Larhyss Journal, ISSN 1112-3680, n°56, Dec 2023, pp. 7-24

FOSTERING INCLUSIVE WATERSHED MANAGEMENT THROUGH MULTIHELIX ENGAGEMENT MODEL ON MICRO HYDROPOWER ELECTRIFICATION IN SABAH, MALAYSIA

LONG A.[1], MOKHTAR M.[1, 2], HALIM S.[1], AHMED F.[1*]

[1] Institute for Environment and Development University Kebangsaan Malaysia, Selangor, Malaysia
[2] United Nations Sustainable Development Solutions Network (UNSDSN), Asia Headquarters, Sunway University, Selangor, Malaysia

(*) minhaz@ukm.edu.my

Research Article – Available at http://larhyss.net/ojs/index.php/larhyss/index
Received March 30, 2023, Received in revised form December 3, 2023, Accepted December 5, 2023

ABSTRACT

Many nations across the globe have incorporated carbon neutrality into their national agendas to see a more sustainable world. The basic sustainable journey is to find the equilibrium between the people, the environment and the economy. By conceptualizing inclusive carbon-neutral electrification, countries may achieve their aspiration at both the macro and micro levels. Macro national energy transition policies emphasized centralized technological shifts for grid systems and in many cases neglected rural communities. Some argued that Borneo's disparity in socioeconomic status was due to a lack of electrification. Hence, this paper explored the decentralized community-based electrification potential through a micro hydropower initiative. Such technologies encourage watershed management and are closely related to the Tagal communities' heritage. The paper explored the complex problem with the multihelix approach to examine each actor's aspirations and concerns. Actors underwent a series of interviews based on five key aspects of sustainable rural electrification. By integrating multicriteria analysis (MCA), the qualitative research data were analyzed to find gaps for implementation. The findings supported the introduction of a new actor to best foster inclusive watershed management through micro hydropower electrification in Sabah, Malaysia.

Keywords: Actors, Carbon neutral, Micro hydropower, Multihelix model, Watershed management.

INTRODUCTION

Sabah Malaysia is the second largest state with more than 3.8 million people. Many still live below the poverty line. The vast majority lived in the following main cities: Kota

Kinabalu, Sandakan, Tawau, Lahat Datu and Keningau (Hassan 2018; Jabatan Perangkaan Malaysia 2020). In 2019, prior to the pandemic, Sabah only managed 1.8% growth, while Selangor, the best performing state, recorded 6.8% (Laporan Sosioekonomi Negeri Sabah, 2020). Sabah's unemployment rate was 5.8%, which is much higher than the national figure of 3.3%. In 2015, agriculture contributed 20% of Sabah's income, followed by the mining and hospitality industry. However, the GDP per capita ranked in the bottom three after Kedah and Kelantan (*Laporan Sosioekonomi Negeri Sabah* 2020). The five years of socioeconomic indicators before the pandemic are reflected in Table 1 below.

Table 1: Sabah's socioeconomic indicators for 2015 to 2019

Indicators	2015	2016	2017	2018	2019
GDP	73,776.00	80,503.00	95,006.00	100,703.00	99,076.00
Population	3.72	3.80	3.86	3.90	3.90
GDP per capita	19,830.00	21,169.00	24,639.00	25,832.00	25,375.00

Development in Sabah has a long history of transformation as an individual, and the community's needs evolve over time. Life progressed in a generally meek style until the 1960s, when an awakening of local identity drove equality for the local community (Er et al. 2012; Tangit et al. 2014). The balanced needs of the community will determine the stability and cohesiveness of the nation. The heritage of a community or people group is closely tied to the rich knowledge of the people (Jelisavka et al., 2019; Bulatović and Rajović, 2022). Traditional knowledge can be classified as heritage of old passed down as an inheritance from ancestors (Latip et al. 2015; UNESCO 1960).

Heritage is made up of traditional knowledge standing for a holistic understanding of an indigenous society toward its day-to-day practice. One key sustainable lifestyle of these heritage sites includes the preservation of trees, the reduction in land erosion, and the avoidance of cutting down trees in hilly areas that may contaminate the river (Ahmed et al. 2020; Besar et al. 2020; Farid Ahmed et al. 2018; UNDP 2017). The Tagal system is an indigenous heritage originating in Sabah that means "forbidden or restricted" in the local kadazandusun. The restriction is from gathering resources prior to the agreement of the community. The traditional Tagal involves an individual marking his territory near the riverine of their residence as a territorial demarcation for his household. The villager would place poles around a deep pool to proclaim ownership. Later, heritage was promoted to become a recognized practice adopted throughout Borneo (Foo 2011; J. Z. Wong et al. 2009).

With the policy and laws in place, the Tagal movement gained momentum back in 2003 through the smart partnership program with the Department of Fisheries (Foo 2011; UNDP 2017). Tagal is now a sustainable heritage way of life for riverine conservation in supporting a growing fish population by taming a certain species of fish that eventually transforms into ecotourism (Foo 2011; J. Z. Wong et al. 2009). This is a key example of community-driven watershed management through the heritage lifestyle (Merous et al.

