everyone. This strong sense of community creates a harmonious and vibrant atmosphere where traditions and customs are preserved and collective values are upheld.
Manado City, one of Indonesia's provincial capitals, is situated at 1.48 latitudes and 124.85 longitudes, with a population of 451.893 people. The city of Manado was hit with heavy rains in 2014, which caused flooding and severe damage. A number of 101 houses were lost, 18 people died, two were missing, and more than 25.000 people lost their houses and had to be relocated to the countryside (BPBD, 2014; Nasional, T.S.J.D.E., 2019). However, these relocation areas often lack the necessary facilities to support the basic needs of the flood victims. The lack of electrical infrastructure compounds the difficulties faced by flood victims in the relocation areas. Without electricity, families are unable to power essential appliances. The difficult living conditions in the relocation areas highlight the urgent need for improved infrastructure and support from the government. The installation of electrical infrastructure in these areas will greatly enhance the quality of life for the flood victims, enabling them to meet their basic needs and improve their overall well-being (Rewah, 2022).
In Indonesia's power sector, sustainability is a significant challenge that needs to be addressed. The electricity shortage is the main problem in most rural areas in Indonesia. One solution that can be proposed is to develop renewable energy

sources, primarily bioenergy, that utilize agricultural waste and animal manure as raw materials because it is abundant in rural areas, also as a solution for waste management. The National Action Plan for the Reduction of Greenhouse Gas Emissions 2010-2020 and the Greenhouse Gas Inventory Implementation Plan were introduced in 2011. Biogas is a promising and eco-friendly energy source that can help reduce our reliance on fossil fuels and improve energy security across the globe. It can be derived from several different biomass resources, including organic waste, energy crops, livestock manure, landfills, and wastewater and sewage (Budzianowski, 2012). The process of anaerobic digestion produces a mixture of gases, including CH4, CO2, and H2S. It has been discovered in previous studies that biogas technology has the potential to significantly reduce the consumption of firewood and promote a clean environment while simultaneously increasing support for agriculture, producing energy, and providing fertilizer. Furthermore, this technology offers a range of socio-economic, health, and gender benefits. Such findings exemplify biogas technology's potential for addressing a range of urgent and pressing societal issues (Ban and Syariffudin, 2005; Roubík, 2016; Yasar, 2017).
The symbiosis bioenergy model is a concept of the two-stage biohythane production system that uses different sources of substrates and produces biogas that can use for different purposes and support the community for many benefits (Fig.1). Symbiosis bioenergy, achieved through biogas production, is an innovative and sustainable approach that leverages the mutual relationship between organic waste management and energy generation. Biogas, a renewable energy source, is generated through the anaerobic digestion of various organic materials, such as agricultural residues, food waste, and sewage sludge. This process not only aids in effective waste management by diverting organic waste from landfills but also produces valuable energy in the form of biogas.

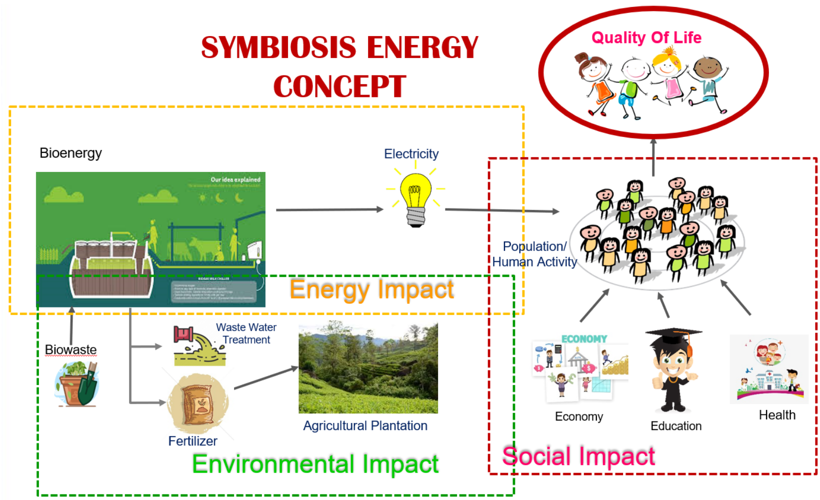

Fig. 1 Concept of Symbiosis bioenergy Model.

A demonstration site is a practical platform where people can witness various energy systems in action. These sites showcase renewable energy technologies such as solar panels, wind turbines, and geothermal systems. By observing these systems in operation, individuals can better understand how they work, their benefits, and their limitations. The advantage of learning by doing is that it provides a hands-on experience that fosters engagement and comprehension. Visitors to demonstration sites can actively participate in activities such as installing solar panels, monitoring energy consumption, or experimenting with energy-efficient appliances. This interactive approach enhances understanding and empowers individuals to make informed choices regarding their energy usage.

