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Unlocking Ecopreneurial Growth: The Power of Marketing Strategies and Key Determinants

Nurainun¹, Farah Akmar Anor Salim²

¹Universitas Malikussaleh, Email: nurainun@unimal.ac.id

²University Technology Malaysia

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ABSTRACT

In the era of the gig economy, individuals are increasingly seeking independent income-generating opportunities rather than traditional full-time employment. Many opt to become freelancers, leveraging flexible business models such as e-hailing—an electronic application-based service for booking public transport—and p-hailing, which facilitates the delivery of packages and food via online platforms. However, beyond these established models, there is a growing inclination toward establishing independent businesses. Given the increasing global emphasis on sustainability, this study examines the factors influencing entrepreneurs in adopting eco-friendly business practices. A structured questionnaire consisting of 43 items was distributed to 200 entrepreneurs across various states in Malaysia, targeting potential entrepreneurs. A total of 119 valid responses were collected and analyzed. The findings highlight key issues in the field, and the study provides recommendations for future research.

Keywords: Ecopreneurship, Ecopreneur, Sustainability, Entrepreneurial intention, Green Entrepreneur, Green Environment, Awareness, Attitude

INTRODUCTION

Opting to establish own business has become an increasingly preferred career choice, particularly among the millennials generation. One of the primary factors contributing to this trend is the high level of competition in the job market, driven by the growing number of university graduates seeking employment. Moreover, within the business sector, job opportunities have become more limited due to the increasing reliance on automation, particularly in the era of artificial intelligence (AI).

The increasing global awareness of environmental sustainability has led to the establishment of various initiatives aimed at promoting responsible business practices. Notably, the United Nations introduced the 17 Sustainable Development Goals (SDGs) as a framework for individuals, businesses, and governments to adopt more sustainable approaches. These goals emphasize key aspects such as responsible consumption, climate action, and environmental protection (Cacciotti et al., 2016). Consequently, there has been a shift in consumer preferences, with more individuals supporting businesses that align with eco-friendly values.

In response to this growing demand, environmentally conscious businesses have become a priority in the entrepreneurial landscape. New ventures that integrate sustainability—through green innovations, waste reduction strategies, and resource efficiency—are increasingly recognized as key drivers of both economic growth and environmental responsibility. As a result, such enterprises often receive preferential treatment, including facilitated access to financial support, such as easier approval for loan applications (Beltramello et al., 2013).

While the transition to sustainable entrepreneurship presents challenges, it also offers significant long-term benefits, both economically and ecologically. Recognizing the potential of this emerging market, various strategic initiatives have been introduced to support sustainable business ventures. These efforts not only contribute to global

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environmental goals but also provide entrepreneurs with a competitive advantage in an evolving marketplace.

This study underscores the growing significance of ecopreneurship, highlighting how green business models integrating marketing strategies with sustainability, waste reduction, and resource efficiency—are increasingly recognized and supported. In response to the global push for sustainability, ecopreneurs are more likely to benefit from policy incentives and financial assistance, positioning them as key drivers of both environmental conservation and business innovation. By analyzing the factors influencing entrepreneurs to adopt sustainable business practices, this research emphasizes the importance of promoting and strategically marketing ecopreneurial products and services in fostering a more responsible and resilient economic future.

LITERATURE REVIEW

Ecopreneurship: Activities, Concepts, Ideas, and Initiatives

Ecopreneurship, a concept derived from the fusion of "entrepreneurship" and "ecology," refers to business ventures that prioritize environmental sustainability while ensuring economic viability. These enterprises are distinguished from conventional businesses by incorporating green innovations, ethical sourcing, and sustainable resource management into their business models(Santini, 2017). Rather than focusing solely on profit generation, ecopreneurs aim to foster long-term ecological balance through their entrepreneurial initiatives. This approach aligns with global sustainability efforts, particularly the United Nations' 17 Sustainable Development Goals (SDGs), which emphasize responsible consumption, climate action, and environmental conservation.

The activities undertaken by ecopreneurs extend beyond renewable energy production, sustainable agriculture, eco-friendly product manufacturing, and waste management solutions, encompassing a wide range of industries. Many ecopreneurs leverage circular economy principles, ensuring that materials and resources are reused, recycled, or repurposed to minimize waste and maximize efficiency. Additionally, businesses that adopt sustainable supply chains and green technologies play a crucial role in reducing carbon footprints and promoting responsible consumption.