2016; S. R. Wong et al. 2018). With the wake of ecotourism, Tagal communities managed to attract a consistent flow of local and international visitors (Ubaidillah, Ab-Rahim, et al. 2018). Some of the key challenges faced by these communities were financial constraints, poor participation from the community, insufficient promotion, resources and weather conditions. (Ahmed et al. 2018; Ubaidillah, Ab-Rahim, et al. 2018; Ubaidillah, Saib, et al. 2018). Sabah inherited one of the richest biospheres from mother earth, wildlife and the natural environment is protected under the wildlife Conservation Enactment (No. 6 of 1997), which is gazette on 24th December 1997. The enactment supplied declarations on three types of protected areas, namely, (i) Wildlife Sanctuaries (section 9(6)), (ii) Conservation Areas (section 21) and (iii) Wildlife Hunting Areas (section 64(2))(Latip et al. 2015; Tangit et al. 2014). These enactments preserve not only the biosphere but also the watershed that is able to supply a sustainable carbon sink for Malaysia. Watershed management helps to create consistent water quality and carbon sequestration to a cleaner earth (Besar et al. 2020; Merous et al. 2016; Rouissat and Smail, 2022).

Researchers have noted the important correlation of environmental stewardship, energy and economic growth, yet it does not influence the entire length and breadth of socioeconomic for all (Energy Sector Management Assistance Program 2019; Kaunda et al. 2012; Kirmani et al. 2010; Vijeyan et al. 2017). Taking Sabah's needs with rich heritage and topographical circumstances into account, this paper explored this complex problem by incorporating micro hydropower into the Tagal communities.

The initiative may help spur community-based watershed management. This paper examined the problem through multistakeholder engagement. The research aspired to best understand the complex problem by engaging all actors in inclusive and carbon-neutral initiatives (Carayannis and Campbell 2014; Long et al. 2022). Taking advantage of the global demand for low-carbon initiatives, this paper investigated qualitative data from various actors using Ilskog's multicriteria analysis (MCA) (Ilskog 2016). The MCA included 5 sustainable development aspects, 19 key variables and 32 indicators to present information that may foster inclusive watershed management. This paper examined the possibilities of micro hydropower electrification in Sabah, Malaysia, through the multihelix engagement model.

METHODS OF DATA COLLECTION WITH MULTI HELIX ACTORS

Applying unstructured interviews was only part of the technique, as the indicators were related directly to distinct aspects, resulting in an astute correlation to sustainability. The justification for interview methods was to gather insights from respective actors about the research questions. Some of the key findings were to name each actor's role and possible contributions, as well as their limitations in the study (Carayannis and Campbell 2013; Halibas et al. 2017).

Through the course of interviews, the study hoped to name any missing actors or subclassified actors that were believed important for the analysis. This paper expounded on semistructured interviews to collate multifactorial data with six different actor clusters

involved in the multihelix model. To do this, experts were selected within its helix with experience related to sustainable development on global goals. Then, the study was taken from the federal level, the state level, the district level and finally to the community level to better understand grassroots needs at an individual level. The interviews were conducted based on expert elicitation; thus, subject matter experts were consulted.

For this paper, nonstructured interviews were deployed as part of the means of gauging the awareness and recognition of many actors. These stakeholders come from different institutions with regard to the novel micro hydropower, environmental management and socioeconomic improvement potentials for the Tagal communities. The criteria to select participants for the interviews were based on actors' classification of the multihelix model. Hence, representatives from all helixes were selected based on recommendations, knowledge in the topic and trained availability. A total of 51 interviews were conducted with six different actor groups. Questions were prepared following the 5 core sustainable development aspects, 19 variables and 32 indicators.

The multicriteria analysis is modeled after Ilskog's research to gain a measurable qualitative response to each of the aspects. The interviewees selected must fit the actors' roles for each helix to respond to the MCA on (i) Technical aspects, (ii) Economic aspects, (iii) Social aspects, (iv) Environmental aspects and (iv) Governance aspects (Ilskog 2016).

Using the Likert scale where 0 being irrelevant or not important to 5 being especially important or must have according to actors' responses. The intention to use the ranking to produce pointers for the indicators within each facet is also challenging because it can either reduce large absolute differences or exaggerate small absolute differences (Ahmed et al. n.d.; Schwan 2011). These qualitative data presented an overall assumption of the respective actor's focus based on the five aspects. The disparities between the actors' responses will be elusive, as the differences were minimal. Hence, these data required weightages for a clearer measurement of interest to further cluster the actors' responses. The findings of the weightages were later used for discussion. Two key prospects from the analysis were to find (i) key missing actors for inclusive electrification as a watershed management solution and (ii) barriers for micro hydropower implementation as clean, secure and inclusive electrification. The following section discusses the process of actors' classification and selection process for the study.

Selecting the multihelix actors

One of the key goals of the paper was to collate an actor's response on micro hydropower electrification as a watershed management solution in meeting the socioeconomic needs of the Tagal communities. To have a better understanding of the compendium of stakeholders, the foundational triple helix model of Etzkowitz and Leydesdorff (Carayannis and Campbell 2010; Etzkowitz and Leydesdorff 2000) was applied and later explicated into a versatile multihelix model (Carayannis et al. 2012; Long et al. 2022). The uniqueness of the multihelix model is to respect individual aspirations while the intention is for them to congeal into a common goal where everyone will benefit.