The pilot plant system was implemented in a slaughterhouse in Bailang village, Manado City, in 2018 (Sinsuw, Wuisang and Chu, 2021) and has been tested and evaluated. In previous studies (Sinsuw, Wuisang and Chu, 2021; Sinsuw *et al.*, 2023) evaluated and analyzed the environmental and social impacts of the installed systems through symbiosis bioenergy modeling. The results show an excellent environmental impact and the community benefits from the system and model. It benefits the community for education, good environmental impacts, and increased economic standard of living. The two-stage biogas system that utilizes slaughterhouse waste as the primary raw material and agricultural waste from local traditional markets has been shown through previous research to be highly beneficial for the community, particularly those living in the vicinity of the slaughterhouse. This model offers a sustainable solution for waste management while also producing biogas that can be used as a renewable energy source. Therefore, this research aim is to evaluate energy literacy by introducing and disseminating the symbiosis bioenergy model with biogas technology to empower the community, especially in rural areas and small islands around Manado City.

Literature Review

Energy literacy refers to the understanding and knowledge about various forms of energy, especially renewable energy, for the sources, production methods, consumption patterns, and the impact on the environment and society. It is an essential aspect of education and awareness today, where energy plays a central role in almost every aspect of people's lives. Energy literacy empowers individuals to make informed decisions, promote energy efficiency, and contribute to a sustainable future (He, Blasch, van Beukering and Wang, 2022). It is also encompasses knowledge about energy production methods and technologies, which involves understanding how electricity is generated in power plants, extracting and refining fossil fuels, and the mechanisms behind renewable energy systems. This includes awareness of emerging technologies such as energy storage, smart grids, and electric vehicles, which are crucial for transitioning to a more sustainable energy future (Bruce and Hogan, 2019). Furthermore, energy literacy extends to comprehending energy production and consumption's environmental and social implications. It involves recognizing the role of energy in climate change and the importance of transitioning to low-carbon and renewable energy sources (Martins, Madaleno and Dias, 2020). In promoting awareness of the environmental impact of energy generation and consumption, the knowledge about renewable energy encouraging rural communities to adopt sustainable practices (Bhattacharyya, 2019). Promoting renewable energy literacy is vital for achieving a sustainable future. It empowers individuals to actively participate in the energy transition, advocate for

renewable energy policies, and make informed choices as consumers. Education plays a crucial role in fostering energy literacy. Public awareness campaigns, workshops, and community programs can help raise awareness and promote energy literacy among the general population.
Energy literacy is crucial in empowering rural communities to make informed decisions regarding energy consumption, conservation, and renewable energy adoption. Some research and scholarly articles examined the significance of energy literacy in rural areas, the challenges these communities face, and potential strategies to enhance energy literacy levels. There are three significance of energy literacy in rural communities: (1) For economic implication. Energy literacy enables rural communities to understand the financial benefits of energy conservation practices and renewable energy installations, leading to cost savings and improved economic stability (Sovacool, Axsen and Sorrell, 2018); (2) Environmental sustainability: Energy literacy promotes awareness of the environmental impact of energy generation and consumption, encouraging rural communities to adopt sustainable practices (Bhattacharyya, 2019; Sovacool, Axsen and Sorrell, 2018); and (3) Energy literacy enhances the capacity of rural communities to manage and respond to energy-related challenges, such as power outages and natural disasters (Reddy, Sharma and Chaudhary, 2022).
Symbiosis bioenergy, specifically through biogas production, is an innovative and sustainable solution for renewable energy generation. It involves the symbiotic relationship between organic waste materials and microorganisms to produce biogas, which is rich in methane. This biogas can then be utilized as an efficient source of renewable energy for various applications, such as electricity generation, heating, and even transportation. The symbiotic nature of this bioenergy system lies in the multiple benefits it provides. Firstly, it offers a viable solution for waste management, reducing the environmental impact of organic waste and mitigating methane emissions from landfills (Nordahl *et al.*, 2020). Instead of allowing the waste to decompose in an uncontrolled manner, biogas production harnesses its potential energy content. Secondly, the produced biogas can be utilized for various applications,

including electricity generation, heat production, and cooking (Kabeyi and Olanrewaju, 2022). It serves as a renewable energy source, reducing reliance on fossil fuels and contributing to the transition towards a more sustainable energy mix (Abanades *et al.*, 2021). Additionally, the digestate residue from the anaerobic digestion process can be used as a nutrient-rich fertilizer, closing the loop in a circular economy approach (Lee, Steiman and Angelo, 2021).

Recent studies and publications highlight the growing interest and advancements in symbiosis bioenergy through biogas production. For instance, a study by Akbay *et al.* (2021) demonstrated the potential of co-digestion of different waste streams for enhanced biogas production, emphasizing the importance of feedstock selection and optimization. In another study by Sinsel *et al.* (2020), the integration of biogas production with other renewable energy technologies, such as solar and wind, was explored to enhance the overall energy system efficiency.