In reflecting to the marketing strategy perspective, these initiatives provide a significant competitive advantage by aligning with the growing consumer demand for sustainable products and services. Several innovative concepts and ideas have emerged within the ecopreneurial space. For instance, businesses are exploring green branding, eco-labelling, and biodegradable packaging. The commitment to environmental responsibility created brand loyalty to customers that are environmentally conscious and thus put themselves as leader in the sustainable business landscape.

Promoting Green Innovation Through Government Incentives

In recent years, Malaysia has placed significant emphasis on fostering a clean and sustainable environment through various initiatives and policies. Green environmental awareness campaigns have been introduced at multiple levels, with early education programs implemented as early as primary school to instil a sense of responsibility toward environmental preservation. These programs aim to educate individuals on the importance of sustainability, emphasizing the need to protect natural resources and maintain a healthy living environment for future generations.

The promotion of green environmental initiatives, however, extends beyond formal educational settings. The awareness efforts have increasingly permeated informal channels, reaching diverse segments of society regardless of age, ethics, races, profession, or background. Community-driven programs, corporate sustainability initiatives, and social media campaigns have played a crucial role in disseminating knowledge and encouraging widespread participation in green practices. By integrating sustainability into both structured education and everyday social interactions, Malaysia continues to cultivate a culture of environmental responsibility, ensuring long-term commitment to ecological preservation.

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2023; NegiN Vaghefi et al., 2017; Zahid et al., 2024).

The Malaysian government has placed significant emphasis on promoting environmental sustainability, demonstrating a strong commitment to fostering a greener economy. This is proven through the introduction of various incentives and support programs aimed at encouraging businesses and individuals to adopt eco-friendly practices. The initiatives are systematically implemented across multiple channels to ensure their effectiveness and seamless execution, reflecting the government's proactive approach to environmental stewardship (Neama et al.,

New business ventures are highly encouraged to incorporate green practices into their operations to align with the green entrepreneurship concepts. In supporting this transition, the government has introduced numerous financial schemes, tax incentives, and regulatory frameworks designed to facilitate the growth of environmentally responsible enterprises (Eltayeb et al., 2010; Neama et al., 2023; Olson, 2008). These measures underscore the seriousness with which the government views sustainability, recognizing it as a critical factor in achieving long-term economic and environmental resilience. Through these concerted efforts, Malaysia continues to strengthen its position as a leader in sustainable development, fostering a business ecosystem that prioritizes environmental responsibility alongside economic growth.

Recognizing the importance of ecopreneurial initiatives, governments and private sectors worldwide have introduced policies, funding programs, and support networks to encourage green business development. In conjunction with the effort, collaborations between academia, industries, and policymakers are instrumental in fostering ecopreneurial growth by providing research, knowledge transfer, and capacity-building programs. In supporting the initiatives, Malaysian government has provided incentives such as tax breaks, grants, and low-interest loans are offered for startups that align with sustainability goals. As the world shifts towards a more sustainable economic model, ecopreneurs will continue to play a vital role in shaping a greener future through innovative and impactful business solutions. These strategies not only drive business growth but also contribute to broader sustainability goals by fostering a shift toward more responsible consumption patterns.

The Influence of Environmental Awareness on Ecopreneurial Marketing Activities in Malaysia.

The core principle of ecopreneurship fundamentally centered on creating business opportunities that integrate sustainability concepts and ideas. The primary objective of this initiative is to enhance environmental awareness within society, thereby fostering greater acceptance and increasing demand for sustainable products and services. In Malaysian context, increasing public consciousness regarding environmental issues plays a crucial role in shaping market dynamics, influencing both consumer behaviour and business strategies. Therefore, the objectives of ecopreneurs extend beyond the development of eco-friendly products and services to the implementation of effective marketing strategies that align with sustainability values.

An environmental awareness and ecopreneurial marketing activities are interconnected in shaping the growth and impact in the green business sector (Alazaiza et al., 2024; Galkina, 2021). Continuous engagement is essential, highlighting the importance of demonstrating impact through collaboration with consumers, policymakers, and industry stakeholders. Thus, the hypothesis that "Environmental awareness positively affects ecopreneurial marketing activities in Malaysia" is supported by the increasing relevance of sustainability-driven consumer behaviour and policy support. Ecopreneurs who effectively align their marketing efforts with the values and expectations of environmentally conscious consumers are more likely to achieve long-term success while contributing to Malaysia's broader sustainability agenda.