Interviewing selected individuals is an especially important method often used by qualitative researchers (Gray et al. 2009; Hardianto et al. 2019; Iemsomboon and Tangtham 2014; Moser and Korstjens 2018). A total of 51 actors were engaged and represented by the multihelix actors.

1. Government actor: The government actor is one key pillar to materialize the project due to approvals, regulations, tariffs and land use (Izadyar et al. 2016; Khengwee et al. 2017). Due to the multidepartmental involvement in hydropower projects in Malaysia, expert elicitation was deployed to specific individuals for details and technical information for the paper.
   The government actors involved in inclusive rural electrification and watershed management were complex; thus, this is the single largest actor group for the study. The paper engaged 24 government actors, as shown in Table 2, who were represented by the federal government with its agencies, the state government with its agencies and the local authorities with its agencies.

Table 2: Government Actors Engaged in the Study

No.	Government actors engaged	No.	Government actors engaged
1	State secretary office	13	District Surveyor
2	Economic Planning Unit	14	Community Development Department
3	Ministry of rural development 1	15	SESB for Tambunan District
4	Ministry of rural development 2	16	Department of Irrigation
5	Ministry of rural development 3	17	Ministry of Agriculture
6	Ministry of Agriculture 1	18	Water Works- Tambunan District
7	Ministry of Agriculture 2	19	Land and Survey Department
8	Ministry of Agriculture 3	20	Land Revenue Collection Department
9	Ministry of Agriculture 4	21	Veterinary Department
10	Local Authority (Tambunan) 1	22	Native Courts Department – Tambunan
11	Local Authority (Tambunan) 2	23	Native Courts Department – Keningau
12	Department of Environment Protection	24	Health Department – Tambunan

2. Industry actor: The actor mainly covered the novel technologies that were tried and tested elsewhere, which may fit the typography of the research sites. Applying appropriate technologies for inclusive electrification in Sabah requires the private sector's novel innovations and cooperation (Energy Sector Management Assistance Program 2019; Power 2000). However, these actors faced hurdles in the tech application due to lack of acceptance and approval from other helixes. This led to the significance of academic actors in substantiating the importance of policy advancement with innovation (Muhyi et al. 2017; Rodprasert et al. 2014). The research combined a few approaches to examine the appropriate environment in creating clean and inclusive electrification as a socioeconomic development alternative.

Table 3: Industry Actors Engaged in the Study

	Industry actors engaged
1	Atech Energy Sdn Bhd
2	Penampang Renewable Energy

3	Sedania Innovation Bhd

3. Academic actor: The importance of check and balance helps validate the study better. Academic actors play a significant role scientifically. These actors contributed their expertise and knowledge by ensuring that the research was conducted accurately. Their expertise allows them to design studies, develop hypotheses, select appropriate research methods, and analyze data in a way that produces meaningful and accurate results. Academic actors are expected to approach their research with objectivity and impartiality, which is essential in ensuring that the study's findings are reliable and unbiased. By conducting research and publishing their findings, academic actors contribute to the collective body of knowledge within their field. Three academic actors were engaged in the study, as stated in Table 4.

Table 4: Academic Actors Engaged in the Study

	Academic actors engaged
1	UMS
2	Asia Pacific University
3	University of Addis Abba

4. Community actor: Social demand is, according to community opinion, used to impose social economic status; thus, the community's input is critical for the study. For the community actor, the local authority invited five community chiefs called "Ketua Anak Negeri" and is tabulated in table 5. Their contributions to the study were most significant in fulfilling the inclusive aspect. The Tagal communities' lifestyle supplied a unique contribution to the study, as these communities have a prominent level of understanding of resource management, such as the riverine, fisheries and natural environment.

Table 5: Community Actors Engaged in the Study

	Community
1	Kampung Monsok
2	Kampung Rompon
3	Kampung Libang Laut
4	Kampung Kaingaran
5	Kampung Monsorulung

5. NGOs actor: Independent bodies such as NGOs played a vital role as overseers. This is to ensure that the environmental and social aspects of a particular undertaking are legitimate. The study placed equal importance on social and environmental aspects; hence, it required unique NGO actors' perspectives in this study. Three actors were selected, as shown in Table 6, with experience in rural electrification, social empowerment and environmental stewardship.

Table 6: NGO Actors Engaged in the Study

	NGOS
1	Energy Action Partners
2	Tonibung
3	GEC

6. Funder actor: The final actor was the outcome of the research findings. The Funder or sponsor is an important element in the success of the project. The funder may originate from the existing actor groups; however, their role in the study has a significant contribution to inclusive sustainable development projects. Four actors were engaged in this study, as shown in Table 7. The significance of the actor for the study will be discussed in detail in the discussion section.