Furthermore, government policies and regulations have played a pivotal role in promoting symbiosis bioenergy. For example, in a study by Gustafson *et al.* (2022) the impact of policy frameworks on biogas development in Europe was analyzed, highlighting the significance of supportive regulations and incentives. The symbiosis bioenergy through biogas production offers a sustainable and mutually beneficial approach to waste management and renewable energy generation. Ongoing research and advancements in the field continue to explore the potential for optimization and integration with other renewable energy technologies, driving the transition towards a more sustainable and circular economy.

Materials and Methods

The study aimed to explore individuals' perceptions, knowledge, and behaviors regarding energy consumption and conservation. The area of this study is located in the Bunaken District of Manado City. The study included a diverse sample of individuals aged 18-65 years residing in rural areas surrounding the slaughterhouse, where residents affected by the 2014 flood were evacuated to the area. A purposive sampling was employed to ensure a mix of participants from different socioeconomic backgrounds and energy consumption patterns. The characteristic of the study area is presented in Table 1. Field observations and surveys were conducted through interviews and questionnaire distribution to 30 respondents using statements with the Likert scale method 1-5 (Likert, 1932).

Area	659 Ha
Total Population	20.971 people
Male	10.332 people
Female	10.639 people
Housing	1.582 houses
House without electric	65 houses
Cooking Fuels	Firewood, Kerosene, 3 kg gas (government subsidized)

Table 1. Characteristics of the study area.

The average education level of the community, ranging from elementary to high school, suggests that the community has not received extensive formal education beyond the high school level. This lower level of education may contribute to a lack of knowledge about renewable energy technology within the community. The lack of knowledge about renewable energy technology could have implications for the community's ability to adopt and utilize these sustainable energy sources effectively. It may hinder their capacity to make informed decisions, implement renewable energy projects, or take advantage of available opportunities for clean energy solutions.

To address this knowledge gap, initiatives could be undertaken to provide educational programs, workshops, or community outreach efforts to enhance the community's understanding of renewable energy technology. By promoting awareness and providing resources, the community can be empowered to embrace renewable energy and contribute to a more sustainable future.

With a primary focus on elementary and high school education, individuals in the community may not have had the opportunity to learn about advanced concepts and technologies related to renewable energy. This could result in a limited understanding

of the benefits, applications, and potential of renewable energy sources.
The Likert scale is a commonly used rating scale in research and surveys to measure attitudes, opinions, and perceptions of individuals. It typically consists of a series of statements or items that respondents are asked to rate based on their level of agreement or disagreement. In the case of a Likert scale with a range of 1-5, respondents are presented with a set of statements and asked to indicate their level of agreement or disagreement using a 5-point scale. The scale usually includes the following response options:

1. Strongly Disagree: This indicates a strong disagreement with the statement or item.
2. Disagree: This indicates a disagreement with the statement or item.
3. Neutral: This indicates a neutral or neither agree nor disagree stance.
4. Agree: This indicates an agreement with the statement or item.
5. Strongly Agree: This indicates a strong agreement with the statement or item.

The scale allows respondents to express their opinions on a continuum from less strong (disagreement) to most strong (agreement). The numerical values assigned to each response option can be used to calculate averages or perform statistical analyses to summarize and compare the data collected from multiple respondents. The statements were formulated regarding the communities' preliminary knowledge about renewable energy, mainly biogas systems, and its impacts on the communities and environment. Table 2 shows the example of the statements in the questionnaire.

Question No.	Respondent statement	1	2	3	4	5
	Basic Knowledge About Bioenergy					
1	Biomass energy is one of renewable energy					
2	Biogas is a product of biomass					
3	Bioenergy pilot plant as a solution of waste management					
4	Biomass energy are environmentally friendly					
5	Bioenergy plant using cow manure and organic waste as feedstock					

Table 2. Questionnaire Statements.

The assessment included three aspects: knowledge about bioenergy, community involvement, and social acceptance. Each aspect had five statements and was scored from 1 to 5, resulting in a total score ranging from 5 to 25. The scores were then added up to obtain the total score for each sample. Validity and reliability tests were conducted to ensure the accuracy and consistency of the data. The data were found to be valid through Pearson's correlation test, as the values were greater than 0.1129 (r-table) with a significance level (α) of 0.05. Additionally, the data showed high reliability with a Cronbach's Alpha (Santos, 1999) value of 0.9, exceeding the threshold of 0.7. Finally, The community acceptance level of the bioenergy pilot module implementation at the study site was categorized as high, medium, or low. Based on statistical calculations, all three aspects fell into the high category with scores of 67%, 51%, and 67% respectively.

The second questionnaire was taken from the respondents after utilization distributed by the government during five years (Fig. 2) to find out whether the utilization of the biogas in the community has increased the knowledge or renewable energy literacy of the communities in rural and small islands.