H1: Environmental awareness positively affects ecopreneurial activities in Malaysia.

Attitude – A Mediator between Environmental Awareness and Ecopreneurial Marketing Activities

Sustainability has emerged as a critical factor influencing entrepreneurial practices, particularly within the field of ecopreneurship. As individuals acquire greater knowledge of environmental issues, their engagement with



sustainable business practices becomes increasingly significant. Environmental awareness plays a crucial role in shaping business decisions, as it fosters a deeper understanding of ecological challenges and the need for responsible entrepreneurial action. As such, this awareness influences individuals' attitudes, prompting them to adopt sustainable business strategies.

According to Mansor & Sheau-Tingi (2019), attitude serves as a key psychological determinant that bridges the gap between environmental awareness and actionable business strategies. Inevitably, ecopreneurs who integrate green marketing practices into their ventures demonstrate a positive attitude toward sustainability. Through the alignment of business operations with environmental values, ecopreneurs not only contribute to sustainability efforts but also respond to the growing consumer demand for eco-friendly products and services.

Based on the considerations above, this study hypothesizes that attitude mediates the relationship between environmental awareness and ecopreneurial marketing activities in Malaysia. This hypothesis suggests that environmental awareness alone may not be sufficient to drive ecopreneurial marketing efforts unless it is accompanied by a positive attitude toward sustainability.

H2: Attitude mediates the relationship between environmental awareness and ecopreneurial marketing activities in Malaysia.

The conceptual framework of this study is shown in Figure 1.

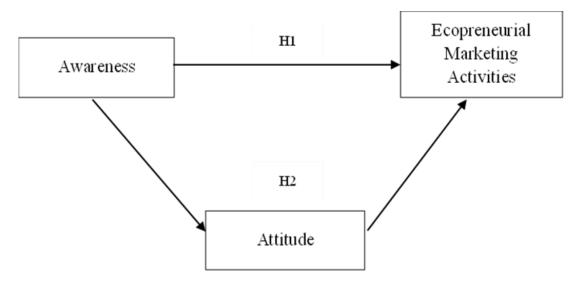


Figure 1: Conceptual Framework

METHODOLOGY

This study aims to examine the impact of ecopreneurial marketing activities by exploring the roles of market awareness and attitude. The scope of study is to get better understanding from the entrepreneurs in adopting ecofriendly business practices in Malaysia. This study employed a quantitative approach to analyze data gathered. A total of 200 entrepreneurs across various states in Malaysia were surveyed through a structured questionnaire, resulting in 119 completed responses, yielding an approximate response rate of 59.5%. The collected data was then analyzed using IBM SPSS Statistics 23 and AMOS Graphics version 23.

Measurement scale development

The questionnaire was structured into two sections. Section A focused on gathering the demographic profiles of respondents, while Section B comprised questions related to the study variables, specifically environmental



awareness, environmental attitude, and ecopreneurial activities. All items were measured using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

The environmental awareness construct was evaluated using five items adapted from Le Loarne Lemaire et al. (2022) and Menon & Menon (1997). Similarly, the environmental attitude construct was assessed through five items derived from Uslu et al. (2015) and Kirkwood & Walton (2010). Finally, ecopreneurial marketing activities were measured using eight items adapted from Choi & Gray (2008) and Ndubisi & Nair (2009). Table 2 provides a summary of the measurement items adapted from prior research.

Background characteristics of respondents

Table 1 presents the demographic profile of the respondents, with a total of 119 valid responses collected. The analysis indicates that 35.3% of the respondents were male (n = 42), while 64.7% were female (n = 77). In terms of age distribution, the largest proportion of respondents were between 16 and 20 years old (n = 66, 54.5%), followed by those aged 31 to 40 (n = 44, 37%).

Geographically, the majority of respondents resided in urban areas (n = 90, 75.6%), while the remaining 24.4% (n = 29) were from rural areas. Regarding ethnicity, Malays constituted the largest group (n = 103, 86.6%), followed by Indians (n = 11, 9.2%), other ethnicities (n = 4, 3.4%), and Chinese (n = 1, 0.8%). Additionally, 59.7% (n = 71) of respondents reported having no prior business background. In terms of education, most respondents had attained either an undergraduate degree (n = 45, 37.8%) or a postgraduate degree (n = 48, 40.3%).