Table 7: Funder Actors Engaged in the Study

	Funder
1	KETSA - AAIBE 1
2	KETSA - AAIBE 2
3	UK-Malaysia PACT
4	AXIATA FOUNDATION

FINDINGS FROM INTERVIEWS

More than fifty interviews were conducted over a period of three years between 2019 and 2021. Pertinent primary data are vital for the complex interdisciplinary study of watershed management and sustainable socioeconomic development with renewable energy. The sustainability theme for the paper was to present actors' response on their role, aspiration and motivation toward the research topic. Subsequently, information was summarized through multicriteria analysis. Using the Likert scale, all qualitative data collected are presented in the tables below based on each aspect, key variable and indicator.

The actors were represented with letters: A) government actors; B) industry actors, C) academic actors; D) community actors; E) NGO actors and F) founder actors. During the discussions, no specific actor or actors were willing to take the key role in funding the pilot micro hydropower project. No specific actor or institution will look at this as their core aim. The prevailing question asked by every actor was to name one helix or individual in funding the pilot project. Thus, the recommendation toward an added actor called "the funder". Nonetheless, the unique role of the actor could be represented by the existing quintuple helix actors. There are four key variables with seven indicators for technical aspects (Bhattacharyya and Palit 2016; Ilskog 2016; Vijeyan et al. 2017). These minor modifications from Ilskog's original MCA were to best complement local scenarios such as market readiness in ASEAN and conformance to local standards. It was important, as some of the actors shared their bad experiences with poor after-sales support that left systems unexploited. In view of the renewable energy policies that were already in place, such as the feed-in-tariff (FIT) and net energy metering (NEM), the indicator may help justify projects with local policy support.

The responses are shown in Table 8 below. Subsequently, the weightages of the responses were calculated based on the average sum for each actor and are presented in Table 9. The industry, funder and government actors placed a higher emphasis on technical aspects, as reflected in table 4 below.

Table 8: Technical Aspect

Sustainable Development Aspects	Key Variables	Indicators	Responses from					
			A	B	C	D	E	F
Technical Aspect	Market ready	Tried and tested in ASEAN	4	4	3	1	1	4
	Operational and Maintenance	Efficiency	4	4	3	1	2	4
		Conformance with national standards	5	4	3	3	2	3
		Availability of support infrastructure/terrain	3	4	3	4	1	5
		Having a local presence	1	4	3	4	0	3
	Technical client-relation Issue	Response time for repair and maintenance	1	4	3	4	0	2
	Qualified for community	Appropriate technology and quota for FIT/NEM	4	4	3	4	0	4

Table 9: Technical Aspect Weightage

Technical Aspect Weightage from interview					
A	**B**	**C**	**D**	**E**	**F**
3.14	4.00	3.00	3.00	0.86	3.57

The economic aspect was represented by five key variables with nine indicators (Gifford et al. 2011; Ilskog 2016; Sanjayan Velautham(ACE) 2016). The minor modification from the original MCA was to best complement local scenarios. One of the most popular tools used to find the viability of technology application was the levelized cost of electrification (LCOE).

Similar to the technical aspect above, FIT and NEM were included. Here, the added potential of renewable energy credit (REC) was introduced as a reward to the funding agent. Responses from actors are summarized and shown in table 10 below.

Subsequently, the weightages of the responses were calculated based on the average sum for each actor and are presented in Table 11. The academician, community and funder actors placed a higher emphasis on technical aspects, as reflected in table 11.

Table 10: Economic Aspect

Sustainable Development Aspects	Key Variables	Indicators	Responses from					
			A	B	C	D	E	F
Economic Aspect	Financial perspective	Profitability	1	1	3	1	0	5
		O&M costs	1	4	3	5	0	2
		CAPEX through LCOE	1	1	3	5	3	5
		Subsidy	1	4	3	5	1	5
	Development of productive uses	Shared of electricity used for business activities	5	0	3	2	3	4
	Employment generation	Pre installation	4	1	3	5	4	3
		Post installation	4	0	3	5	4	3
	Opportunity Cost	Expected grid connection to reach community	5	0	3	1	3	1
	Community Income	FIT, NEM, REC	4	2	3	5	3	4

Table 11: Economic Aspect Weightage

Economic Aspect Weightage from interview					
A	**B**	**C**	**D**	**E**	**F**
2.89	1.44	3.00	3.78	2.33	3.56

The environmental aspect was represented by three key variables with four indicators (Ilskog 2016; Samadi 2017; Yong, Au 2018). The minor modification from the original MCA was to discuss the global impact through local initiatives. The local impact is particularly important to the local communities, as they are the main custodians to the watershed in their compound.

Communities will not accept technology that may have a negative impact on the environment. Hence, this further supports the hypothesis of community-based watershed management by empowering these communities. During the interviews, there was a demand for current sustainability trends that may help sustain the project. The other interesting indicator that was recommended from the list of interviews was the social cost. Responses are presented in Table 12 below.

Subsequently, the weightages of the responses were calculated based on the average sum for each actor and are presented in Table 13. The funder, community, academician and government actors placed higher emphasis on technical aspects, as reflected in the table below.