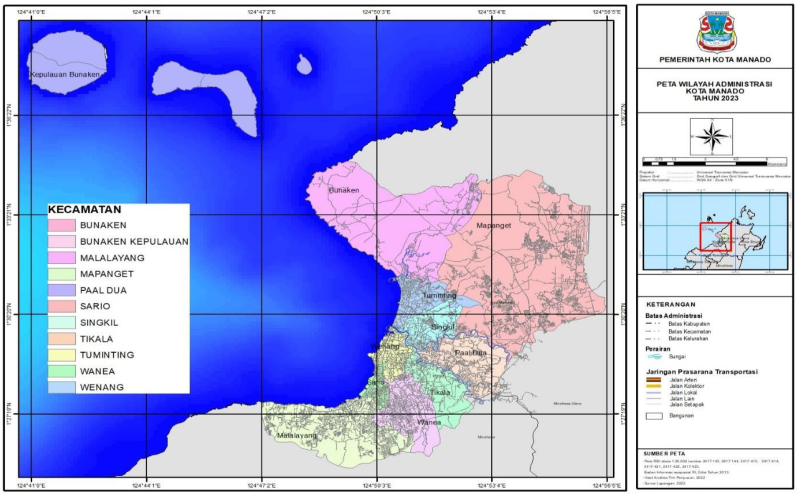

Fig. 2 Distribution Map of the affordable Bioenergy in Manado area.

Semi-structured interviews were conducted as the primary method of data collection. The interviews were conducted face-to-face and lasted between 15-30 minutes. An interview guide was developed to ensure interview consistency while allowing flexibility to explore individual experiences and perspectives. The guide included open-ended questions about energy literacy, energy consumption habits, and attitudes toward energy conservation. Ethical approval was obtained from the Institutional Review Board prior to conducting the research. Informed consent was obtained from all participants, ensuring their voluntary participation and confidentiality. Participants were assured of their right to withdraw from the study without consequences. Pseudonyms were used to ensure anonymity in reporting the findings. Multiple strategies were employed to ensure the study's validity and reliability. Triangulation was used by collecting data from multiple sources, such as interviews and field observations. Member checking was conducted by sharing preliminary findings with participants to ensure accuracy and credibility. Additionally, the research team engaged in regular discussions and debriefing sessions to minimize bias and enhance the study's trustworthiness. Overall, this study utilized a qualitative research approach to explore energy literacy. The methods employed aimed to provide rich and in-depth insights into individuals' perceptions, knowledge, and behaviors regarding energy consumption and conservation. The findings from this research will contribute to the development of effective energy literacy programs and policies.

The symbiosis bioenergy model tested and evaluated in previous studies was disseminated and applied to communities around the Bunaken archipelago sub-district. By accommodating the initial idea that has been tested through a two-stage biogas system in the Manado slaughterhouse (Sinsuw, Wuisang and Chu, 2021), some material simplifications have been made using local materials for an affordable price. From the pilot plant system that has been installed in the slaughterhouse (Fig.1), the symbiosis bioenergy model is simplified into a single-stage system because the price is more affordable for the community, and the biogas produced is only prioritized for use as fuel for cooking (Fig. 3).

The Manado City government disseminated the biogas system to the rural areas and small islands, initiated by the Regional Research and Development Planning Agency. The city government assembled several single-stage biogas units using local materials at an affordable price per unit to support the community, giving literacy about renewable energy and demonstrating how food/kitchen waste can be turned into an energy source. The unit price of one single system of biogas was about USD 130. This price is very affordable. The gas produced was used to sell some snacks or food that can get profit so that the biogas investment can be returned after 3.5 months, and after four months, the community already gets profit from using the biogas for cooking fuel. These household-scale biogas units were then delivered to Bunaken Island eight units, Manado Tua Island four units, and four other units distributed to small villages nearby. The communities interested in self-assembling were trained by the supervisor, and at the same time, they became the local assistant for troubleshooting when the supervisor was not at the location. The Manado city government carries out the distribution of biogas units on small islands around the city of Manado through sub-district heads and community involvement.

Fig. 3 Two-stage Biogas Plant at Manado Slaughterhouse.

Fig. 4 Distribution of affordable biogas unit to small islands.

This single-stage system uses inoculum from the slaughterhouse and mixes it with food waste in the district where the biogas is placed. After the single-stage biogas units had been distributed, the government conducted training and demonstration on the usage and maintenance of the system to the communities. Biogas supervisors from the Manado city government carried out training for the community. This supervisor was one of the operators recruited and given training when the two-stage biogas construction at the slaughterhouse was carried out. Apart from providing training, this supervisor also monitors and troubleshoots if people experience problems with their system. When troubleshooting, supervisors also show the public how to overcome common problems often encountered.