Table 1 Demographic profile

Category	Frequency	Percentage (%)
Gender		
Male	42	35.3
Female	77	64.7
Age Group		
25 and below	33	27.7
26 to 30	13	10.9
31 to 40	44	37.0
41 to 50	25	21.0
51 and above	4	3.4
Place of Origin		
Rural	29	24.4
Urban	90	75.6
Ethnicity		
Malay	103	86.6
Chinese	1	0.8
Indian	11	9.2
Others	4	3.4



Business Background		
Yes	48	40.3
No	71	59.7
Education		
Secondary/High school	16	13.4
Undergraduate degree	45	37.8
Postgraduate degree	48	40.3
Professional certificates	9	7.6
Others	1	0.8

 Table 2
 The test of the scale

Construct	Assigned Code	Items	Adopted/Adapted From	Mean	SD	КМО	α
Awareness (AW)	AW1	I know the different types of support offered to people who want to start a new business.	1. Le Loarne Lemaire et al. (2022). https://doi.org/10.1007/s113 65-021-00791-1 2. Menon & Menon (1997). https://www.mendeley.com/ catalogue/afe322b5-1b29- 3162-a79d-9c3cd11f7ff2/	3.482	0.64	0.805	0.73
	AW2	Information from the government's support towards a 'go green' environment is easily found.	Same as above				
	AW3	My level of knowledge about this support offered to people who want to start a business is high.	Same as above				
	AW4	The government provides adequate support to start a business.	Same as above				
	AW5	The government provides quality support to start a business.	Same as above				
Attitude (AT)	AT1	Being an entrepreneur implies more advantages than disadvantages to me.	1. Uslu et al. (2015). https://doi.org/10.1016/j.sbs pro.2015.06.266 2. Kirkwood & Walton (2010). https://doi.org/10.1108/1355 2551011042799	3.621	0.49	0.721	0.87





	AT2	Entrepreneurship would present more ups than downsides.	Same as above				
	AT3	A career as an entrepreneur is (totally) attractive.	Same as above				
	AT4	I am willing to start a firm (business) if I have enough resources.					
	AT5	Being an entrepreneur would entail great satisfaction for me.	Same as above				
Ecopreneurial Marketing Activities (EA)	EA1	Ecopreneur should have sufficient knowledge in marketing techniques and strategies.	1. Choi & Gray (2008). https://doi.org/10.1108/0140 9170810892127 2. Ndubisi & Nair (2009). International Journal of Entrepreneurship, 13(SPECIAL ISSUE), 21– 34.	4.024	0.58	0.871	0.89
	EA2	The market opportunity for growth in business is important even if it involves risk.	Same as above				
	EA3	Ecopreneur should have sufficient knowledge to market the green business products.	Same as above				
	EA4	Ecopreneur should improve the marketing abilities.	Same as above				
	EA5	Marketing skills and knowledge is important to all ecopreneurs to build a	Same as above				

Note: * These items and scale have been excluded from further analyses due to low factor loadings (0.6) ** p<0.00

good network of friends, professionals and business

acquaintances.

FINDINGS

Validity and reliability

The data collected were first subjected to Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity to test the scale's structure validity (refer Table 2). The KMO measure yielded a value



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of more than 0.6 with a significant Bartlett's test (p < 0.001) for each construct. No item was removed during this process as all reported adequate factor loadings (> 0.6). All values of Cronbach's alpha for all constructs ranged from 0.727 to 0.891, greater than the requirement of 0.7, suggesting that the measurement for all constructs had good internal consistency reliability (refer Table 2).

Confirmatory Factor Analysis (CFA)

An examination of the fitness indices revealed that the measurement model had a satisfactory fit with the data, where the value of RMSEA and X^2/df were .072 and 59.072 respectively. Other indices also revealed a satisfactory fit, where CFI = .988 and GFI = .992. The results are shown in Table 3.

Table 3. Results of Fitness Indices for the Measurement Model

Name of Index	Index Value	Level of Acceptance	Comments
RMSEA		RMSEA < 0.08	The acceptance level is achieved
CFI		CFI > 0.90	The acceptance level is achieved
GFI		TLI > 0.90	The acceptance level is achieved
X^2/df		Chisq/df < 5.0	The acceptance level is achieved

The mediating effect of attitude

The study runs direct path technique to investigate an interaction between independent variables; mediator and dependent variable. The rational of adopting direct path technique is to test the relevancy between all stipulated variables in the study; thus to determine the significant impact of the mediator (Baron & Kenny, 1986). Figure 3 explains the conception basis for mediation effect for the study.