Table 12: Environmental Aspect weightage

Sustainable Development Aspects	Key Variables	Indicators	Responses from					
			A	B	C	D	E	F
Environmental Aspect	Global impact	Renewable energy production percentage	4	1	3	0	3	4
		Emissions of carbon dioxide from production	3	1	3	0	3	5
	Local impact	Any serious local environmental impact identified	4	3	3	4	2	5
	Social costs	Renewable energy credits	2	1	3	2	3	5

Table 13: Environmental Aspect weightage

Environmental Weightage from interview					
A	B	C	D	E	F
3.25	1.50	3.00	1.50	2.75	4.75

The social aspect was represented by five key variables with nine indicators (Ilskog 2016; Lewis et al. 2015; Nasrudin Abd Rahim et al. 2010). The minor modification was to discuss the balanced distribution for three age groups of generation x (aged above 50), y (aged 25-49) and z (aged 0-24).

During the interviews, many actors requested skills development as an empowerment aspect. The other interesting indicator recommended from the list of interviews was the social cost or the opportunity cost.

The acceptance of work as payment was also discussed, as the study could spread to communities that are living below the poverty line. The responses from the respective actors were compiled and are shown in Table 14. Subsequently, the weightages of the responses were calculated based on the average sum for each actor and are presented in Table 15. The community, funder and NGO actors placed higher emphasis on technical aspects, as reflected in the summary table.

Table 14: Social Aspect

Sustainable Development Aspects	Key Variables	Indicators	Responses from					
			A	B	C	D	E	F
Social Aspect	Improved availability of social electricity services	Share of health centers and schools with electricity	4	1	3	4	4	5
	Credit facilities	For industry and communities to apply technology	2	1	3	3	4	1
	Balanced distribution	Share of population for Gen Z	2	0	3	4	3	3
		Share of population for Gen Y	2	0	3	4	3	3
		Share of population for Gen X	2	0	3	4	3	3
		Paying scheme - (i) produce (ii) work	2	0	3	4	4	3
		Share of public spaces for empowerment activities	3	0	3	4	3	4
	Skills development	Training on green technology and skills	2	1	3	3	4	4
	Social Costs	Avoided the need for grid connection	4	2	3	2	3	5

Table 15: Social Aspect weightage

Social Aspect Weightage from interview					
A	**B**	**C**	**D**	**E**	**F**
2.56	0.56	3.00	3.56	3.44	3.44

The governance aspect was represented by two key variables with four indicators (Carayannis and Campbell 2014; Hardianto et al. 2019; Ilskog 2016; Schmutz and Elliott 2016). The local aspect focused on the empowerment factors. During the interviews, it was raised by various actors, especially those from the government and NGOs, that their main concern was for the community to take over the project. Hence, empowerment goes beyond mere skills and knowledge development. The community requires fund management and governance skills to be sustained. Responses are presented in Table 16 below.

Table 16: Governance Aspect

Sustainable Development Aspects	Key Variables	Indicators	Responses from					
			A	B	C	D	E	F
Governance Aspect	Capacity strengthening	Established committee for technology maintenance	1	0	3	2	3	3
		Established committee for fund management	3	0	3	4	3	4
	Sustainability	Annual auditing of performance reports	3	0	3	2	4	5

Subsequently, the weightages of the responses were calculated based on the average sum for each actor and are presented in Table 17. The funder, community, academician and NGO actors placed higher emphasis on technical aspects, as reflected in the table below.

Table 17: Governance Aspect weightage

Governance Weightage from interview					
A	B	C	D	E	F
2.33	-	3.00	2.67	3.33	4.00

DISCUSSION OF THE WEIGHTAGE RESULTS

Findings from this study endorsed a new actor to assure all stakeholders on the funding aspect. It was interesting to note the diversity among these multihelix actors for inclusive electrification. Thus, it is not a wonder why the complex problem was not commonly solved collectively. The imbalanced preference and priority may deter the implementation process or be avoided completely. Respective actors' motivations were highlighted on their highest weightage result for each aspect and presented in table 18 below.

Table 18: Average criteria weightage

Criteria (Aspects)	Average Criteria Weightage					
	Government	Industry	Academician	Community	NGOs	Funder
Technical	3.14	4.00	3.00	3.00	0.86	3.57
Economic	2.89	1.44	3.00	3.78	2.33	3.56
Social	2.56	0.56	3.00	3.56	3.44	3.44
Environmental	3.25	1.50	3.00	1.50	2.75	4.75
Governance	2.33	-	3.00	2.67	3.33	4.00

From the table above, the government actors were more prone to make techno-economic decisions on electrification matters. Industry actors have a higher motivation for technology and environmental aspects due to changes in buying patterns and demand. The academicians rated every aspect above average due to the relevance of adding to knowledge. The community has a high emphasis on economic and social concerns, especially among rural societies. The results may differ greatly for city dwellers and suburban scenarios. The NGOs' motivations were social, environmental and governance. This was due to the engagement of various NGOs that have different focuses. Finally, the new actor, funder, was more environmentally savvy and hoped to align these projects to meet their corporate goals.

The diverse results from the findings confirmed the multihelix approach that respected each actor's unique position while uniting them toward the same goal. To have a more pertinent outcome, there was a need to bring equilibrium among actors' understanding of all the sustainable development aspects. Perhaps awareness training on respective aspects and their importance to the project will seamlessly improve the adoption of inclusive electrification projects.