Results And Discussion

The affordable symbiosis bioenergy from a single-stage biogas system is a technology for processing organic matter with the addition of microorganism bacteria as a starter to speed up the process of decomposition of organic matter in an aerobic. The dissemination of biogas technology through the symbiosis bioenergy model to rural and small island communities is not only to implement government programs to reduce CO2 emission levels but is also an alternative for providing energy literacy to the community. Learning by doing is appropriate for people in rural areas and small islands who generally have low education but adequate skills. Therefore, implementing energy literacy through site demonstrations and training on how to make biogas as an energy source, especially fuel for cooking and dealing with troubleshooting problems, is very suitable for this type of community, where the results show significant improvements. From 2019 to 2023, the total system distributed to small districts and islands is 52 units (Table 3). The content of effluent used as biofertilizer has been tested in the government laboratory with the result of Nitrogen 0.47% and Phosphorus ←0.00002%, which is moderate for the plant's nutrition (Sinsuw, Chen *et al.*, 2023).
Biogas training and maintenance play a crucial role in empowering rural communities, not only in terms of ensuring the sustainability of their biogas systems but also in enhancing their energy literacy. Learning by doing is a crucial component of this process. Firstly, biogas training and maintenance are

essential for the long-term functioning of biogas systems. These systems convert organic waste into clean energy and require regular upkeep to operate efficiently. Without proper training, community members may lack the knowledge and skills to maintain their biogas systems, leading to breakdowns and reduced energy production. By providing training on system maintenance, rural communities can ensure the longevity and reliability of their biogas systems, thus maximizing their energy potential.
Moreover, biogas training and maintenance contribute to energy literacy within rural communities. Energy literacy refers to understanding energy sources, their production, and their environmental impact. By engaging in hands-on maintenance activities, community members gain a deeper understanding of the inner workings of biogas systems and the principles behind them. This practical knowledge equips them to make informed decisions about energy usage and appreciate biogas's environmental benefits as a renewable energy source. Learning by doing is an efficient approach to biogas training and maintenance. Rather than relying solely on theoretical knowledge, community members actively engage in maintenance, troubleshooting issues, and making necessary repairs. This hands-on experience builds technical skills and fosters a sense of ownership and confidence among participants. They become self-reliant in maintaining their biogas systems, reducing the need for external assistance, and ensuring the sustainability of their energy source.

Year	**Units**	**Districts**
2019	1	Wenang
	7	Tuminting
2020	1	Mapanget
	1	Tuminting
	1	Paaldua
	5	Bunaken
	4	Malalayang
	8	Tikala
2021	2	Wenang
2022	12	Bunaken
2023	1	Singkil

Table 2. Distribution of single-stage biogas unit.

Besides energy literacy, certain socio-economic factors can significantly affect a household's decision-making when adopting biogas technology. These factors include income level, education level, and overall living conditions. For example, households with higher income levels may be more likely to adopt biogas technology due to its potential cost savings. Similarly, households with higher levels of education may be more inclined to adopt biogas technology due to a better understanding of its benefits and how it works. On the other hand, households with poor living conditions may be less likely to adopt biogas technology due to the initial costs associated with setting up the system. Overall, it's important to consider these factors when determining how to promote and encourage the adoption of biogas technology in households.

Fig. 5 Biofertilizer for plants.

Biogas is becoming a popular alternative to traditional cooking fuels in many communities. This clean energy source is not only sustainable, but it also helps to reduce the environmental impact caused by other types of fuels. As more people become aware of the benefits of biogas, there will be greater adoption of this technology in the years to come. This single-stage system for households can produce gas around 300-500 L/day, with a processing capacity of 15-30 L of organic wastewater with a ratio of 1:1. The gas produced can be used for cooking purposes for 1-1.5 hours/day, and the fermented liquid that comes out every day can be used as liquid fertilizer. In the previous study, Katuwal *et al*. (2019) found that a small-scale biogas plant saves approximately three metric tons of firewood and 576 kilograms of manure from being burned each year directly, reducing CO2 emissions to the atmosphere by approximately 4.5 tons. In addition to reducing household organic waste, this system can cut costs and the carbon footprint of LPG distribution and produce fertilizer to fertilize plants.

Regarding energy literacy in rural and small island communities, there are also some challenges faced by the communities, such as (1) Limited access to information: rural communities often lack access to reliable energy-related information, making it difficult for them to make informed decisions about energy usage; (2) Infrastructure constraints: inadequate energy infrastructure, including limited electricity grid connectivity, hampers the adoption of renewable energy solutions in rural areas; and (3) Socio-economic barriers: economic constraints, low educational attainment, and cultural factors can hinder the development of energy literacy in rural communities. Therefore, it has to consider the strategies to enhance Energy Literacy to rural and small island communities, as follows: (1) Community engagement: Collaborative initiatives involving local organizations, community leaders, and educational institutions can facilitate energy literacy programs tailored to the needs and cultural context of rural communities; (2) Technology and information dissemination: leveraging digital platforms, mobile applications, and community radio can help overcome information barriers and provide accessible energy-related knowledge; and (3) Capacity building: Training programs, workshops, and skill development initiatives can empower individuals in rural communities to understand energy concepts, energy-efficient practices, and renewable energy technologies (Reddy *et al*., 2022).