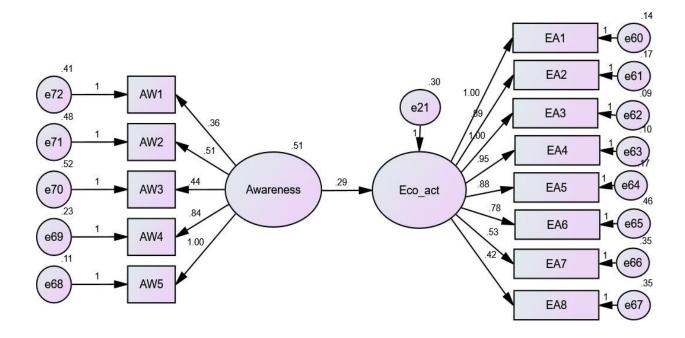


Figure 3: Mediation Conceptual Basis



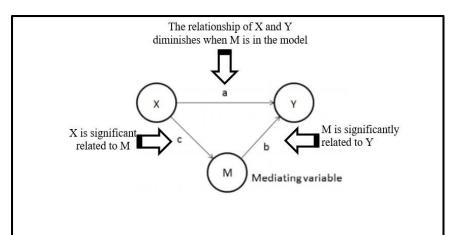


Figure 3: Conceptual Basis of Mediation

With regard to the above Figure 3 on mediation conceptual basis, attitude which signifying as a mediator variable are represented as "M". There are 2 paths created; namely the direct and indirect path within the diagram. The direct path shows the relationship between awareness (X) and ecopreneurs (Y) while indirect path is constructed via the mediating variable attitude.

The analysis shown in Figure 4 depicts the standard coefficient or beta regression weights to confirm whether attitude mediates between awareness and ecopreneur intention. The analysis (see Figure 4) demonstrated that when attitude is present, the weight between awareness to attitude is .62. In contrast, the weight between attitude and ecopreneur is 1.02 while the weight between awareness to ecopreneur -.36.

In summarizing the results, each path is significant. To test the standardized coefficient, or beta regression between the direct and indirect values, the analysis shows that the direct effect between entrepreneur's curriculum and resilient entrepreneur is -0.36. On the other hand, the indirect effect is 0.63 (0.62 x 1.02). Therefore, this indicates that there is a mediation effect between the awareness and ecopreneurial activities.

The result shows that there are significant in the indirect paths which relates between awareness to attitude and ecopreneurial. This explains that attitude mediates between awareness and ecopreneurial marketing activities. However, to confirm whether attitude is partially or completely mediates between awareness and ecopreneurial activities, standard regression weight is tested. Based on the standard regression weight report, awareness to ecopreneurial marketing activities is not significant with a p-value of .002 (see Table 7). As a result, the result did not support the hypothesis (*H1*), which entails that attitude is completely mediates between awareness and ecopreneur.

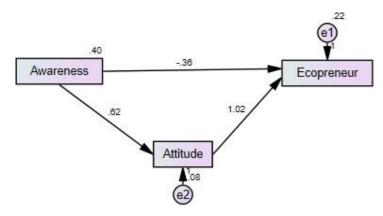


Figure 4: Mediating variable in study



Table 7: Mediating Variables in the study - Attitude

			Estimate	S.E.	C.R.	P	Label
Attitude	<	Awareness	.622	.040	15.397	***	
Ecopreneur	<	Awareness	364	.119	-3.057	.002	
Ecopreneur	<	Attitude	1.021	.157	6.522	***	

DISCUSSION

This study empirically examined and developed a model to enhance the understanding of the relationship between awareness and ecopreneurial marketing activities. In addressing the research questions, the study explored the influence of awareness on the intention to engage in and sustain ecopreneurial marketing activities. Additionally, attitude was introduced as a mediating factor to establish a linkage between these variables. The findings provide empirical evidence supporting the significance of each hypothesis, demonstrating the critical role of awareness and attitude in trigerring the ecopreneurial marketing activities.

In conclusion, Table 8 below summarizes the hypothesis results of mediation test for the study.

Table 8: The result of mediation test

			Estimate	P	Results on Hypothesis
Attitude	<	Awareness	.622	***	Significant
Ecopreneur	<	Awareness	364	.002	Not significant
Ecopreneur	<	Attitude	1.021	***	significant

Notes. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.10

It is therefore concluded that the awareness is important in shaping the ecopreneurial marketing activities with the existence of attitude as mediator between these variables.