CONCLUSION AND FURTHER STUDY

The research findings from various stakeholders will help motivate inclusive watershed management from inclusive electrification. This is especially true for micro hydropower-related technologies, as watershed management will ensure the constant supply of renewable resources, specifically water for power generation. Such practices may aid in the preservation of Sabah's rich biosphere and sustain the livelihood of Tagal communities. Now with the element of renewable energy with minimal environmental impact, this study calls for a larger acceptance of the adoption of such innovation. With valuable input from the multihelix actors, the paper concluded that the incorporation of social cost as an added consideration apart from the standard costs and technology is realistic.

There is a need to evaluate the possibility of micro hydropower systems as capital to foster sustainable watershed management in Malaysia. The following are some further study recommendations: 1) actual implementation of micro hydropower electrification or 2) scenario simulations should be carried out using novel micro hydropower systems.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The researchers were thankful for the support and approval from the state of Sabah's Economic Planning Unit.

REFERENCES

AHMED M.F., ALAM L., MOHAMED C.A.R., MOKHTAR M.B., TA G.C. (2018b). Health risk of polonium 210 ingestion via drinking water: An experience of Malaysia, International Journal of Environmental Research and Public Health, Vol. 15, Issue 10, pp.1–19. doi:10.3390/ijerph15102056

AHMED M.F., MOKHTAR M.B., RAHMAH E., ALAM L., TA G.C., LEE K.E. (2018c). Role of Local Authority in Integrated Lake Basin Management : Experiences from Malaysia, 17th World Lake Conference, Lake Kasumigaura, Ibaraki, Japan, 2018.

BESAR N.A., SUARDI H., PHUA M.H., JAMES D., MOKHTAR M.B., AHMED M.F. (2020). Carbon stock and sequestration potential of an agroforestry system in Sabah, Malaysia, Forests, Vol. 11, Issue 2, pp.1–16. doi:10.3390/f11020210

BHATTACHARYYA S.C., PALIT D. (2016). Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required? Energy Policy, Vol. 94, pp.166–178. doi:10.1016/j.enpol.2016.04.010

BULATOVIĆ J., RAJOVIĆ G. (2022). Case study of recreational fishing in Rajova (Rajovic) river (Montenegro) preliminary research: part 2, Larhyss Journal, No 51, pp. 43-65.

CARAYANNIS E.G., BARTH T.D., CAMPBELL D.F. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation, Journal of Innovation and Entrepreneurship, Vol. 1, Issue 1, Article number 2. doi:10.1186/2192-5372-1-2.

CARAYANNIS E.G., CAMPBELL D.F. (2014). Developed democracies versus emerging autocracies: arts, democracy, and innovation in Quadruple Helix innovation systems, Journal of Innovation and Entrepreneurship, Vol. 3, Issue 1, pp.1–23. doi:10.1186/s13731-014-0012-2

CARAYANNIS E.G., CAMPBELL D.F. (2010). Triple helix, Quadruple helix and Quintuple helix and how do Knowledge, Innovation and the Environment relate to Each other? a proposed framework for a trans-disciplinary analysis of sustainable development and social ecology, International Journal of Social Ecology and Sustainable Development, Vol. 1, Issue 1, pp.41–69. doi:10.4018/jsesd.2010010105

CARAYANNIS E.G., CAMPBELL D.F. (2013). Mode 3 Knowledge Production in Quadruple Helix Innovation Systems: Quintuple Helix and Social Ecology. Dlm. Carayannis (pnyt.). Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship, hlm. 1293–1300. New York, NY: Springer New York. doi:10.1007/978-1-4614-3858-8_310

ESMAP. (2019). Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. Executive Summary. Energy Sector Management Assistance Program (ESMAP) Technical Report 014/19. Washington, DC: World Bank.

Retrieved from https://openknowledge.worldbank.org/handle/10986/31926

ER A.C., SELVADURAI S., LYNDON N., CHONG S.T., ADAM J.H., MOHD FUAD M.J., HABIBAH A. et al. (2012). The Evolvement of Tagal on Ecotourism and Environmental Conservation: A Case Study in Kampong Luanti Baru, Sabah, Advances in Natural and Applied Sciences, Vol. 6, Issue 1, pp.61–64.

ETZKOWITZ H., LEYDESDORFF L. (2000). The dynamics of innovation: From National Systems and "mode 2" to a Triple Helix of university-industry-government relations, Research Policy, Vol. 29, Issue 2, pp.109–123. doi:10.1016/S0048-7333(99)00055-4.

FOO J. (2011). Sistem tagal dalam industri pelancongan : Manfaat kepada komuniti Tagal tourism , environmental management and the community, GEOGRAFIA Malaysia Journal of Society and Space, Vol. 7, Issue 1, pp.14–25.