Fig 5. Rural and Small Island Communities' Capacity Building and Energy Literacy.

Conclusions

Energy literacy is essential for rural communities to achieve sustainable development, mitigate climate change, and improve their socio-economic well-being. However, challenges such as limited access to information and infrastructure constraints must be addressed through targeted community engagement, technological interventions, and capacity-building initiatives. By enhancing energy literacy, rural communities can make informed choices and actively participate in the transition towards a more sustainable energy future.

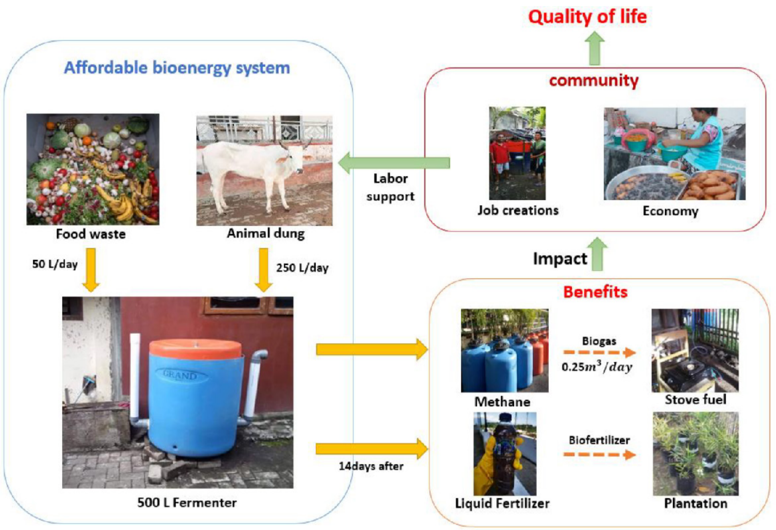

Fig. 6 Symbiosis bioenergy of Affordable Biogas System.

The symbiosis bioenergy model emphasizes the interconnectedness and interdependence of different energy sources and systems. Biogas technology aligns perfectly with this model as it utilizes organic waste materials, such as agricultural residues, animal manure, and food waste, to produce biogas. Using biogas technology, organic waste, which would otherwise contribute to environmental pollution, can be converted into a valuable source of renewable energy. This process involves the anaerobic digestion of organic materials such as agricultural residues, food waste, and animal manure to produce biogas, which can be used for cooking, heating, and electricity generation. Additionally, the byproduct of this process, known as digestate, can be used as a nutrient-rich fertilizer. The dissemination of biogas technology to promote energy literacy involves various components. Firstly, educational campaigns and workshops can be conducted to raise awareness about the benefits and principles of biogas technology. These initiatives can highlight the environmental advantages of biogas production, such as reducing greenhouse gas emissions and mitigating climate change. Additionally, they can educate individuals on biogas production, the types of organic waste suitable for biogas generation, and the potential applications of biogas as a clean energy source. As a tribute to pollution and greenhouse gas

emissions, it is converted into a valuable energy resource.
The Symbiosis bioenergy model taught the community about biogas technology and managing household food waste and animal dung. The community also have opportunities to get training and education from the experts or supervisor supported by the Manado City government. At the same time, the usage of biogas is supporting the Indonesian government in reducing GHG emissions. The resulting biogas production is used for cooking. Therefore, women no longer need to go to the forest looking for firewood but can save time using their biogas production. They can get extra income by selling snacks from cooking using biogas. The effluent as a byproduct is used as fertilizer for their vegetable plants. Thus, the community, especially women, is more empowered; apart from saving their time, they also get extra income to help support the family finances.
As the demand for farm animal products continues to rise, so does the population of livestock and the resulting organic waste. This waste can be utilized in biogas technology, which has the potential for widespread implementation due to its significant advantages in energy, environmental sustainability, and economic development. However, there are challenges to this development, including technical and policy implications, socio-economic obstacles, and lack of institutional support. These challenges must be addressed adequately. Biogas technology not only has the potential to mitigate the negative impact of livestock and waste generation but also to alleviate poverty by supporting agriculture and providing clean energy in the form of biogas and fertilizer as a byproduct. It can also open job opportunities for the communities to be recruited as technician teams to assist in troubleshooting or maintaining the small island's distributed biogas system.
Furthermore, the dissemination of biogas technology can involve practical demonstrations and training programs. This hands-on approach allows individuals to witness the process of biogas production and understand the technical aspects of biogas systems. Training programs can provide individuals with the skills and knowledge necessary to install, operate, and maintain biogas digesters, ensuring the long-term sustainability of the technology. Community engagement is also crucial to disseminating biogas technology as energy

literacy. By fostering community involvement, individuals can share their experiences and knowledge of biogas technology, creating a supportive network for those interested in adopting this sustainable energy solution. Community-based initiatives, such as biogas cooperatives or shared biogas systems, can be established to encourage collaboration and resource sharing among community members. By disseminating biogas technology as an energy literacy initiative, individuals gain a deeper understanding of sustainable energy practices and the potential of organic waste as a renewable energy source. They become aware of biogas production's environmental benefits and waste management's importance. Additionally, individuals acquire practical skills and knowledge that empower them to participate in sustainable energy practices actively.