Implication

The findings provide valuable insights for academia, industry, and global sustainability efforts. While entrepreneurial activities play a crucial role in contributing to national and economic growth, fostering awareness of environmental protection remains essential.

Limitation

Several limitations of this study have been acknowledged. Notably, the research focused solely on potential ecopreneurs in Malaysia, considering only the country's demographic characteristics, ecological factors, and local climate. Additionally, the study did not examine the impact of ecopreneurship on local economic performance and contributions. Therefore, these limitations highlight areas for further research to expand the understanding of ecopreneurial influence beyond the current scope.

Future studies

Future research should extend its focus to other continents with diverse ecological and climatic conditions, utilizing larger sample sizes for broader applicability. Additionally, comparative studies could be conducted to explore the

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fundamental economic principles in relation to ecological business activities, providing deeper insights into the intersection of sustainability and entrepreneurship across different regions.

CONCLUSION

The hypothesized model in this study demonstrates a strong fit with the data structure, validating the influence of attitude on awareness in determining the marketing activities in green business setting. The findings confirm that both awareness and attitude play a crucial role in determining ecopreneurial marketing activities, highlighting their significance in fostering sustainable business practices.

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BIBLIOGRAPHY

- 1. Alazaiza, M. Y. D., Alzghoul, T. M., Al Maskari, T., Amr, S. A., & Nassani, D. E. (2024). Analyzing the Evolution of Research on Student Awareness of Solid Waste Management in Higher Education Institutions: A Bibliometric Perspective. *Sustainability (Switzerland)*, 16(13). https://doi.org/10.3390/su16135422
- 2. Beltramello, A., Haie-Fayle, L., & Pilat, D. (2013). Why New Business Models Matter for Green Growth. Paris, France: OECD, 01(February), 1–107. https://doi.org/10.1787/5k97gk40v3ln-en
- 3. Cacciotti, G., Hayton, J. C., Mitchell, J. R., & Giazitzoglu, A. (2016). A reconceptualization of fear of failure in entrepreneurship. Journal of Business Venturing, 31(3), 302–325. https://doi.org/10.1016/j.jbusvent.2016.02.002
- 4. Eltayeb, T. K., Zailani, S., & Filho, W. L. (2010). Green business among certified companies in Malaysia towards environmental sustainability: Benchmarking on the drivers, initiatives and outcomes. International Journal of Environmental Technology and Management, 12(1), 95–125. https://doi.org/10.1504/IJETM.2010.029983
- 5. Galkina, T. (2021). International ECOpreneurship: Environmental commitment and international partner selection of Finnish firms from the energy sector. Journal of International Entrepreneurship, 19(2), 300–320. https://doi.org/10.1007/s10843-021-00286-8
- Mansor, R., & Sheau-Tingi, L. (2019). The psychological determinants of energy saving behavior. IOP Conference Series: Materials Science and Engineering, 620(1). https://doi.org/10.1088/1757-899X/620/1/012006
- 7. Neama, N. H., Abbood, R. H., & Yahya, A. E. (2023). Role of Green Entrepreneurship in Supporting Small and Medium Entrepreneurial Projects/Case Study of Malaysia. Open Journal of Business and Management, 11(06), 2908–2913. https://doi.org/10.4236/ojbm.2023.116161
- 8. NegiN Vaghefi, C. S. & S. aziz abdul ghaNi aziz, ABSTRACT Model, M., Hijau, E., & Sosioekonomi, P. (2017). Building Malaysian green economy model for socio-economic development. International Journal of the Malay World and Civilizations, 5(SI)(1), 27–32.
- 9. Olson, E. G. (2008). Creating an enterprise-level "green" strategy. Journal of Business Strategy, 29(2), 22–30. https://doi.org/10.1108/02756660810858125
- 10. Santini, C. (2017). Ecopreneurship and Ecopreneurs: Limits, trends and characteristics. Sustainability (Switzerland), 9(4). https://doi.org/10.3390/su9040492
- 11. Zahid, Z., Zhang, J., Shahzad, M. A., Junaid, M., & Shrivastava, A. (2024). Green Synergy: Interplay of corporate social responsibility, green intellectual capital, and green ambidextrous innovation for sustainable performance in the industry 4.0 era. PLoS ONE, 19(8), 1–23. https://doi.org/10.1371/journal.pone.0306349