GIFFORD J., GRACE R., RICKERSON W. (2011). Renewable Energy Cost Modeling: A Toolkit for Establishing Cost-Based Incentives in the United States; March 2010-March 2011. Contract 303(March): 275–3000. doi:10.2172/1016428

GRAY A.E., JACKSON J., FARRALL S. (2009). Title: In Search of the Fear of Crime: Using Interdisciplinary Insights to Improve the Conceptualisation and Measurement of Everyday Insecurities. Authors: Emily Gray, Jonathan Jackson and Stephen Farrall, pp.1–20.

HALIBAS A.S., SIBAYAN R.O., MAATA R.L.R. (2017). The penta helix model of innovation in Oman: An hei perspective, Interdisciplinary Journal of Information, Knowledge, and Management, Vol. 12, pp.159–172.

HARDIANTO W.T., SUMARTONO, MULUK M.R.K., WIJAYA F. (2019). PentaHelix synergy on tourism development in Batu, East Java, International Journal of Innovation, Creativity and Change, Vol. 10, Issue 6, pp.137–149.

HASSAN K. (2018). The dependency of economy of Sabah on foreign workers: A study using Labour Force Survey, 2018. Department of Statistics Malaysia, Sabah. Retrieved from https://www.dosm.gov.my/v1/uploads/files/7_Publication/Research_Papers/3_ JP SABAH - The dependency of economy of Sabah on foreign workers.pdf

IEMSOMBOON P., TANGTHAM N. (2014). Problems and barriers on SHSs management in Thailand's rural areas based on SWOT analysis, Energy Procedia, Vol. 56(C), pp.598–603. doi:10.1016/j.egypro.2014.07.198

ILSKOG E. (2004). And Then They Lived Sustainably Ever After ? : Experiences from Rural And Then They Lived Sustainably Ever After ? - Experiences from Rural Electrification in Tanzania , Zambia and Kenya. PhD Thesis, Luleå University of Technology Department of Applied Physics and Mechanical Engineering, Luleå, Sweden.

IZADYAR N., ONG H.C., CHONG W.T., MOJUMDER J.C., LEONG K.Y. (2016). Investigation of potential hybrid renewable energy at various rural areas in Malaysia, Journal of Cleaner Production, Vol. 139, pp.61–73. doi:10.1016/j.jclepro.2016.07.167

JABATAN PERANGKAAN MALAYSIA. (2020). Poket Stats Negeri Sabah ST4 2019 (Februari).

JELISAVKA B., ALEKSANDRA M., GORAN R. (2019). Analysis of the population survey in the basin of Rajova (Rajović River): problems and prospects of development with a focus on ecological awareness, Larhyss Journal, No 39, pp. 109-141.

KAUNDA C.S., KIMAMBO C.Z., NIELSEN T.K. (2012). Potential of Small-Scale Hydropower for Electricity Generation in Sub-Saharan Africa, ISRN Renewable Energy, Vol. 2012, pp.1–15. doi:10.5402/2012/132606

KHENGWEE T., HOOLE P.R.P., PIRAPAHARAN K., JULAI N., OTHMAN A.K.H., ANYI M., HAIDAR A.M.A. (2017). A review of sarawak off-grid renewable energy potential and challenges, Journal of Telecommunication, Electronic and Computer Engineering, Vol. 9, Issue 3–10, pp.29–33.

KIRMANI S., JAMIL M., KUMAR C., AHMED M.J. (2010). Techno Economic Feasibility Analysis of a Stand-Alone PV System to Electrify a Rural Area Household in India. International Journal of Engineering Science and Technology, Vol. 2, Issue 10, pp.5231–5237.

LAPORAN SOSIOEKONOMI NEGERI SABAH. (2020).Jabatan Perangkaan Malaysia Blok C6, Kompleks C, Pusat Pentadbiran Kerajaan Persekutuan 62514 Putrajaya, Malaysia.

LATIP N.A., MARZUKI A., OMAR M.U., PIMID M. (2015). Sustainable Tourism's Indicator in the Protected Area: the Case of Kinabalu Park, Sabah, Australian Journal of Basic and Applied Sciences, Vol. 2016, pp.95–103.

LEWIS J., MENGERSEN K., BUYS L., VINE D., BELL J., MORRIS P., LEDWICH G. (2015). Systems modelling of the sociotechnical aspects of residential electricity use and network peak demand, PLoS ONE, Vol. 10, Issue 7, pp.1–21. doi:10.1371/journal.pone.0134086

LONG A., MOKHTAR M.B., AHMED M.F., KIM L.C. (2022). Enhancing sustainable development via low carbon energy transition approaches, Journal of Cleaner Production, Vol. 379(P2), Paper 134678. doi:10.1016/j.jclepro.2022.134678

MEROUS N.H., MAMAT M.P., AZREENA A. K., NORLIYANA A. (2016). Ecosystem Services Assessment on Protected Area(PA) in Malaysia. 4th Kuala Lumpur International Agriculture, Forestry and Plantation (May), pp.169–175. Retrieved from https://www.researchgate.net/profile/Noor_M/publication/325396082_Ecosystem_services_assessment_on_protected_area_PA_in_Malaysia/links/5b0b714aa6fdcc8c25345e21/Ecosystem-services-assessment-on-protected-area-PA-in-Malaysia.pdf.