Additionally, biogas training and maintenance are vital for rural communities, as they ensure the proper functioning of biogas systems and contribute to energy literacy. Learning by doing allows community members to actively participate in the maintenance process, gaining valuable skills and knowledge that empower them to manage their energy needs sustainably.

In conclusion, the symbiosis bioenergy model can be effectively applied by disseminating biogas technology as an energy literacy initiative. By raising awareness, providing hands-on training, fostering community engagement, and offering policy support, individuals can better understand sustainable energy practices and contribute to a more sustainable future. The dissemination of biogas technology not only promotes energy literacy, addresses waste management challenges, and reduces greenhouse gas emissions, making it a valuable tool for sustainable development.

References

Abanades S., Abbaspour H., Ahmadi A., Das B., Ehyaei M.A., Esmaeilion F., El Haj Assad M., Hajilounezhad T., Jamali D.H., Hmida A., Ozgoli H.A., Safari S., AlShabi M., Bani-Hani E.H. (2021). «A critical review of biogas production and usage with legislations framework across the globe». *International Journal of Environmental Science and Technology*, 19:3377–3400.

Akbay H.E.G., Dizge N., Kumbur H. (2021). «Enhancing biogas production of anaerobic co-digestion of industrial waste and municipal sewage sludge with mechanical, chemical, thermal, and hybrid pretreatment». *Bioresource Technology*, 340: 125688.

Ban P., Syariffudin J. (2005). «Penggunaan Kayu Bakar Untuk Rumah Tangga Di Desa Sekitar Taman Hutan Raya Rajolelo Bengkulu». *Jurnal AGRISEP: Kajian Masalah Sosial Ekonomi Pertanian dan Agribisnis*: 33-41.

Bhattacharyya S.C. (2019). *Energy economics: concepts, issues, markets and governance*. Springer Nature.

BPBD (2014). *Badan Penanggulangan Bencana Daerah*, Manado.

Bruce B.C., Hogan M.P. (2019). «The disappearance of technology: Toward an ecological model of literacy». In: Lutkewitte C., *Writing in a Technological World*. New York: Routledge, pp. 191-207.

Budzianowski W.M. (2012). «Sustainable biogas energy in Poland: Prospects and challenges». *Renewable and Sustainable Energy Reviews*, 16(1): 342-349.

Gustafsson M., Anderberg S. (2022). *«Biogas policies and production development in Europe: A comparative analysis of eight countries»*. *Biofuels*, 13(8): 931-944.

He S., Blasch J., van Beukering P., Wang J. (2022). «Energy labels and heuristic decision-making: The role of cognition and energy literacy». *Energy Economics*, 114: 106279.

Lee M.E., Steiman M.W., Angelo S.K.S. (2021). «Biogas digestate as a renewable fertilizer: Effects of digestate application on crop growth and nutrient composition». Renewable Agriculture and Food Systems, 36(2): 173-181.

Kabeyi M.J.B., Olanrewaju O.A. (2022). «Biogas production and applications in the sustainable energy transition». *Journal of Energy* : 1-43.

Katuwal H., Bohara A.K. (2019). «Biogas: A promising renewable technology and its impact on rural households in Nepal». *Renewable and sustainable energy reviews*, 13(9): 2668-2674.

Likert R. (1932). *«A technique for the measurement of attitudes».*

Archives of psychology, 140(22): 5-55.

Martins A., Madaleno M., Dias M.F. (2020). «Energy literacy: What is out there to know?». *Energy Reports*, 6: 454-459.National T.S.J.D.E. (2019). «Indonesia energy outlook 2019». *J. Chem. Inf. Model*, 53(9): 1689-1699.

Nordahl S.L., Devkota J.P., Amirebrahimi J., Smith S.J., Breunig H.M., Preble C.V., Satchwell A.J., Jin L., Brown N.J., Kirchstetter T.W., Scown C.D. (2020). «Life-cycle greenhouse gas emissions and human health trade-offs of organic waste management strategies». *Environmental science & technology*, 54(15): 9200-9209.

Reddy P., Sharma B., Chaudhary K. (2022). «Digital literacy: a review in the South Pacific». *Journal of Computing in Higher Education*, 34(1): 83-108.

Rewah F. (2022). «Community Participation in Reducing the Risk of Flood Disaster in Tuminting District Manado City». *SHS Web of Conferences*. EDP Sciences.