MOSER A., KORSTJENS I. (2018). Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis. European Journal of General Practice, Vol. 24, Issue 1, pp.9–18. doi:10.1080/13814788.2017.1375091

MUHYI H.A., CHAN A., SUKOCO I., HERAWATY T. (2017). The Penta Helix Collaboration Model in Developing Centers of Flagship Industry in Bandung City, Review of Integrative Business and Economics Research, Vol. 6, Issue 1, pp.412–417. Retrieved from http://buscompress.com/journal-home.html

RAHIM N.A., ISLAM M.R., RAHMAN S. (2010). Rural Electrification in Malaysia. International Conference "Innovations for Renewable Energy" (September): 20–23.

ROUISSAT B., SMAIL N. (2022). Contribution of water resource systems analysis for the dynamics of territorial rebalancing, case of Tafna system, Algeria, Larhyss Journal, No 50, pp. 69-94. POWER S.H. (2000). Smart Free Stream Turbine 1. Retrieved from http://www.smart-hydro.de/renewable-energy-systems/hydrokinetic-turbines-river-canal/

RODPRASERT R., CHANDARASUPSANG T., CHAKPITAK N., YUPAPIN P.P. (2014). Green energy community with smart society for sustainable living. Energy Procedia, Vol. 56(C), pp.678–689. doi:10.1016/j.egypro.2014.07.208

SAMADI S. (2017). The Social Costs of Electricity Generation — Categorising Different Types of Costs and Evaluating Their Respective Relevance (April). doi:10.3390/en10030356

ASEAN Centre for Energy. (2016). Levelised Cost of Electricity of Selected Renewable Technologies in the ASEAN Member States, Jakarta, Indonesia.

Retrived from https://agep.aseanenergy.org/wp-content/uploads/2018/04/Levelised-Cost-of-Electricity-of-Selected-Renewable-Technologies-in-ASEAN-Member-States.pdf

SCHMUTZ V., ELLIOTT M.A. (2016). Tourism and sustainability in the evaluation of World Heritage Sites, 1980-2010, Sustainability, Vol. 8, Issue 3, pp.1–14. doi:10.3390/su8030261

SCHWAN S. (2011). Overcoming Barriers to Rural Electrification An Analysis of Micro-Energy Lending and its Potentials in the International Carbon Market on the Example of Solar Home Systems in Bangladesh. Master Thesis, Aarhus School of Business, Aarhus University.
Retrived from
https://energypedia.info/images/f/f2/Overcoming_Barriers_to_Rural_Electrification_-_Example_of_Solar_Home_System_in_Bangladesh.pdf

TANGIT T.M., HASIM M.A.K., ADANAN A. (2014). Rural Tourism at its Peak: Socio-Cultural Impacts towards Host Communities of Kinabalu Park, Sabah (Malaysian-Borneo). SHS Web of Conferences, Vol. 12, Paper 01097. doi:10.1051/shsconf/20141201097

UBAIDILLAH N.Z., AB-RAHIM R., JUL S., EDMAN A.B.N.A.S., HAMDAN R. (2018). Analysing the Local Communities' Perception on the Economic and Environmental Factors of Ecotourism in Tagang System Framework: The Case of Semedang Village, Sarawak, Malaysia. International Journal of Academic Research in Business and Social Sciences, Vol. 8, Issue 11, pp.1056–1068. doi:10.6007/ijarbss/v8-i11/4984

UBAIDILLAH N.Z., SAIB R., AB-RAHIM R., ISMAIL F. (2018). Tagang System Development: The Impacts and Perception of Local Communities in Terbat Mawang Village, Sarawak, Malaysia. International Journal of Academic Research in Business and Social Sciences, Vol. 8, Issue 12, pp.1203–1222. doi:10.6007/ijarbss/v8-i12/5192

UNDP. (2022). Mainstreaming of Biodiversity Conservation into River Management. United Nations Development Program (UNDP). Retrived from https://erc.undp.org/evaluation/documents/download/19854

UNESCO. (1960). Director General of UNESCO Report, Paris.

VIJEYAN V., RAHMAN M.M., HASAN M.F., SAAT A., WAHID M.A. (2017). Renewable resource based decentralized power system to a remote village in Malaysia: Optimization and technoeconomic evaluation, Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, Vol. 37, Issue 1, pp.1–17.

WONG J.Z., ETOH S., SUJANG A.B. (2009). Towards Sustainable Community-based Fishery Resources Management: The Tagal System of Sabah, Malaysia. Fish for the People, Vol. 7, Issue 2, pp.18–23. Retrieved from http://mahseertrust.org/wp-content/uploads/2016/05/Wong-2009.pdf

WONG S.R., CHARS B., JAINIH L., FIKRI A.H., HARUN S., MOH P.Y. (2018). Comparative assessment of Moyog River Watershed and Malaysia Water Quality Index, ASM Science Journal, Vol. 11, Issue 2, pp.29–35.

YONG H.N.A. (2018). The Impact of Electric Power Consumption on Green Economy Development in Malaysia, Journal of KATHA, Vol. 14, Issue 1, pp.73–95. doi:10.22452/katha.vol14no1.4