Roubík H., Mazancová J., Heller T., Brunerová A., Herák D. (2016). «Biogas as a promising energy source for Sumatra». *6th International Conference on Trends in Agricultural Engineering*, pp. 537-544.

Santos J.R.A. (1999). *«Cronbach's alpha: A tool for assessing the reliability of scales». Journal of extension*, 37(2): 1-5.

Sinsel S.R., Riemke R.L., Hoffmann V.H. (2020). *«Challenges and solution technologies for the integration of variable renewable energy sources—a review». Renewable Energy*, 145: 2271-2285.

Sinsuw A.A.E., Wuisang C.E., Chu C.-Y. (2021). «Assessment of environmental and social impacts on rural community by two-stage biogas production pilot plant from slaughterhouse wastewater». *Journal of Water Process Engineering*, 40: 101796.

Sinsuw A.A.E., Chen T. H., Dokmaingam P., Suriandjo H.S., Chu C.Y. (2023). «Life cycle assessment of environmental impacts for two-stage anaerobic biogas plant between commercial and pilot scales». *International Journal of Hydrogen Energy*, 52(A): 58-70.

Sovacool B.K., Axsen J., Sorrell S. (2018). «Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design». *Energy research & Social Science*, 45: 12-42.

Yasar A., Nazir S., Tabinda A.B., Nazar M., Rasheed R., Afzaal M. (2017). «Socio-economic, health and agriculture benefits of rural household biogas plants in energy scarce developing countries: A case study from Pakistan». *Renewable Energy*, 108(C): 19-25.

Alicia Amelia Elizabeth Sinsuw, is an Assistant Professor at Sam Ratulangi University, Faculty of Engineering in Manado City, Indonesia. Her research focus concerns rural community development, especially on the remote islands in Indonesia. She completed her Ph.D. at the Mechanical and Aeronautical Department, at Feng Chia University, with a Dissertation on "Symbiosis bioenergy Modeling and Environmental Performance Evaluation for Rural Communities Empowerment and Quality of Life". Her research interest is Education, Life Cycle Analysis, Community and Women Empowerment through bioenergy technology, for sustaining rural communities and its added value for human development and a better quality of life. aliciasinsuw@mail.fcu.edu.tw, aliciasinsuw@gmail.com

Sangkertadi, Professor in Building Science at Faculty of Engineering, Dept. of Architecture, Sam Ratulangi University. Graduated from ITS, Surabaya (Architecture), Indonesia, in 1985, Master Degree at INSA de Lyon (Civil Engineering and Planning), Lyon, France, in 1990, and complete his PhD at INSA de Lyon (Building Science) , Lyon, France, in 1994. He has several professional membership of Green Building and Architect association. He is now is a Vice-Rector for Planning, Budgeting, and International Collaboration Affairs at Sam Ratulangi University, Indonesia. sangkertadi@unsrat.ac.id

Hendrik Suryo Suriandjo, born in Ujung Pandang, 26 November 1979, Graduated from Bachelor's Degree in the Architecture Study Program, Faculty of Engineering, Sam Ratulangi University, Manado in 2002, graduated with a master's degree in the Urban Management Study in 2009 and took another course at the same degree in 2010 in the Master of Architecture Study Program with a concentration in Coastal Tropical City Design and graduated in 2013. In 2020 he continued his doctoral studies in the Doctoral Program in Regional and Urban Planning Science at Bosowa University Makassar and graduated in 2023 with the title Cum Laude. hsurianjo@gmail.com

Liny Anna Maria Tambajong, Head of Regional Planning, Development and Innovation Agency of Manado City, North Sulawesi, Indonesia. She graduated from Department of Architecture, Faculty of Engineering, Sam Ratulangi University in 1993, Master of Urban Management, Sam Ratulangi University in 2003, and completed her Doctor of Development on Natural Resources and Environment at the Institute of Agricultural Bogor, Indonesia in 2009. She is also the initiator and mentor of Manado Eco-community. linytambajong@gmail.com

Ivana Marcia Florence, born in Manado, 31 January 1998, Graduated from Bachelor's Degree in the Urban Planning Study Program, Faculty of Engineering, Sam Ratulangi University, Manado in 2021, and get her Master Degree in the Green Energy Science and Technology, Feng Chia University, Taiwan. ivanamarcia88@gmail.com

Oktovian Berty Alexander Sompie, graduated from his bachelor study of Civil Engineering Department, Faculty of Engineering, Sam Ratulangi University, Indonesia in 1992, achieved his Master Degree in the Department of Architecture and Civil Engineering, Fukui University, Japan in 2000, and get his PhD in the Department of Agricultural Engineering at Institute of Agricultural Bogor, in the year of 2010. He is now the Rector of Sam Ratulangi University, Manado City, North Sulawesi, Indonesia. bsompie@unsrat.ac.id